ENVIRONMENTAL PROTECTION, TERRORISM AND TOURISM NEXUS IN AFRICA

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ABSTRACT

Amid escalating climate change impacts in Africa, marked by rising temperatures, erratic rainfall, extreme heatwaves, sea-level rise, droughts, and biodiversity loss, this study empirically examines the effects of terrorism and international tourism on environmental quality across the continent. In addition, it evaluates the validity of the Environmental Kuznets Curve (EKC) hypothesis within the African context. To achieve these objectives, the study employs a fixed effects model with Driscoll and Kraay standard errors to address cross-sectional dependence and heteroskedasticity. The empirical findings yield several key insights. First, tourism development is found to significantly increase CO_2 emissions in Africa. Second, terrorism shows a positive but statistically insignificant link to CO_2 emissions, suggesting localized impacts with limited continental influence. Third, the results provide empirical support for the U-shaped EKC hypothesis, implying that environmental degradation initially rises with economic growth but declines after surpassing a certain income threshold. Lastly, macroeconomic variables such as economic growth, trade openness, and urbanization are positively associated with CO_2 emissions, whereas renewable energy consumption and gross capital formation are found to mitigate environmental degradation. Policy implications are subsequently discussed.

Keywords: Environmental Quality; Terrorism; Tourism; Driscoll and Kraay standard errors; Africa

JEL Codes: D74; Q53, Q56; L83; Z32; C23; O55

1. INTRODUCTION

In the last decades, human-induced global warming has become a fundamental topic in sustainability arguments. This was due to its extensive consequences for the achievement of the Sustainable Development Goals (SDGs). Defined by the United Nations as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (United Nations, 2024; Menegaki, 2025). Hence, anthropogenic climate change reverses progress towards a range of fundamental SDGs, including those focused on eradicating poverty, hunger, disease, clean water, energy, safe cities, and taking climate action. Such interrelationships highlight the complex, cross-cutting nature of the climate crisis and the need for holistic, cross-sectoral action. While fossil fuels have powered economic growth and industrialization, particularly in low- and middle-income nations (Ikhide, 2021), their environmental consequences have increasingly become evident. CO_2 emissions from the combustion of fossil fuels are increasingly becoming recognized as being primarily responsible for anthropogenic global climate change (Sun et al., 2022; Chowdhury et al., 2024). Ongoing reliance on fossil-based energy infrastructure has contributed to rising global greenhouse gas (GHG) emissions, peaking at 53.8 billion metric tons of CO_2 equivalent in 2022 (Tiseo, 2024). This emission spike has led to severe environmental impacts, including global warming, sea-level rise, land degradation, and more frequent extreme events such as droughts and wildfires. These impacts are most acute in Africa, given its high vulnerability and limited adaptive capacity (Tahir et al., 2022; Ogbeide-Osaretin & Efe, 2022; Dube et al., 2024; Efayena & Olele, 2024;). Therefore, climate change action is not only an environmental imperative but a fundamental necessity for achieving sustainable and just global development.

Africa, the second-largest and second-most populous continent, is home to approximately 1.5 billion people, representing about 18.83% of the global population (Yang et al., 2021; Lam, 2025). The continent has been experiencing enormous economic growth, with a GDP of $2.58 trillion and a per capita GDP of $1,970 as of 2020 (Robertson, 2013). Despite these advancements, the continent remains a minor contributor to global greenhouse gas (GHG) emissions, accounting for only 4%, compared to 53% from Asia, 18% from North America, and 12% from Europe. Nonetheless, both aggregate and per capita CO_2 emissions in Africa are on the rise, reflecting mounting environmental pressures. A growing body of literature attributes this trend to socio-economic, political, and geographical factors, including population growth, fossil fuel reliance, unsustainable agriculture, industrialization, urbanization, weak governance, resource depletion, trade openness, and foreign investment (Kılıç et al., 2024; Chowdhury et al., 2024; Akbar & Emalia, 2025; Raifu & Obaniyi, 2025).

However, beyond the conventional socio-economic and institutional drivers, terrorism has emerged as a critical yet understudied factor influencing environmental degradation in Africa (Bildirici & Gökmenoğlu, 2020; Tahir et al., 2022; Efayena & Olele, 2024). In the last few years, terrorist attacks in the continent have intensified with catastrophic consequences on human security, sustainable development, and environmental stability. West-Central Africa has particularly been beset by armed insurgencies spearheaded by Boko Haram, the Islamic State West Africa Province (ISWAP), and Jama'at Nasr al-Islam wal Muslimin (JNIM). Eastern Africa remains menaced by Al-Shabaab, and Southern Africa by the Allied Democratic Forces (ADF) and Ansar al-Sunna. North Africa remains susceptible to attacks from Islamic State-affiliated cells (Institute for Economics and Peace, 2025; Iheonu et al., 2022; United Nations, 2025). In 2024, they carried out a total of approximately 3,400 attacks and killed over 13,900 individuals.

Moreover, Sub-Saharan Africa was responsible for 59% of all terrorism-related deaths globally (United Nations, 2025). Furthermore, the Sahel region, particularly Mali, Burkina Faso, and Niger suffered 19% of the globe's terrorist attacks and 51% of terrorism-related deaths, up from 48% in 2023 (Institute for Economics and Peace, 2025). Such violence contributes to economic hardship, displacement of people, compromised institutional control and poor resource management.

Moreover, besides its documented security and development impacts, terrorism in Africa is now also associated with environmental degradation. For instance, empirical evidence (Bildirici & Gokmenoglu, 2020; Tahir et al., 2022; Efayena & Olele, 2024) shows that terror activities such as armed conflict, rebel camps, and guerrilla warfare exert considerable environmental stress through their consumption of energy and reliance on fossil fuels. Such activities often use explosives and heavy weapons with poisonous metals like iron, copper, and depleted uranium, causing long-term air, land, and water contamination and serious ecological and health risks (Farhani, 2022). Besides, terror groups also rely heavily on fossil fuel for transport, weapons production, and sustenance (Bildirici, 2021). Likewise, counterterrorist campaigns initiated by the government are a major source of carbon footprint through aircraft, gun, and machinery deployment, which tends to produce deforestation, land degradation, and loss of habitats (Tahir, 2022; Tarkhani, 2024). Crawford (2019), for instance, estimated that military activities linked with global "War on Terror" accounted for nearly 35% of global CO_2 emissions of the 21st century. In Africa, Boko Haram's insurgency in northeastern Nigeria exemplifies the environmental toll of terrorism through forced displacement, extensive deforestation, bush burning, and explosive use (Ya'u, 2022).

On the other hand, akin to terrorism, tourism development is an increasingly important yet often overlooked contributor to environmental degradation in Africa. While global studies highlight tourism's ecological costs, Africa-specific research remains limited despite the continent's increasing integration into global tourism. Globally, tourism is a major economic driver, contributing \$8.8 trillion to GDP, about 10.4% of global output (Karantzavelou, 2019; Le & Nguyen, 2021; Nawaz & Shakeel, 2023; Kwakwa, 2024). In Africa, the sector supports job creation, foreign investment, infrastructure development, and foreign exchange earnings (Seraj et al., 2025). In 2021, tourism contributed over \$169 billion to Africa's GDP and supported more than 24 million jobs, representing 8.1% of GDP and 6.5% of total employment (WTTC, 2022). Besides, countries such as Uganda, Egypt, Morocco, South Africa, Tunisia, and Kenya have particularly benefited by leveraging their natural and cultural assets (Smith & Fitchett, 2019; UNWTO, 2024). Also, the sector's rapid post-COVID-19 recovery further underscores its importance to Africa's economic resilience and long-term development.

On the other hand, despite all its economic benefits, tourism is facing increasing criticism for being high in environmental impact, particularly in developing nations like Africa (Nawaz & Shakeel, 2023; Chowdhury et al., 2024; Akbar & Emalia, 2025). Tourism has been identified as among the world's most energy-intensive and carbon-emitting sectors since the 2002 World Summit on Sustainable Development in Johannesburg (Nepal, 2008). Its environmental effect is driven by high-energy activities like aviation, road transport, accommodation, and recreational services (Wang & Wu, 2022; Akbar & Emalia, 2025). In addition, the sector is estimated to account for approximately 8% of the world's greenhouse gas emissions and approximately 4.6% of global warming (Danish & Wang, 2018; Koçak et al., 2020). Similarly, Infrastructure development such as seaports, airports, and resorts, typically leads to deforestation, habitat loss, and wetland degradation, and thereby threatens biodiversity (Stern et al., 2020; Katircioglu & Katircioglu, 2024). Coastal zones are the most vulnerable; tourism waste, especially plastics, negatively impacts marine ecosystems and water quality (Pásková et al., 2024; Baltranaitė et al., 2025). Furthermore, water sport tourism activities like boating and diving release oil, fuel, and chemicals into the water, which exacerbates environmental degradation (Landrigan et al., 2020). These environmental pressures indicate the necessity for sustainable tourism governance in Africa to balance economic development with environmental protection.

Hence, this study contributes to the environmental sustainability literature by examining the joint impact of terrorism and tourism on environmental quality in Africa. The study is guided by two core objectives: (1) to assess the effect of terrorism on environmental quality, and (2) to evaluate the influence of tourism development on environmental quality in the region. To the best of the authors' knowledge, the combined effect of these factors remains largely unexplored in existing literature. Previous studies, such as Bildirici and Gokmenoglu (2020), Bildirici et al. (2022), Kılıç et al. (2024), and Efayena and Olele (2024), have analysed the terrorism-environment nexus in isolation. Similarly, research by Nawaz and Shakeel (2023), Chowdhury et al. (2024), Akbar and Emalia (2025), and Raifu and Obaniyi (2025) has focused solely on the tourism-environment relationship. By adopting an integrative approach, this study addresses a critical gap and provides a nuanced understanding of environmental dynamics in the African context.

Moreover, this study contributes to environmental literature by empirically testing the Environmental Kuznets Curve (EKC) hypothesis in Africa. Using panel data from 32 African countries from 2011–2022, the study applies a fixed effects model with Driscoll and Kraay standard errors. The paper is structured as follows: Section 2 reviews relevant literature; Section 3 details data and methodology; Section 4 presents and discusses results; and Section 5 concludes with policy implications

.2. LITERATURE REVIEW

2.1 Theoretical Framework

Over the past decades, environmental-centric literature has advanced several theoretical frameworks to explain the drivers of environmental degradation. Prominent among these are the Pollution Haven Hypothesis (Copeland & Taylor, 1994), which posits that polluting industries relocate to countries with lax environmental standards; the Pollution Halo Hypothesis, suggesting foreign investment can improve environmental outcomes; and the Green Haven Hypothesis, emphasizing the role of green finance in sustainable development. While these theories offer valuable insights, the theoretical foundation of this study is the Environmental Kuznets Curve (EKC) proposed by Grossman and Krueger (1991), which adapts Kuznets' (1955) hypothesis to the environment–growth nexus. The EKC posits an inverted U-shaped relationship between economic growth and environmental degradation: pollution rises with industrialization but declines after reaching a certain income level due to cleaner technologies and stricter regulations. Despite its widespread application, the EKC has been criticized for omitting key variables (Cole, 2004; Stern, 2004), particularly socio-political and institutional factors. To address this limitation, the present study extends the EKC framework by incorporating terrorism and tourism as additional determinants. Drawing on recent studies (e.g., Tahir et al., 2020; Paramati et al., 2017), this approach aims to provide a more comprehensive understanding of the environmental challenges specific to African economies.

2. 2 Empirical Literature

This section is structured into two sub-sections: the first explores the relationship between terrorism and environmental pollution, while the second examines the nexus between tourism and environmental pollution.

2.2.1 Nexus between Terrorism and Environmental Quality

Recent literature has increasingly highlighted the environmental consequences of terrorism. For instance, Nwabueze and Ekwughe (2014) employed the chi-square method to analyze data from three national newspapers, revealing that Boko Haram's violent activities had a significantly detrimental impact on environmental quality in Nigeria. In a broader context, Bildirici and Gokmenoglu (2020) utilized various panel data regression techniques to examine the relationships among terrorism, foreign direct investment (FDI), energy consumption, economic growth, and environmental pollution in Afghanistan, Nigeria, Iraq, Yemen, the Philippines, Somalia, Thailand, Syria, and Pakistan over the period 1975–2017. The study found that terrorism had a significant long-run positive effect on CO_2 emissions. Additionally, their results further indicated a unidirectional short-run causality from terrorism to CO_2 emissions, and a bidirectional long-run causality between terrorism and CO_2 emissions. Likewise, Bildirici (2021) employed panel data estimation approaches to analyze the impact of terrorism, foreign direct investment (FDI), economic growth, and energy consumption on environmental pollution in Turkey, China, Israel, and India from 1975 to 2017. The findings reveal that terrorist activities have a significant positive effect on CO_2 emissions.

In addition, Tahir et al. (2020) also assessed the impact of terrorism on environmental sustainability in MENA countries from 2002-2019. Their empirical results indicate that terrorism significantly undermines environmental sustainability. Also, the causality analysis further shows one-way causality from CO_2 emissions and urbanization to terrorism. Furthermore, the study validates evidence of the Environmental Kuznets Curve (EKC) hypothesis in the region. Furthermore, Bildirici et al. (2022) used a panel data estimation approach to assess the relationship between drinking water, terrorism, and environmental pollution across 12 conflict-affected countries from 2000 to 2020. The study provided empirical evidence of unidirectional causality from terrorism to both drinking water quality and CO_2 emissions. Additionally, Kılıç et al. (2024) examined the relationship between terrorism, foreign direct investment (FDI), and environmental pollution across 17 countries with the highest incidence of terrorism from 2002 to 2018. Their empirical findings indicate that terrorism does not have a statistically significant impact on the ecological footprint. In a related study, Efayena and Olele (2024) applied the quantile ARDL model to assess the effects of terrorism and military expenditure on environmental degradation in 35 Sub-Saharan African countries over the period 1990–2021. The results reveal that both terrorism and military spending exert a positive impact on CO_2 emissions across different quantiles. Complementing these findings, Tarkhani (2024) adopted a qualitative approach to explore environmental degradation in Iraq. The study highlights that a combination of factors, including unexploded ordnance, activities of extremist groups, and pollution from the oil industry has significantly contributed to environmental decline in the country.

2.2.2 Nexus between Tourism and Environmental Quality

On the other hand, contemporary environment-centric literature remains divided on tourism's impact, with some studies highlighting its harmful effects and others suggesting more nuanced or positive outcomes. For example, Eyuboglu and Uzar (2020) investigated the relationship between tourism and CO_2 emissions in Turkey over the period 1960–2014. Using the Autoregressive

Distributed Lag (ARDL) model, their findings reveal that tourism has a positive and statistically significant effect on CO_2 emissions. Similarly, Ehigiamusoe (2020) employed the Generalized Method of Moments (GMM) approach to examine the tourism–environmental pollution nexus across 31 African economies from 1995 to 2016. The study found that tourism contributes positively and significantly to environmental degradation. Additionally, Usman et al. (2021) used a panel data regression approach to analyze the relationship between tourism and carbon emissions in 52 countries spanning 1995–2015. Their results indicate a proportionally positive association between tourism and CO_2 emissions. This finding is further supported by Villanthenkodath et al. (2021), who identified a reinforcing role of tourism in environmental pollution in India between 1995 and 2016.

Importantly, Nawaz and Shakeel (2023) also explored the dynamic relationship among tourism, institutional quality, and CO_2 emissions across 15 EU economies from 1995–2018. The study finding indicates that tourism development significantly increases CO_2 emissions. Similarly, Chowdhury et al. (2024) investigated the tourism–emissions nexus in Eastern African countries from 1990–2021. The study reported that a 1% rise in tourism correlates with a 0.08% increase in CO_2 emissions. Moreover, Akbar and Emalia (2025) also found that international tourist inflows degraded environmental quality in Indonesia's key destinations from 2010–2019. In the same vein, Shah et al. (2025) demonstrated tourism's adverse environmental impact in leading Asian tourism economies. While Raifu and Obaniyi (2025) used the Granger causality approach to establishes that tourism Granger-causes environmental pollution across 134 global economies. In contrast, Khan and Hou (2021), employing the FMOLS method for 38 countries over the period 1995–2018, found that tourism development contributes to improvements in environmental quality. Similarly, Tian et al. (2021), using panel dynamic OLS, identified a negative relationship between tourism and CO_2 emissions across G20 countries from 1995 to 2015. In line with these findings, Le and Nguyen (2021) analyzed data from 95 countries between 1994 and 2014 and observed that tourism contributed to a reduction in CO_2 emissions from electricity and heat production. However, the study also reported an increase in emissions from transportation, attributed to a rise in tourist arrivals.

A review of the literature reveals a significant dearth in research on the tourism– and terrorism–environmental pollution nexus, particularly within the African context. Notably, there is little empirical evidence on their joint impact within a single framework. This study addresses that gap by examining their combined effects on environmental degradation in Africa. By employing a fixed effects regression model with Driscoll and Kraay standard errors, the analysis accounts for cross-sectional dependence, an econometric concern often overlooked in prior studies. Additionally, the study also tests the Environmental Kuznets Curve (EKC) hypothesis, offering nuanced insights and practical policy recommendations for sustainable environmental governance in the region.

3. METHODOLOGY

3.1 Data Source and Description

This study investigate a panel of 32 African economies with data: (i) World development indicators (WDI) of the World Bank; (ii) the Global Terrorism Database (GTD) and (iii) the Global Carbon Budget (GCB) for the period 2011-2022.[1] The adopted periodicity is based on constraints

[1] The 32 economies are: Algeria, Angola, Chad, Burundi, Cameroon, Egypt, Central Africa Republic, Burkina Faso, Benin, DR. Congo, Republic of Congo, Cote d'Ivoire, Ethiopia, Guinea-

in data availability and the motivation discussed in the introduction. Consistent with recent environmental literature on Africa (Onyechi & Ejiofor, 2021; Ifelunini et al, 2023; Efayena & Olele, 2024; Chowdhury et al., 2024; Danpome et al., 2025), environmental quality is proxy using annual CO2 emissions per capita. As per these studies CO2 emissions includes those emissions stemming from the burning of fossils and manufacture of cement. They also include carbon emission produce during consumption of solid, liquid and fuels and gas flaring. Our two core dependent variables are terrorism and international tourism. Terrorism is proxy using numbers of terrorism incidence in line with (Bildirici & Gokmenoglu, 2020; Bildirici, 2021; Bildirici et al., 2022; Kılıç et al., 2024; Efayena & Olele, 2024) and international tourism is measured in total number of international tourists arrivals (Ehigiamusoe, 2020; Nawaz & Shakeel, 2023; Chowdhury et al., 2024; Raifu & Obaniyi, 2025; Akbar & Emalia, 2025).

In order to avoid variable omission bias, the study include five important control variables grounded in economic theories (pollution haven hypothesis, Pollution Halo Hypothesis and Environmental Kuznets Curve hypothesis), as well as environmental empirical insight (Bildirici, 2021;Tahir et al., 2020; Le and Nguyen, 2021; Ifelunini et al., 2023; Kılıç et al., 2024; Raifu & Obaniyi; 2025) into the modeling framework. These control variables include economic growth proxy using GDP per capita (constant 2015 US$); trade openness measured in Trade (% of GDP); renewable energy calculated in Renewable energy consumption (% of total final energy consumption); urbanization measured in Urban population growth (annual %) and gross capital formation calculated in Gross capital formation (% of GDP).

Additionally, Table 1 presents summary statistics for the study variables, including mean, minimum, maximum, and standard deviation. Average values for CO_2 emissions, tourism, terrorism, economic growth, trade openness, renewable energy, urbanization, and gross capital formation are 0.9422, 1,640,000, 41.638, 1,866.3251, 58.4672, 62.288, 3.5904, and 24.0625, respectively. Among these variables, tourism exhibits the highest standard deviation, indicating substantial variability across observations, while urbanization shows the lowest, suggesting a relatively stable distribution. Table 2 displays the correlation matrix, indicating significant relationships: tourism is positively correlated with CO_2 emissions, while terrorism shows a negative correlation. Overall, the correlation matrix demonstrates a general absence of strong linear associations among the study variables. This finding reduces concerns related to multicollinearity and indicates that each variable potentially contributes distinct information to the model.

Table 1: Descriptive Statistics

Variables	Obs	Mean	Std. Dev.	Min	Max
CO2 emissions	384	.9422	1.5673	.0253	8.7915
Tourism	384	1640000	3820000	-17934200	18066000
Terrorism incidence	384	41.638	106.674	-138	713
GDP	384	1866.3251	1967.6722	262.1848	11000
Trade openness	384	58.4672	23.7398	2.6988	135.5604
Renewable energy	384	62.288	29.6059	.1	97
Urbanization	384	3.5904	1.3265	-.2156	6.0913
Gross capital formation	372	24.0625	9.9298	2.1783	76.7823

Bissau, Kenya, Mali, Mauritius, Madagascar, Nigeria, Sudan, Sierra Leon, Morocco, Rwanda, South Africa, Mozambique, Niger, Senegal, Tunisia, Tanzania, Ghana, Uganda and Zimbabwe.

Table 2: Correlation Matrix

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1) CO_2	1.0000							
(2) TOU	0.4728	1.0000						
(3) TER	-0.0106	0.1280	1.0000					
(4) GDP	0.8012	0.3147	-0.0455	1.0000				
(5) TOP	0.1773	-0.0557	-0.1898	0.3499	1.0000			
(6) REC	-0.7718	-0.4483	-0.0155	-0.8090	-0.2707	1.0000		
(7) URB	-0.5701	-0.2805	0.0367	-0.7120	-0.3200	0.6488	1.0000	
(8) GCF	0.0068	-0.0276	-0.1375	0.0064	0.3145	-0.0625	0.1619	1.0000

Source: Authors. **Note:** CO_2: Carbon dioxide emissions; TOU: Tourism; TER: Terrorism incidence; GDP: Economic growth; TOP: Trade openness; REC: Renewable energy; URB: Urbanization; GCF: Gross capital formation.

3.2 Econometric Model Specification

To investigate the dual effect of terrorism and tourism on environmental quality in Africa, this study adopts the Fixed Effects (FE) regression with Driscoll and Kraay (1998) standard errors as the econometric framework. The adoption of the Fixed Effects regression is primary motivated due its ability to adequately account for country-specific characteristics which are unobservable. However, recognizing the limitations of the standard Fixed Effects estimation, the study adopts the Fixed Effects estimator with Driscoll and Kraay (1998) standard errors to account for heteroskedasticity and cross-sectional dependence, following the methodologies of Iheonu et al. (2022) and Iheonu and Oladipupo (2024). Hence, The Fixed Effects model specification is as follows:

$$\boldsymbol{CO2_{i,t} = \alpha_0 + \Phi_1 TER_{i,t} + \Phi_2 TOU_{i,t} + \Phi_3 GDP_{i,t} + \Phi_4 GDP^2_{i,t} + \Phi_5 TOP_{i,t} + \Phi_6 REC_{i,t} + \Phi_7 URB_{i,t} + \Phi_8 GCF_{i,t} + \pi_{i,t}} \quad (\mathbf{1})$$

Where: The indices i and t represent the cross-sectional and time dimensions, respectively. CO_2 denotes carbon dioxide emissions; TER refers to terrorism incidence; TOU represents international tourism; GDP indicates economic growth; GDP^2 denotes the square of economic growth, included to validate the EKC hypothesis; TOP stands for trade openness; REC refers to renewable energy consumption; URB captures urbanization; and GCF denotes gross capital formation. $\pi_{i,t} = \tau_i + \varepsilon_{i,t}$, where τ_i is the country fixed effect, capturing the unobservable heterogeneities; ε_{it} is the error term. Φ_1-Φ_8 represent the vectors of parameters to be estimated; and α the intercept.

Our choice of the fixed effects regression model for estimating Equation (1) is guided by several methodological considerations. First, the fixed effects approach is well-suited for panel data structures where the number of cross-sectional units (N = 32) exceeds the number of time periods (T = 11). Second, it effectively controls for time-invariant unobserved heterogeneity (e.g., polity, culture, language, religion, and geography), common across African countries. Third, it does not require strict exogeneity of time-invariant variables and helps reduce endogeneity bias (Greene, 2008). Furthermore, the outcome of the Hausman test rejects the null hypothesis at the 5% significance level, indicating that individual effects are correlated with the regressors $\boldsymbol{[COV\ (X_{i,t}, \tau_i) \neq 0]}$, thus confirming the fixed effects model as more appropriate than the random effects alternative. However, despite these advantages, the fixed effects model is known to produce unreliable estimates when econometric issues such as cross-sectional dependence, heteroskedasticity, and serial correlation are present (Hoechle, 2007; Iheonu & Ichoku, 2022). Hence, diagnostic tests including Pesaran's (2021) test for cross-sectional dependence, the modified Wald test for groupwise heteroskedasticity, and the Wooldridge test for autocorrelation confirmed the presence of these biases. To mitigate these concerns and enhance the reliability of the findings, the model was re-estimated using Driscoll and Kraay's (1998) robust standard errors, which are specifically designed to correct for these issues in panel data settings.

4. PRESENTATION AND DISCUSSION OF FINDINGS

The discussion of results begins with the presentation of key diagnostic tests. First, the Breusch-Pagan Lagrange Multiplier (LM) test was conducted to determine the appropriate estimation technique for Equation (1), specifically to choose between the pooled OLS and random effects models. Next, the Hausman test was employed to identify the more consistent and efficient estimator between the fixed effects and random effects models. The outcome of the test favored the use of the fixed effects estimator for estimating Equation (1). To further ensure the robustness and reliability of the fixed effects results, the study assessed the presence of common econometric issues, including cross-sectional dependence, groupwise heteroskedasticity, and autocorrelation. The confirmation of these biases, as reported in the diagnostic section of Table 1, justifies the application of Driscoll and Kraay standard errors in the modelling process.

The regression results presented in Table 3 are organized into four columns, each reflecting a different estimation technique. Column (1) reports the results from the pooled OLS estimator, while Column (2) presents the fixed effects estimates. Column (3) contains the results from the random effects model, and Column (4) provides the fixed effects estimates adjusted with Driscoll and Kraay standard errors. This modelling approach facilitates the assessment of the consistency and evolution of the relationships among the variables across different estimation techniques. Nevertheless, the conclusions of this study are primarily based on the results from the fixed effects regression with Driscoll and Kraay standard errors. As reported in Column (4) of Table 3, the Driscoll-Kraay standard error estimates reveal that tourism development has a statistically significant positive effect on CO_2 emissions in Africa at the 5% level. Specifically, a 1% increase in international tourist arrivals is associated with a 0.0511% decline in environmental quality. This finding lends support to the tourism-induced environmental degradation hypothesis and is consistent with the empirical evidence of Chowdhury et al. (2024), Akbar and Emalia (2025), and Raifu and Obaniyi (2025), who link increased tourism activity to greater fossil fuel consumption. These results underscore the environmentally unsustainable nature of tourism practices across the Africa region.

Table 3: Estimation Results for the Relationship Between Terrorism, Tourism, and Environmental Quality (Dependent Variable: CO_2 Emissions)

VARIABLES	Pooled OLS	Fixed Effect	Random Effect	Driscoll-Kraay SD.
	(1)	**(2)**	**(3)**	**(4)**
TOU	0.0702***	0.0511**	0.0464**	0.0511***
	(0.0194)	(0.0213)	(0.0204)	(0.0115)
TER	-0.0005	0.0000	0.0000	0.0000
	(0.0003)	(0.0002)	(0.0002)	(0.0002)
GDP	3.4917***	2.2207**	1.8969**	2.2207***
	(0.4247)	(0.8594)	(0.7380)	(0.6784)
GDP^2	-0.1566***	-0.1109*	-0.0702	-0.1109**
	(0.0299)	(0.0622)	(0.0526)	(0.0476)
TOP	0.2991***	0.0496	0.0899**	0.0496*
	(0.0620)	(0.0461)	(0.0454)	(0.0263)
REC	-0.2219***	-0.4675***	-0.3775***	-0.4675***
	(0.0269)	(0.0978)	(0.0620)	(0.1074)
URB	0.0379	0.0638**	0.0476**	0.0638**
	(0.0244)	(0.0247)	(0.0240)	(0.0233)
GCF	-0.3280***	-0.0961**	-0.1428***	-0.0961*
	(0.0676)	(0.0420)	(0.0410)	(0.0453)
Constant	-18.2143***	-10.1851***	-10.1935***	-10.1851***
	(1.4716)	(3.0055)	(2.5977)	(2.5641)
Observations	346	346	346	346
Groups	32	32	32	32
Country Effect	NO	YES	YES	YES
Year Effect	NO	NO	NO	NO
rmse	0.398	0.136	0.139	---
Fisher stat.	**453.5*** **	**16.46*** **	**---**	**1542.09*** **
F-test(u_i=0)	---	86.01***	---	---
Chi-squared			**379.5*** **	
R-squared:				
within =	**---**	**0.3001**	**0.2901**	**0.3001**
between =	---	0.8344	0.8898	---
overall =	**0.9150**	0.8287	**0.8809**	---
Diagnostic Test				
Breusch-Pagan LM test		**1269.04*** **		
Hausman test		**21.13*** **		
Heteroscedasticity		**3747.09*** **		
Wooldridge Xserial test		**39.431*** **		
CD test		**0.774*** **		

Source: Authors **Note:** Standard errors in parentheses. *,**,***: significance levels of 10%, 5% and 1% respectively. TOU: International tourism. TER: Terrorism incidence. GDP: economic growth. GDP^2: economic growth squared. TOP: Trade openness. REC: Renewable energy consumption. URB: Urbanization. GCF: Gross capital formation. SD: Standard errors. CD: Cross-section dependence.

In contrast, the result presented in Column (4) of Table 3 indicates that the coefficient of terrorism is positive but statistically insignificant. This finding suggest, although terrorism may affect environmental quality in Africa, its influence on CO_2 emissions is neither strong nor consistent enough to be statistically significant continentally. This finding is consistent with Kılıç et al. (2024), who observed a similar positive but insignificant relationship between terrorism and environmental degradation across 17 terrorism-prone countries. However, it contrasts with the empirical evidence of Bildirici (2021) and Efayena and Olele (2024), who documented a significant positive impact. A plausible explanation for this result lies in the spatial concentration of terrorist activities. For instance, approximately 80% of Boko Haram's operations in Nigeria are concentrated in the northeastern states of Borno, Yobe, and Adamawa. As such, while these localized areas may experience substantial environmental degradation, the effect may be insufficient to influence national-level CO_2 emissions.

Furthermore, the empirical results reported in Column 4 also indicate that GDP exerts a positive and statistically significant effect on CO_2 emissions in Africa, whereby a 1% increase in GDP corresponds to a 2.2207% rise in emissions. However, the squared GDP term enters the model with a negative and statistically significant coefficient, thereby validating the U-shaped Environmental Kuznets Curve (EKC) hypothesis. This suggests that economic growth may initially intensify environmental degradation; however, beyond a certain income threshold, further increases in income are associated with a decline in emissions. This finding is consistent with the study's theoretical framework and corroborates previous empirical evidence by Tahir et al. (2022) and Ifelunini et al. (2023). In addition, trade openness is positively and significantly associated with CO_2 emissions, reinforcing the pollution haven hypothesis as highlighted by Ansari et al. (2020). Conversely, renewable energy consumption is significantly associated with lower emissions, as a 1% increase in its use results in a 0.4675% reduction in CO_2 emissions. The finding is consistent with the findings of Wang and Dong (2019) and Asogwa et al. (2018). Furthermore, urbanization has a significant positive effect on CO_2 emissions, corroborating the findings of Ifelunini et al. (2023). Finally, gross capital formation is found to exert a negative and statistically significant effect on CO_2 emissions, consistent with the findings of Södersten et al. (2018).

5. CONCLUSION AND POLICY RECOMMENDATION

Given the growing emphasis on achieving a clean and sustainable environment across national and regional economies, this study investigated the impacts of terrorism and tourism on environmental quality in Africa, alongside testing the validity of the Environmental Kuznets Curve (EKC) hypothesis. To this end, a fixed effects model with Driscoll and Kraay standard errors was employed using panel data from 32 African countries spanning 2011 to 2022. Environmental quality was proxied by per capita CO_2 emissions, with international tourist arrivals and terrorism incidents used to measure tourism and terrorism, respectively. The analysis yielded three key findings. First, tourism development has a positive and statistically significant impact on CO_2 emissions in Africa. Second, terrorism exerts a positive but statistically insignificant effect on emissions. Third, the results confirm the U-shaped EKC hypothesis across the sampled countries. Additionally, macroeconomic variables such as economic growth, trade openness, and urbanization were found to increase emissions, whereas renewable energy consumption and gross capital formation contributed to emission reductions.

The foregoing findings carry important policy implications. Specifically, the rising CO_2 emissions linked to tourism development highlight the need for policymakers to promote investment in sustainable tourism infrastructure across Africa. This includes the promotion of green-certified accommodations, renewable energy integration, and low-emission transport systems, facilitated through fiscal incentives such as tax rebates, subsidies, and public-private partnerships. Moreover, governments should also institutionalize mandatory Environmental Impact Assessments (EIAs) and implement enforceable sustainability standards for tourism operators. This can be achieved by introducing carbon pricing instruments, such as tourism-related levies or carbon taxes to internalize the environmental costs of tourism activities. Moreover, aligning national tourism policies with UNWTO and Africa Union frameworks will also enhance access to technical and financial support for sustainable tourism aligned with the post-2015 SDGs.

As revealed in our findings, terrorism exerts a positive but statistically insignificant impact on CO_2 emissions in Africa, implying that while localized environmental effects may be severe, they do not significantly influence emissions at the continental scale. Accordingly, African policymakers should implement region-specific interventions in terrorism-affected areas, including green reconstruction, renewable energy expansion, and climate-resilient infrastructure. Establishing localized environmental monitoring systems is essential for tracking emissions linked to conflict-induced displacement, military operations, and infrastructure damage. Moreover, promoting economic diversification can further reduce reliance on high-emission sectors and enhance community resilience. At the continental level, the African Union should integrate peacebuilding into climate and energy policy and establish a centralized platform for monitoring terrorism–environment dynamics. Post-conflict recovery initiatives must prioritize sustainable rebuilding, reforestation, environmental restoration, and green job creation to advance low-carbon development in fragile and conflict-prone regions. Future research can enhance the existing literature by conducting regional comparative analyses to assess the robustness of these findings across diverse contexts. Country-specific studies are also recommended to account for national heterogeneity. Moreover, applying dynamic econometric techniques could offer deeper insights into the evolving relationships among the variables over time, capturing temporal dynamics that static models may overlook.

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Competing interests
The authors declare no competing interests.

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