ARTICLE | Article in Press

Ecological capacity in water-stressed Somalia under globalization, institutional change and human capital development

Abdisalan Aden Mohamed · Abdikafi Hassan Abdi · Ahmed Olow Addow · Abas Mohamed Hassan · Sidomar Osman Farah

Received: 11 November 2025 / Accepted: 31 August 2026

Abstract
This study empirically examines the determinants of ecological sustainability in Somalia by analysing the relationships among globalization, water stress, institutional quality, and human capital using annual data from 1990 to 2020. The Load Capacity Factor (LCF), which captures the balance between biocapacity and ecological demand, is employed as the principal measure of ecological sustainability. ARDL bounds testing is used to assess cointegration, while Fully Modified Ordinary Least Squares (FMOLS) and Dynamic Ordinary Least Squares (DOLS) validate the long-run estimates, and the Toda–Yamamoto procedure examines predictive causality. The results indicate that globalization reduces Somalia's LCF in both the short and long run, whereas water stress has a significant adverse effect in the long run. Conversely, institutional quality, proxied by the ICRG Government Stability indicator, and human capital, represented by the population of official secondary-school age for both sexes, have positive and statistically significant long-run associations with the LCF. The causality results further show that globalization, water stress, institutional quality, and human capital predict changes in the LCF, while feedback from the LCF is primarily observed toward globalization. Overall, Somalia's ecological sustainability is constrained by water stress, institutional fragility, and environmentally unsustainable forms of global integration. The findings support a sequenced policy agenda that reconciles globalization with environmental stewardship, strengthens water-resource governance, promotes institutional development, and expands investment in human-capital formation.

Keywords Water stress · Load capacity factor · Ecological footprint · Globalization · Institutional quality · Human capital

Introduction

Recurrent droughts, hydroclimatic variability, rapid urbanization, rising energy demand, and limited natural-resource buffers are placing increasing pressure on Somalia's environmental sustainability. Persistent soil-moisture deficits and inadequate rooting-zone water storage reduce vegetation recovery, weaken land productivity,

This Article in Press is shared early to give you faster access to new research. It is citable and carries a permanent DOI. The final edited version will replace it automatically.

 https://doi.org/10.1038/s41598-026-69829-0

Published online: 07 September 2026

and constrain ecosystem regeneration[1–3]. These ecological pressures are intensified by globalization, which can expand production, imports, transport, and resource-intensive consumption, although it may also support cleaner production through technology transfer, foreign investment, and efficiency-enhancing innovation[4–8]. The environmental outcome therefore depends on how external finance and economic integration are managed. Investment in renewable energy and green technologies may strengthen ecological capacity, whereas capital directed toward fossil-fuel-intensive and resource-depleting activities may worsen environmental degradation[9,10]. Remittance inflows and broader globalization may also produce uneven environmental effects where economic expansion is not supported by effective regulation, cleaner technologies, and sustainable resource management[11,12]. This concern is particularly relevant to Somalia, where import dependence, infrastructure constraints, rapid urban expansion, and weak regulatory enforcement may limit the environmental benefits of globalization. Stronger institutions and greater human capital can help offset these pressures by improving land and water governance, strengthening compliance, increasing energy efficiency, and supporting the adoption of sustainable technologies[13–16]. Accordingly, examining water stress, globalization, institutional quality, and human capital together provides a suitable framework for assessing Somalia's ecological capacity[17,18].

Water stress alters environmental capacity on both the supply and demand sides. On the supply side, deficits in rooting-zone water reduce photosynthesis, vegetation cover, and crop–livestock productivity, as soil-moisture thresholds for evapotranspiration are crossed and recovery slows[2,3]. Additional constraints arise where infiltration is limited during intense rainfall, subsurface storage is small, or salinity raises osmotic stress, each narrowing plant-available water and weakening biocapacity[19,20]. On the demand side, drought elevates the energy and logistics required to secure water—pumping, transfers, emergency deliveries—which enlarges the human footprint in places with seasonal and spatial scarcity, while river ecosystems under low flows exhibit metabolic shifts and biodiversity losses that further diminish ecological services[1,21,22]. Management and climate feedback modulate these outcomes as reservoir operations and plant physiological responses alter low-flow regimes, evapotranspiration, and runoff under warming[23,24]. Consistent with this evidence, credible assessments of carrying capacity in drylands require joint attention to blue-water deficits and green-water (soil-moisture) limits[17,18].

Institutional quality converts environmental intentions into measurable outcomes through credible rules, secure property rights, routine monitoring, and transparent allocation of land and water[25]. Where corruption control, the rule of law, and political stability are stronger, agencies enforce grazing and land-use limits, police resource extraction, and coordinate drought and flood responses with neighboring jurisdictions[14,15]. Governance also guides finance because effective permitting and oversight channel capital toward efficiency upgrades and cleaner technologies rather than fossil- and resource-intensive projects[26]. Integrity thresholds matter since basic administrative capacity increases compliance and raises the likelihood that investment funds water- and energy-saving uses, whereas corruption weakens these channels[27]. Digital public services and environmental information systems further reduce enforcement costs and improve planning in resource-intensive economies[28]. Consistent with this framing, countries with stronger governance exhibit lighter ecological pressure and more resilient environmental capacity even at comparable income levels[14,29].

Education and skills are a primary lever for environmental capacity in drylands. Better-educated households and firms conserve energy more effectively and switch toward cleaner sources, which lowers total demand and reduces "dirty" energy use[16,30]. Schooling also speeds the uptake of water-saving irrigation, sustainable pastoral and cropping practices, and renewable technologies[31–33]. Human capital strengthens environmental stewardship more broadly by improving ecosystem management and biodiversity outcomes, which is visible in cross-country performance indices[34]. The effects are often nonlinear because environmental improvements tend to accelerate once educational attainment crosses key thresholds, and they are stronger in more advanced economies than in emerging ones[35–37]. Education also moderates the environmental costs of finance and growth by improving project appraisal, compliance, and the diffusion of efficiency-enhancing technologies[38]. In drought-exposed nations, these channels work together with disaster preparedness and risk literacy to reduce the footprint of emergency responses and to preserve biocapacity during shocks[32].

Somalia's environmental condition is precarious even by regional standards. The country has run a sustained ecological deficit since roughly 2014, which indicates that domestic demand on ecosystems exceeds regenerative capacity and leaves little buffer against shocks[4]. Reliance on traditional biomass remains pervasive, with about 82% of household energy derived from firewood and charcoal, and forest cover has fallen from around 13% of land area in 1990 to about 9.5% in 2020[39]. Rapid urbanization has compounded these stresses, as the urban share reached roughly 47% in 2021 after decades of in-migration that raised energy demand, waste generation, and exposure to heat and flood risks (World Bank 2023). Recurrent droughts and episodic floods further erode land and livelihoods, while weak enforcement enables overgrazing and charcoal production to persist[4,39]. External economic ties are deep and most goods are imported, which heightens exposure to global price swings. At the same time, substantial untapped solar, wind, and small-hydro potential could reduce the footprint if mobilized[40]. Institutional effectiveness remains uneven, and recent evidence from Somalia suggests limited near-term influence of governance indicators on the ecological footprint[25,29]. The country's human capital remains a practical lever, since higher educational attainment is associated with smaller ecological footprints and can accelerate efficiency practices, renewable uptake, and risk literacy in drought-prone settings[4].

Despite the expansion of research on ecological sustainability, three important gaps remain. First, much of the existing literature concentrates on energy consumption, trade openness, economic growth, and emissions, while water stress receives comparatively limited attention as a direct constraint on ecological capacity. This omission is particularly important in Somalia, where recurrent droughts, declining soil moisture, and increasing pressure on renewable water resources directly affect biocapacity and livelihood systems. Second, Somalia-specific studies generally examine factors such as globalization, governance, energy use, and human capital separately rather than evaluating their combined influence on the Load Capacity Factor. Consequently, the interaction between hydrological constraints and socio-economic conditions remains insufficiently understood. Third, relatively little empirical evidence applies time-series methods that can estimate both short- and long-run relationships in small, fragile, and data-constrained economies. To the best of our knowledge, this study provides the first systematic country-specific empirical assessment of how water stress, globalization, institutional quality, and human capital collectively influence Somalia's Load Capacity Factor over the period 1990–2020. Its empirical contribution lies in estimating the short- and long-run relationships among these determinants within a single time-series framework. Conceptually, the study advances the ecological-sustainability literature by positioning water stress as a core biophysical constraint that interacts with socio-economic and institutional conditions, rather than treating hydrological pressure as an isolated environmental factor. Methodologically, the analysis combines ARDL bounds testing and an error-correction model with FMOLS, DOLS, and Toda–Yamamoto causality procedures to assess cointegration, dynamic adjustment, robustness, and predictive directionality. Together, these contributions provide a more integrated explanation of ecological capacity in drought-prone and institutionally fragile economies and offer policy-relevant evidence for sequencing interventions in water governance, institutional development, human-capital formation, and environmentally responsible globalization.

The rest of this paper proceeds as follows. Section Two summarizes the available empirical literature. Section 3 describes the data architecture, variable formulation, and econometric approach that underpins the study. Section Four summarizes and evaluates the empirical findings, combining short- and long-run dynamics with contextual information. Finally, Section Five summarizes the important findings and offers policy-oriented suggestions for improving ecological resilience and sustainable resource management in unstable economies.

Literature review

Globalization and load capacity factor

Evidence on how globalization affects the Load Capacity Factor remains divided. In some settings, globalization appears to strengthen ecological capacity by widening access to cleaner technologies, renewable energy, and efficiency-enhancing investment. Studies from South Africa, Brazil, Mexico, and Japan report that globalization or trade integration can improve the LCF, particularly when it is accompanied by technological innovation and greater use of renewable energy[5,8,10,41]. Jin et al.[9] reached a similar conclusion, showing that investment in green and energy-efficiency research can raise ecological capacity. These findings suggest that the environmental gains from globalization depend heavily on the way international finance, technology, and investment are directed. A different body of evidence points to adverse effects. In Somalia, Warsame et al.[39] found that globalization weakens environmental quality in the long run, while Abdi et al.[4] reported that trade openness has harmful effects in both the short and long run. Similar patterns have been observed in E7 and BRICS economies, where globalization, industrial expansion, and economic growth reduce ecological capacity unless their effects are moderated by cleaner technologies and more responsible resource management[12,42]. Jahanger et al.[43] also found that globalization can weaken the LCF in leading Sustainable Development Goal countries under certain environmental conditions. Related evidence from developing economies indicates that the environmental consequences of globalization are conditioned by technological capacity, renewable-energy use, urbanization, and the structure of industrial production. Rasool[44] found that the technology sector, renewable energy, and urbanization jointly influence environmental sustainability in developing economies, while Zaman et al.[45] showed that traditional energy dependence and industrial production can intensify ecological pressure. These findings reinforce the view that the effects of globalization depend on countries' productive, technological, and energy structures.

Taken together, these studies indicate that globalization does not have a uniform environmental effect. Political globalization may improve the LCF, whereas financial or aggregate globalization may reduce it, and the effect of trade openness often depends on the energy mix, institutional quality, technological capacity, fiscal governance, and the direction of investment[6,7,46,47]. This variation makes country-specific analysis especially important for Somalia, where heavy import dependence, weak environmental enforcement, limited technological capacity, and recurring water stress may shape the environmental consequences of globalization in ways that differ from other economies. Examining globalization together with water stress, institutional quality, and human capital therefore offers a more grounded explanation of Somalia's ecological capacity.

Institutional quality and load capacity factor

Research from developing and emerging economies generally shows that stronger institutions improve environmental performance by reinforcing regulatory enforcement, controlling corruption, and directing resources toward cleaner activities. Institutional quality has been associated with higher environmental load capacity and lower ecological footprints and carbon emissions across E7 economies, South Asia, Southeast Asia, and Middle Eastern and African contexts[14,15,48–51]. Institutions also shape the environmental consequences of finance, trade, and natural-resource use. Stronger governance and human capital can reduce finance-related ecological pressure and redirect investment toward efficiency-enhancing activities, although corruption weakens these gains[26,2738]. Likewise, corruption control and responsible resource-rent management can improve the environmental effects of trade openness, while institutional impacts vary across governance levels and environmental conditions[11,52,53]. In resource-intensive economies, digitalization and good governance further strengthen the LCF by improving planning and regulatory effectiveness[28]. The environmental contribution of institutions also depends on their capacity to implement and coordinate sustainability policies. Zaman et al., (2022) found that supportive leadership, stakeholder engagement, and institutional coordination improve the sustainable performance of renewable-energy projects. Similarly, Wang et al.[54] showed that government effectiveness, technological innovation, and natural-resource protection significantly influence environmental performance. These findings indicate that institutional quality affects ecological sustainability through both policy formulation and effective implementation.

Findings from advanced and regional economies broadly support these mechanisms, although the results are not uniform. Institutional quality has been linked to lower emissions and stronger environmental performance in APEC, G20, EU, and OECD countries[55–57]. However, studies using the inverted LCF suggest that institutional improvement may not automatically enhance sustainability unless it is accompanied by renewable-energy adoption and effective green-growth policies[58,59]. Overall, institutions influence ecological capacity through enforcement, financial allocation, trade governance, and resource management. Nevertheless, the limited evidence from fragile states makes a Somalia-specific assessment necessary, given the country's weak administrative capacity, dependence on natural resources, and recurrent exposure to water stress.

Human capital and load capacity factor

Studies from developing and emerging economies generally indicate that human capital can improve environmental performance, although the relationship is often weaker and more context-dependent than in advanced economies. Evidence from India shows that higher human capital reduces the ecological footprint, while findings for China suggest that it raises the Load Capacity Factor by promoting environmental awareness and more efficient resource use[13,60]. Similar outcomes have been reported in Türkiye, ASEAN countries, and BRICS-T economies, where human capital and renewable energy jointly contribute to greater ecological sustainability[31–33,61,]. In Somalia, education has also been associated with a lower ecological footprint, although rising energy consumption and population pressure continue to undermine environmental quality[4]. These benefits may not emerge immediately. Nathaniel et al.[36] found that human capital lowers ecological pressure in BRICS countries, but its effect remains weak at existing levels of educational development. Likewise, Khan[35] showed that environmental gains become more evident only after human capital passes a certain threshold. Ahmad et al.[38] further demonstrated that these gains are stronger when human capital is supported by effective institutions, especially in reducing the ecological costs of financial development. Related evidence shows that the environmental benefits of human capital are strengthened when education and employment are supported by renewable-energy development. Zaman et al.[62] found that education expenditure, female employment, and renewable-energy consumption significantly influence environmental outcomes in China. Zaman et al.[63,64] similarly reported that female employment, agricultural production, and renewable energy jointly shape environmental quality in developing economies. These findings suggest that human capital contributes more effectively to ecological sustainability when knowledge and labor participation are connected to cleaner energy systems and sustainable production.

The evidence is generally more consistent in developed economies. Research covering G7 and OECD countries shows that human capital lowers ecological pressure, reduces energy use and carbon emissions, and encourages the adoption of cleaner energy sources[16,3065,66]. In the EU-28, education also contributes to better environmental outcomes when combined with strong institutions, renewable energy, and financial development[57]. Nevertheless, the relationship remains sensitive to structural conditions. Çakar et al.[67] found that human capital reduces emissions where institutional capacity is strong and growth is moderate, but its influence becomes less favourable when rapid expansion coincides with weak financial development. The difference between developed and emerging economies is particularly clear in the G20, where human capital significantly reduces ecological footprints in advanced members but has no significant effect in emerging countries[37]. This contrast is important for Somalia, where low secondary-school participation, weak institutional capacity, and limited access to environmental technologies may constrain the ecological returns to human-capital development. Assessing human capital together with institutional quality, globalization, and water stress is therefore necessary for understanding its role in shaping Somalia's Load Capacity Factor.

Water-stress and load capacity factor

Water stress influences the Load Capacity Factor through both biocapacity and ecological demand. Because the LCF represents the ratio of biocapacity to ecological demand, declining water availability can lower the LCF by weakening ecosystems' regenerative capacity while simultaneously increasing the resources required to obtain and manage water. Stocker[3] indicated that rooting-zone plant-available water follows rooting depth and water-deficit extremes, which sets ecosystem sensitivity to drought and constrains the biocapacity side of the LCF. Groenevelt et al.[68] integrated conductivity, aeration, and penetration resistance into an "integral water capacity," while Groenevelt et al.[19] incorporated salinity's osmotic effects to bound plant-available water. Moreover, Grant and Groenevelt[69] revealed that drying-induced conductivity loss sharply curtails availability. Process theory links these controls to timing and persistence, as Ridolfi et al.[2] derived closed-form expressions for the frequency and duration of vegetation water-stress periods. By reducing vegetation growth, agricultural productivity, soil functioning, and ecosystem recovery, these hydrological constraints weaken biocapacity and reduce the numerator of the LCF.

At a broader scale, hydrologic scarcity and operations alter ecological flows and the services that underpin biocapacity. Hoekstra et al.[1] mapped monthly blue-water scarcity after reserving environmental flows and found severe seasonal stress for billions of people, while Vörösmarty et al.[70] projected near-term vulnerability dominated by demand growth. Reservoirs and allocation rules modulate outcomes. Beek et al.[23] improved global low-flow realism with a prognostic reservoir scheme, Eldardiry et al.[21] located seasonal stress hotspots within an ostensibly water-abundant region, Garcia et al.[71] showed that operating rules stabilize environmental flows beyond the buffering from storage size, and Mehran et al.[72] projected southeastern Australia's stress meeting or exceeding Millennium-Drought levels without adaptive operations. Environment-first allocation metrics reveal stronger dry-season stress when ecological requirements are deducted from supply[73]. Water scarcity can also raise the ecological-demand component of the LCF because pumping, storage, irrigation, water transfers, and emergency delivery require additional energy, infrastructure, and transport resources. Water stress therefore reduces the LCF through a dual pathway by lowering ecosystem biocapacity and increasing the ecological demand associated with securing scarce water resources.

Data and methods

This study utilizes annual time-series data for Somalia from 1990 to 2020 to examine the key factors affecting Somalia's ecological sustainability, evaluated through the Load Capacity Factor (LCF). The explanatory variables consist of globalization, water stress, institutional quality, and education, all of which are theoretically associated with ecological performance[74–76]. Globalization (GLO) is quantified through the KOF Globalization Index, which encompasses the economic, social, and political aspects of global integration. Water stress (WS) is represented by agricultural water withdrawal as a percentage of total renewable water resources, reflecting the pressure on freshwater ecosystems. Institutional quality (IQ) is proxied by the Government Stability indicator from the International Country Risk Guide (ICRG). This indicator reflects the government's ability to implement its declared programmes and remain in office and is constructed from government unity, legislative strength, and popular support (PRS Group, 2022). Education (EDU) is proxied by the population of official secondary-school age, both sexes, measured as a number. Although it does not capture actual enrollment, it provides an indirect measure of potential human-capital formation and was selected because more direct education indicators lack consistent annual data for Somalia over 1990–2020. Given Somalia's conflict-affected statistical environment, the final dataset was checked for completeness, contained 31 annual observations for each variable, required no interpolation by the authors, and may still reflect provider-generated estimates where original administrative records were unavailable. Table 1 presents a concise summary of the study variables, outlining their symbols, operational definitions, and corresponding data sources. In continuation, Fig. 1 illustrates the temporal evolution of these variables, demonstrating their respective tendencies from 1990 to 2020. This provides preliminary insights into their long-term trajectories and dynamic interactions.

Model specification

Consistent with the theoretical and empirical foundations established in previous studies[25,61,77,78], this study employs a log-linear functional model to examine the determinants of environmental sustainability, measured by the Load Capacity Factor:

Table 1 Data and variables description.

Variable	Symbol	Measurement	Source
Explained variable			
Load capacity factor	LCF	LCF = BiocapPerCap/EFConsPerCap	GFN
Explanatory variable			
Globalization	GLO	KOF Globalization index	KOF
Water Stress	WS	Agricultural water withdrawal as % of total renewable water resources	FAO AQUASTAT
Institutional Quality	IQ	Government Stability	ICRG
Education	EDU	School age population, secondary education, both sexes (number)	UNESCO

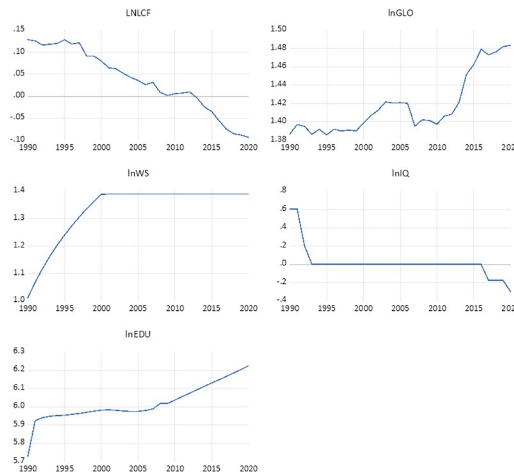


Fig. 1 Trend of the variables.

$$\mathrm{ln}LCF_t = \gamma_0 + \gamma_1\mathrm{ln}GLO_t + \gamma_2\mathrm{ln}WS_t + \gamma_3\mathrm{ln}IQ_t + \gamma_4\mathrm{ln}EDU_t + \epsilon_t \tag{1}$$

Within this framework, LCFrepresents the Load Capacity Factor, GLOdenotes the globalization index, WS measures water stress, IQrepresents institutional quality, and EDUdenotes the population of official secondary-school age, both sexes, which is used as a proxy for potential human-capital formation. The coefficients $\gamma_1 - \gamma_4$ represent the long-run elasticities, while ϵ_t denotes the stochastic error term.

Building on Eq. (1), the unrestricted error-correction representation of the ARDL model used for the bounds test is specified as follows:

$$\begin{aligned}\Delta \ln LCF_t =& \alpha_0 + \lambda_1 \ln LCF_{t-1} + \lambda_2 \ln GLO_{t-1} + \lambda_3 \ln WS_{t-1} + \lambda_4 \ln IQ_{t-1} + \lambda_5 \ln EDU_{t-1} \\ &+ \sum\nolimits_{i=1}^{p-1}\phi_i \Delta \ln LCF_{t-i} + \sum\nolimits_{j=0}^{q_1-1}\theta_{1j}\Delta \ln GLO_{t-j} + \sum\nolimits_{j=0}^{q_2-1}\theta_{2j}\Delta \ln WS_{t-j} \\ &+ \sum\nolimits_{j=0}^{q_3-1}\theta_{3j}\Delta \ln IQ_{t-j} + \sum\nolimits_{j=0}^{q_4-1}\theta_{4j}\Delta \ln EDU_{t-j} + \epsilon_t\end{aligned} \tag{2}$$

In Eq. (2), α_0 denotes the intercept, while $\lambda_1 - \lambda_5$ are the coefficients of the lagged-level variables used to test for a long-run relationship. The parameters ϕ_i and θ_{kj} capture the short-run dynamics. The lag orders p, q_1, q_2 , q_3, and q_4 correspond to the selected lag lengths of the dependent and explanatory variables. The optimal lag structure was selected using the Akaike Information Criterion, with the specification producing the lowest AIC value retained for estimation.

The existence of cointegration is examined through the joint significance of the lagged-level variables using the following hypotheses:

$$H_0 : \lambda_1 = \lambda_2 = \lambda_3 = \lambda_4 = \lambda_5 = 0$$

$$H_a : \exists k \in \{1,2,3,4,5\} : \lambda_k \neq 0$$

The null hypothesis indicates the absence of a long-run relationship, whereas its rejection supports cointegration. An F-statistic exceeding the upper critical bound, $I\left(1\right)$, confirms cointegration, while a value below the lower critical bound, $I\left(0\right)$, indicates no cointegration. A statistic falling between the two bounds produces an inconclusive result.

Once cointegration is established, the lagged error-correction term is generated from the residuals of the estimated long-run relationship in Eq. (1):

$$ECT_{t-1} = \ln LCF_{t-1} - (\acute{\gamma}_0 + \acute{\gamma}_1 \ln GLO_{t-1} + \acute{\gamma}_2 \ln WS_{t-1} + \acute{\gamma}_3 \ln IQ_{t-1} + \acute{\gamma}_4 \ln EDU_{t-1}) \quad (3)$$

The corresponding restricted short-run error-correction model is then specified as:

$$\begin{aligned}\Delta \ln LCF_t =& \beta_0 + \sum\nolimits_{i=1}^{p-1} \phi_i \Delta \ln LCF_{t-i} + \sum\nolimits_{j=0}^{q_1-1} \theta_{1j} \Delta \ln GLO_{t-j} + \sum\nolimits_{j=0}^{q_2-1} \theta_{2j} \Delta \ln WS_{t-j} \\ &+ \sum\nolimits_{j=0}^{q_3-1} \theta_{3j} \Delta \ln IQ_{t-j} + \sum\nolimits_{j=0}^{q_4-1} \theta_{4j} \Delta \ln EDU_{t-j} + \psi ECT_{t-1} + \epsilon_t\end{aligned} \quad (4)$$

In Eq. (4), ψ denotes the speed-of-adjustment coefficient and is expected to be negative and statistically significant. Its magnitude indicates the proportion of the previous period's disequilibrium corrected within one year. The operator $\varDelta$ represents first differences and therefore captures short-run changes in the variables.

Empirical results and discussion

Descriptive and correlation statistics

Table 2 provides a statistical summary of the study variables. Among them, Education demonstrates the highest mean value (6.0199), signifying its greater magnitude in comparison to the other indicators. Conversely, institutional quality exhibits the lowest mean (0.0185), indicating relatively weaker governance performance over the study period. In terms of dispersion, institutional quality exhibits the highest standard deviation (0.1768), indicating significant variability in governance effectiveness across time periods. In contrast, globalization exhibits the lowest standard deviation (0.0325), indicating that the degree of global integration has been relatively stable throughout the sample period. The normality tests indicate that water stress and institutional quality exhibit significant deviations from a normal distribution, while the remaining variables approximate normality.

Furthermore, the correlation results shown in Table 3 reveal clear patterns in the associations between the independent variables and the load capacity factor. Specifically, globalization exhibits a strong negative correlation with the load capacity factor (–0.8877), indicating that increased global integration corresponds with a decline in ecological sustainability. Likewise, education also shows a strong negative association (–0.9021). Furthermore, water stress exhibits a negative correlation of −0.6740, indicating that increased agricultural water withdrawals in relation to renewable resources disrupt ecological balance. On the other hand, the quality of institutions shows a positive correlation with the load capacity factor (0.6029), indicating that better governance is associated with advancements in ecological sustainability.

Table 2 Descriptive result.

	LNLCF	LNGLO	LNWS	LNIQ	LNEDU
Mean	0.0363	1.4177	1.3310	0.0185	6.0199
Maximum	0.1286	1.4836	1.3897	0.6021	6.2237
Minimum	-0.0939	1.3857	1.0120	-0.3010	5.7308
Std. Dev.	0.0712	0.0325	0.1074	0.1768	0.1013
Probability	0.4039	0.0578	0.0000	0.0000	0.6221
Observations	31	31	31	31	31

Table 3 Correlation matrix.

	LNLCF	LNGLO	LNWS	LNIQ	LNEDU
LNLCF	1	-0.88767	-0.673955	0.602883	-0.902062
LNGLO	-0.88767	1	0.465503	-0.503938	0.85129
LNWS	-0.673955	0.465503	1	-0.774708	0.662751
LNIQ	0.602883	-0.503938	-0.774708	1	-0.737246
LNEDU	-0.902062	0.85129	0.662751	-0.737246	1

Table 4 Variance inflation factor.

Variable	Centered VIF
LNGLO	4.156
LNWS	2.634
LNIQ	3.452
LNEDU	6.985

Table 5 unit root result.

Variable	ADF		PP	
	Level	1st Diff	Level	1st Diff
LNLCF	0.8757	-5.4373***	0.9588	-5.4369***
LNGLO	0.2859	-4.5214***	-0.0844	-4.6474***
LNWS	-2.7228*	-2.7920*	-8.628***	-2.934*
LNIQ	0.067	-3.8807***	-3.4835**	-3.8808***
LNEDU	-2.3604	-19.5270***	-2.2936	-11.9577***

Notes: *** denotes 1% significance, ** indicates 5%, and * represents 10%.

Given the comparatively strong pairwise correlations among some of the explanatory variables, particularly between LNGLO and LNEDU, variance inflation factor diagnostics were undertaken to assess whether multicollinearity might affect the precision and stability of the estimated coefficients. As presented in Table 4, the centered VIF values range from 2.634 to 6.985. Although these values remain below the conventional threshold of 10, thereby indicating the absence of severe multicollinearity, the VIF for LNEDU exceeds the more conservative benchmark of 5. Accordingly, this result points to a moderate degree of multicollinearity involving the education variable. Nevertheless, the magnitude of the reported VIF values does not warrant the exclusion of any explanatory variable from the model. Therefore, all variables were retained, while the estimated coefficient of LNEDU was interpreted with appropriate caution.

Stationarity Tests

Prior to engaging in any time series analysis, it is crucial to assess the integration properties of the variables to guarantee the accuracy of regression outcomes[79,80–82]. The Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests were utilized to evaluate the stationarity of the variables in the study. The ADF test incorporates lagged difference terms to address autocorrelation, whereas the PP test provides a non-parametric adjustment for serial correlation and heteroskedasticity. The findings shown in Table 5 reveal that the load capacity factor, globalization, institutional quality, and education exhibit non-stationarity at levels, as evidenced by their ADF and PP statistics not reaching significance at conventional thresholds. Nonetheless, all these variables achieve stationarity following first differencing, demonstrating significance at the 1% level, thereby confirming their integration of order one, I(1). Water stress presents mixed evidence, demonstrating weak significance at the 10% level in the ADF test, yet it attains stationarity following first differencing. The results support the use of econometric methods capable of handling variables integrated at different orders. The autoregressive distributed lag (ARDL) methodology is well suited for this research, since it adeptly handles a combination of I(0) and I(1) variables, providing consistent estimates of both long-term and short-term associations[83–86].

Table 6 Bounds testing result.

	Bounds test critical values			
	k = 4			
Model	F-statistic	I(0)	I(1)	Decision
lnLCF = f(lnGLO, lnWS, lnIQ, lnEDU)	5.642981	3.276**	4.63**	Cointegration
		2.696*	3.898*	

Notes: *** denotes 1% significance, ** indicates 5%, and * represents 10%.

Table 7 Long run and short run result.

	Variable	Coefficient	Std. Error	t-Statistic	Prob.
Long run	$lnGLO_{t-1}$	-0.3403	0.1135	-2.9979	0.0085
	$lnWS_{t-1}$	-0.0657	0.0287	-2.2920	0.0358
	$lnIQ_{t-1}$	0.0654	0.0248	2.6360	0.0180
	$lnEDU_{t-1}$	0.0976	0.0293	3.3321	0.0042
Short run	Constant	-0.0017	0.0036	-0.4560	0.6539
	ΔLnGLO	-0.4377	0.1978	-2.2126	0.0401
	$\Delta lnGLO_{t-2}$	-0.4445	0.1985	-2.2396	0.0380
	$\Delta lnWS_{t}$	0.3123	0.3467	0.9007	0.3796
	$\Delta lnWS_{t-1}$	-0.5622	0.4468	-1.2583	0.2244
	$\Delta lnWS_{t-2}$	0.5773	0.3340	1.7286	0.1010
	$\Delta lnIQ_{t}$	0.0927	0.0445	2.0838	0.0517
	$\Delta lnEDU_{t-1}$	-0.4928	0.3212	-1.5342	0.1424
	$\Delta lnEDU_{t-2}$	0.1250	0.0674	1.8547	0.0801
	$ECT1_{t-1}$	-0.1577	0.0716	-2.2036	0.0408
ARDL(1, 2, 3, 1, 2)	R-squared	0.7388			
	Adjusted R-squared	0.5592			

ARDL bounds testing

The bounds testing results for the autoregressive distributed lag (ARDL) model are presented in Table 6. Notably, the F-statistic for the model, which investigates the relationship between the load capacity factor and its determinants—globalization, water stress, institutional quality, and education—is 5.643. This value exceeds the upper bound critical values at both the 5% (4.63) and 10% (3.898) significance levels, thereby indicating the existence of a long-run equilibrium relationship among the variables. Consequently, the null hypothesis of no cointegration is rejected, confirming that the selected explanatory variables are jointly associated with the load capacity factor in the long term.

Long run and short run ARDL result

The long-run estimates of the ARDL model in Table 7 reveal both negative and positive impacts of the explanatory variables on the load capacity factor, highlighting their varied contributions to ecological sustainability. Globalization has a detrimental long-term effect, as a 1% rise in globalization is associated with a 0.34% decrease in the load capacity factor. This indicates that increased integration into the global economy may intensify ecological pressures and diminish environmental carrying capacity over time. Water stress has a negative effect, with a 1% rise leading to a 0.07% reduction in the load capacity factor, highlighting the ecological vulnerability associated with increased agricultural water use. On the other hand, institutional quality has a positive long-term impact; for example, a 1% improvement in governance effectiveness leads to a 0.07% rise in load capacity factor. This underscores the critical role that strong institutions play in fostering environmentally sustainable management. Education has a beneficial impact, as a 1% increase in the load capacity factor leads to a 0.10% increase. This implies that the cultivation of human capital fosters ecological resilience and sustainable resource utilization.

Moreover, the short-run dynamics of the ARDL model demonstrate that globalization and institutional quality have a significant impact on the load capacity factor. Globalization has a detrimental short-term impact, as a 1%

increase in both current and lagged period's results in a reduction of the load capacity factor by roughly 0.44%. This highlights the immediate and delayed ecological challenges associated with increased global integration. Institutional quality has a positive short-run impact, with a 1% improvement in governance resulting in a proportionate increase in the load capacity factor, underscoring the significance of effective institutions in mitigating environmental stresses and promoting stability. The second lag of education has a positive and substantial short-term impact, implying that previous advances in human capital may increase ecological sustainability with a temporal lag in response. Other short-term coefficients, such as water stress and the first lag of education, lack statistical significance, indicating that their effects are predominantly observed in the long term. In particular, the positive but insignificant short-run coefficient of water stress should not be interpreted as evidence of an immediate improvement in the Load Capacity Factor. Rather, it may reflect a temporary adjustment process in which households, farmers, and institutions respond to short-term water shortages through changes in water use, emergency coping mechanisms, or seasonal adaptation. However, these responses may only delay the ecological consequences of water scarcity.

On the other hand, the negative and significant error-correction term, with a coefficient of -0.1577, indicates the existence of a self-correcting mechanism that adjusts deviations from the long-run equilibrium over time. More specifically, approximately 15.77% of any disequilibrium is corrected within one year, implying that a complete return to equilibrium may require roughly six to seven years. Although this adjustment process appears relatively slow, it is plausible in the Somali context, where weak institutional capacity, fragmented environmental and water governance, inadequate infrastructure, and recurrent climatic and political shocks can delay policy implementation and ecological recovery. Furthermore, processes such as soil restoration, vegetation regeneration, water-resource rehabilitation, and institutional reform generally require sustained interventions over several years. Therefore, the relatively low adjustment speed reflects the structural and institutional constraints that limit Somalia's capacity to restore ecological equilibrium rapidly. The model demonstrates significant explanatory power, evidenced by an R-squared value of 0.7388 and an adjusted R-squared of 0.5592, indicating the ability of the chosen variables to explain considerable short-term variation in the load capacity factor.

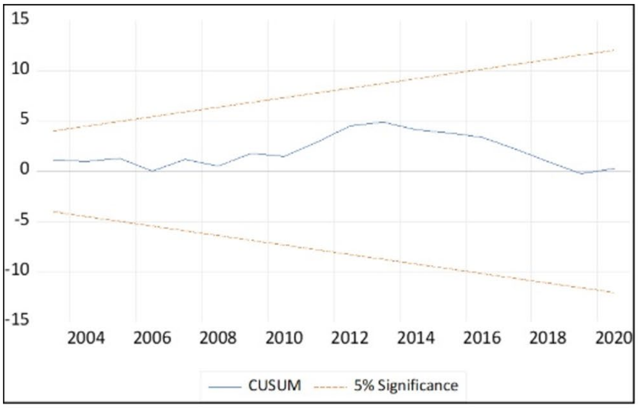
Diagnostic tests

The diagnostic results reported in Table 8 support the adequacy and reliability of the estimated ARDL model. The Breusch–Godfrey LM test fails to reject the null hypothesis of no serial correlation, as its probability value exceeds the 5% significance level. Similarly, the Ramsey RESET test provides no evidence of functional-form misspecification. The Breusch–Pagan–Godfrey test also indicates that the residuals are homoscedastic, suggesting that heteroskedasticity does not materially affect the estimated coefficients. In addition, the Jarque–Bera normality test confirms that the residuals are approximately normally distributed. The stability of the model is further supported by the CUSUM and CUSUM of squares plots, which remain within the 5% critical bounds throughout the sample period, as illustrated in Fig. 2. Overall, these findings provide no evidence of serial correlation, heteroskedasticity, non-normal residuals, functional-form misspecification, or parameter instability, thereby supporting the interpretation of the long-run and short-run estimates.

Table 8 Diagnostic results.

Test	Statistic (*p*-value)
Breusch-Godfrey LM(1)	2.526 (0.112)
Ramsey RESET	2.056 (0.165)
Breusch-Pagan-Godfrey (heteroskedasticity)	13.688 (0.321)
J–B normality	0.600(0.740)

 https://doi.org/10.1038/s41598-026-69829-0



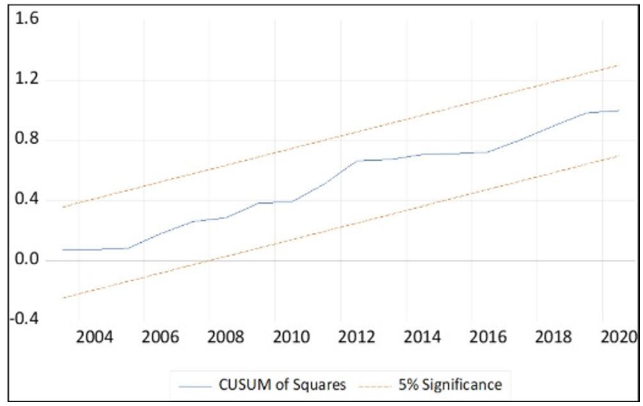


Fig. 2 Stability diagnostic tests. The left panel presents the CUSUM test, while the right panel presents the CUSUM-of-squares test.

Table 9 Sensitivity result.

Dependent variable: LNLCF				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
Fully Modified Least Squares (FMOLS)				
lnGLO	-1.3655	0.6047	-2.2582	0.0326
lnWS	-0.1684	0.1431	-1.1767	0.2500
lnIQ	0.2487	0.0850	2.9263	0.0070
lnEDU	0.3647	0.1463	2.4937	0.0193
R-squared	0.5589			
Adjusted R-squared	0.5080			
Dynamic Least Squares (DOLS)				
lnGLO	-0.3662	0.2135	-1.7152	0.1120
lnWS	-0.1286	0.0918	-1.4013	0.1865
lnIQ	0.3555	0.0390	9.1222	0.0000
lnEDU	0.1246	0.0564	2.2093	0.0473
R-squared	0.9882			
Adjusted R-squared	0.9734			

Sensitivity tests

The ARDL findings are reinforced by robustness tests using Dynamic Ordinary Least Squares (DOLS) and Fully Modified Ordinary Least Squares (FMOLS) in Table 9 which confirm the long-term relationships observed in the primary analysis. The load capacity factor is positively influenced by institutional quality and education, while the negative effects of globalization and water stress are confirmed by both estimators. Specifically, globalization tends to adversely impact ecological sustainability, while the quality of institutions and education contribute positively to environmental resilience. Although water stress continues to be a negative factor, its importance appears to be diminished, indicating a less severe influence. The significance of the chosen variables is highlighted by the FMOLS model, which elucidates around 56% of the variation in the load capacity factor, while the DOLS model captures nearly 99% of the variation. Although the DOLS estimates broadly support the long-run findings, the model's high $R^2$of 0.9882 should be interpreted cautiously. Given the small sample and the inclusion of leads and lags, the specification may be vulnerable to overfitting. Therefore, the DOLS results are used primarily as a robustness check, with greater emphasis placed on their consistency with the ARDL and FMOLS estimates.

The FMOLS and DOLS results provide partial robustness for the long-run ARDL estimates. Institutional quality and education are the most robust determinants because both remain positive and statistically significant under the two estimators. Globalization retains a negative coefficient in both models, but it is statistically significant

Table 10 Results of Toda-Yamamoto Granger Causality.

Dependent variable	LNLCF	LNGLO	LNWS	LNIQ	LNEDU
LNLCF		9.286***	12.642***	6.864**	10.814***
LNGLO	8.934**		6.973**	1.306	14.843**
LNWS	3.334	3.057		2.64	2.853
LNIQ	0.45	5.692*	2.404		0.027
LNEDU	2.501	20.976***	3.054	15.960***	

Notes: *** denotes 1% significance, ** indicates 5%, and * represents 10%.

only under FMOLS. Water stress also remains negative across the estimators, although its effect is statistically insignificant in both cases. Therefore, the sensitivity analysis confirms the directional consistency of all coefficients but provides stronger statistical support for institutional quality and education than for globalization and water stress. The DOLS $R^2$of 0.9882 indicates a very strong model fit; however, this result should be viewed with caution because the limited sample size and the use of leads and lags may inflate the model's explanatory power.

Toda-Yamamoto granger causality test

The Toda–Yamamoto causality results reported in Table 10 reveal important predictive relationships among the Load Capacity Factor, globalization, water stress, institutional quality, and education. Globalization, water stress, institutional quality, and education significantly Granger-cause the Load Capacity Factor, indicating that these variables contain useful information for predicting changes in Somalia's ecological capacity. Among them, globalization and education exhibit comparatively strong predictive effects, underscoring the relevance of economic integration and potential human-capital formation to environmental outcomes. Water stress and institutional quality also significantly predict the Load Capacity Factor, reflecting the importance of freshwater pressure and governance conditions in shaping ecological sustainability. However, the reverse relationships are not uniform. The Load Capacity Factor significantly Granger-causes globalization, indicating bidirectional causality between these two variables. By contrast, no significant reverse causality is found from the Load Capacity Factor to water stress, institutional quality, or education. Therefore, the results indicate bidirectional predictive causality only between the Load Capacity Factor and globalization, whereas unidirectional causality runs from water stress, institutional quality, and education to the Load Capacity Factor.

Discussion of the findings

The long-term ARDL estimates underscore the substantial detrimental impact of globalization on the ecological sustainability of Somalia, as quantified by the load capacity factor (LCF). This suggests that increasing trade openness, industrialization, and global integration place additional pressure on already fragile ecosystems. Earlier research reinforces this result, indicating that globalization tends to aggravate ecological degradation in Somalia and other developing countries, primarily because of inadequate environmental regulation and accelerated urban growth[49,87–90]. These results are consistent with broader cross-country evidence, which demonstrates that unless economic integration is coupled with strong governance, globalization exacerbates ecological burdens rather than alleviates them[91].

Water stress exhibits a negative long-term correlation with the LCF. This illustrates the effects of repeated droughts, excessive agricultural extractions, and ineffective irrigation systems on the ecosystems of Somalia. Water scarcity undermines soil fertility, reduces vegetation cover, and threatens food security and ecological balance[92,93]. The findings indicate that climate variability and inadequate water management significantly contribute to ecological degradation in vulnerable regions, especially in Somalia, where persistent droughts and desertification exacerbate ecological stress. Conversely, institutional quality demonstrates a beneficial effect on ecological sustainability. This finding highlights the significance of efficient governance, environmental regulation, and strategic long-term planning in alleviating the negative impacts of globalization and demographic challenges.

Research indicates that robust institutions contribute to greater adherence to environmental regulations and enhance resource governance, as evidenced by findings from Somalia and other developing regions[49,81,94,95]. Some studies indicate that although institutional reforms in Somalia are present, their effectiveness is potentially constrained by inadequate enforcement capacity, underscoring the necessity for more comprehensive governance reforms.

Finally, Education is demonstrated to have a positive impact on the LCF, highlighting the importance of human capital in enhancing ecological resilience. Education promotes environmental awareness, facilitates sustainable practices, and enhances innovation in tackling ecological challenges. Recent evidence indicates that elevated education levels contribute to reduced ecological footprints in Somalia by fostering pro-environmental behavior and enhancing public support for sustainability policies[96,97]. In addition to influencing individual behavior, education strengthens institutional capacity by cultivating a more knowledgeable workforce that can engage in policymaking, environmental monitoring, and the execution of sustainability initiatives. In rural regions characterized by a reliance on agriculture and natural resources, literacy and environmental education enhance community engagement in climate adaptation practices and water conservation strategies.

Conclusion and policy implication

Grasping the fundamental factors that influence ecological sustainability is a crucial focus, especially for nations that are developing and vulnerable to climate change. This study examines the factors influencing Somalia's environmental capacity by utilizing the Load Capacity Factor. It incorporates essential elements such as globalization, water stress, institutional quality, and human capital within a dynamic econometric framework. Employing the ARDL bounds testing method, causality analysis, and robustness estimators, this study highlights the intricate socio-ecological interconnections that influence sustainability results in a highly drought-prone and institutionally vulnerable economy.

The empirical evidence reveals four key findings. Initially, globalization has a persistent and negative impact on the ecological sustainability of Somalia throughout various timeframes. The findings suggest that the nation's approach to global integration—marked by reliance on imports, insufficient regulatory frameworks, and restricted technological uptake—has intensified environmental degradation instead of alleviating it. Secondly, water stress stands out as a significant limitation on ecological capacity, highlighting that repeated droughts, unsustainable irrigation methods, and the overuse of limited water resources have gradually diminished the nation's biocapacity, consequently increasing its ecological deficit. Third, the quality of institutions shows a positive and statistically significant impact, highlighting governance as a crucial mechanism for attaining ecological stability. Robust institutions enable efficient enforcement, clear resource management, and synchronized adaptation strategies, all of which are crucial for environmental resilience. Fourth, educational attainment serves as a significant indicator of human capital, positively impacting long-term outcomes. This reinforces the idea that education increases awareness, drives innovation, and facilitates the spread of sustainable technologies and practices.

From a policy perspective, Somalia's environmental trajectory depends on shifting towards eco-structural transformation. Policymakers should promote green globalization through sustainable trade, clean-technology transfer, and environmental certification in livestock, fisheries, hides and skins, sesame, bananas, and other agricultural exports. Livestock certification should incorporate traceability, sustainable rangeland management, and responsible water use, while fisheries require catch monitoring, licensing controls, and measures against illegal fishing. The charcoal sector instead requires stricter monitoring of production and export routes, enforcement against illegal trade, and support for alternative energy and livelihoods. Water resilience should also become a national development priority through watershed management, groundwater recharge, and efficient irrigation. Groundwater over-abstraction in Mogadishu and Hargeisa should be addressed through borehole registration, abstraction monitoring, recharge-zone protection, and rainwater harvesting. Somalia should also strengthen cooperation over the Juba and Shabelle rivers through hydrological data sharing and coordinated drought and flood management. These measures require a national water-policy framework that clearly defines federal, federal member state, and local responsibilities.

Institutional modernization should focus on stronger environmental regulation, data transparency, ecological accounting, and anti-corruption safeguards. Capacity-building should prioritize the Ministry of Environment and Climate Change and related institutions responsible for water, agriculture, livestock, fisheries, energy, trade, and planning. Federal and federal member state coordination should be improved through clearer mandates, harmonized standards, and shared environmental information systems. Education and professional training in renewable energy, water management, climate-resilient agriculture, and environmental monitoring should support this transition. Somalia also requires a National Ecological Transition Framework integrating economic diversification, water security, and green innovation. Implementation should proceed in phases: institutional coordination and baseline assessments within one to two years, sectoral programmes and monitoring systems within three to five years, and large-scale ecosystem restoration beyond five years. Funding could be mobilized from national budgets, the Green Climate Fund, the Adaptation Fund, development partners, and responsible private investment, supported by transparent monitoring and reporting.

This study recognizes several limitations despite its contributions. The analysis focuses on selected macro-structural determinants and therefore excludes other potentially important factors, including renewable energy adoption, conflict dynamics, and land-use change. Human capital is proxied by the population of official secondary-school age, both sexes, measured as a number. Because this indicator is influenced by population size and does not capture actual enrollment or completed educational attainment, it may represent potential rather than realized human-capital formation. The use of the aggregate KOF Globalization Index is another limitation, as its economic, social, and political dimensions may influence the Load Capacity Factor through different or even opposing channels. Moreover, the water-stress indicator, measured as agricultural water withdrawal relative to total renewable water resources, captures aggregate pressure on freshwater availability but does not account for irrigation efficiency, water-distribution losses, drought frequency, seasonal scarcity, groundwater depletion, or regional differences in water demand and availability. The analysis also does not capture ecological heterogeneity across Somali regions. In addition, the Toda–Yamamoto results indicate reverse predictive causality from the Load Capacity Factor to some of its determinants, particularly globalization. This raises a potential endogeneity concern because the ARDL framework treats the explanatory variables as weakly exogenous. Consequently, the estimated coefficients should be interpreted as conditional long-run associations rather than definitive causal effects. Future studies should therefore employ more direct human-capital indicators when consistent data become available, disaggregate the dimensions of globalization, combine withdrawal-based water indicators with measures of drought and water-use efficiency, incorporate additional environmental and political variables, and apply instrumental-variable, simultaneous-equation, or structural VAR methods to address potential endogeneity. Region-specific, nonlinear, and machine-learning approaches may also help capture more complex interactions between ecological and socioeconomic systems.

Author contributions The study was conceptualized and designed by Abdisalan Aden Mohamed, who also conducted data collection, performed the empirical analysis, and prepared the initial draft of the manuscript. Abdikafi Hassan Abdi contributed to the study's development by critically reviewing the manuscript, assisting in data collection, and providing methodological guidance. Ahmed Olow Addow was responsible for formulating and writing the Methodology section, while Abas Mohamed Hassan developed the Introduction. Sidomar Osman Farah contributed by compiling and synthesizing the Literature Review. All authors reviewed and approved the final version of the manuscript.

Funding This research is supported by SIMAD University, Somalia.

Data availability The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Competing interests The authors declare no competing interests.

Ethical approval This study follows all ethical practices during writing. We declare that this manuscript is original, has not been published before and is not currently being considered for publication elsewhere.

References

1. Hoekstra, A. Y., Mekonnen, M. M., Chapagain, A. K., Mathews, R. E. & Richter, B. D. Global Monthly Water Scarcity: Blue Water Footprints versus Blue Water Availability. *PLOS ONE*. **7**(2), e32688. https://doi.org/10.1371/journal.pone.0032688 (2012).
2. Ridolfi, L., D'Odorico, P., Porporato, A. & Rodriguez-Iturbe, I. Duration and frequency of water stress in vegetation: An analytical model. (2000). https://doi.org/10.1029/2000WR900104
3. Stocker, B. D. et al. Global patterns of water storage in the rooting zones of vegetation. *Nat. Geosci.* **16**(3), 250–256. https://doi.org/10.1038/s41561-023-01125-2 (2023).
4. Abdi, A. H., Mohamed, A. A. & Mohamed, M. A. Education for sustainable development in Somalia: Do economic growth, energy consumption, and population density affect ecological footprints? *Discover Sustain.* **6**(1), 292. https://doi.org/10.1007/s43621-025-01019-w (2025).
5. Awosusi, A. A., Adebayo, T. S., Kirikkaleli, D., Rjoub, H. & Altuntaş, M. Evaluating the determinants of load capacity factor in Japan: The impact of economic complexity and trade globalization. https://onlinelibrary.wiley.com/doi/ (2023). https://doi.org/10.1111/1477-8947.12334
6. Liu, Z., Mehmood, U. & Nassani, A. A. How do energy efficiency, technology, natural resources and globalization impact environmental sustainability? Fresh evidence from load capacity curve theory. *Front. Environ. Sci.* 12. https://doi.org/10.3389/fenvs.2024.1447808 (2024).
7. Pata, U. K., Kartal, M. T., Dam, M. M. & Kaya, F. Navigating the Impact of Renewable Energy, Trade Openness, Income, and Globalization on Load Capacity Factor: The Case of Latin American and Caribbean (LAC) Countries. (2023). https://doi.org/10.1155/2023/6828781
8. Xu, D. et al. Load Capacity Factor and Financial Globalization in Brazil: The Role of Renewable Energy and Urbanization. *Front. Environ. Sci.* 9. https://doi.org/10.3389/fenvs.2021.823185 (2022).
9. Jin, X., Ahmed, Z., Pata, U. K., Kartal, M. T. & Erdogan, S. Do investments in green energy, energy efficiency, and nuclear energy R&D improve the load capacity factor? An augmented ARDL approach. *Geosci. Front.* **15**(4), 101646. https://doi.org/10.1016/j.gsf.2023.101646 (2024).
10. Raihan, A., Rashid, M., Voumik, L. C., Akter, S. & Esquivias, M. A. The Dynamic Impacts of Economic Growth, Financial Globalization, Fossil Fuel, Renewable Energy, and Urbanization on Load Capacity Factor in Mexico. *Sustainability* **15**(18), 13462. https://doi.org/10.3390/su151813462 (2023).
11. Usman, M. & Jahanger, A. Heterogeneous effects of remittances and institutional quality in reducing environmental deficit in the presence of EKC hypothesis: A global study with the application of panel quantile regression. *Environ. Sci. Pollut. Res.* **28**(28), 37292–37310. https://doi.org/10.1007/s11356-021-13216-x (2021).
12. Wang, B. & Xu, R. How Industrial Output, Economic Growth, Environmental Technology, and Globalization Impact Load Capacity Factor in E7 Nations. *Sustainability* **17**(4), 1419. https://doi.org/10.3390/su17041419 (2025).
13. Ahmed, Z. & Wang, Z. Investigating the impact of human capital on the ecological footprint in India: An empirical analysis. *Environ. Sci. Pollut. Res.* **26**(26), 26782–26796. https://doi.org/10.1007/s11356-019-05911-7 (2019).
14. Alharbey, M. & Ben-Salha, O. Do institutions contribute to environmental sustainability? A global analysis using the dynamic spatial Durbin and threshold models. *J. Environ. Manage.* **357**, 120681. https://doi.org/10.1016/j.jenvman.2024.120681 (2024a).

15. Uzar, U. The relationship between institutional quality and ecological footprint: Is there a connection? https://onlinelibrary.wiley.com/doi/ (2021). https://doi.org/10.1111/1477-8947.12235
16. Yao, Y., Ivanovski, K., Inekwe, J. & Smyth, R. Human capital and energy consumption: Evidence from OECD countries. *Energy Econ.* **84**, 104534. https://doi.org/10.1016/j.eneco.2019.104534 (2019).
17. Fatichi, S., Pappas, C. & Ivanov, V. Y. Modeling plant–water interactions: An ecohydrological overview from the cell to the global scale. (2016). https://doi.org/10.1002/wat2.1125
18. Schyns, J. F., Hoekstra, A. Y. & Booij, M. J. Review and classification of indicators of green water availability and scarcity. *Hydrol. Earth Syst. Sci.* **19**(11), 4581–4608. https://doi.org/10.5194/hess-19-4581-2015 (2015).
19. Groenevelt, P. H., Grant, C. D. & Murray, R. S. On water availability in saline soils. *Soil. Res.* **42**(7), 833–840. https://doi.org/10.1071/SR03054 (2004).
20. Manfreda, S., Scanlon, T. M. & Caylor, K. K. On the importance of accurate depiction of infiltration processes on modelled soil moisture and vegetation water stress (2009). https://doi.org/10.1002/eco.79
21. Eldardiry, H., Habib, E. & Borrok, D. M. Small-scale catchment analysis of water stress in wet regions of the U.S.: An example from Louisiana. *Environ. Res. Lett.* **11**(12), 124031. https://doi.org/10.1088/1748-9326/aa51dc (2016).
22. Sabater, S. et al. Effects of human-driven water stress on river ecosystems: A meta-analysis. *Sci. Rep.* **8**(1), 11462. https://doi.org/10.1038/s41598-018-29807-7 (2018).
23. van Beek, L. P. H., Wada, Y. & Bierkens, M. F. P. Global monthly water stress: 1. *Water balance water Availab.* https://doi.org/10.1029/2010WR009791 (2011).
24. Lemordant, L., Gentine, P., Swann, A. S., Cook, B. I. & Scheff, J. Critical impact of vegetation physiology on the continental hydrologic cycle in response to increasing CO2. *Proc. Natl. Acad. Sci.* **115**(16), 4093–4098. https://doi.org/10.1073/pnas.1720712115 (2018).
25. Mohamed, A. A., Abdi, A. H., Mohamud, S. S. & Osman, B. M. Institutional quality, economic growth, and environmental sustainability: A long-run analysis of the ecological footprint in Somalia. *Discover Sustain.* **6**(1), 490. https://doi.org/10.1007/s43621-025-01063-6 (2025a).
26. Latif, N. & Faridi, M. Z. Examining the impact of financial development on load capacity factor (LCF): System GMM analysis for Asian economies. *Front. Energy Res.* 10. https://doi.org/10.3389/fenrg.2022.1063212 (2023).
27. Kumar, A., Kalhoro, M. R., Kumar, R., Bhutto, N. A. & Shaikh, R. Environmental quality: Examining role of financial development, institutional capacity, and corruption. *Environ. Sci. Pollut. Res.* **28**(38), 53781–53792. https://doi.org/10.1007/s11356-021-14430-3 (2021).
28. Ni, Z., Yang, J. & Razzaq, A. How do natural resources, digitalization, and institutional governance contribute to ecological sustainability through load capacity factors in highly resource-consuming economies? *Resour. Policy*. **79**, 103068. https://doi.org/10.1016/j.resourpol.2022.103068 (2022).
29. Hussein, H. A., Warsame, A. A. & Abdi, A. H. Exploring the impacts of institutional quality, urbanization, and disaggregate globalization on environmental pollution in Somalia. *Cogent Econ. Finance*. https://doi.org/10.1080/23322039.2025.2528438 (2025). https://www.tandfonline.com/doi/abs/
30. Hondroyiannis, G., Papapetrou, E. & Tsalaporta, P. New insights on the contribution of human capital to environmental degradation: Evidence from heterogeneous and cross-correlated countries. *Energy Econ.* **116**, 106416. https://doi.org/10.1016/j.eneco.2022.106416 (2022).
31. Caglar, A. E., Destek, M. A. & Manga, M. Analyzing the load capacity curve hypothesis for the Turkiye: A perspective for the sustainable environment. *J. Clean. Prod.* **444**, 141232. https://doi.org/10.1016/j.jclepro.2024.141232 (2024).
32. Dai, J., Ahmed, Z., Alvarado, R. & Ahmad, M. Assessing the nexus between human capital, green energy, and load capacity factor: Policymaking for achieving sustainable development goals. *Gondwana Res.* **129**, 452–464. https://doi.org/10.1016/j.gr.2023.04.009 (2024a).
33. Samour, A., Adebayo, T. S., Agyekum, E. B., Khan, B. & Kamel, S. Insights from BRICS-T economies on the impact of human capital and renewable electricity consumption on environmental quality. *Sci. Rep.* **13**(1), 5245. https://doi.org/10.1038/s41598-023-32134-1 (2023).
34. Kim, D. & Go, S. Human Capital and Environmental Sustainability. *Sustainability* **12**(11), 4736. https://doi.org/10.3390/su12114736 (2020).
35. Khan, M. CO2 emissions and sustainable economic development: New evidence on the role of human capital. (2020). https://doi.org/10.1002/sd.2083
36. Nathaniel, S. P., Yalçiner, K. & Bekun, F. V. Assessing the environmental sustainability corridor: Linking natural resources, renewable energy, human capital, and ecological footprint in BRICS. *Resour. Policy*. **70**, 101924 (2021).
37. Ünal, H. & Aktuğ, M. The impact of human capital and bio-capacity on the environmental quality: Evidence from G20 countries. *Environ. Sci. Pollut. Res.* **29**(30), 45635–45645. https://doi.org/10.1007/s11356-022-19122-0 (2022).
38. Ahmad, M., Ahmed, Z., Yang, X., Hussain, N. & Sinha, A. Financial development and environmental degradation: Do human capital and institutional quality make a difference? *Gondwana Res.* **105**, 299–310. https://doi.org/10.1016/j.gr.2021.09.012 (2022).

39. Warsame, A. A., Abdi, A. H., Amir, A. Y. & Azman-Saini, W. N. W. Towards sustainable environment in Somalia: The role of conflicts, urbanization, and globalization on environmental degradation and emissions. *J. Clean. Prod.* **406**, 136856 (2023).
40. Mohamud, I. H. & Mohamud, A. A. The impact of renewable energy consumption and economic growth on environmental degradation in Somalia. *Int. J. Energy Econ. Policy*. **13**(5), 533–543 (2023).
41. Awosusi, A. A. et al. A Roadmap toward Achieving Sustainable Environment: Evaluating the Impact of Technological Innovation and Globalization on Load Capacity Factor. *Int. J. Environ. Res. Public Health*. **19**(6). https://doi.org/10.3390/ijerph19063288 (2022). Article 6.
42. Yang, M., Magazzino, C., Awosusi, A. A. & Abdulloev, N. Determinants of Load capacity factor in BRICS countries: A panel data analysis. *Nat. Resour. Forum*. **48**(2), 525–548. https://doi.org/10.1111/1477-8947.12331 (2024).
43. Jahanger, A., Ogwu, S. O., Onwe, J. C. & Awan, A. The prominence of technological innovation and renewable energy for the ecological sustainability in top SDGs nations: Insights from the load capacity factor. *Gondwana Res.* **129**, 381–397. https://doi.org/10.1016/j.gr.2023.05.021 (2024).
44. Rasool, S. F. et al. Investigating the role of the tech industry, renewable energy, and urbanization in sustainable environment: Policy directions in the context of developing economies. *Technol. Forecast. Soc. Chang.* **183**, 121935. https://doi.org/10.1016/j.techfore.2022.121935 (2022).
45. Zaman, Q. U., Zhao, Y., Zaman, S. & Shah, A. H. Examining the symmetrical effect of traditional energy resources, industrial production, and poverty lessening on ecological sustainability: Policy track in the milieu of five neighboring Asian economies. *Resour. Policy*. **83**, 103606. https://doi.org/10.1016/j.resourpol.2023.103606 (2023).
46. Lu, C., Hua, X., Peng, Y., Tian, J. & Tian, G. Achieving ecological sustainability in OECD countries: The role of fiscal decentralization and green energy. *J. Clean. Prod.* **466**, 142814. https://doi.org/10.1016/j.jclepro.2024.142814 (2024).
47. Sharif, A., Bashir, U., Mehmood, S., Cheong, C. W. H. & Bashir, M. F. Exploring the impact of green technology, renewable energy and globalization towards environmental sustainability in the top ecological impacted countries. *Geosci. Front.* **15**(6), 101895. https://doi.org/10.1016/j.gsf.2024.101895 (2024).
48. Abid, M. Does economic, financial and institutional developments matter for environmental quality? A comparative analysis of EU and MEA countries. *J. Environ. Manage.* **188**, 183–194. https://doi.org/10.1016/j.jenvman.2016.12.007 (2017).
49. Alharbey, M. & Ben-Salha, O. Do institutions contribute to environmental sustainability? A global analysis using the dynamic spatial Durbin and threshold models. *J. Environ. Manage.* **357**, 120681. https://doi.org/10.1016/j.jenvman.2024.120681 (2024b).
50. Salman, M., Long, X., Dauda, L. & Mensah, C. N. The impact of institutional quality on economic growth and carbon emissions: Evidence from Indonesia, South Korea and Thailand. *J. Clean. Prod.* **241**, 118331. https://doi.org/10.1016/j.jclepro.2019.118331 (2019).
51. Zakaria, M. & Bibi, S. Financial development and environment in South Asia: The role of institutional quality. *Environ. Sci. Pollut. Res.* **26**(8), 7926–7937. https://doi.org/10.1007/s11356-019-04284-1 (2019).
52. Rafei, M., Esmaeili, P. & Balsalobre-Lorente, D. A step towards environmental mitigation: How do economic complexity and natural resources matter? Focusing on different institutional quality level countries. *Resour. Policy*. **78**, 102848. https://doi.org/10.1016/j.resourpol.2022.102848 (2022).
53. Wang, Q., Sun, J., Li, R., Pata, K. & U Linking trade openness to load capacity factor: The threshold effects of natural resource rent and corruption control. *Gondwana Res.* **129**, 371–380. https://doi.org/10.1016/j.gr.2023.05.016 (2024).
54. Wang, X. et al. The role of government effectiveness, technological innovations, natural resource protection on carbon emissions in Gulf Cooperation Council region: A pathway for achieving sustainable development goals by 2030. *J. Environ. Manage.* **377**, 124506. https://doi.org/10.1016/j.jenvman.2025.124506 (2025).
55. Danish & Ulucak, R. The pathway toward pollution mitigation: Does institutional quality make a difference? (2020). https://doi.org/10.1002/bse.2597
56. Mavragani, A., Nikolaou, I. E. & Tsagarakis, K. P. Open Economy, Institutional Quality, and Environmental Performance: A Macroeconomic Approach. *Sustainability* **8**(7), 601. https://doi.org/10.3390/su8070601 (2016).
57. Musa, M. S., Jelilov, G., Iorember, P. T. & Usman, O. Effects of tourism, financial development, and renewable energy on environmental performance in EU-28: Does institutional quality matter? *Environ. Sci. Pollut. Res.* **28**(38), 53328–53339. https://doi.org/10.1007/s11356-021-14450-z (2021).
58. Dam, M. M., Durmaz, A., Bekun, F. V. & Tiwari, A. K. The role of green growth and institutional quality on environmental sustainability: A comparison of CO2 emissions, ecological footprint and inverted load capacity factor for OECD countries. *J. Environ. Manage.* **365**, 121551. https://doi.org/10.1016/j.jenvman.2024.121551 (2024).
59. DAM, M. M., Işık, C. & Ongan, S. The impacts of renewable energy and institutional quality in environmental sustainability in the context of the sustainable development goals: A novel approach with the inverted load capacity factor. *Environ. Sci. Pollut. Res.* **30**(42), 95394–95409. https://doi.org/10.1007/s11356-023-29020-8 (2023).
60. Pata, U. K. & Isik, C. Determinants of the load capacity factor in China: A novel dynamic ARDL approach for ecological footprint accounting. *Resour. Policy*. **74**, 102313. https://doi.org/10.1016/j.resourpol.2021.102313 (2021).

61. Dai, J., Ahmed, Z., Alvarado, R. & Ahmad, M. Assessing the nexus between human capital, green energy, and load capacity factor: Policymaking for achieving sustainable development goals. *Gondwana Res.* **129**, 452–464. https://doi.org/10.1016/j.gr.2023.04.009 (2024b).
62. Zaman, Q. U., Wang, Z., Zaman, S. & Rasool, S. F. Investigating the nexus between education expenditure, female employers, renewable energy consumption and CO_2 emission: Evidence from China. *J. Clean. Prod.* **312**, 127824. https://doi.org/10.1016/j.jclepro.2021.127824 (2021).
63. Zaman, S., Wang, Z., Rasool, S. F., Zaman, Q. U. & Raza, H. Impact of critical success factors and supportive leadership on sustainable success of renewable energy projects: Empirical evidence from Pakistan. *Energy Policy*. **162**, 112793. https://doi.org/10.1016/j.enpol.2022.112793 (2022a).
64. Zaman, S., Zaman, Q. U., Zhang, L., Wang, Z. & Jehan, N. Interaction between agricultural production, female employment, renewable energy, and environmental quality: Policy directions in context of developing economies. *Renew. Energy*. **186**, 288–298. https://doi.org/10.1016/j.renene.2021.12.131 (2022b).
65. Ahmed, Z., Zafar, M. W., Ali, S. & Danish. Linking urbanization, human capital, and the ecological footprint in G7 countries: An empirical analysis. *Sustainable Cities Soc.* **55**, 102064. https://doi.org/10.1016/j.scs.2020.102064 (2020).
66. Guloglu, B., Emre Caglar, A. & Korkut Pata, U. Analyzing the determinants of the load capacity factor in OECD countries: Evidence from advanced quantile panel data methods. *Gondwana Res.* **118**, 92–104. https://doi.org/10.1016/j.gr.2023.02.013 (2023).
67. Çakar, N. D., Gedikli, A., Erdoğan, S. & Yıldırım, D. Ç. Exploring the nexus between human capital and environmental degradation: The case of EU countries. *J. Environ. Manage.* **295**, 113057. https://doi.org/10.1016/j.jenvman.2021.113057 (2021).
68. Groenevelt, P. H., Grant, C. D. & Semetsa, S. A new procedure to determine soil water availability. *Soil. Res.* **39**(3), 577–598. https://doi.org/10.1071/sr99084 (2001).
69. Grant, C. D. & Groenevelt, P. H. Weighting the differential water capacity to account for declining hydraulic conductivity in a drying coarse-textured soil. *Soil. Res.* **53**(4), 386–391. https://doi.org/10.1071/SR14258 (2015).
70. Vörösmarty, C. J., Green, P., Salisbury, J. & Lammers, R. B. Global Water Resources: Vulnerability from Climate Change and Population Growth. *Science* https://doi.org/10.1126/science.289.5477.284 (2000).
71. Garcia, M., Ridolfi, E. & Di Baldassarre, G. The interplay between reservoir storage and operating rules under evolving conditions. *J. Hydrol.* **590**, 125270. https://doi.org/10.1016/j.jhydrol.2020.125270 (2020).
72. Mehran, A. et al. Compounding Impacts of Human-Induced Water Stress and Climate Change on Water Availability. *Sci. Rep.* **7**(1), 6282. https://doi.org/10.1038/s41598-017-06765-0 (2017).
73. Nilsalab, P. & Gheewala, S. H. Assessing the Effect of Incorporating Environmental Water Requirement in the Water Stress Index for Thailand. *Sustainability* **11**(1), 152. https://doi.org/10.3390/su11010152 (2019).
74. Abdulmagid Basheer Agila, B. et al. Determinants of load capacity factor in South Korea: Does structural change matter? *Environ. Sci. Pollut. Res.* **29**(46), 69932–69948. https://doi.org/10.1007/s11356-022-20676-2 (2022).
75. Destek, M. A. & Sinha, A. Renewable, non-renewable energy consumption, economic growth, trade openness and ecological footprint: Evidence from organisation for economic Co-operation and development countries. *J. Clean. Prod.* **242**, 118537 (2020). https://www.sciencedirect.com/science/article/pii/S0959652619334079
76. Pata, U. K. & Caglar, A. E. Investigating the EKC hypothesis with renewable energy consumption, human capital, globalization and trade openness for China: Evidence from augmented ARDL approach with a structural break. *Energy* **216**, 119220. https://doi.org/10.1016/j.energy.2020.119220 (2021).
77. Abdi, A. H. & Muhumed, A. M. Modelling the marginal effects of energy consumption, ICT, industrialization, and urbanization on environmental sustainability in Somalia: Dynamic ARDL and KRLS approaches. *Discover Sustain.* **6**(1). https://doi.org/10.1007/s43621-025-01027-w (2025).
78. Alam, Q., Voumik, L. C., Rahman, M. H. & Khan, M. A. K. A. Impact of globalization, tourism, energy, and education on load capacity factors in selected 14 Indo-Pacific nations: An advanced econometric analysis. *All Earth*. **37**(1), 1–16. https://doi.org/10.1080/27669645.2025.2477413 (2025).
79. Abdi, A. H., mohamed, A. A. & Mohamed, M. A. *Education for Sustainable Development: The effects of Economic Growth, Energy Consumption, and Population Density on Ecological Sustainability in Somalia* (Discover Sustainability, 2025).
80. Mohamed, A. A. Economic growth and unemployment nexus: Empirical test of Okun's law in Somalia. *J. Economic Struct.* **13**(1), 16. https://doi.org/10.1186/s40008-024-00337-y (2024).
81. Mohamed, A. A., Abdi, A. H., Mohamud, S. S. & Osman, B. M. Institutional quality, economic growth, and environmental sustainability: A long-run analysis of the ecological footprint in Somalia. *Discover Sustain.* **6**(1), 490. https://doi.org/10.1007/s43621-025-01063-6 (2025b).
82. Osman, B. M., Shire, S. A., Ali, F. H. & Mohamed, A. A. Examining the drivers of environmental degradation in Somalia: The role of agriculture, economic and population growth. *Discover Sustain.* **6**(1), 150. https://doi.org/10.1007/s43621-024-00786-2 (2025).

83. Abdi, A. H., Mohamed, A. A., Sugow, M. O. & Halane, D. R. Examining the confluence of climate change and conflicts on agricultural and livestock exports in Somalia. *Environ. Res. Commun.* **6**(7), 075033. https://doi.org/10.1088/2515-7620/ad5cce (2024).
84. Mohamed, A. A. & Abdi, A. H. Exploring the dynamics of inflation, unemployment, and economic growth in Somalia: A VECM analysis. *Cogent Econ. Finance*. **12**(1), 2385644. https://doi.org/10.1080/23322039.2024.2385644 (2024).
85. Pesaran, M. H., Shin, Y. & Smith, R. J. Bounds testing approaches to the analysis of level relationships. *J. Appl. Econom.* **16**(3), 289–326. https://doi.org/10.1002/jae.616 (2001).
86. Warsame, A. A., Sheik-Ali, I. A., Hassan, A. A. & Sarkodie, S. A. Extreme climatic effects hamper livestock production in Somalia. *Environ. Sci. Pollut. Res.* **29**(27), 40755–40767. https://doi.org/10.1007/s11356-021-18114-w (2022).
87. Abdi, A. H., Warsame, A. A., Sugow, M. O. & Hussein, H. A. Transitioning to sustainable energy and enhanced environmental quality in Somalia through renewable energy, globalisation and trade openness. *Sci. Rep.* **15**(1), 6367. https://doi.org/10.1038/s41598-025-87819-6 (2025a).
88. Abdi, A. H., Warsame, A. A., Sugow, M. O. & Hussein, H. A. Transitioning to sustainable energy and enhanced environmental quality in Somalia through renewable energy, globalisation and trade openness. *Sci. Rep.* **15**(1), 6367. https://doi.org/10.1038/s41598-025-87819-6 (2025b).
89. Hussein, O. A. & Mohamed, K. S. Renewable energy and globalization influence: Assessing environmental degradation in Somalia. *Cogent Econ. Finance*. **12**(1), 2387245. https://doi.org/10.1080/23322039.2024.2387245 (2024).
90. Warsame, A. A. Towards sustainable environment in Somalia: The role of conflicts, urbanization, and globalization on environmental degradation and emissions. *J. Environ. Manage.* **323**, 116264. https://doi.org/10.1016/j.jenvman.2023.116264 (2023).
91. Amegavi, G. B., Langnel, Z., Ahenkan, A. & Buabeng, T. The dynamic relationship between economic globalisation, institutional quality, and ecological footprint: Evidence from Ghana. *J. Int. Trade Economic Dev.* **31**(6), 876–893. https://doi.org/10.1080/09638199.2022.2033303 (2022).
92. Ali, O. A. et al. From scarcity to sustainability: A review of the causes, consequences, and management strategies of water scarcity in Somalia. *Discover Sustain.* **6**(1), 927. https://doi.org/10.1007/s43621-025-01695-8 (2025).
93. World Bank. *Somalia Country Environmental Analysis: Diagnostic Study on Trends and Threats for Environmental and Natural Resources Challenges* (World Bank Group, 2019). https://openknowledge.worldbank.org/handle/10986/33409
94. Hussein, O. A. & Abdullahi, A. M. Assessing the impact of agricultural production and institutional quality on environmental degradation in Somalia. *Discover Food*. **5**(1), 63. https://doi.org/10.1007/s44187-025-00310-z (2025).
95. Warsame, A. A., Sheik-Ali, I. A., Mohamed, J. & Sarkodie, S. A. Renewables and institutional quality mitigate environmental degradation in Somalia. *Renew. Energy*. **194**, 1184–1191. https://doi.org/10.1016/j.renene.2022.05.109 (2022).
96. Abdi, A. H. Education for sustainable development in Somalia: The dynamic impact of economic growth, energy consumption, education, and population density on Somalia's ecological footprint. *Discover Sustain.* **6**(1), 1. https://doi.org/10.1007/s43621-025-01019-w (2025).
97. Mohamed, M. J., Omar, A. M. & Walusansa, A. The Status of Awareness About Climate Change and Environmental Conservation Among Higher Education Students in Mogadishu City, Somalia. *Int. J. Sustain. Dev. Plann.* **19**(4), 1539–1545. https://doi.org/10.18280/ijsdp.190430 (2024).

Authors and Affiliations

Abdisalan Aden Mohamed[1] · Abdikafi Hassan Abdi[1,2] · Ahmed Olow Addow[1] · Abas Mohamed Hassan[3] · Sidomar Osman Farah[1]

✉ Abdisalan Aden Mohamed
abdisalanaden09@gmail.com

1 Faculty of Economics, SIMAD University, Mogadishu, Somalia

2 Institute of Climate and Environment, SIMAD University, Mogadishu, Somalia

3 Faculty of Management Sciences, SIMAD University, Mogadishu, Somalia