

A Statistical Trend Analysis of Urban Water Access in Nigeria, 2000–2024: Implications for Infrastructural Governance and Basic Service Delivery

RADIYA S. M. 

Statistics Department, Federal Polytechnic Kaltungo, Gombe State, Nigeria

Mustapha Mohammed Mansur 

Statistics Department, Federal Polytechnic Kaltungo, Gombe State, Nigeria

Isah Adamu 

Statistics Department, Federal Polytechnic Kaltungo, Gombe State, Nigeria

Bashir Abdulhaq 

Statistics Department, Federal Polytechnic Kaltungo, Gombe State, Nigeria

Rasheeda Nuhu Ahmad 

Statistics Department, Federal Polytechnic Kaltungo, Gombe State, Nigeria

Abstract

Access to safe and reliable drinking water is a critical dimension of sustainable development and effective infrastructural governance. This study examines the trajectory of urban water access in Nigeria between 2000 and 2024 and assesses whether changes in water access are statistically associated with selected governance-related indicators. Annual secondary data from the World Bank World Development Indicators were analyzed using descriptive statistics, ordinary least-squares trend regression, the Mann–Kendall test, Sen’s slope estimator, Pearson correlation, Augmented Dickey–Fuller and Durbin–Watson diagnostics, detrended and first-differenced correlations, and leave-one-out sensitivity analysis. Urban access to at least basic drinking water services increased from 68.72% in 2000 to 95.08% in 2024, with a strong positive linear trend ($\beta = 1.13$ percentage points per year, $R^2 = .999$, $p < .001$), while access to safely managed drinking water services increased more gradually ($\beta = 0.75$, $R^2 = .987$, $p < .001$). Although urban water access was strongly and negatively correlated with government expenditure on education during 2012–2024 ($r = -.955$, $p < .001$), the association disappeared after detrending ($r = .05$, $p = .876$) and first-differencing ($r = .05$, $p = .875$), indicating that the observed relationship was driven by opposing time trends rather than a substantive fiscal association. The relationship between water access and women’s parliamentary representation was weak and statistically non-significant ($r = -.10$, $p = .652$). The findings demonstrate substantial improvement in reported urban water access but provide no robust statistical evidence that the governance indicators examined explain this trajectory. The exceptionally high trend fit also warrants caution because the underlying international water-service estimates are modelled and interpolated. The study highlights the need for functionality-based monitoring, transparent WASH-specific expenditure data, and greater caution in interpreting national access indicators as evidence of infrastructure delivery or governance performance.

Keywords: urban water access; infrastructural governance; basic services; statistical trend analysis; spurious correlation; Nigeria; Sustainable Development Goal 6

Introduction

Access to safe and reliable water supply remains one of the most visible indicators of the quality of public governance in developing economies, and Nigeria's urban centres present a particularly instructive case. As the country's urban population has expanded rapidly under the pressures of

rural-urban migration, natural population growth, and unplanned settlement expansion, the capacity of state and federal institutions to extend, maintain, and regulate water infrastructure has been persistently tested. Water is not merely a technical commodity delivered through pipes and boreholes; it is, as a growing body of scholarship argues, a governance good whose availability, quality, and equity of distribution reflect the institutional architecture, financing arrangements, and political priorities of the state (Adeoti et al., 2023; Ogunkan, 2022).

This study, and the concepts it draws on, distinguish deliberately among five related but non-identical terms that are frequently used interchangeably in the water-policy literature: water access, the proportion of a population that is classified, typically via a household-survey-based indicator, as reaching an improved source within a defined standard; water supply, the physical infrastructure and service arrangements through which water is delivered; water service delivery, the operational process by which supply is converted into a usable household service; water infrastructure, the fixed physical assets underlying supply; and water governance, the institutional rules, financing, and accountability arrangements that determine how infrastructure is planned, funded, and regulated. A household counted as having "access" to an improved or basic source may nonetheless experience intermittent supply, poor water quality, high effective cost, long queues, considerable distance to source, or unreliable infrastructure; access, in other words, is a necessary but not sufficient condition for adequate water service delivery. This distinction, introduced here at the outset rather than late in the manuscript, is treated as central to the conceptual framework used throughout the study, and it directly qualifies how the statistical trends reported below should be read: the analysis that follows measures water access, as officially defined and reported, and does not itself measure availability, continuity, quality, or functionality.

Nigeria's water sector has undergone successive waves of reform since the early 2000s, including three phases of the National Urban Water Sector Reform Programme implemented between 2003 and 2020, alongside donor-supported interventions from the World Bank and other development partners aimed at strengthening institutional capacity, tariff regimes, and service delivery (Ohwo, 2016). Despite these interventions, the sector continues to be characterized by fragmented regulatory oversight across federal, state, and local tiers of government, weak cost recovery, deteriorating infrastructure, and wide disparities between official coverage statistics and the lived experience of households who depend on informal vendors, boreholes, and untreated sources (Adeoti et al., 2023; World Bank, 2017).

This apparent tension between rising official water-access figures and the persistence of infrastructural decay documented in field-based studies motivates the present inquiry. Rather than beginning from a governance framework and searching for illustrative water statistics, this study inverts the analytical sequence: it begins with a statistical trend analysis of urban water-access data spanning 2000–2024 the full period for which the underlying WHO/UNICEF Joint Monitoring Programme access series are available and only then interprets what the resulting trends imply for infrastructural governance and the broader architecture of access to basic services in Nigeria. This ordering is deliberate. It allows the numbers to set the agenda for the governance discussion, rather than allowing prior governance assumptions to shape the reading of the numbers.

The study contributes to the management, policy, and administrative studies literature in two ways. First, it demonstrates how a fuller time-series toolkit not only trend regression and correlation, but also stationarity testing, autocorrelation diagnostics, non-parametric trend confirmation, and detrended/differenced robustness checks can be used to interrogate the credibility of official access indicators before governance conclusions are drawn from them. Second, and largely as a result of applying that toolkit, the study finds that at least one relationship reported in the original analysis

of these data (an apparently strong negative association between water access and education expenditure) does not survive standard robustness testing for common time trends, and it uses this finding as a substantive methodological caution for applied governance research that correlates two independently trending national time series without first testing for spurious association. The problem motivating this inquiry, and the study's specific objectives, are set out below.

Statement of the Problem

Nigeria's official statistics on urban drinking-water access have followed a consistently upward path over the past two decades, a trajectory that, on its face, would suggest steady success in extending basic infrastructure to a rapidly urbanizing population. Yet this reported progress sits uneasily alongside a substantial body of field-based and institutional evidence showing that Nigeria's urban water utilities remain financially unsustainable, technically degraded, and poorly coordinated across federal, state, and local tiers of government (Adeoti et al., 2023; Ohwo, 2016; World Bank, 2017). Non-revenue water losses, unmetered tariff systems, ageing treatment plants, and fragmented regulatory mandates are routinely documented in the qualitative literature, painting a picture of a sector under considerable strain a picture that is difficult to reconcile with a headline statistic showing urban basic water access rising smoothly toward 95%.

This disjuncture constitutes the central problem addressed by the study. Two possibilities present themselves, and existing scholarship does not adequately resolve between them: either the official access indicator genuinely captures meaningful, if imperfect, infrastructural progress that the case-study literature, by its narrower and more localized focus, understates; or the indicator's statistical smoothness is itself a product of how the underlying estimates are constructed, masking a more uneven and governance-compromised reality on the ground. A methodological caution is warranted here and is maintained throughout the remainder of the study: measurement smoothness is not, by itself, evidence of governance failure, nor is it evidence of governance success. A very high R^2 in a trend regression can arise equally from genuine, steady infrastructural expansion or from an interpolation procedure that mathematically smooths sparse underlying survey observations into an annual series; the statistic alone cannot adjudicate between these explanations, and the present study treats this as an open empirical question to be examined explicitly, rather than resolved by assumption, in the Discussion.

Compounding this uncertainty is the absence, in the readily available national data, of a direct, long-run measure of public investment specifically in water infrastructure, which makes it difficult to test statistically whether rising access has been accompanied by a commensurate strengthening or weakening of public-sector commitment. In the absence of such a direct measure, this study uses two indirect, structural comparators government expenditure on education as a share of total government expenditure, and women's parliamentary representation and treats both explicitly as general fiscal and political-inclusion indicators rather than as validated, sector-specific measures of water governance (see Section VI(d) and Table B). Without subjecting the official trend to formal statistical scrutiny including tests for spurious association and relating it cautiously to these indirect comparators, policymakers and researchers alike risk either overstating the sector's success or dismissing a genuine, if partial, improvement. It is this gap between a statistically smooth national indicator and a governance literature that suggests a far less smooth institutional reality that the present study sets out to interrogate.

Objectives of the Study

The broad objective of this study is to conduct a statistical trend analysis of urban water access in Nigeria (2000–2024) and to interpret its implications for infrastructural governance and access to basic services. The specific objectives are to:

- i. Examine the statistical trend in the proportion of the urban population using at least basic drinking water services, and in the proportion of the population using safely managed drinking water services, in Nigeria between 2000 and 2024, using both parametric (OLS) and non-parametric (Mann-Kendall/Sen's slope) trend methods;
- ii. Determine the rate and statistical significance of annual change in urban water access over the period, and assess the time-series properties (stationarity, autocorrelation) of the underlying regression models;
- iii. Assess the strength and direction of the raw statistical association between urban water access and two indirect, governance-sensitive comparators government expenditure on education and women's representation in the National Assembly and test explicitly whether any observed association is robust to detrending and first-differencing, or is instead attributable to common time trends; and
- iv. Interpret the resulting statistical patterns, including the robustness findings in (iii), against the qualitative and institutional literature on Nigeria's water governance architecture, in order to draw appropriately cautious, policy-relevant conclusions.

Literature Review

Conceptual Review: Infrastructural Governance

Infrastructural governance refers to the institutional arrangements, rules, financing mechanisms, and accountability structures through which public infrastructure is planned, funded, operated, and regulated. In the water sector specifically, the Organization for Economic Co-operation and Development has articulated a set of water governance principles built around three broad dimensions, commonly summarized as effectiveness (clarity of roles and objectives), efficiency (value for money in resource use), and trust and engagement (legitimacy and inclusiveness of decision-making). Applying this framework to Nigeria, recent scholarship finds that the water sector remains highly decentralized and fragmented, with overlapping mandates among the Federal Ministry of Water Resources, River Basin Development Authorities, and thirty-six state water agencies, producing coordination failures that undermine effectiveness even where policy frameworks exist on paper.

Ogunkan (2022) similarly situates environmental and infrastructural governance in Nigeria within a broader crisis of institutional capacity, arguing that policy pronouncements are frequently not matched by the administrative and financial follow-through required for implementation. This gap between policy design and policy delivery is a recurring theme in the Nigerian infrastructural governance literature, and it is directly relevant to how official access statistics should be interpreted: a rising coverage figure may reflect genuine service expansion, or it may reflect an accounting or estimation convention that does not fully capture functionality, water quality, or continuity of supply a distinction that this study's terminology framework (Section I) and later robustness analysis (Section VII) are designed to keep separate.

Urban Water Supply in Nigeria: Structure and Performance

Urban water supply in Nigeria is formally the responsibility of state water agencies, most of which operate as government-owned utilities with limited financial autonomy. A systematic review of the water infrastructure sustainability literature identified technical, financial, environmental, social, political, and institutional factors as the dominant categories of challenge confronting Nigerian water infrastructure, with institutional reform, governance, and capacity-building solutions accounting for roughly a fifth of all proposed remedies across the reviewed studies (Adeoti et al., 2023). Among the technical and financial constraints repeatedly identified are ageing treatment and distribution infrastructure, high levels of non-revenue water arising from an

unmetered tariff system, and insufficient operating revenue to sustain maintenance, all of which constrain the capacity of urban utilities to convert nominal coverage into reliable, continuous supply (Ohwo, 2016).

A World Bank diagnostic of Nigeria's water, sanitation, and hygiene sector similarly found that piped water access through household connections had regressed over time even as other forms of "improved" access nominally expanded, and that poor households in both urban and rural areas continue to be disproportionately excluded from safe water sources (World Bank, 2017). Ngene et al. (2021) reach a comparable conclusion in their review of integrated water resources management in Nigeria, noting that weak inter-agency coordination and inadequate investment continue to undermine the translation of abundant water resources into dependable urban supply. Taken together, this body of work suggests that national or urban-aggregate access statistics, however statistically well-behaved, should be read alongside evidence of functional and distributional strain within the sector.

Governance, Public Investment, and Access to Basic Services

The relationship between public investment priorities and infrastructural outcomes is central to the governance literature. Nigeria's Voluntary National Review of Sustainable Development Goal 6 acknowledged persistent gaps in sanitation and water access sufficient to warrant a presidential declaration of a state of emergency in the WASH sector in 2018, alongside major donor-financed interventions intended to accelerate progress toward universal coverage (Ogunbode, 2025; United Nations Department of Economic and Social Affairs, 2020). Nigeria's own WASH sector finance advocacy strategy documents a persistent and substantial funding gap between the domestic resources currently allocated to water, sanitation, and hygiene and the levels required to meet national and SDG 6 targets, and calls explicitly for improved budget monitoring and disaggregated financial data collection precisely the kind of WASH-specific expenditure series that is not yet available for long-run national trend analysis and that this study is consequently unable to use directly (UNICEF, 2023). Declarations of emergency and donor financing therefore operate alongside domestic budgetary trends that do not always signal a commensurate shift in governmental prioritization, an issue this study returns to directly, and treats with considerably more caution than in the original analysis, through its use of general public expenditure on education as an indirect fiscal comparator.

Inclusive governance, understood through the lens of participation and representation, is a further dimension emphasized in the water governance literature: stakeholder engagement, transparency, and the representation of historically marginalized groups, including women, are increasingly framed as preconditions for legitimate and sustainable resource governance, since women and children bear a disproportionate share of the burden of water collection where infrastructure is inadequate. World Bank programme monitoring of Nigeria's ongoing Sustainable Urban and Rural Water Supply, Sanitation and Hygiene programme has itself noted that data on women's participation in community-level water-management structures remain limited, with anecdotal evidence suggesting that women rarely occupy leadership positions within water-user committees a further indication that women's parliamentary representation, the only long-run inclusive-governance proxy available in the WDI series, is a distal structural indicator rather than a direct measure of gendered participation in water-sector decision-making (World Bank, 2025b).

Empirical Review

A number of empirical studies have examined specific dimensions of Nigeria's water infrastructure and governance performance, using predominantly qualitative, review-based, or localized case-study methodologies. Adeoti et al. (2023) conducted a systematic literature review, applying the

PRISMA protocol to synthesize findings from fifteen peer-reviewed studies on water infrastructure failure in Nigeria; their analysis classified reported challenges into technical, financial, environmental, social, political, and institutional categories, and proposed a Sustainability Framework for Water Infrastructure spanning pre-construction, construction, and post-construction stages. Their review found institutional reform and governance-related solutions to be among the most frequently proposed remedies, accounting for roughly a fifth of all solutions identified across the reviewed literature, highlighting the centrality of governance failure to infrastructural underperformance.

Ngene et al. (2021) undertook a review of integrated water resources management practice in Nigeria, examining policy documents and sector reports to assess the extent to which River Basin Development Authorities and related institutions have achieved coordinated management of the country's water resources. Their review found that weak inter-agency coordination, overlapping statutory mandates, and inadequate capital investment have persistently constrained the sector's ability to convert Nigeria's substantial water resource endowment into reliable urban supply, a finding that parallels the institutional fragmentation highlighted in the broader governance literature.

Using a poverty-diagnostic approach that combined national household survey data with sector expenditure review, the World Bank (2017) found that piped water access through in-house connections had regressed over time even as headline "improved water source" statistics continued to rise, and that fewer than a third of poor Nigerians had access to an improved water source, with rural households disproportionately required to undertake long round-trips to fetch water. This finding is particularly significant for the present study, as it demonstrates empirically, using an earlier tranche of the same broad indicator family analyzed here, that a rising national access statistic can coexist with deteriorating service quality along a more specific sub-indicator (piped, in-house connections).

More recently, Ogunbode (2025) conducted a qualitative secondary-data review of Nigeria's progress toward Sustainable Development Goal 6 between 2016 and 2024, drawing on reports from the Federal Ministry of Water Resources, the National Bureau of Statistics, and international agencies, and using a multi-theoretical framework combining sustainability and institutional perspectives. That review found that Nigeria's 2023 Voluntary National Review highlighted ongoing poor infrastructure maintenance, limited funding, and weak institutional coordination, and concluded more broadly that the country's SDG 6 reporting still lacks the timeliness, detail, and consistency required to support inclusive planning and accountability, but the review stopped short of applying formal statistical trend or regression techniques to the underlying access time series. Ohwo (2016), in an earlier review of public water provision in Nigerian cities, similarly catalogued institutional, financial, and infrastructural constraints on urban utilities without subjecting national access statistics to quantitative trend testing.

Across this body of empirical work, a consistent methodological pattern emerges: existing studies are overwhelmingly qualitative, review-based, or confined to localized case studies of individual states, utilities, or donor-funded programmes, and rely on document review, household surveys, expert interviews, or programme monitoring data as their primary data-collection technique. Few, if any, apply structured statistical trend regression, non-parametric trend confirmation, and time-series diagnostic testing to Nigeria's long-run, national-level water-access time series, and none of the reviewed studies explicitly tests, and then interrogates for spuriousness, the statistical association between that trend and independent governance-sensitive proxies such as public expenditure prioritization or inclusive political representation.

Research Gap

The empirical review above reveals a methodological and substantive gap that this study is designed to address, though the scale of that contribution should be stated precisely rather than asserted broadly. Methodologically, the Nigerian water governance literature is dominated by systematic qualitative reviews (Adeoti et al., 2023; Ohwo, 2016; Ogunbode, 2025) and survey- or programme-monitoring-based diagnostics confined to selected states, utilities, or donor programmes (World Bank, 2017; World Bank, 2025b; Ngene et al., 2021), rather than formal statistical trend analysis, applied with time-series diagnostics, to the full national time series. The mere fact that few prior studies have applied OLS trend regression and Pearson correlation to this series does not, on its own, constitute a major theoretical contribution; the more defensible and precisely stated contribution of this study is that it provides an exploratory quantitative assessment of long-run official water-access indicators, subjects that assessment to standard time-series robustness checks, and thereby demonstrates the limitations of interpreting national access indicators, and of correlating them with indirect governance proxies, independently of institutional evidence and formal diagnostic testing.

Substantively, while the reviewed studies establish, largely through qualitative and case-based evidence, that Nigeria's water governance architecture is fragmented and underfinanced, none explicitly tests, using both raw and detrended statistical association, whether the long-run national water-access trend moves together with, diverges from, or is merely coincidentally correlated with a governance-sensitive fiscal proxy such as public expenditure on education, or a governance-sensitive political proxy such as women's parliamentary representation. This study addresses both gaps, and, in a further departure from the qualitative literature it reviews, uses the resulting robustness evidence itself as a substantive finding: namely, that an apparently strong statistical relationship between two governance-relevant national time series can arise entirely from shared temporal trend rather than from any underlying fiscal or institutional mechanism, a methodological caution of direct relevance to future quantitative governance research in this and comparable policy domains.

Methodology

Research Design

The study adopts a quantitative, ex post facto trend-analysis design using secondary annual time-series data. This design is appropriate because the study neither manipulates any variable nor collects data prospectively; rather, it analyses pre-existing, publicly documented national statistics to establish patterns of change and association that already exist in the historical record. Because annual observations of the same national indicator are not statistically independent of one another, the design is treated explicitly, and diagnosed accordingly (Section V(c)), as a time-series design rather than as a simple cross-sectional correlational design, consistent with peer-review guidance received on the original submission. As the study relies exclusively on secondary, aggregate, publicly available statistics rather than on human subjects or personally identifiable information, no institutional ethics approval was required; nonetheless, all figures are reported without alteration from their original source, all missing observations are disclosed rather than silently estimated, and every secondary source drawn upon is explicitly cited in-text and listed in the References in accordance with APA 7th edition conventions, consistent with standard expectations of data integrity and intellectual honesty in empirical social-science research.

Research Instrument and Data Source

Because the study is based entirely on documentary, secondary data rather than primary fieldwork, no questionnaire, interview schedule, or observational checklist was administered. The research

instrument consisted instead of a structured secondary-data extraction template, used to systematically retrieve, code, and organize the relevant indicator values, by year, from the World Bank World Development Indicators (WDI) database for Nigeria. The WDI database in turn compiles internationally harmonized statistics, including the WHO/UNICEF Joint Monitoring Programme (JMP) series on drinking water access, UNESCO Institute for Statistics data on education expenditure, and Inter-Parliamentary Union data on legislative representation; the credibility of the instrument therefore rests on the standardized data-collection and harmonization protocols of these originating international agencies, rather than on a researcher-designed measurement scale. Table A reports the exact WDI indicator code for each series, the precise period for which each series is available, and the download reference, so that the extraction is fully reproducible.

Variable	Operational Definition	WDI Indicator Code	Data Source	Period Covered	N
Urban basic drinking-water access	Proportion of the urban population using at least basic drinking-water services (%)	SH.H2O.BASW.UR.ZS	World Bank WDI / WHO-UNICEF JMP	2000–2024	25
Safely managed drinking-water services	Proportion of the total population using safely managed drinking-water services (%)	SH.H2O.SMDW.ZS	World Bank WDI / WHO-UNICEF JMP	2000–2024	25
Government expenditure on education	Government expenditure on education, total (% of total government expenditure)	SE.XPD.TOTL.GB.ZS	World Bank WDI (UNESCO Institute for Statistics)	2012–2024	13
Women's seats in National Assembly	Proportion of seats held by women in the national parliament (%)	SG.GEN.PARL.ZS	World Bank WDI (Inter-Parliamentary Union)	2000–2024 ^a	25

Note. Table A. Data Sources and Operational Definitions of Study Indicators. WDI = World Development Indicators; JMP = Joint Monitoring Programme. WHO/UNICEF JMP estimates are themselves partly modelled through interpolation between household survey rounds, a feature that is revisited critically in the Discussion. ^aA single further observation for women's parliamentary representation is available for 2025 (4.21%) in the WDI extract, but is excluded from the primary 2000–2024 analysis window because the water-access series and the education-expenditure series do not extend to 2025.

Conceptual and Model Specification

Drawing on the OECD water governance principles and institutional theory outlined above, the study conceptualises urban water access at time t as a function of public investment prioritisation, institutional coordination, inclusive governance, and the passage of time itself (capturing cumulative infrastructural build-out), expressed in general functional form as:

$$\text{Water_Access}(t) = f[\text{Public_Investment}(t), \text{Institutional_Coordination}(t), \text{Inclusive_Governance}(t), \text{Time}] + \varepsilon(t) \text{ (Eq. 1)}$$

Institutional_Coordination(t) is discussed qualitatively through the literature reviewed above but is not directly measurable within the available secondary dataset; Public_Investment(t) and Inclusive_Governance(t) are proxied, imperfectly and indirectly, by government expenditure on education and women's parliamentary representation respectively; and Time captures the cumulative, path-dependent component of infrastructural expansion. Equation 1 is not estimated in full; it provides the conceptual framework within which the reduced-form statistical models below are estimated and interpreted, and within which the indirect status of the two available proxies should be read throughout.

The first reduced-form model estimates the statistical trend in each water-access indicator using simple linear (OLS) regression, with year as the predictor:

$$Y(t) = \beta_0 + \beta_1 \times \text{Year}(t) + \varepsilon(t) \text{ (Eq. 2)}$$

where Y(t) is the value of the water-access indicator in year t, β_0 is the model intercept, β_1 is the unstandardized slope coefficient representing the average annual change in the indicator, and $\varepsilon(t)$ is the residual error term. Model fit is evaluated using the coefficient of determination, $R^2 = 1 - (\text{SS}_{\text{residual}} / \text{SS}_{\text{total}})$, and overall significance is tested using the F-ratio, with a conventional threshold of $p < .05$ adopted throughout.

Four further diagnostic procedures were added to every trend regression and to the correlation analysis, because annual observations of a national indicator cannot be assumed to be independent, and a very high R^2 in an annual time series can reflect auto correlated, non-stationary series rather than a well-specified causal model:

- a. Durbin-Watson statistic, to test the OLS residuals for first-order autocorrelation (values close to 2 indicate no autocorrelation; values close to 0 or 4 indicate strong positive or negative autocorrelation, respectively);
- b. The Augmented Dickey-Fuller (ADF) test, applied to each series in levels and, where the level series was found to be non-stationary, to its first difference, to test formally for the presence of a unit root (non-stationarity) that would render simple OLS trend and correlation statistics potentially spurious;
- c. The non-parametric Mann-Kendall trend test and the associated Sen's slope estimator, as a distribution-free cross-check on the direction, significance, and magnitude of each OLS trend, since Mann-Kendall does not assume normally distributed, homoscedastic residuals and is widely used for robustness confirmation of environmental and infrastructural trend series; and
- d. Detrended and first-differenced correlation, applied specifically to the water-access/education-expenditure relationship identified in the original submission as the most consequential and most vulnerable to common-trend confounding, together with a leave-one-out sensitivity analysis across the thirteen overlapping observations.

Detrended correlation was computed by first regressing each series on Year (Equation 2), retaining the residuals from that regression, and then computing the Pearson correlation between the two sets of residuals; because a linear time trend common to both series is removed prior to correlation, any relationship that survives this procedure cannot be attributed to the two series simply moving together over time. First-differenced correlation was computed analogously, by correlating the year-on-year changes:

$$(\Delta Y_t = Y_t - Y_{t-1})$$

in each series rather than their levels. The Pearson product-moment correlation coefficient itself was computed, in all cases, as:

$$r = \Sigma[(X_i - M_X)(Y_i - M_Y)] / \sqrt{\Sigma(X_i - M_X)^2 \times \Sigma(Y_i - M_Y)^2} \quad (Eq. 3)$$

where X_i and Y_i are paired observations on the two variables being correlated and M_X and M_Y are their respective means; coefficients are interpreted using conventional benchmarks (values at or above .70 regarded as strong, .30–.69 as moderate, and below .30 as weak), alongside their associated significance levels. As a supplementary descriptive measure of long-run growth, the compound annual growth rate of each water-access indicator was also computed as:

$$CAGR = [(Value_end / Value_start)^{(1/n)}] - 1 \quad (Eq. 4)$$

where Value_end and Value_start are the indicator's values in the final and initial years of the series, respectively, and n is the number of year-on-year intervals spanned. Because CAGR can be difficult to interpret intuitively for percentage series that are themselves approaching an upper bound, this analysis reports it only as supplementary information alongside the more directly interpretable average annual percentage-point change (the first-difference mean) for each series. All computations were performed in Python (pandas, statsmodels, scipy, and pymannkendall), with descriptive and OLS results cross-checked against procedures equivalent to those implemented in IBM SPSS Statistics.

(d) Variables

Variable	Role	Measurement Level	Unit	Status as Governance Indicator
Urban basic drinking-water access	Dependent	Ratio (continuous)	% of urban population	Outcome indicator
Safely managed drinking-water services	Dependent	Ratio (continuous)	% of population	Outcome indicator
Government expenditure on education	Indirect fiscal comparator	Ratio (continuous)	% of total govt. expenditure	General social-sector fiscal indicator (not a water-sector expenditure measure)
Women's seats in National Assembly	Indirect political comparator	Ratio (continuous)	% of legislative seats	Structural political-inclusion indicator (not a direct water-governance measure)
Year	Trend predictor	Interval (continuous)	Calendar year	—

Note. Table B. Classification of Study Variables by Role, Measurement Level, and Governance Status. Government expenditure on education and women's parliamentary representation are no longer labelled “governance proxies” in the variable classification; they are relabelled, respectively, as a general public-sector fiscal indicator and a structural political-inclusion indicator. Neither variable measures water-sector investment, institutional coordination, or gender-responsive water governance directly, and their statistical relationships with water access reported in Section VII should be read as indirect and, in the case of education expenditure, as demonstrably confounded by common time trend (see Section VII, Robustness Analysis) rather than as evidence of a direct governance mechanism.

Figure 6. Suggested Revised Analytical Framework:
Governance-to-Access Pathway

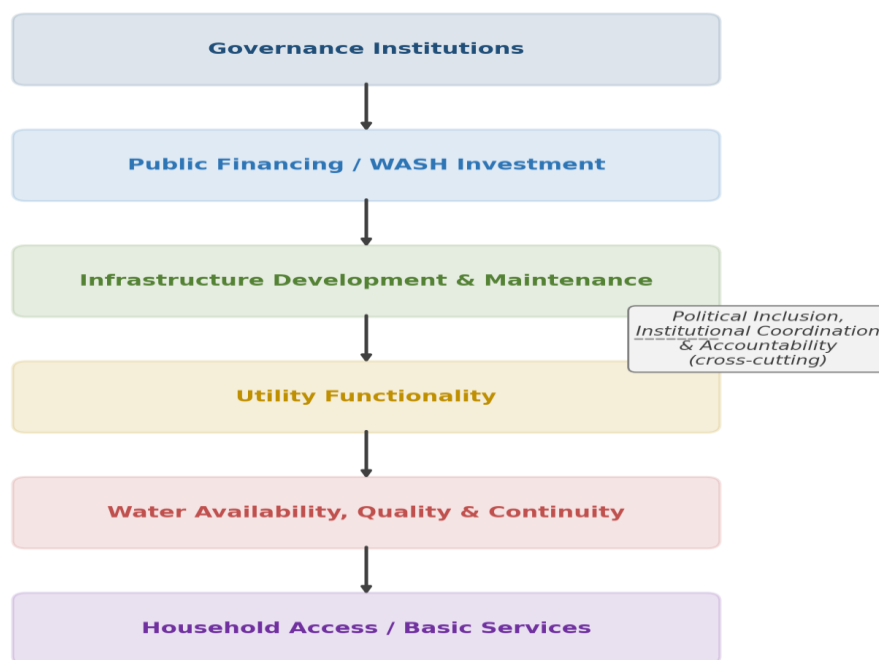


Figure 6: Analytical framework: governance-to-access pathway, with political inclusion, institutional coordination, and accountability treated as cross-cutting conditions rather than a single directly estimated variable (cf. Equation 1).

VI. Results

Descriptive Statistics

Table 1 presents descriptive statistics for the four indicators analysed over 2000–2024, include the median, range, coefficient of variation, and average annual first-difference (percentage-point change) alongside the original mean, standard deviation, and shape statistics. Urban basic drinking-water access averaged 81.57% (SD = 8.35, median = 81.37, range = 26.36 percentage points) over 2000–2024, increasing by an average of 1.10 percentage points per year (SD of annual change = 0.16), with a near-symmetric distribution (skewness = 0.06) and a flat, platykurtic shape (kurtosis = -1.23) consistent with steady, low-variance annual increments rather than episodic jumps. Safely managed drinking-water services averaged 22.01% (SD = 5.59, median = 23.19, CV = 25.41%), roughly a quarter of the level of basic access, increasing by an average of 0.72 percentage points per year underscoring a substantial and persistent quality gap between merely “basic” and “safely managed” water services nationally, which is examined further below (Figure 2).

Government expenditure on education averaged 6.25% of total government expenditure over the thirteen years for which data were available (SD = 2.09, CV = 33.34%, the highest relative variability of the four series), and fell by an average of 0.46 percentage points per year over that window; the proportion of parliamentary seats held by women averaged 5.39% (SD = 1.43, CV = 26.59%), with an average annual change statistically indistinguishable from zero (mean first difference = 0.02, SD = 1.31), consistent with the flat, non-significant trend confirmed in Table 3.

Variable	N	Mean	SD	Median	Min	Max	Range	CV (%)	Mean Δ / yr
Urban basic drinking water access (%)	25	81.57	8.35	81.37	68.72	95.08	26.36	10.23	+1.10
Safely managed drinking water services (%)	25	22.01	5.59	23.19	12.61	29.90	17.29	25.41	+0.72
Govt. expenditure on education (% of total)	13	6.25	2.09	5.95	2.98	9.26	6.28	33.34	-0.46
Women's seats in National Assembly (%)	25	5.39	1.43	5.56	3.38	7.22	3.84	26.59	+0.02

Note. Table 1. Descriptive Statistics for Study Variables, Nigeria, 2000–2024 (education expenditure, 2012–2024). CV = coefficient of variation ($SD \div \text{mean} \times 100$). Mean Δ /yr is the average year-on-year first difference, reported as a more directly interpretable supplement to CAGR (see Eq. 4 and accompanying text). All water-access and women's-representation figures cover 2000–2024 only, consistent with the corrected study period; the single available 2025 observation for women's representation (4.21%) is excluded from this window for consistency (Table A).

Trend Regression and Time-Series Diagnostics

A simple linear regression of urban basic drinking-water access on year produced an exceptionally strong linear fit (Table 2): year accounted for 99.9% of the variance in the access indicator, $F(1, 23) = 30,661.77$, $p < .001$, with each additional year associated with an average increase of 1.13 percentage points in urban basic water access. The non-parametric Mann-Kendall test confirmed a statistically significant increasing trend ($Z = 6.98$, $p < .001$) with an associated Sen's slope of 1.14 percentage points per year, closely matching the OLS estimate and indicating that the trend result is not an artefact of the linear-model assumptions. However, the Durbin-Watson statistic for the OLS residuals was 0.50, far below the neutral benchmark of 2, indicating strong positive first-order autocorrelation, and the Augmented Dickey-Fuller test failed to reject the null hypothesis of a unit root in the level series ($ADF = -2.01$, $p = .281$), indicating that the series is non-stationary. Both diagnostics are expected, and unsurprising, in a series this close to deterministic linear growth, but they carry an important methodological implication addressed in the Discussion: the very high R^2 and F-statistic reported here should not be read as evidence of a well-specified causal model of infrastructural expansion, but rather as a description of an extremely smooth, non-stationary trend whose statistical behaviour is consistent with the modelled/interpolated construction of the underlying JMP series.

Indicator	N	b_1 (pts/yr)	R^2	F (df)	p	Durbin-Watson	ADF (level), p	Mann-Kendall p	Sen's slope
Urban basic water access	25	1.13	.999	30,661.77 (1,23)	<.001	0.50	-2.01, .281	<.001	1.14

Safely managed water services	25	0.75	.987	1,682.62 (1,23)	<.001	0.10	−2.15, .226	<.001	0.76
Govt. expenditure on education	13	−0.51	.914	117.32 (1,11)	<.001	1.53	−0.09, .951	<.001 ^b	−0.49
Women's seats in National Assembly	25	−0.01	.006	0.13 (1,23)	.721	0.80	−1.40, .583	.742 ^c	0.00

Note. Table 2. Trend Regression and Time-Series Diagnostics for All Four Series, Nigeria, 2000–2024 (education expenditure, 2012–2024). ^bMann-Kendall confirms a significant decreasing trend for education expenditure ($Z = -3.84$, $p < .001$), consistent with the OLS estimate. ^cMann-Kendall for women's representation confirms “no trend” ($Z = -0.33$, $p = .742$), consistent with the non-significant OLS slope. ADF tests were conducted on level series; where the level series was non-stationary (all four indicators, $p > .05$), first-differenced ADF results are reported and discussed in the text. All four level series fail to reject the unit-root null, indicating that none of the four indicators is stationary in levels over the analysis window a diagnostic finding that directly motivates the detrended and first-differenced robustness analysis reported below.

For the two education-expenditure and water-access series specifically, first-differenced ADF tests were also examined. The first-differenced basic-access series did not clearly reject the unit-root null either (ADF = -0.67 , $p = .854$), which is unsurprising given that the series' first differences are themselves extremely stable (SD = 0.16 percentage points; Table 1) and therefore close to a constant, a pattern the ADF test is not well powered to distinguish from persistent non-stationarity in a series of only 25 annual observations. The first-differenced education-expenditure series showed a very strong rejection of the unit-root null ($p < .001$); however, given the short series length ($N = 13$, $N = 12$ after differencing), this result is reported with caution rather than treated as definitive, consistent with the general caution urged throughout this revised analysis regarding statistical inference from short annual series (see Limitations, Section VIII).

Figure 1. Urban Basic and Safely Managed Drinking Water Access, Nigeria, 2000–2024

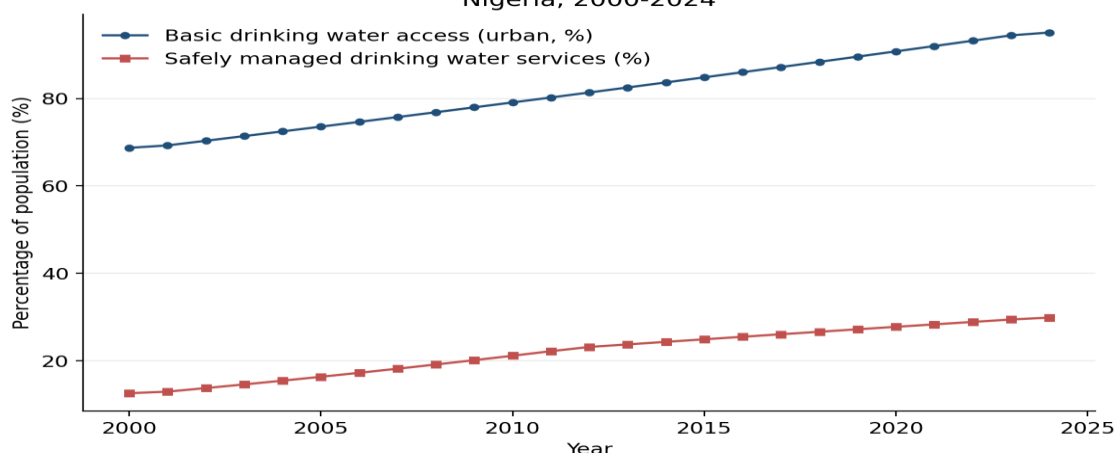


Figure 1. Trend in urban basic and safely managed drinking water access in Nigeria, 2000–2024.

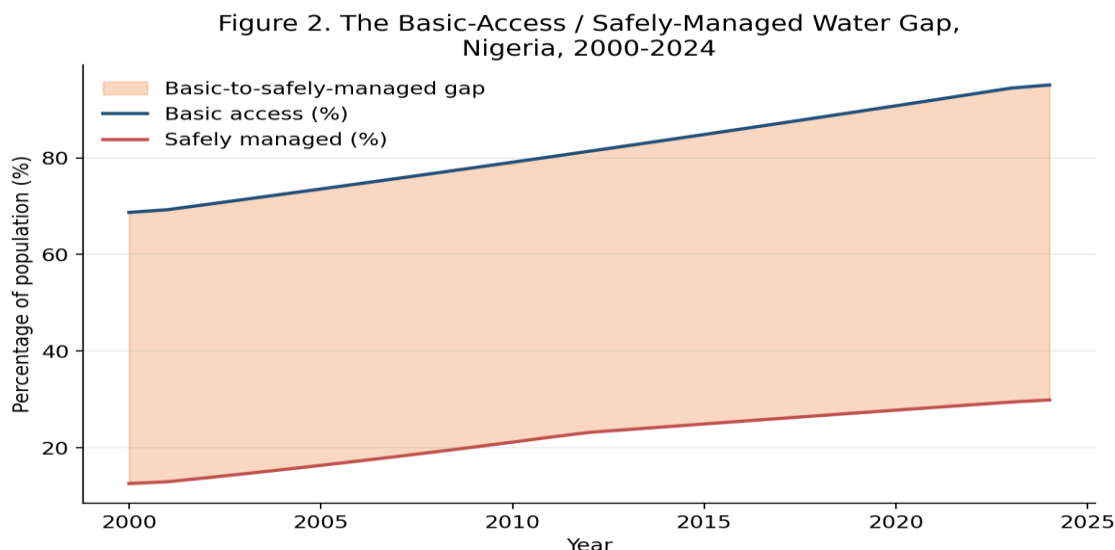


Figure 2. The basic-access / safely-managed water gap, Nigeria, 2000–2024.

The correlation between the two water-access indicators was very strong and positive ($r = .991$, $p < .001$, $N = 25$), indicating that, at the national-aggregate level, improvements in basic access have been broadly accompanied by improvements in safely managed access. Because both series share the same underlying upward time trend, however, this correlation is, in line with the methodological caution developed throughout this revision, unsurprising and adds relatively little independent information; the more analytically important finding is the large and persistent absolute gap between the two measures (Figure 2). Over 2000–2024, urban basic water access averaged 81.57% while safely managed water services averaged only 22.01% a gap that was already substantial at the start of the period (56.1 percentage points in 2000) and widened further, to 65.2 percentage points, by 2024, because basic access has been rising in absolute percentage-point terms faster than safely managed access even though the latter's proportionate (CAGR) growth rate is higher. This persistent and widening gap indicates that classification as having access to a basic or improved source does not, for the large majority of the urban population so classified, correspond to access to a safely managed water service, and it is this distinction rather than the high correlation between the two series that carries the more meaningful governance implication: substantial numbers of Nigerians counted as having “access” continue to face unresolved concerns around water quality, on-premises availability, and contamination risk.

Applying Equation 4, the compound annual growth rate over 2000–2024 was 1.36% per annum for urban basic water access, compared with a markedly higher 3.66% per annum for safely managed drinking-water services indicating that, although safely managed access remains at a much lower absolute level, it has been closing the proportionate gap with basic access at more than twice the annual rate. Because CAGR compresses information about a percentage series approaching an upper bound, the average annual percentage-point changes reported in Table 1 (+1.10 and +0.72 points per year, respectively) are offered as the primary, more directly interpretable descriptive measures of annual progress, with CAGR retained only as supplementary information.

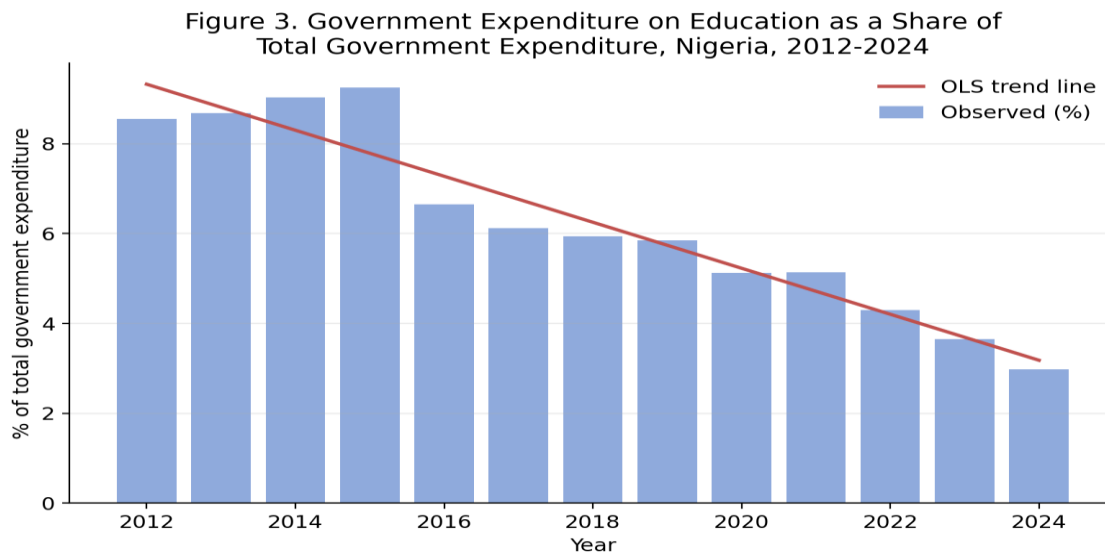


Figure 3. Government expenditure on education as a share of total government expenditure, Nigeria, 2012–2024.

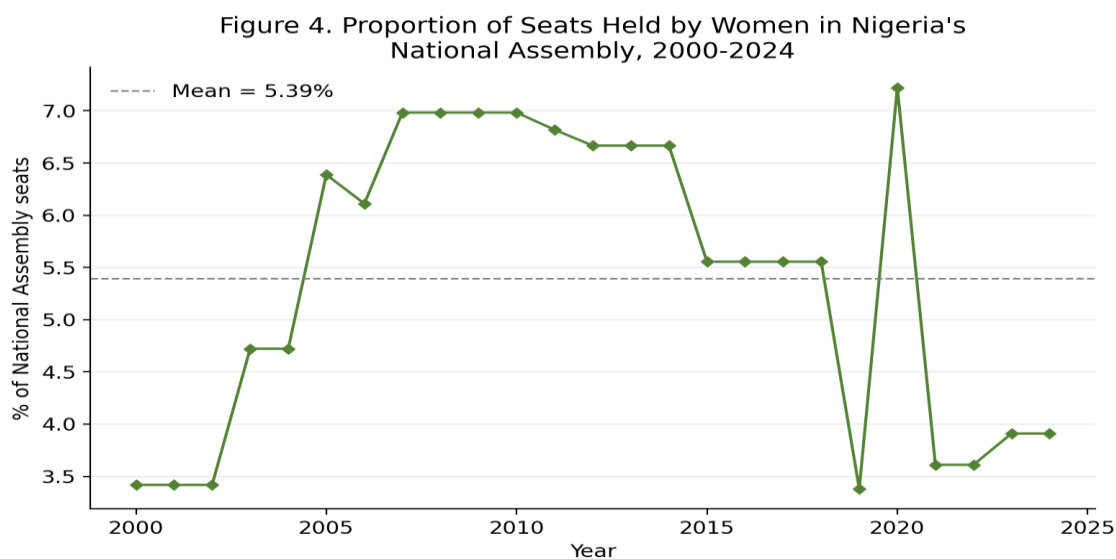


Figure 4. Proportion of seats held by women in Nigeria's National Assembly, 2000–2024.
Correlation with Indirect Fiscal and Political Comparators

Table 3 presents raw (level) Pearson correlations between the two water-access indicators and the two indirect comparators. Urban basic water access was strongly and negatively correlated with government expenditure on education over the overlapping 2012–2024 period ($r = -.955$, $p < .001$, $N = 13$): as the official water-access indicator continued its steady ascent, the share of government spending allocated to education fell from 9.26% in 2015 to 2.98% in 2024. The correlation between urban basic water access and women's parliamentary representation was weak, negative, and not statistically significant ($r = -.095$, $p = .652$, $N = 25$), indicating that gains in water-access statistics over the study period have occurred independently of any corresponding gain in this particular measure of inclusive political representation, which itself showed no significant trend (Table 2; Figure 4).

Variable	N	1	2	3
1. Urban basic water access (%)	25	—		
2. Safely managed water services (%)	25	.991**	—	
3. Govt. expenditure on education (%)	13	-.955**	-.955**	—
4. Women's seats in National Assembly (%)	25	-.095	-.007	n/a

Note. Table 3. Raw (Level) Pearson Correlation Matrix, Urban Water Access and Indirect Comparators.

**Correlation is significant at the .01 level (2-tailed). Correlations involving government expenditure on education are computed over the overlapping $N = 13$ years (2012–2024) for which both series are available. As flagged in Table 2, all four series are non-stationary in levels; the raw correlations reported here are therefore examined for common-trend confounding in the robustness analysis immediately below, before any substantive interpretation is offered.

Robustness Analysis: Testing for Spurious Correlation

The raw correlation between urban basic water access and government expenditure on education ($r = -.955$), the result most vulnerable to a specific and well-documented statistical analysis: two independently trending, non-stationary time series will very often produce a strong Pearson correlation coefficient purely because both are trending in some direction against calendar time, even in the complete absence of any substantive relationship between them. Because Table 2 confirms that both water access (increasing) and education expenditure (decreasing) are non-stationary trending series over the overlapping window, this concern is directly applicable here and was tested formally, as follows.

First, both series were detrended by regressing each on Year and retaining the OLS residuals, which represent each series' deviation from its own linear time trend in a given year. The correlation between these two residual series the association between water access and education expenditure with the shared calendar-time trend removed from both fell from $r = -.955$ to $r = .048$ ($p = .876$, $N = 13$), a result indistinguishable from zero. Second, the same test was repeated using first-differenced series (year-on-year change in each variable), which removes any linear or smoothly varying trend by construction; this produced a materially identical result ($r = .051$, $p = .875$, $N = 12$). Figure 5 displays both the raw and detrended scatterplots side by side.

Figure 5. Raw versus Detrended Association Between Urban Basic Water Access and Government Expenditure on Education, Nigeria, 2012–2024

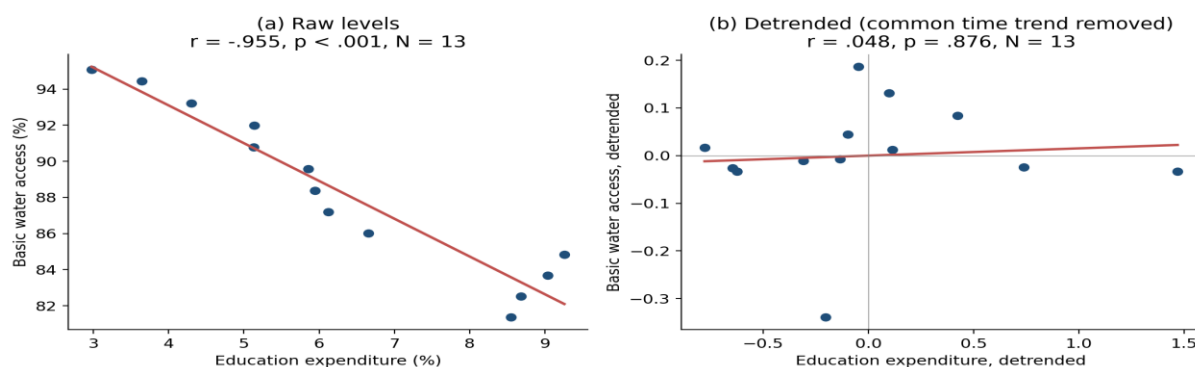


Figure 5. Raw versus detrended association between urban basic water access and government expenditure on education, Nigeria, 2012–2024.

Panel (a) reproduces the strong raw correlation;

Panel (b) shows the same thirteen years after the linear time trend common to both series has been removed, at which point the association is statistically indistinguishable from zero.

This result is unambiguous, the strong negative raw correlation between water access and education expenditure does not survive either detrending or first-differencing, and should therefore be interpreted as a statistical artefact of two series independently trending across the same seventeen-year window in opposite directions (water access rising, education expenditure falling) rather than as evidence of any substantive fiscal relationship, causal or otherwise, between education spending and water-access outcomes.

A leave-one-out sensitivity analysis was also conducted on the raw correlation, sequentially excluding each of the thirteen overlapping years in turn: the recomputed correlation coefficient ranged narrowly from $r = -.944$ to $r = -.975$ across all thirteen exclusions, indicating that the raw correlation itself is not driven by any single influential year and is a stable feature of the raw, trending data. This stability, however, is fully consistent with the trend-confounding explanation rather than evidence against it: a correlation produced by two smooth, monotonic trends will typically be highly stable to the removal of any one observation, precisely because the coefficient is being driven by the shared trend rather than by any specific data point. The $N = 13$ sample available for this comparator also remains a material limitation independent of the trend issue, and is discussed further in Section VIII (Limitations).

Discussion

The statistical analysis yields three findings that carry distinct,

First, the near-deterministic linearity of the urban basic water-access series ($R^2 = .999$) is, on reflection, more a methodological artefact than a substantive finding, and this reading is now further supported, rather than merely asserted, by the time-series diagnostics reported in Table 2: the series is non-stationary in levels (ADF $p = .281$), its OLS residuals are strongly autocorrelated (Durbin-Watson = 0.50), and it's extremely low year-on-year variability (SD of first difference = 0.16 percentage points) is difficult to reconcile with a process subject to normal annual administrative, fiscal, and infrastructural variation. Because Joint Monitoring Programme estimates are interpolated and modelled between sparse household survey rounds rather than measured annually on the ground, the resulting smooth trend line should not be mistaken for evidence of uniformly incremental, well-managed infrastructural expansion. This caution is reinforced by the qualitative and case-study literature, which documents persistent technical, financial, and institutional failure within Nigeria's urban water utilities, including high non-revenue water, poor cost recovery, and infrastructure operating well beyond its designed lifespan (Adeoti et al., 2023; Ohwo, 2016). The statistical smoothness of the official indicator and the documented unevenness of ground-level service delivery are not necessarily contradictory; rather, they point to a governance environment in which national accounting and estimation conventions and lived infrastructural experience diverge, a gap that is itself an indicator of weak monitoring and disaggregated reporting capacity within the sector, and precisely the reasoning underlying the principle, stated in Section II and maintained throughout this revision, that measurement smoothness should not by itself be read as evidence of either governance success or governance failure.

Second, and in the most substantial revision to the original analysis, the strong negative raw correlation between rising urban water access and falling government expenditure on education is

not a genuinely interpretable governance signal. The robustness analysis reported in Section VI shows that this association is fully explained by both series independently trending across the same period; once that shared trend is removed, by detrending or by first-differencing, the association is statistically indistinguishable from zero ($r = .05$ in both cases). The original manuscript's discussion of this correlation offered two plausible substantive readings non-state and donor-driven provision substituting for public investment, and a broader fiscal contraction squeezing multiple social sectors simultaneously; both readings remain independently plausible as general propositions about the Nigerian fiscal and water-governance environment, and are consistent with the wider literature on non-state water provision and fiscal-space constraints (Ogunkan, 2022; Ohwo, 2016; World Bank, 2017), but neither reading is any longer supported, specifically, by the statistical relationship between these two particular WDI series, and the study accordingly withdraws the earlier suggestion that the correlation itself constituted evidence for either reading. This is offered as a substantive methodological lesson in its own right: a strong correlation between two independently trending national governance-relevant time series should be treated as a hypothesis requiring detrended or differenced confirmation, not as a finding in its own right, before it is used to support a governance narrative.

Third, the statistically weak and non-significant relationship between water access and women's parliamentary representation ($r = -.10$, $p = .652$, stable and consistent whether tested in levels via Pearson correlation or via the non-significant Mann-Kendall trend for women's representation itself) suggests that gains in one dimension of inclusive governance have not been mirrored in another. This finding should be interpreted cautiously, given that women's representation in the National Assembly is, as reframed in Table B, a distal structural indicator of political inclusion rather than a direct measure of gender-responsive water governance; nonetheless, it is consistent with observations elsewhere in the governance literature, and with World Bank programme-monitoring evidence on the limited representation of women in local water-user committees (World Bank, 2025b), that infrastructural service expansion and the depth of inclusive political and institutional participation do not automatically move together, and that each requires distinct, deliberate institutional attention.

Collectively, these findings support a narrower, more defensible version of this study's central argument than that offered in the original submission: statistical trend analysis, properly interrogated with time-series diagnostics rather than accepted at face value, does not simply confirm a narrative of steady infrastructural progress, but it also does not, on the evidence presented here, support a specific causal or even confidently associative governance narrative linking rising water-access statistics to falling public education expenditure. What the analysis does support, robustly, is that (a) the water-access trend is exceptionally and probably artificially smooth, most plausibly reflecting JMP estimation methodology; (b) the water-access trend and the education-expenditure trend are both real, statistically confirmed (Mann-Kendall) directional trends in their own right, moving in opposite directions over the same calendar period, without this co-movement constituting evidence of a relationship between them once common trend is accounted for; and (c) women's parliamentary representation, as a proxy for inclusive governance, shows neither a significant trend of its own nor any significant association with water-access outcomes. It bears repeating, consistent with the proxy status of the governance variables set out in Table B and Equation 1, that none of the correlational associations reported here even where they had survived robustness testing would establish direct causation, and the revised analysis accordingly avoids causal language throughout.

Limitations

The findings of this study should be interpreted within the scope of the data, indicators, and analytical design employed. The principal limitations are as follows:

1. **Study period and data availability:** The analysis covers 2000–2024, reflecting the period for which sufficiently consistent observations were available across the principal indicators used in the study. The analysis therefore does not incorporate subsequent observations that may become available in future statistical releases.
2. **Use of broad governance-related indicators:** The study employs government education expenditure and women’s parliamentary representation as contextual indicators of broader fiscal and institutional conditions. These indicators are not sector-specific measures of water governance and should therefore be interpreted as complementary contextual variables rather than direct measures of water-sector governance.
3. **Absence of direct WASH expenditure data:** The study does not directly examine government expenditure on water, sanitation and hygiene (WASH). Consequently, the findings cannot be interpreted as establishing a direct relationship between public expenditure specifically allocated to the water sector and changes in water access. Future studies using sufficiently consistent WASH-specific expenditure data could provide a more direct assessment of the financing–outcome relationship.
4. **Interpretation of education expenditure:** The fiscal indicator represents government expenditure on education as a proportion of total government expenditure. Changes in this ratio may reflect variations in other components of public expenditure, government revenue, or the overall expenditure structure and should not be interpreted as evidence of corresponding changes in absolute education spending or water-sector financing.
5. **Limited observations for the fiscal comparison:** The water-access and education-expenditure comparison is based on 13 overlapping annual observations (2012–2024). Although sensitivity analysis indicates that the observed raw association is not attributable to a single observation, the relatively small sample warrants caution in generalizing the correlation beyond the period examined.
6. **Time-series and non-stationarity considerations:** The variables exhibit substantial temporal trends. The study therefore incorporates detrending and first-differencing to reduce the possibility of spurious correlation. Nevertheless, unit-root and related time-series diagnostics applied to relatively short annual series have limited statistical power. The results should consequently be interpreted primarily as evidence of temporal association rather than causal relationships.
7. **Nature of internationally reported water-access estimates:** The water-access indicators are based on internationally harmonized estimates produced through the WHO/UNICEF Joint Monitoring Programme and subsequently reported through the World Bank database. Such estimates may incorporate modelling and interpolation between available observations. Accordingly, the exceptionally strong linear trend observed for urban basic water access should be interpreted as a feature of the reported statistical series rather than as evidence that physical infrastructure expanded at a uniform annual rate.
8. **National-level aggregation:** The study uses nationally aggregated indicators and therefore does not capture potentially important differences among states, cities, regions, or population groups. Variations in infrastructure condition, institutional capacity, financing, service reliability, and socioeconomic circumstances may therefore be obscured by national averages.
9. **Scope of the water-access indicators:** Access indicators provide an important measure of population coverage but do not fully capture continuity of supply, water quality, affordability,

reliability, on-premises availability, or infrastructure functionality. The findings should therefore be understood as evidence concerning reported access rather than a comprehensive assessment of water-service performance.

10. **Limited quantitative measurement of institutional coordination:** Institutional coordination among government agencies and levels of government is relevant to water-sector performance but was not represented by a dedicated quantitative indicator in the present analysis. Its role is consequently considered primarily within the interpretive and policy discussion rather than estimated statistically.

Taken together, these limitations define the appropriate scope of inference rather than invalidate the study's findings. The analysis provides evidence on the temporal trajectory of reported water access and demonstrates the importance of accounting for common trends when interpreting relationships between national development indicators. Future research could extend the analysis through disaggregated state- or city-level data, sector-specific WASH expenditure, service-functionality measures, water-quality indicators, and longer time series as more comprehensive data become available. Such extensions would permit more direct examination of the institutional, fiscal, and infrastructural mechanisms underlying changes in water-service outcomes in Nigeria.

Future Research

Future research should extend this analysis in at least four directions, several of which respond directly to the limitations identified above. First, state-disaggregated water-access and public-expenditure data, where they become available, would allow the national-level trends and the trend-confounding finding reported here to be tested for consistency across Nigeria's thirty-six states and the Federal Capital Territory, since governance capacity and fiscal performance are known to vary considerably at the subnational level. Second, future studies should incorporate a direct measure of public capital or recurrent expenditure on the water sector specifically for example, water-sector budget allocation, Federal Ministry of Water Resources expenditure, or state water-agency funding rather than the general education-expenditure comparator used in this study, once a sufficiently long and consistent series becomes publicly available; the WASH sector finance advocacy literature (UNICEF, 2023) explicitly identifies improved budget monitoring and disaggregated financial data collection as a current sector priority, and such data, once available, would allow the governance relationship examined here to be tested far more precisely and without the trend-confounding vulnerability documented in Section VI.

Third, statistical trend analysis of the kind conducted here should be complemented by primary household-level survey evidence and utility-level operational data such as non-revenue water rates, continuity of supply, and water-quality testing results, to test more directly the distinction, developed throughout this revised study, between official access classification and lived infrastructural and governance experience. Fourth, future work might extend the regression framework used here to a multiple regression, panel-data, or structural time-series specification of Equation 1 once a fuller set of governance indicators becomes available, allowing the relative contribution of public investment, institutional coordination, and inclusive governance to be estimated jointly, with appropriate stationarity and co-integration testing built in from the outset, rather than proxy-by-proxy as in the present exploratory analysis.

Conclusion

This study set out to place statistical trend analysis, strengthened in this revision by a fuller time-series diagnostic toolkit, ahead of governance interpretation in examining urban water access in Nigeria between 2000 and 2024. The evidence shows a strong, statistically robust, and non-parametrically confirmed upward trend in both urban basic and safely managed drinking-water

access, but one whose near-perfect linearity and non-stationary, strongly autocorrelated statistical signature should be read as evidence of the modelled, interpolated nature of the underlying JMP estimates rather than as proof of frictionless infrastructural delivery. When tested against the two available indirect comparators, the raw water-access trend moved in the opposite direction to government expenditure on education, but this association did not survive detrending or first-differencing and is accordingly interpreted here as a statistical artefact of common time trend rather than as a substantive governance relationship; water access also showed no meaningful relationship, at any stage of testing, with women's parliamentary representation. Jointly, these findings suggest that rising access statistics cannot, on the evidence available in this study, be shown either to be underwritten by strengthening public investment or to be undermined by its absence, and that a credible test of that relationship instead requires direct, disaggregated WASH-sector expenditure data that are not yet consistently available at the national level.

On this basis, four recommendations are offered, one of which is substantially revised from the original submission in light of the robustness findings above. First, federal and state water authorities should invest in disaggregated, functionality-based monitoring systems capturing continuity of supply, water quality, and infrastructure downtime that go beyond binary or modelled “access” classifications, so that policy responds to service reliability and not solely to nominal coverage. Second, rather than the original recommendation to protect education-expenditure shares (a recommendation this revised analysis no longer considers adequately supported by the evidence), government should improve the transparency and disaggregation of WASH-specific expenditure and infrastructure investment data, so that the relationship between public financing and water-service outcomes can be tested directly and independently in future research, rather than inferred indirectly through a general social-sector fiscal comparator. Third, institutional coordination among the Federal Ministry of Water Resources, River Basin Development Authorities, and state water agencies should be strengthened through clearer delineation of mandates and joint accountability mechanisms, consistent with the institutional-reform priorities identified in the water infrastructure sustainability literature. Fourth, deliberate measures to broaden inclusive participation in water governance including women's representation in both political office and water-sector decision-making bodies specifically should be pursued as a distinct policy objective in its own right, rather than assumed to follow automatically from infrastructural expansion, since the statistical evidence in this study finds no basis for such an assumption.

References

- Adeoti, O. S., Kandasamy, J., & Vigneswaran, S. (2023). Water infrastructure sustainability in Nigeria: A systematic review of challenges and sustainable solutions. *Water Policy*, 25(11), 1094–1111.
- Ngene, B. U., Nwafor, C. O., Bamigboye, G. O., Ogbiye, A. S., Ogundare, J. O., & Akpan, V. E. (2021). Assessment of water resources development and exploitation in Nigeria: A review of integrated water resources management approach. *Heliyon*, 7(1), Article e05955.
- Ogunbode, T. O. (2025). A nine-year critical review of progress and future strategies for sustainable development goal 6 in Nigeria from 2016 to 2024. *Discover Sustainability*, 6.
- Ogunkan, D. V. (2022). Achieving sustainable environmental governance in Nigeria: A review for policy consideration. *Urban Governance*, 2(1), 212–220.
- Ohwo, O. (2016). Challenges of public water provision in Nigerian cities: A review. *Journal of Water, Sanitation and Hygiene for Development*, 6(1), 1–12.

- UNICEF. (2023). Nigeria water, sanitation and hygiene sector: Finance advocacy strategy and plan. United Nations Children's Fund, Accelerating Sanitation and Water for All (ASWA) Programme.
- United Nations Department of Economic and Social Affairs. (2020). Nigeria: Voluntary national review Progress on achieving SDG 6. United Nations Sustainable Development Goals Knowledge Platform.
- World Bank. (2017). A wake-up call: Nigeria water supply, sanitation, and hygiene poverty diagnostic. World Bank Group.
- World Bank. (2025a). World development indicators [Data set; extract file API_NGA_DS2_en_excel_v2_4520.xlsx, accessed 15 August 2026]. World Bank Group.
- World Bank. (2025b). Nigeria Sustainable Urban and Rural Water Supply, Sanitation and Hygiene Program-for-Results (P170734): Implementation status and results report. World Bank Group.