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WHEN THE WELLS RUN DRY: EMPIRICAL EVIDENCE ON WATER STRESS, GOVERNANCE QUALITY AND HUMAN DEVELOPMENT IN SUB-SAHARAN AFRICA

Don OKELLO[1], Tibor FARKAS[2], Diána KOPONICSNÉ GYÖRKE[2]
[1]Hungarian University of Agriculture and Life Sciences, Doctoral School of Economics and Regional Science, 2100 Gödöllő, Páter Károly utca 1, Hungary
[2]Hungarian University of Agriculture and Life Sciences, Institute for Rural Development and Sustainable Economy, 2100 Gödöllő, Páter Károly utca 1, Hungary

ABSTRACT

The Sub-Saharan Africa region is faced by a severe and multidimensional water crisis threatening to undermine sustainable development efforts across the region. Despite the global commitment to SDG 6, 387 million from SSA by 2020 had no basic drinking water service access with pronounced disparities between urban and rural areas. Accordingly, whereas existing studies have explored water scarcity in relation to population pressures, human activities, and climate change, the relationship between human development, water stress and environmental governance quality remains underexplored. Specifically, the study aimed: to determine the influence of level of water stress on human development in SSA; and to establish the influence of environmental governance quality on human development in SSA. The study used secondary data from the World Bank for 24 SSA countries spanning 17 years from 2005 to 2021. The study employed Random-effects GLS regression using Stata 17. The model demonstrates that both water stress and environmental governance quality explain about 58.80% of the variation in human development overall. Similarly, both water stress and environmental governance quality explain approximately 40.33% and 37.60% variation in human development between and within the 24 Sub Saharan Africa countries respectively. The findings show how much both the level of water stress (β=.03092, p value = 0.000) and the quality of environmental governance (β=.03618, p value = 0.000) positively stress-impacted and influenced human development. This reveals the need for more robust environmental governance and integrated water resource management in Sub- Saharan Africa.
Keywords: human development, water stress, environmental governance quality, panel

INTRODUCTION

Water stress in the form of water withdrawal intensity is a major challenge that impacts sustainable development. In the context of the Sub-Saharan Africa (SSA) region, marked with high population growth, poor environmental governance, and climate change, water stress in the form of water scarcity have been heightened (*Nyika & Dinka*, 2023). The SSA region is also marked with a multi-faceted water crisis in the form of physical and economic water scarcity in arid and semi-arid zones, and in resource-constrained areas, respectively. In a similar manner, water crises in the SSA region are also marked with quality-induced water scarcity in the form of water pollution and contamination (*Jones et al.*, 2024). Despite the measures in place to mitigate the effects of climate change, most countries in the SSA region continue to experience heightened water stress in their water resources due to high demands from the industrial, domestic, and agricultural sectors, and poor water management practices (*Kadigi et al.*, 2019). Nevertheless, the nexus between human development, water stress, and quality of environmental governance is yet to be adequately investigated despite its importance in informing policy development and sustainable management of resources.

About half of SSA's population have no access to basic drinking water service, and this has been shown to have significant differences when comparing rural and urban areas (*Terefe et al.*, 2024). This situation has been further exacerbated by its linkages to other development challenges such as poverty, food security, and lack of capacity within institutions. In this regard, recent data has indicated that the poverty rate measured by headcount ratio (% of population) for 2019 was 47.5% (*World Bank*, 2025). On a similar note, *Abdou & Rajab* (2023) contended, "As countries in Sub-Saharan region embark on economic growth and social development, these countries have witnessed increasing water demand, hence increasing pressures on water resources." In this regard, SSA region presents one of these challenges as approximately 387 million people have no access to basic drinking water service as of 2020 (*World Bank Group*, 2024). In this case, it can be noted that Sustainable Development Goal number six by the United Nations has placed emphasis on ensuring sanitation and water for all. Nevertheless, this goal has not been achieved in SSA due to lack of capacity within institutions and water demand pressures.

The intensity of water withdrawal is defined as the volume of freshwater abstracted from natural sources over the total renewable water resources - which is a key indicator of water stress among the Sub-Saharan African states (*Zhang et al.*, 2022). Generally, the states of SSA face a comparable level of hydrological risk conditions but with varying degrees of intensity and causes. On the African continent, it has been noted that at least 14 states of the Sub-Saharan region are under high water stress with withdrawal levels nearing the limits of sustainability (*Dinka & Nyika*, 2024). Moreover, states in the SSA region are also facing very rapid population increase; hence, the stress on the limited water resources keeps escalating with concerns being raised over its sustainability (*Abdou & Rajab,* 2023).

The current literature emphasizes the rising water crisis in SSA, where research link water scarcity to population pressures, economic activities, and climate change (*Filho et al.*, 2022; *Ofori et al.*, 2021). Notably, *Ladi et al.* (2021) brought forth water poverty index as a conceptual tool to interpret how water scarcity affects human development in a multidimensional framework. Likewise, other research such as *Mishra et al.* (2021) also established the concept of 'water security' as a sine qua non for human development, claiming that a lack of proper access to water resources hinders economic development. *Morante-Carballo et al.* (2022) assert that water scarcity affects agricultural productivity, health, and economic activities. Notably, *Morante-Carballo et al.* (2022) study found a negative relationship between water stress indicators and other human development indicators. Nevertheless, the relationship between water stress and human development is a topic of controversy, where some research claim that a high level of human development is positively correlated to high demand for water resources due to increased economic activities resulting from industrialization and urbanization processes (*Wang et al.*, 2022). Likewise, other research studies such as *Chang & Zhu* (2020) proved that good governance and technological advancements make it possible to separate water use from development.

Accordingly, the role of environmental governance in the management of water resources has also received scholarly attention. As a result, *Megens & Warner* (2025) conceptualized water governance as a multi-level system encompassing formal institutions, informal norms, and stakeholder interactions that collectively shape water resource management outcomes. Particularly, *Jiménez et al.* (2020) in their study on Unpacking Water Governance, they found that water governance quality significantly influences the effectiveness of water management policies. However, in Sub-Saharan Africa, studies indicate that weak enforcement of water policies, fragmented institutions and corruption are associated with unsustainable water use (*Tariq & Zhang*, 2021). Despite existing studies that have been conducted, the empirical evidence regarding the relationship between governance quality and water stress remains limited with focus in SSA.

In the view of the identified gaps, this article seeks to address these gaps by determining the link between human development, water stress and environmental governance quality in selected SSA countries. Similarly, the significance of this study extends beyond academic inquiry to practical policy formulation, resource allocation, and environmental management across SSA. In particular, through analysis of the interrelationships, the study aimed to contribute insights that could guide regional efforts towards achieving sustainable development goal 6, regarding clean water and sanitation, and other related goals for sustainable development.

Problem Statement

The SSA region faces a severe and multidimensional water crisis that threatens sustainable development in the region. Despite the global commitment to achieving SDG 6, a total of 387 million SSA citizens in 2020 lacked basic drinking water service access, with a large gap between urban and rural areas. This water crisis is worsened by population growth, climate change, and a lack of good governance structures, which has significant implications for sustainable development

Accordingly, whereas existing studies have explored water scarcity in relation to population pressures, climate change, and human activities, the association between water stress, human development, and environmental governance quality remains underexplored.Regarding the relationship between water stress and human development, existing literature presents conflicting perspectives with some studies suggesting that water stress constrains economic growth and social progress, while others suggest that higher human development levels may increase water demand through industrialization and urbanization. Similarly, while environmental governance quality has been conceptualized as crucial for water resource management, empirical evidence regarding its relationship with human development in SSA remains limited.

As a result of the identified gaps, this paper aims to determine the link between human development, water stress, and environmental governance quality in selected

Sub-Saharan African countries (*Appendix 1*). This paper analyses the relationships between human development, water stress, and environmental governance quality in 24 countries in SSA between 2005 and 2021, aiming to address these knowledge gaps and provide insights that could guide policy formulation regarding environmental management practices across the SSA region to help the region in achieving SDG 6 and related sustainable development objectives.

Aim

The study examined how the level of water stress and environmental governance quality influence human development in SSA.

Specific objective

1. To determine the influence of the level of water stress on human development in SSA.
2. To establish the influence of environmental governance quality on human development in SSA.

Structure of the Paper

The paper is organized into six large sections to ensure the proper flow of the paper. Section I includes study background, study problem, and study objectives to focus on water stress, human development, and environmental governance for Sub-Saharan Africa. Section II includes (Literature Review), which includes the compilation of different studies s regarding water stress, quality of environmental governance, and linkages of water stress to human development, and different gaps which have not been addressed yet by any empirical study. Section III includes the methodology which presents research design, data, and techniques used to measure water stress, quality of environmental governance, and human development. Section IV presents the findings which includes different data and statistics regarding trends and observations made for different countries of Sub-Saharan Africa. Section V discusses the results, which includes explanation and interpretation of findings regarding different studies carried out, including various aspects of policies covered, including limitations. The conclusion has been included in Section VI, which includes a summary of different findings and different future directions to be taken regarding water security and development for Sub-Saharan Africa.

Literature Review

Human Development and Water Stress

Water scarcity in the Yellow River Basin (YRB) was examined in relation to future human activities and climate change to forecast water scarcity and its driving factors using the Water Use-to-Availability Ratio (WUAR) as a criterion (*Omer et al.,* 2020). The study coupled climate change scenarios (RCP8.5 & RCP4.5) and the hydrological model (SWAT) and used statistical techniques such as correlation analysis and regression analysis to examine relationships between water scarcity, climate-related factors and human factors such as land use change and consumptive water use. Results showed that future water scarcity in YRB is forecasted to increase, especially in its lower course, where human factors such as cropland expansion and urbanization have a greater weight than climate change. The important limitation of *Omer et al.* (2020) study is its regional specificity in China and its limited applicability to other regions in general and in Sub-Saharan Africa (SSA) in particular, where water scarcity is exacerbated by governance problems and low human development indices. Although *Omer et al.*'s (2020) study concentrates on human factors as drivers of water scarcity in YRB, its results do not specifically examine relationships between water scarcity and human development as in SSA's case in which water scarcity is a critical issue in addition to governance problems and low human development indices. The study addresses these gaps by empirically examining how governance quality affects relationships between human development and water scarcity in SSA to provide comparative insights to *Omer et al.* (2020) study in YRB.

The role of industries in aggravating the scarcity of water and the opposing effects of such conditions on human and environmental health, particularly regarding the release of untreated industrial wastewater chock-full of toxic organic and inorganic compounds, was investigated by *Chowdhary et al.* (2020). The authors aimed to highlight the effects of industries on water resources, emphasizing the relationship between environmental degradation, water pollution, and human health. The method used was a thorough review of the literature, including case studies, to evaluate the types of pollutants from industries such as distilleries, tanneries, and textile mills, and their pathways into water resources. The results showed that the entry of effluents from industries has a significant effect on water scarcity because it introduces toxic materials such as heavy metals, phenolics, and dyes, leading to the destruction of aquatic life, soil infertility, and cancers, as well as dermatitis and gastrointestinal infections in human populations. A major gap in empirical studies that was noted was that there were no up-to-date studies on the socio-economic effects of water pollution from industries in newly developing areas, particularly in SSA, where water scarcity, caused by the rapid industrial growth and poor environmental policies, retards socio-economic development. This study closes the gap in that it investigates the relationship between water scarcity and human development in SSA, where the effects of rapid growth of industries and poor environmental policies contribute to water scarcity, thus hampering socio-economic development.

A thorough analysis of human responses to water scarcity triggered by climate change in the African continent has been carried out by *Filho et al.* in 2022 in Sub-Saharan Africa (SSA). The purpose of the analysis was to review the knowledge of water scarcity trends and its impacts on different sectors and adaptation measures using a mixed methods approach, which combines the Falkenmark Water Stress Indicator, EM-DAT disaster database, and 240 articles from the Global Adaptation Mapping Initiative (GAMI) and other databases. The result showed that the most common response actors were household/autonomous actors such as individuals and local governments who responded to water stress using behaviour-related, technological, and nature-based methods. However, most of these responses were minor modifications of already practiced methods, which show that the adaptations are not very substantial and lack proper institutional structures. The paper has found that the current empirical research has many gaps, such as the under-representation of vulnerable groups and inadequate incorporation of indigenous knowledge into adaptable measures. This paper fills these gaps by critically analysing the relationship of human development and water stress in SSA.

Environmental Governance Quality and Human Development

The connection between environmental governance quality and human development in SSA has been underexplored in the literature, with existing studies primarily focusing on high water-stress regions outside Africa on corporate water disclosures.

The extent and quality of corporate water management disclosure in extremely high water-stress countries were examined using a framework analysing institutions across different tiers to assess micro (company), meso (stock exchange), and macro (country) influences (*Farooq et al.*, 2025). Their study utilized a GRI 303-based index in assessing top listed firms' disclosures in 12 stock exchanges over five years. The study found that disclosure rates of water and quality continue to be relatively low, with only marginal progress observed. Key drivers included robust corporate governance (CG) at the micro level, regulatory stringency levels and advocacy at the meso level, and cultural dimensions at the macro level, though country-level governance quality surprisingly had a negative impact on disclosure quality in water-sensitive industries. While this study provides insights into institutional pressures shaping water disclosures, it primarily focuses on non-African contexts, leaving a gap in understanding of how environmental governance quality interacts with human development in SSA, where institutional frameworks and resource challenges differ significantly.

Research on the efficiency of water environmental governance in China's Yangtze River Delta region employed DPSIR-TOPSIS & Social Network Analysis (SNA) techniques to analyse the involvement of governments, enterprises, and citizens in environmental governance between 2006 and 2017 (*Liu et al.*, 2022). The findings showed that efficiency of environmental governance increased over the years due to government policies, technological development, and public engagement, although inequalities among cities were also on the rise. Although this study provides important information on multi-stakeholder environmental governance and regional collaboration, it focuses on a very industrialized and government-regulated environment. This is quite opposite of the situation in Sub-Saharan Africa, where environmental water scarcity is worsened by climate change and very rapid urbanization. The major research gap in the present topic is that no studies exist on the efficiency of environmental governance in less resource-rich regions. Another gap is that the DPSIR-TOPSIS approach needs to consider the specific combination of informal and formal environmental governance systems in Sub-Saharan Africa. This study will close these research gaps by applying DPSIR-TOPSIS & including the specific socio-political factors and people's water resource governance practices in Sub-Saharan Africa.

The research conducted in China, which comprehensively assessed the scarcity of water at the national level, incorporating both the quality and quantity aspects of water scarcity, was conducted by *Ma et al.* (2020), an essential aspect previously omitted in the assessment of water scarcity at the macro level, which only considered the quantity of water. The research sought to quantify the effect of poor water quality on water scarcity on various time and spatial scales, employing high-resolution data on water availability water quality indicators (COD, $NH4^{+}$-N, and EC), as well as water withdrawals according to sectors. The research used the technique of downscaling data from the provincial level to the grid cell and the basin levels, using the dilution method to convert water quality constraints into scarcity measures of water quantity (WSqua, WSpol, and WScom). The research showed the effect of water pollution on water scarcity, especially in North China, where there is both quantity and quality scarcity of water on an annual basis, as well as in South China, where there is seasonal scarcity of water due to quality deterioration. Over half of the population of China is affected, indicating the urgency of the combined management approach. An essential empirical aspect previously omitted in the research on water scarcity at the macro level was the lack of global application of the assessment due to the lack of water quality data, especially SSA. This research is essential in indicating the need to incorporate the aspect of quality, although it is limited to the assessment of China, which cannot be directly generalized to SSA because of the vast differences in environmental management and data.

The study on the effectiveness of water governance in three river basins in Latin America-Guandu (Brazil), Alto Mayo (Peru), and Bogotá (Colombia)-was also conducted by *Vollmer et al.* (2020) using Freshwater Health Index (FHI). They sought to quantitatively measure the quality of governance through stakeholder surveys, which were perception-driven. Their methodical approach comprised administering a Likert-type survey to various stakeholders, which were further subjected to a weighting process via the Analytic Hierarchy Process (AHP), a multicriteria analysis tool was used to identify the relative importance of components. Results indicate low scores for overall governance (Alto Mayo = 38, Guandu = 26, Bogotá = 43), which suggest systemic deficiencies, especially in terms of financial resources, monitoring, and stakeholder engagement. Interestingly, a difference in perceptions regarding governance performance was observed among government and non-governmental stakeholders, where the former tended to rate more positively. One major research gap identified in the literature analysis is the relative unaddressed area regarding the relationship between biophysical outcomes, such as water stress, and the role of governance quality, which has been unaddressed comparatively among regions with disparate hydrological and political systems. This study contributes meaningfully to filling the research gap regarding the relationship between environmental governance quality and human development in the SSA regions.

MATERIALS AND METHODS

Research Design

A correlational research design was used in this study to determine the influence of water stress, and environmental governance quality on human development. According to *Oso & Onen* (2009), this design helps in predicting variables from other variables, and establishing whether and to what level, a relationship exists between variables. The paper sought to determine the following research hypotheses:

H_0: Water stress has no significant influence of human development in SSA.

H_1: Environmental governance quality has no significant influence on human development in SSA.

Econometric Model

The study employed panel data analysis and the relationship among the variables (1).

$$HDI_{it} = \beta_0 + \beta_1 WS_{it} + \beta_2 EGQ_{it} + \varepsilon_{it} \tag{1}$$

Where:

HDI_{it} Human Development Index
WS_{it} Water stress in country *i* at time t
EGQ_{it} Environmental Governance Quality in country *i* at time t
ε_{it} Error term
β_1, β_2 regressors of WS and EGQ

Measurement of variables

Water Stress

Water stress measured as ratio of freshwater usage to total available freshwater resources, is an indicator that assesses the pressure exerted on a country's freshwater resources by human water use (*World Development Indicators*, 2025). The study used annual level of water stress data for the period 2005 to 2021.

Human Development

Human Development refers to the progression of enhancing individuals' liberties, broadening their prospects, and elevating their overall quality of life. The study used individual country -level annual human development index data for the period 2005 to 2021.

Environmental Governance Quality

Environmental Governance Quality refers to the effectiveness of a country's policies, institutions, and regulatory frameworks in managing natural resources and protecting the environment in a sustainable and equitable manner (*World Development Indicators*, 2023). Environmental governance quality has been measured using the CPIA Policy and Institutions for Environmental Sustainability Rating from the World Development Indicators (*World Development Indicators,* 2023). The CPIA rating scale is 1 to 6, with 1 signifying the lowest and 6 the highest. The rating measures the extent to which a country is able to positively manage and sustain the use of its natural resources, protect the environment, and firmly regulate and enforce policies. More specifically, the rating measures the formulation of policies, the quality of regulations, the capacity to enforce regulations, and the inter-institutional collaboration. The CPIA rating is appropriate for empirical, cross-country studies and time-series studies. The study used individual country -level annual institutional and policy data for environmental sustainability rating for the period 2005 to 2021.

Data Analysis

The paper employed inferential data analysis including regression and correlation analyses. The analysis was conducted using STATA software version 17. Alternative specifications of the models were evaluated to verify the estimated relationships.

Apart from Unit root tests, the Hausman specification test and fixed-effects estimation was applied. Hausman specification test was used to establish the preferred model. The consistency of the coefficient signs and statistical relevance across specifications denotes the robustness of the primary results.

RESULTS AND DISCUSSION

Descriptive Statistics

As depicted in *Table 1*, the descriptive statistics reveal notable patterns in the study variable across 24 countries over the period 2005–2021. In particular, human development, proxied by Human Development Index had a mean of 0.482 and a median (p50) of 0.49, which shows a relatively low human development level within the SSA region's development challenges. Similarly, the standard deviation of 0.069 indicates moderate variability across countries and over time. Moreover, the stability in the HDI distribution depicted by skewness (0.077) and kurtosis (0.083) reflect persistent structural constraints in the region. Additionally, the level of water stress demonstrates substantial heterogeneity with a mean of 7.7 and a considerably lower median (5.1) suggesting that some countries within the region are exposed disproportionately high-water stress levels. This is supported by the large standard deviation of 8.53, interquartile range (8.15), range (46.06). Notably, the wide gap between 75th percentile (10.19) and the maximum value (46.09) reflect acute water scarcity in some countries within the region. Furthermore, environmental governance quality demonstrates intermediate variability indicated by a mean of 3.2 and a standard deviation of 0.46. Accordingly, the relatively narrow range (2) and interquartile range (0.5) suggest that, although differences exist, environmental governance quality remains somewhat clustered across the region.

Table 1: Descriptive Analysis

	Human development	Level of water stress	Environmental governance quality
Mean	0.482	7.713	3.235
p50	0.490	5.155	5.155
SD	0.069	8.538	0.465
IQR	0.1	8.15	0.5
Range	0.31	46.06	2
p25	0.43	2.04	3
p75	0.53	10.19	3.50
Min	0.3	0.03	2
Max	0.61	46.09	4
Skewness	0.077	0.083	0.630
Kurtosis	0.083	0.065	0.466
Observation	408	408	408

Testing for Stationarity

The study employed Harris–Tzavalis test for stationarity given its suitability for datasets with few/small time periods and larger panel number (*Karavias & Tzavalis,* 2014). This is premised on the assumption of fixed time periods while panel numbers tend to be infinite. Accordingly, *Table 2* shows that all the variables were non-stationary at level as demonstrated by the statistic, z and their respectively p values which are greater than 0.05. Contrastingly, all the variables were stationary at first difference as depicted by the statistic, z and their respectively p values which are less than 0.05.

Table 2: Harris-Tzavalis Unit Root Test

H0: Panels contain unit roots Ha: Panels are stationary AR parameter: Common Panel means: Included Time trend: Not included					Number of panels = 24 Number of periods = 17 Asymptotics: N -> Infinity T Fixed		
Level					First Difference		
		Statistic	z	p-value	Statistic	z	p-value
HDI	rho	0.9068	2.0946	0.9819	0.1150	-19.1183	0.0000
WS		0.9902	4.4738	1.0000	0.2296	-16.0262	0.0000
EGQ		0.8004	-0.9384	0.1740	-0.0398	-23.2947	0.0000

Correlation analysis of Study Variables

Accordingly, *Table 3* below shows the correlational analysis. Specifically, results demonstrate that human development exhibits a weak but nonetheless statistically significant positive association with the level of water stress (r = 0.1131, p = 0.0224). The weak but significant positive correlation implies that higher human development levels are marginally related to increase water stress. Similarly, human development demonstrates a stronger and highly significant positive correlation with environmental governance quality (r = 0.3028, p < 0.001). Additionally, the level of water stress shows a modest yet statistically significant positive association with environmental governance quality (r = 0.1456, p = 0.0032).

Table 3: Correlation Matrix

	Human development	**Level of water stress**	**Environmental governance quality**
Human development	1.000		
Level of water stress	0.1131 (0.0224)**	1.000	
Environmental governance quality	0.3028 (0.000)**	0.1456 (0.0032)**	1.0000
Correlation coefficients are shown in the upper row for each variable pair. p-values are reported in parentheses below each coefficient. Statistical significance is denoted as ** = Significant at 5% level (p < 0.05)			

Hausman Specification Test

The study conducted a Hausman test to determine the appropriate model for fixed effects and random effects by testing whether the individual-specific effects are correlated with the regressors. As indicated in *Table 4*, the results show that the random effect model gave consistent and efficient estimates since the p value of 0.1129 is greater than 0.05.

Table 4: Hausman Test Results

	Coefficients			
	(b)	(B)	(b-B)	sqrt(diag(V_b-V_B))
	fixed	random	Difference	Std. err.
d.ws	043363	030929	012434	.0006007
d.egq	035263	0361777	0009147	.0005832
b = Consistent under H0 and Ha; obtained from xtreg. B = Inconsistent under Ha, efficient under H0; obtained from xtreg. Test of H0: Difference in coefficients not systematic chi2(2) = (b-B)'[(V_b-V_B)^(-1)](b-B) = 4.36 Prob > chi2 = 0.1129				

Random-effects GLS Regression Results

As represented in *Table 5*, both the level of water stress and the environmental governance quality significantly and positively impact human development. The model demonstrates that both water stress and environmental governance quality explain about 58.80% of the variation in human development overall. Similarly, both water stress and environmental governance quality explain approximately 40.33% and 37.60% of the variation in human development between and within the 24 Sub- Saharan African countries, respectively. In particular, the level of water stress (β=.03092, p value = 0.000) exhibited direct and significant relationship with human development. The positive coefficient implies that for every unit increase in level of water stress, human development increases by 0.031 points. Similarly, environmental governance quality (β=.03618, p value = 0.000) also demonstrated an even stronger positive relationship with human development. In particular, with a one-unit improvement in governance corresponding to a 0.036-point increase in HDI. Additionally, a high fraction of variance attributable to country-specific effects (rho = 0.8198) indicates substantial unobserved heterogeneity across nations that persists over time, highlighting the importance of country-specific factors beyond the measured variables.

The GLS regression results showed that both levels of water stress and environmental governance exhibited direct and significant influence on human development across the 24 countries in SSA. Specifically, the statistically significant positive relationship between human development and water stress (β = 0.03092, p value = 0.000), aligns and expands upon the findings of the previous studies. Accordingly, *Omer et al.* (2020) demonstrated that anthropogenic factors, such as land-use changes and urbanization, exacerbate water stress, but their focus on the Yellow River Basin overlooked the unique governance and developmental challenges present in Sub-Saharan Africa (SSA).

Table 5: Random-effects GLS Regression Results

Random-effects GLS regression Group variable: id			Number of obs = 408 Number of groups = 24		
R-squared: Within = 0.4033 Between = 0.3760 Overall = 0.5880			Obs per group: min = 17 avg = 17.0 max = 17		
corr (u_i, X) = 0 (assumed)			Wald chi2(2) = 95.86 Prob > chi2 = 0.0000		
d.hdi	Coefficient	Std. err.	z	P>z	[95% conf. interval]
d.ws	.0309290	.0868792	3.56	0.000	.0013910 .0047948
d.egq	.0361777	.0042841	8.44	0.000	.0277811 .0445744
_cons	.3414153	.0192623	17.72	0.000	.3036619 .3791687
sigma_u	.06202011				
sigma_e	.02907444				
rho	.8198304 (fraction of variance due to u_i)				

The positive correlation between water stress and human development means that, in the short term, development activities in Sub-Saharan Africa are likely to create new tensions regarding the use of water, rather than reduce them. This can be explained in terms of water-use intensity and the Environmental Kuznets Curve (EKC) hypothesis. In the early stages of development, water stress in a given area principally derives from an increase in the withdrawal of water for multiple uses and the subsequent associated pollution that results, particularly from the various activities of the developed economy (i.e., the service, commercial, and industrial sectors) in conjunction with the major urban centers and the agricultural sector. This has also been observed in multiple developing countries where development, at least in the early stages, led to worsening environmental issues at hand until they were positive for the development of the country (*Wang et al.,* 2022). Thus, the positive relationship in question does not mean that water stress creates a conducive environment for development, rather it indicates that the current development paths in SSA are still very water dependent and only partially decoupled from the use of resources.

The findings of this study demonstrate that higher human development, which is often associated with industrialization, urban expansion and agricultural intensification may inadvertently exacerbate demand for water and pollution. This supports *Chowdhary et al.* (2020) argument that industrial activities degrade water quality, particularly in regions with weak regulatory enforcement. Although *Chowdhary et al.* (2020) highlighted industrial pollution in their research, this study suggests an even broader socio-economic framework, in which development processes, and severe institutional voids, may catalyze water stress.

This also aligns with *Filho et al.* (2021) argument as autonomous localized actions addressing water shortage in SSA, leaving much to be desired in terms of systemic institutional resolutions. Therefore, water stress and human development findings in the 24 SSA countries illustrate that human development, in the absence of considerable and effective institutional frameworks, and the practice of integrated water management systems, simply cannot be operationalized in the context of water stress.

In the same line, the study found that environmental governance quality and human development have a statistically significant positive relationship (β = 0.03617, p-value = 0.000). This helps close a significant gap, particularly in SSA, where this has not been as comprehensively documented. Even when *Farooq et al.* (2025) examined corporate water disclosures in countries with high water stress, their lack of focus on Africa, and the surprising negative effect of country-level governance quality and disclosure quality, provided an impetus to develop such analyses in the context of Sub-Saharan Africa. As such, *Liu et al.* (2022) and *Ma et al.* (2020) emphasized centralized policies and technological solutions in China, which may not translate to Sub-Saharan Africa's resource-constrained environments, where bottom-up approaches and traditional knowledge play pivotal roles. Similarly, *Vollmer et al.* (2020) further highlighted governance deficiencies in Latin America but left unanswered how these dynamics manifest in Sub-Saharan Africa. Consequently, the results of this study demonstrate that incremental improvements in environmental governance quality enhance human development which aligns with DPSIR-TOPSIS framework's emphasis on adaptive governance (*Wu & Liu*, 2022). However, the findings of this study diverge from those of *Farooq et al.* (2025) on governance's negative role in disclosures.

Though short-term benefits such as greater industrial production, urban job creation, and agricultural productivity will occur with increased water usage, the long-term sustainability of these benefits is in jeopardy. Uncontrolled water withdrawal and pollution will create ecosystem degradation, water scarcity, and increased development risks linked to climate change. These issues create a clear trade-off in Sub-Saharan Africa (SSA). Increases in short-term human development in the region due to the use of water-intensive practices will harm long-term development potential without improvements in water management and governance.

CONCLUSIONS

The study demonstrated that, in Africa's Sub-Saharan region, human development is positively influenced by both water stress and the quality of environmental governance. There is, however, sustainability pressure, that must be taken into consideration. Although development gains are evident, there is increasing stress on water resources which and adds to the development-related critiques of being unsustainable, and that development pathways will lead to water resource depletion (*UNEP*, 2023; *World Bank*, 2024).

Country-level heterogeneity suggests that institutional, environmental, and socio-economic forces although often invisible, play a critical role in shaping development outcomes. This exemplifies the limitations of one-size-fits-all policy prescriptions and underscores the importance of nuanced, adaptive, participatory and culturally sensitive governance systems. In line with the new tide of sustainability around SDG 6 and the 2030 Agenda, results provide strong support for the idea that development planning will not lead to human development in a sustainable manner without solid environmental governance and integrated water resources management in place.

The present study indicates an emerging global consensus. Economic and social advancement, without effective governance and sustainability approaches, can impede long-term development prospects. Enhancements in environmental governance are not a matter of choice; they are necessary for sustaining human development in water-scarce regions such as Sub-Saharan Africa.

Recommendations

Given the distinct relationship between water stress, the quality of environmental governance, and human development, it is necessary that the institutional frameworks in Sub-Saharan African region be strengthened to improve transparency and accountability (which is associated with improved HDI) and foster effective regulation. More focus is needed on the management of water-related consequences of rapid urbanization and industrialization, which are key drivers of increased water stress in the region. Water availability limitations should be considered in urban planning policies, while industrial development strategies should be complemented by stronger regulations on water use and controls on water pollution.

Furthermore, the principles of Integrated Water Resource Management (IWRM) should be applied to mitigate urban expansion, intensification of agriculture and industrialization as they worsen water stresss. The use of water-saving technologies in agriculture and industry should be encouraged through positive incentives, regulations, transfer of technology, and partnerships between the public and private sectors. Improved governance at the watershed and basin levels will help to mitigate the impact of upstream users, on both midstream and downstream users and will lower the potential for conflict and environmental degradation.

A key concept in incorporating environmental governance in the planning of both national and sub-national development is of great importance. Environmental sustainability is to be regarded not as a peripheral concern, but rather central within human development frameworks. This entails the integration of development and environmental sustainability as well as the integration of governance quality into national frameworks of monitoring and evaluation.

The findings from this paper also highlight the need for adaptive and bottom-up governance approaches. While some contexts benefit from centralized policies, the Sub-Saharan African region is diverse and resource-constrained, needing more agile and inclusive frameworks. Community-based water management systems can be instrumental, and therefore, legal and institutional support will be needed. In addition, local and traditional governance systems can be integrated to make formal governance systems more applicable and legitimate to the community.

In addition to the findings that highlight national and regional policy responses, there needs to be more transboundary and global policy initiatives. Unilateral policy efforts will not work in Sub-Saharan Africa, given the region's numerous transboundary freshwater resources. More needs to be done to optimize the governance, regulation, and developed tributaries of cross-border infrastructure and monitoring systems, and to develop international partnerships through River Basin Organizations, the African Union, and global development institutions. These partnerships will facilitate the effective management of transboundary water stress challenges.

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Corresponding author:

Don OKELLO
Hungarian University of Agriculture and Life Sciences
Doctoral School of Economics and Regional Science
2100 Gödöllő, Páter Károly utca 1, Hungary
e-mail: okello.don.ouma@phd.uni-mate.hu

APPENDIX

Appendix 1: Selected SSA Countries

Angola	Gambia	Nigeria
Burundi	Kenya	Senegal
Benin	Lesotho	Sierra Leone
Cote d' Ivoire	Madagascar	Chad
Cameroon	Malawi	Togo
Congo Rep.	Mali	Uganda
Djibouti	Mozambique	Zambia
Ghana	Niger	Zimbabwe