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Impact of Urbanization on the Ecological Footprint: Evidence from Cote d'Ivoire

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Abstract

This study examines the impact of urbanization on environmental degradation in Cote d'Ivoire. Unlike most existing studies that focused on carbon dioxide emissions, this study uses ecological footprint, which is a broader indicator of environmental degradation. Annual time series covering the period 1970-2021 are analyzed through ARDL, Dynamic Ordinary Least Square (DOLS) and Fully Modified Least Square (FMOLS) methods. The results prove that urbanization contributes to environmental degradation in Cote d'Ivoire by increasing ecological footprint. Besides, the results provide support for the EKC hypothesis. Further, there are casual relationships running from urbanization and economic growth to ecological footprint. The study suggests policies that can help mitigate the adverse effects of urbanization on ecological sustainability in Cote d'Ivoire.

Keywords

Urbanization, Ecological Footprint, ARDL, Cote d'Ivoire

1. Introduction

Protecting the environment has become an increasing concern that has received global attention in political, economic and social discussions. This is because the degrading conditions of the global climate have started to seriously threaten the well-being of the society. It is admitted that environmental degradation is caused by the excessive exploitation of natural resources ascribed by our economic development model. Even though the contribution of African countries to environmental degradation is low compared to advanced countries, the region is the most vulnerable to climate change and global warming (Kifle 2008; Nathaniel & Iheonu, 2019). This is because African countries heavily depend on a wide range of natural resources to survive. According to WFSE (2009), about 20% of poor households come from the forest, and 85% of the wood removed from the forest and woodlands is utilized as fuel by African households. Today, the region faces significant environmental problems ranging from blood, famine, rise of temperature, soil erosion, desertification, deforestation, and air and water pollution. The forests that provide protection for the environment by sequestering carbon dioxide emitted into the atmosphere are disappearing driven by urbanization and economic activities.

A growing body of literature has sought to investigate the factors influencing environmental degradation. The first strand of this literature has examined the relationship between economic growth and environmental degradation with a focus on the popular Environmental Kuznets Curve (EKC) hypothesis. Another strand of the literature has examined the effects associated with other variables such as energy consumption, financial development, foreign direct investment, and trade. Recently, the role of urbanization in shaping environmental degradation has been analyzed. Basically, urbanization causes upward pressure on the environment and this is visible in urban areas of many developing countries. At the global level, urban populations are responsible for two-thirds of global greenhouse gas emissions (Yazdi & Dariani, 2019). Accordingly, the relationship between urbanization and environmental degradation has received much attention from scholars and policymakers.

The empirical evidence regarding the environmental consequences of urbanization is mixed and conflicting. While numerous studies confirmed that urbanization degrades the environment, others documented the environment-enhancing role of urban development. Some studies also reported an insignificant relationship between urbanization and environmental degradation. The effect of urbanization on environmental degradation was found to vary across income groups and countries. Therefore, results from panel studies cannot be generalized to all countries. This provides justification for country-level studies. Furthermore, most existing studies focus on carbon dioxide emissions as an indicator of environmental degradation. However, carbon dioxide emission does not give a complete picture of all damage to the environment. In particular, carbon emission does not inform about other important aspects of environmental degradation such as deforestation, soil erosion, and loss of biodiversity as well as pollution from water and waste.

Against this backdrop, this study aims to examine the impact of urbanization on environmental degradation in Cote d'Ivoire using ecological footprint. Cote d'Ivoire is the world's largest producer and exporter of cocoa and cashew nuts. It is also the largest economy of the West African Economic and Monetary Union (WAEMU). The country has witnessed one of the fastest sustained economic growth rates in Sub-Saharan Africa over the recent decade. The economic growth rate averaged 7.3% during 2012-2022 despite the adverse effects of the coronavirus pandemic in 2020 and the Russia-Ukraine conflict in 2022. Economic growth is fueled mainly by the dynamics of extractive industry, manufacturing, construction, trade, and telecommunications, as well as investment and consumption. Along with this remarkable economic growth, Cote d'Ivoire has also witnessed a growing urbanization. Statistics from World Development Indicators of the World Bank indicate that urban population has been multiplied by 8.4 from 1970 to 2020, with an increase of 4.3% each year. The urbanization rate rose significantly from 28% in 1970 to 52% in 2020, implying that more than half of the inhabitants are living in urban areas. However, the rapid growth of the economy combined with increasing urbanization exerts serious pressure on the environment. This effect is reflected by the substantial depletion of environmental resources. Some two-thirds of Cote d'Ivoire's coastline is affected by coastal erosion (World Bank, 2021). The economic cost of environmental degradation from flooding, erosion and pollution has been estimated at 4.9% of GDP for 2017 (Lelia et al., 2019). Furthermore, the economy and population are dependent on climate-sensitive sectors such as agriculture, forestry, livestock, aquaculture, fishing and energy. Forest cover is undergoing alarming destruction reducing dramatically the ecosystem's capacity of carbon sequestration and storage. From 16 million hectares of forest at the beginning of the 20th century, the forest cover dropped to about 7.8 million hectares in 1990 and 3.4 million hectares in 2015. At this rate, there will be less than two million hectares of forest surface in Cote d'Ivoire by 2040. By the same horizon of time, more than 62% of the Ivorian population is expected to reside in urban areas, compared to 52% today. The destruction of forest cover is driven by uncontrolled exploitation of forests for timber and wood energy, extensive agriculture, and inadequately planned urban development. The overall ecological footprint has been multiplied by 2.7 from 1970 to 2020, increasing at an average growth rate of 2% per year.

The rising trend in both urbanization and ecological footprint is not good news as it suggests that Cote d'Ivoire's urbanization path may not be ecologically sustainable. By continuing with the ongoing trend, Cote d'Ivoire could experience serious detrimental consequences at ecological, economic, social and even political levels. A deep look at the composition of the ecological footprint shows that cropland remains the major source of ecological degradation in Cote d'Ivoire in 2020, accounting for 30% of the total ecological footprint. It is followed by forest products, carbon footprint and fishing grounds, which account for 22%, 19.5% and 16.7% of total ecological footprint, respectively. These figures show that Cote d'Ivoire's ecological degradation is mainly ascribed to deforestation that results from destroying forests for agriculture, charcoal and timber production for domestic consumption and exports. This also provides strong justification for using ecological footprint as the appropriate indicator for environmental impact analysis.

Urbanization is expected to increase considerably in the future in Cote d'Ivoire and understanding its relationship with the environmental degradation is a timely topic to investigate. Accordingly, the present study addresses the following research questions. Does urbanization cause environmental degradation in Cote d'Ivoire? Which of urbanization and economic growth contributes the most to environmental degradation in Cote d'Ivoire? Is the EKC hypothesis valid for ecological footprint in Cote d'Ivoire? To the best of our knowledge, this study is the first to discuss the link between urbanization and ecological footprint in Cote d'Ivoire. Besides, the study adds to the empirical literature testing the EKC hypothesis using ecological footprint and controlling for urbanization. From the methodological perspective, the study employs the ARDL approach developed by Pesaran et al. (2001). This approach was found to be reliable in presence of variables integrated of mixed orders, small sample size, and endogeneity of some regressors.

The remainder of the study is organized as follows. Section 2 refers to literature on the effect of urbanization on environmental degradation. Section 3 introduces the data source and the modeling framework for empirical examination of the relationship between urbanization and ecological footprint. Section 4 presents and discusses the empirical results. Conclusion and policy implications are discussed in Section 5.

2. Literature Review

Urbanization is a process resulting mainly from three dynamics. Firstly, urban population increases as a result of the natural growth of population. Secondly, as population grows and develops, areas previously considered rural are transformed into urban areas. Thirdly, because there are more job opportunities and better living standards in the cities, people move from rural to urban areas. Growing urbanization induces a number of environmental problems. It is believed that urbanization stimulates demand for energy, housing, food, clothing, and transport, adding to environmental degradation. However, the relationship between urbanization and environmental degradation is subject of controversy both in the theoretical and empirical literature. The theories of ecological modernization, urban environmental transition and compact city explain that urbanization can have both positive and negative effects on the environment (Mol & Spaargaren, 2000; Poumanyvong & Kaneko, 2010). Urban development breeds economic growth which induces increased per capita income. Wealthier people consume more ecological resource-intensive goods and services, which can diminish the biocapacity and worsen the ecological footprint. On the other hand, wealthier citizens are likely to be more concerned about environmental issues. Accordingly, various environmentally-friendly measures may be implemented easily aiming at reducing ecological footprint through resource efficiency practices. Moreover, wealthier citizens will be prompted to give money to support green projects and investment in modern technology. Urbanization also generates economies of scale for public infrastructure such as water supply, health facilities, education and transport. These economies of scale mitigate environmental damages associated with urbanization (Hartmann & Vachon, 2018).

On the empirical side, an overwhelming body of literature has investigated the connection between urbanization and environmental degradation for individual countries or group of countries. The findings from this literature are mixed across countries, methodologies and data. The relationship was either positive, negative, *U*-shaped, inverted *U*-shaped, *N*-shaped, inverted *N*-shaped or insignificant. For instance, Cole and Neumayer (2004) used a panel of 86 countries to empirically examine the interplay between demographic factors and environmental quality. Their findings reveal that urbanization and population have a positive effect on increasing CO_2 emissions. For European Union member countries, Martínez-Zarzoso et al. (2007) find that population growth increases CO_2 emissions. Martínez-Zarzoso and Maruotti (2011) analyze the impact of urbanization on carbon emissions in 88 developing countries. The results unfold an inverted-U shaped interplay between urbanization and CO_2 emissions. Sharma (2011) investigates the determinants of CO_2 emissions for a global panel of 69 countries. Results reveal that urbanization has a negative impact on CO_2 emissions.

Table 1 presents a summary of the recent empirical studies on the impact of urbanization on environmental degradation. Summing up, evidence regarding the environmental effects of urbanization is mixed and studies on single countries especially on Sub-Saharan African countries are rather limited. Over the 135 studies reviewed, 60% support the deteriorating impact of urban expansion on the environment. The majority of these studies (80%) have used carbon dioxide emissions as measure of environmental degradation and only 33% of the studies focus on African countries. Considering studies on African countries, about 20% have used ecological footprint to examine the environmental effect of urbanization. Besides, there is still no research that has examined the effect of urbanization on the ecological footprint in Cote d'Ivoire. The present study fills this gap in the empirical literature. The next section outlines the methodological framework used in the empirical analysis.

3. Models, Data and Methodology

3.1. Models

The objective of this research is to investigate the relationship between urbanization and environmental degradation in Cote d'Ivoire. Based on the literature review, the empirical model is specified as follows:

$$Ef_t = \beta_0 + \beta_1 Gdp_t + \beta_2 Urb_t + \beta_2 Pop_t + \mu_t \tag{1}$$

where Ef_t symbolizes ecological footprint as a proxy for environmental degradation, Gdp_t stands for real GDP per capita, Urb_t is urbanization, Pop_t represents total population, and μ_t is an error term.

As regards the expected signs, economic growth is hypothesized to trigger the consumption of energy, foods, water and other natural resources, which in turn deteriorates the environment. Therefore, the sign of the parameter β_1 is expected

Table 1. Summary of recent literature review on the impact of urbanization on the environment.

Authors	Country	Period	Methodology	Findings
Afriyie et al. (2023)	37 African countries	1995-2017	PMG	URB has no significant effect on CO_2
Aladejare (2023)	29 African countries	1970-2019	CS-ARDL	URB increases EF
Abid (2023)	Saudi Arabia	1990-2015	QR	URB increases CO_2
Huang et al. (2023)	ASEAN countries	1995-2018	CS-ARDL, AMG, CCEMG	URB increases GHG
Khan and Majeed (2023)	Pakistan	1980-2018	OLS	URB increases CO_2
Kwakwa et al. (2023)	Ghana	1971-2018	ARDL	URB decreases CO_2
Liu et al. (2023)	China	1995-2020	PMG	URB has no significant effect on CO_2
Opuala et al. (2023)	West Africa	1980-2017	PMG, AMG	URB increases EF
Otim et al. (2023)	Kenya	1971-2014	ARDL	URB decreases CO_2
Raza et al. (2023)	Bangladesh	1980-2020	ARDL	URB increases CO_2
Sofuoğlu et al. (2023)	Türkiye	1970-2020	FARDL	URB increases CO_2
Voumik et al. (2023)	5 Asian countries	1972-2021	CS-ARDL, AMG, MG, CCEMG	URB increases CO_2
Wang et al. (2023)	China	1970-2021	ARDL	URB increases CO_2
Warsame et al. (2023)	Somalia	1985-2016	ARDL, KRLS	URB increases CO_2
Zhang et al. (2023)	10 nations	1990-2019	PMG	URB increases CO_2
Aladejare (2022)	5 African countries	1990-2019	FE, RE, FGLS, AGM	URB decreases CO_2
Alvarado et al. (2022)	95 countries	1990-2018	AMG, CCEMG, DCCE	URB increases EF
Azam et al. (2022)	7 Asian countries	1990-2018	CS-ARDL, PMG	URB increases CO_2
Baajike et al. (2022)	16 West African countries	2005-2018	GMM, OLS, FE, RE	URB increases CO_2
Chen et al. (2022)	China	1998-2019	FE, RE	URB reduces NDVI
Dada et al. (2022)	Nigeria	1970-2017	ARDL	URB decreases EF
Ehigiamusoe et al. (2022)	31 African countries	1990-2019	FMOLS, PMG, AMG	URB has an inverted U-shaped impact on CO2 and a U-shaped impact on EF
Hussain et al. (2022)	54 African Union countries	1996-2019	QR, FMOLS	URB increases CO_2
Li et al. (2022)	16 West African countries	1990-2018	AMG, CCEMG	URB increases CO_2
Jóźwik et al. (2022)	28 EU countries	2000-2018	FMOLS, MG, CCEMG, AMG	URB mitigates CO_2
Kahouli et al. (2022)	Saudi Arabia	1971-2019	ARDL	URB causes CO_2
Mignamissi and Djeufack (2022)	48 African countries	1980-2016	QR	URB increases CO_2
Sahoo and Sethi (2022)	NICs	1990-2017	MG, PMG, AMG, CCEMG	URB increases EF

Continued

Voumik and Sultana (2022)	BRICS	1972-2021	CS-ARDL	URB increases CO_2
Wang et al. (2022)	156 countries		Threshold regression	URB increases CO_2 and EF
Yang and Khan (2022)	30 nations	1992-2016	AMG, CCE	URB increases EF
Adebayo et al. (2021)	Latin America	1980-2017	FMOLS, DOLS	URB increases CO_2
Dimnwobi et al. (2021)	5 African countries	1990-2019	CS-ARDL	URB has no significant effect on EF
Erdogan et al. (2021)	23 African countries	1960-2016	CUP-FM, CUP-BC	URB increases EF
Iheonu et al. (2021)	34 African countries	1990-2016	QR	URB increases CO_2
Islam et al. (2021)	Bangladesh	1972-2016	ARDL	URB increases CO_2
Liu et al. (2021)	5 Asian countries	1995-2014	DOLS, FMOLS	URB increases CO_2
Majeed et al. (2021)	GCC	1990-2018	CS-ARDL	URB increases CO_2
Musah et al. (2021)	16 West African countries	1990-2018	Driscoll-Kraay regression	URB increases CO_2
Nathaniel (2021)	Indonesia	1971-2014	ARDL	URB increases EF
Nathaniel et al. (2021b)	Latin American and Caribbean countries	1990-2017	AMG, CCEMG	URB increases CO_2
Nathaniel et al. (2021a)	10 countries	1995-2016	CUP-FM, CUP-BC	URB reduces EF
Nurgazina et al. (2021)	Malaysia	1978-2018	ARDL	URB increases CO_2
Onifade et al. (2021)	E7 economies	1990-2016	AMG, FMOLS, DOLS	URB increases CO_2 and EF
Qayyum et al. (2021)	5 Asian countries	1991-2017	ARDL	URB increases EF, but it moderates the impact of informal economy on EF
Rafiq et al. (2016)	22 countries	1980-2010	MG, DOLS, FMOLS	URB has insignificant impact on CO_2
Raghutla and Chittedi (2021)	BRICS	1998-2016	FMOLS	URB reduces CO_2
Rahman and Alam (2021)	Bangladesh	1973-2014	ARDL	URB increases CO_2
Villanthenkodath et al. (2021)	India	1971-2014	ARDL	URB reduces CO_2
Yameogo (2021)	Burkina Faso	1980-2017	ARDL	URB increases DF
Younis et al. (2021)	BRICS	1993-2018	GMM	URB increases CO_2
Zhou et al. (2022)	Pakistan	1980-2018	ARDL	URB decreases EF
Abbasi et al. (2020)	8 Asian countries	1982-2017	FMOLS	URB increases CO_2
Adams et al. (2020)	19 African countries	1980-2011	IV-GMM	URB decreases CO_2
Adedoyin and Bekun (2020)	6 island countries	1995-2014	FMOLS, PMG	URB reduces CO_2
Adedoyin et al. (2020)	12 African countries	1980-2014	PMG	URB increases CO_2
Ahmed et al. (2020b)	G7 countries	1971-2014	CUP-FM, CUP-BC	URB increases EF
Ahmed et al. (2020a)	China	1970-2016	ARDL	URB increases EF
Akorede and Afroz (2020)	Nigeria	1970-2017	ARDL	URB reduces CO_2

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Amin et al. (2020)	13 Asian countries	1985-2019	FMOLS	URB mitigates CO_2
Anser et al. (2020)	SAARC	1994-2013	FE	URB has a U-shaped impact on CO_2
Anwar et al. (2020)	9 Asian countries	1980-2017	FE	URB increases CO_2
Asongu et al. (2020)	African countries	1980-2014	PMG	URB increases CO_2
Danish et al. (2020)	BRICS	1992-2016	FMOLS, DOLS	URB decreases EF
Langnel and Amegavi (2020)	Ghana	1971-2016	ARDL	URB increases EF
Mosikari and Eita (2020)	African countries	2005-2019	PSTR	URB reduces CO_2
Muhammad et al. (2020)	65 countries	2000-2016	QR, 2TLS	URB has an inverted U-shaped impact on CO_2
Nathaniel (2020)	Nigeria	1980-2016	ARDL	URB increases CO_2
Nathaniel and Khan (2020)	6 ASEAN	1990-2016	AMG	URB has no significant effect on EF
Nathaniel et al. (2020a)	MENA countries	1990-2016	AMG	URB increases CO_2
Nathaniel et al. (2020b)	6 countries	1990-2014	AMG	URB increases EF
Nosheen et al. (2020)	11 Asian countries	1995-2018	FMOLS, DOLS	URB increases CO_2
Rahman and Vu (2020)	Australia and Canada	1960-2015	ARDL	URB increases CO_2
Shehu (2020)	Nigeria	1974-2015	ARDL	URB reduces CO_2
Yu (2020)	China	2003-2017	Dynamic spatial panel	URB reduces CO_2
Acheampong (2019)	46 African countries	2000-2015	GMM	URB increases CO_2
Adams and Nsiah (2019)	28 African countries	1980-2014	FOLS, GMM	URB mitigates CO_2
Ali et al. (2019)	Pakistan	1972-2014	ARDL	URB triggers CO_2
Baloch et al. (2019)	59 countries	1990-2016	Driscoll-Kraay regression	URB increases EF
Danish and Wang (2019)	11 countries	1971-2014	CCEMG	URB increases EF
Dogan et al. (2019)	4 countries	1971-2013	ARDL	URB increases EF
Gasimli et al. (2019)	Sri Lanka	1978-2014	ARDL, FMOLS	URB reduces CO_2
Khan et al. (2019)	Pakistan	1971-2016	ARDL	URB reduces CO_2
Khoshnevis and Dariani (2019)	18 Asian countries	1980-2014	PMG	URB increases CO_2
Nathaniel et al. (2019)	South Africa	1965-2014	ARDL, FMOLS, DOLS, CCR	URB mitigates EF
Li and Zhou (2019)	China	1996-2015	FMOLS	URB increases CO_2
Lv and Xu (2019)	55 middle-income countries	1992-2012	PMG	URB reduces CO_2
Phong (2019)	ASEAN-5	1971-2014	FE, RE	URB increases CO_2
Ponce and Alvarado (2019)	100 countries	1980-2017	DOLS	URB increases CO_2
Salahuddin et al. (2019a)	44 African countries	1984-2016	MG, PMG, CCEMG, AMG	URB increases CO_2

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Salahuddin et al. (2019b)	South Africa	1980-2017	ARDL	URB increases CO_2
Salim et al. (2019)	13 Asian countries	1980-2010	MG, PMG, AMG	URB has no significant effect on CO_2
Wang and Dong (2019)	14 African countries	1990-2014	AMG	URB increases EF
Adams and Klobodu (2018)	26 African countries	1985-2011	GMM	URB increases CO_2
Effiong (2018)	49 African countries	1990-2010	FE	URB reduces CO_2
Hanif (2018)	34 African countries	1995-2015	GMM	URB increases CO_2
Kwakwa and Alhassan (2018)	Ghana	1971-2013	FMOLS	URB increases CO_2
Liu and Bae (2018)	China	1970-2015	ARDL	URB increases CO_2
Pata (2018)	Türkiye	1974-2014	ARDL, FMOLS	URB triggers CO_2
Phong et al. (2018)	Vietnam	1985-2015	ARDL	URB has no significant effect on CO_2
Raggad (2018)	Saudi Arabia	1971-2014	ARDL	URB reduces CO_2
Ali et al. (2017)	Singapore	1970-2015	ARDL	URB mitigates CO_2
Asumadu-Sarkodie and Owusu (2017)	Senegal	1980-2011	NIPALS	URB decreases CO_2
Charfeddine (2017)	Qatar	1970-2015	MS	URB increases EF
Charfeddine and Mrabet (2017)	15 MENA countries	1975-2007	DOLS, FMOLS	URB reduces EF
Behera and Dash (2017)	17 Asian nations	1980-2012	DOLS, FMOLS	URB has insignificant impact on CO_2
Bekhet and Othman (2017)	Malaysia	1971-2015	ARDL	URB has an inverted U-shaped impact on CO_2
Saidi and Mbarek (2017)	19 emerging nations	1990-2013	GMM	URB reduces CO_2
Zhang et al. (2017)	141 countries	1961-2011	FE	URB has an inverted U-shaped impact on CO_2
Adusah-Poku (2016)	45 African countries	1990-2010	PMG	URB increases CO_2
Ali et al. (2016)	Nigeria	1971-2011	ARDL	URB has no significant effect on CO_2
Azam and Khan (2016)	India, Bangladesh, Sri Lanka, and Pakistan	1982-2013	OLS	URB decreases CO_2 in Bangladesh and India, UBR increases CO_2 in Sri Lanka. URB has no significant effect on CO_2 in Pakistan
Destek et al. (2016)	10 European countries	1991-2011	DOLS, FMOLS	URB reduces CO_2
Dogan and Turkekul (2016)	USA	1960-2010	ARDL	URB increases CO_2
Li et al. (2016)	28 Chinese provinces	1996-2012	GMM, MG, PMG, DFE	URB increases CO_2, waste water, and waste solid
Lin et al. (2016)	5 African countries		FMOLS	URB reduces CO_2
Shahbaz et al. (2016)	Malaysia	1997-2011	ARDL	URB has a U-shaped impact on CO_2
Sheng and Guo (2016)	China	1995-2011	MG, PMG, DFE	URB increases CO_2

Continued

Siddique et al. (2016)	5 Asian countries	1983-2013	OLS	URB increases CO_2
Wang et al. (2016a)	ASEAN	1980-2009	FMOLS	URB increases CO_2
Wang et al. (2016b)	BRICS	1985-2014	FMOLS	URB increases CO_2
Cao et al. (2016)	China	1979-2013	TR	URB increases CO_2
Al-Mulali and Ozturk (2015)	14 MENA nations	1996-2012	FMOLS	URB increases EF
Al-Mulali et al. (2015b)	93 countries	1980-2008	FE, GMM	URB aggravates EF
Al-Mulali et al. (2015a)	129 countries	1980-2011	DOLS	URB increases CO_2 in lower-middle, upper-middle and high-income countries while no effect in low-income countries.
Asane-Otoo (2015)	45 African countries	1980-2009		URB has no significant effect on CO_2
Çetin and Ecevit (2015)	19 African countries	1985-2010	VAR	URB increases CO_2
Keho (2015)	Cote d'Ivoire	1970-2010	ARDL	URB reduces CO_2
Li and Lin (2015)	73 countries	1971-2010	FE, RE	URB reduces CO_2 in middle-/high-income nations, and increases CO_2 in low-income, middle-/low-income and high-income nations
Wang et al. (2015)	OECD	1960-2010	FE	URB has an inverted U-shaped impact on CO_2
Xu and Lin (2015)	30 China 30 provinces	1990-2011	Nonparametric additive regression	URB has an inverted U-shaped impact on CO_2 in eastern region, a positive U-shaped effect in central region, and insignificant nexus in western region
Onoja et al. (2014)	Africa	1960-2010	ARDL	URB has no significant effect on CO_2
Sadorsky (2014)	16 countries	1971-2009	MG, AMG, CCEMG	URB has no significant effect on CO_2
Shahbaz et al. (2014)	United Arab Emirates	1975-2011	ARDL	URB increases CO_2
Al-Mulali et al. (2013)	MENA	1980-2009	DOLS	URB triggers CO_2

Notes: URB = Urbanization; CO_2 = Carbon dioxide emissions; EF = Ecological Footprint; DF = Deforestation; GHG = Greenhouse Gas; NDVI = Normalized Difference Vegetation Index; AMG = Augmented Mean Group; ARDL = Autoregressive Distributed Lag; FARDL = Fourier Autoregressive Distributed Lag; CCEMG = Common Correlated Effects Mean Group; DCCE = Dynamic Common Correlated Effects; DOLS = Dynamic Ordinary Least Squares; FE = Fixed Effect; FMOLS = Fully Modified Ordinary Least Square; GMM = Generalized Method of Moment; IV-GMM = Instrumental Variable-GMM; MG = Mean Group; OLS = Ordinary Least Square; PMG = Pooled Mean Group, RE = Random Effect; LSDVC = Least Squares Dummy Variable Corrected; TR = Threshold Regression; MS = Markov Switching; DSUR = Dynamic Seemingly Unrelated Regression; CCR = Canonical Cointegrating Regression; PSTR = Panel Smooth Transition Regression; CUP-FM = Continuously Updated Fully Modified; CUP-BC = Continuously Updated Bias-Corrected; KRLS = Kernelized Regularized Least Squares; CS-ARDL = Cross-Sectional augmented ARDL; QR = Quantile Regression; FGLS = Feasible Generalized Least Squares; NIPALS = Nonlinear Iterative Partial Least Square.

to be positive. The sign of urbanization is ambiguous. Urbanization may increase housing, transport, and energy demands, thereby worsening environmental degradation. On the other hand, urbanization may promote resource efficiency that will mitigate environmental degradation. In the case of Cote d'Ivoire, we hypothesize the coefficients of urbanization and population to be positive.

In line with the theoretical argument of the EKC hypothesis, we augment Equation (1) with the squared term of the real GDP per capita as follows:

$$Ef_t = \gamma_0 + \gamma_1 Gdp_t + \gamma_2 Gdps + \gamma_3 Urb_t + \gamma_4 Pop_t + \mu_t \tag{2}$$

where $Gdps$ is the squared term of real GDP per capita.

The EKC hypothesis is validated if Gdp enters with a positive coefficient and $Gdps$ enters with a negative coefficient.

3.2. Econometric Methodology

The study employs time-series econometric techniques to scrutinize the relationship between urbanization and ecological footprint. Firstly, it examines the order of integration of the variables by mean of the PP unit root test of Phillips and Perron (1988) and the KPSS test of Kwiatkowski et al. (1992) are applied. Next, we test whether there exists a cointegrating relationship between the variables.

To ascertain the presence of a long-term relationship among the variables, the study relies on the Autoregressive Distributed Lag (ARDL) bounds test proposed by Pesaran et al. (2001). This approach enjoys several advantages over the conventional type of cointegration methods. It can be applied to data set which is a mixture of I(0) and I(1) variables provided the dependent variable is I(1) and the explanatory variables are I(0) or I(1) series. Moreover, it allows the variables in the model to have different lags. Technically, the ARDL approach is based on the estimation of the following error correction model:

$$\begin{aligned}\Delta Ef_t = {} & \phi_0 + \phi_1 Ef_{t-1} + \phi_2 Gdp_{t-1} + \phi_3 Urb_{t-1} + \phi_4 Pop_{t-1} + \sum_{i=1}^{p1} \theta_{1i} \Delta Ef_{t-i} \\ & + \sum_{i=0}^{p2} \theta_{2i} \Delta Gdp_{t-i} + \sum_{i=0}^{p3} \theta_{3i} \Delta Urb_{t-i} + \sum_{i=0}^{p4} \theta_{4i} \Delta Pop_{t-i} + e_t\end{aligned} \tag{3}$$

where Δ is the difference operator defined as $\Delta Z_t = Z_t - Z_{t-1}$.

The appropriate lag structure ($p1$, $p2$, $p3$, $p4$) was selected using the AIC criterion. The first part of the equation with the coefficients ϕ_1 - ϕ_4 represents the long-run relationship of the model whereas the parameters θ_{1i} - θ_{4i} represent the short-run dynamics. The null hypothesis of no long-run relationship is H_0: $\phi_1 = \phi_2 = \phi_3 = \phi_4 = 0$. This hypothesis is tested through an F-test. Under the null hypothesis, however, the distribution of the F-statistic is non-standard. Pesaran et al. (2001) have provided critical values that account for integrating properties of the variables. The lower bound value assumes that all explanatory variables are I(0), while the upper bound value assumes that they are I(1). Once the null of no cointegration is rejected, the estimated long-run coefficients are obtained as the negative value of the coefficients for the lagged explanatory variables divided by the coefficient for the lagged dependent variable (Ef_{t-1}).

3.3. Data Description

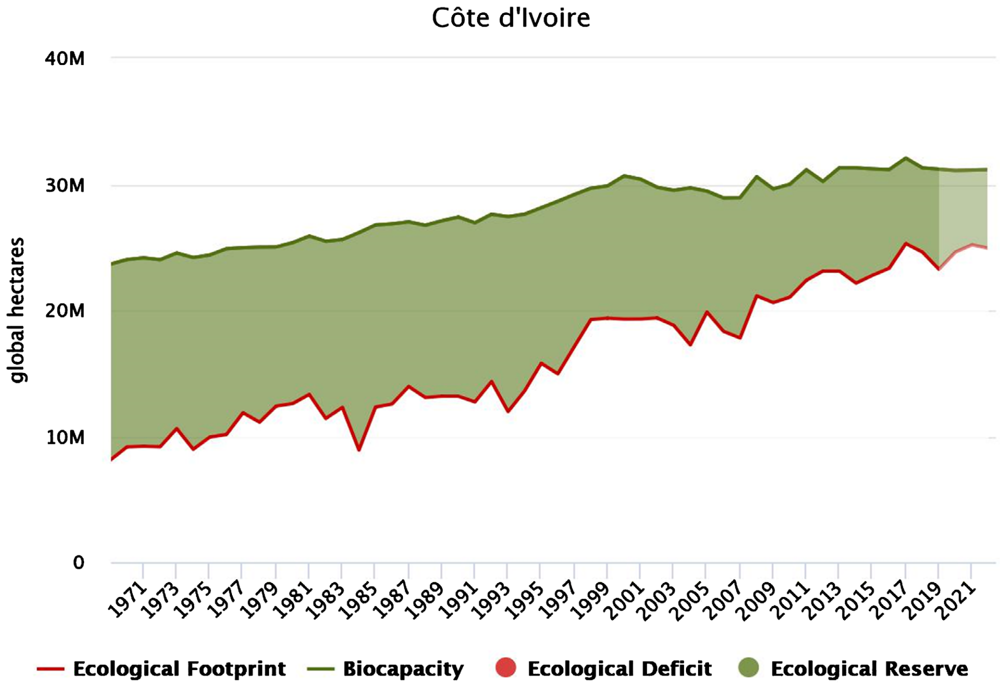
The research employs annual time series data covering the period from 1970 to 2021. We use ecological footprint as a proxy for environmental degradation following many previous studies (e.g. Dogan et al., 2019; Erdogan et al., 2021; Alvarado et al., 2022; Aladejare, 2023; Opuala et al., 2023). The explanatory variable of the study include real GDP per capita, urbanization and population. Real GDP and population are included as control variables to avoid misspecification of the empirical model. The description, unit of measurement and sources of the variables are shown in **Table 2**. For the econometric analysis, the variables were converted into natural logarithm in order to scale down values and provide direct interpretation of estimates in term of elasticity.

The ecological footprint and biocapacity of Cote d'Ivoire over the sample period are plotted in **Figure 1**. As can be seen, Cote d'Ivoire is facing the challenges of

Table 2. Variables of the study and description.

Variable	Description	Sources
EF	Ecological footprint (global hectare)	Global Footprint Network
GDP	GDP per capita (constant 2015 US$)	WDI
URB	Urban population (% of population)	WDI
POP	Total population	WDI

Note: WDI—World Development Indicators (World Bank).



Jniversity, FoDaFo, Global Footprint Network, 2023 National Footprint and Biocapacity Accounts Note: last three years are estimates

Source: Global Footprint Network, accessed 2 July, 2023.

Figure 1. Ecological footprint and biocapacity in Cote d'Ivoire (1970-2021).

growing ecological degradation. Even through the country is a net biocapacity exporter, its ecological reserve is reducing over time. Efforts should be made to widen the difference between biocapacity and ecological footprint in order to keep a sustainable lifestyle over the long term.

Table 3 shows the trends of different components of ecological footprint. As depicted by Table 3, the structure of ecological footprint has changed between 1970 and 2020. The share of forest products has decreased from 38.56% in 1970 to 22.01% in 2020, whereas that of cropland has increased from 24.10% to 30.02%, becoming the major source of ecological degradation in Cote d'Ivoire. Carbon footprint and fishing grounds account for 19.51% and 16.7% of total ecological footprint in 2020, respectively. These figures clearly provide rational of using ecological footprint as indicator of environmental degradation instead of carbon footprint which explains no more than 20% of the overall ecological footprint in the context of Cote d'Ivoire.

Before starting the econometric analysis, we first examine the descriptive statistics and correlation matrix of the variables. The descriptive statistics of the variables reported in Table 4 show that ecological footprint averages 16.56 over the

Table 3. Components of ecological footprint in Cote d'Ivoire, 1970-2020.

Component	1970	1980	1990	2000	2010	2020
Built up land	1.70	2.61	3.42	3.45	3.61	5.54
Carbon	13.48	15.61	10.86	16.05	17.73	19.51
Cropland	24.10	25.64	25.39	38.33	34.21	30.02
Fishing grounds	14.06	13.70	12.49	8.94	14.78	16.70
Forest products	38.56	34.04	36.07	28.16	23.41	22.01
Grazing land	8.11	8.42	11.77	5.07	6.26	6.23
Total	**100**	**100**	**100**	**100**	**100**	**100**

Source: Global Footprint Network, accessed 2 July, 2023.

Table 4. Descriptive statistics.

Variables	EF	GDP	URB	POP
Mean	16.560	7.600	3.713	16.422
Median	16.547	7.587	3.723	16.493
Maximum	17.045	8.012	3.954	17.128
Minimum	16.002	7.317	3.338	15.516
Std. deviation	0.324	0.195	0.159	0.476
Jarque-Bera	3.583	2.461	2.681	3.592
Prob.	0.166	0.292	0.261	0.165
n	52	52	52	52

Note: EF = log of ecological footprint as global hectare; GDP = log of real GDP per capita; URB = log of urbanization rate; POP = log of total population.

period 1970-2021, and ranges between 16.002 and 17.045. Likewise, real income per capita has a mean value of 7.6 along with its minimum and maximum of 7.317 and 8.012, respectively. During the study period, urbanization as a share of total population has a mean value of 3.713, and runs between 3.338 and 3.954. The Jarque-Bera test statistic suggests that all the variables are normally distributed as the *p*-values are greater than the five percent level.

The correlation matrix in Table 5 unveils that real GDP per capita (GDP) has a negative relationship with Ecological Footprint (EFP) whereas urbanization and population show a positive relationship with ecological footprint. This suggests that economic growth and demographic dynamics play a role in shaping the environmental sustainability in Cote d'Ivoire. Further, there could be a problem of multicolinearity among the explanatory variables. Firstly, the correlation coefficients between urbanization and population are greater than 0.80. Secondly, the values of Variance Inflation Factor (VIF) and tolerance unravel that multicolinearity is a serious concern in this study. Therefore, we exclude population from the analysis and consider the model with real GDP per capita and urbanization, which does not suffer from multicolinearity problem.

4. Results and Discussion

Before moving on to regression, we check the order of integration of the variables. Table 6 shows the results of the unit root tests. Results indicate that all the variables have unit root at level but are stationary at first difference.

The next step of our empirical analysis is to test for the existence of a long-run relationship between the variables. Results from the bounds test are reported in Table 7. The computed F-statistics are greater than the upper bounds critical values at 5% level of significance. This confirms a significant presence of a long-run relationship between the variables. Thus, we can conclude that real GDP per capita and urbanization have a long-run relationship with ecological footprint. The diagnostic tests show that the error terms of the estimated models are normally distributed, and free from correlation and heteroskedasticity.

We proceed to estimate the long-run coefficients associated with real income

Table 5. Correlation matrix and colinearity test results.

Variables	Correlation coefficients				Colinearity results	
	EF	GDP	URB	POP	VIF	Tolerance
EF	1.000	−0.541*	0.947*	0.959*	-	-
GDP		1.000	−0.567*	−0.643*	2.262	0.441
URB			1.000	0.984*	43.766	0.023
POP				1.000	50.629	0.019

Note: EF = log of ecological footprint as global hectare; GDP = log of real GDP per capita; URB = log of urbanization rate; POP = log of total population. The general rule is Tol > 0.2 and VIF < 5. The asterisk * indicates significance at the 5% level.

Table 6. Results of unit root tests.

Series	Level		First difference		Decision
	PP	KPSS	PP	KPSS	
EF	−0.884	0.955*	−13.612*	0.224	I(1)
GDP	−1.220	0.501*	−4.450*	0.270	I(1)
GDPS	−1.222	0.502*	−4.464*	0.268	I(1)
URB	−3.307*	0.956*	−2.921	0.394	I(1)

Note: EF = log of ecological footprint as global hectare; GDP = log of real GDP per capita; GDPS = squared term of GDP; URB = log of urbanization rate. The tests were carried out with the presence of intercept in unit root estimating equation. The 5% critical values are −2.919 and 0.463 for PP and KPSS tests, respectively. The asterisk * indicates the rejection of the null hypothesis at 5% level.

Table 7. Bounds test for cointegration.

Model	Order	F-stat.	Normality	Correlation	Heteroskedasticity
EF = f(GDP, URB)	ARDL(1, 5, 0)	12.980*	4.375 [0.112]	1.057 [0.303]	8.015 [0.431]
EF = f(GDP, GDPS, URB)	ARDL(1, 0, 5, 0)	12.956*	4.886 [0.086]	1.144 [0.284]	7.763 [0.558]
		5% critical values		10% critical values	
		I(0)	I(1)	I(0)	I(1)
	k = 2	3.100	3.870	2.630	3.350
	k = 3	2.450	3.630	2.010	3.100

Note: EF = log of ecological footprint as global hectare; GDP = log of real GDP per capita; GDPS = squared term of GDP; URB = log of urbanization rate. The selected model were based on AIC with maximum lag was set to 5. Normality is Jarque-Bera test; Correlation is Breusch-Godfrey test of order one; Heteroskedasticity is White test. Figures in [.] are p-values. The asterisk * indicates the rejection of the null hypothesis at 5% level of significance.

Table 8. Estimated long-run coefficients.

Variables	(1)			(2)		
	ARDL	DOLS	FMOLS	ARDL	DOLS	FMOLS
GDP	−0.349* [−3.203]	−0.140 [−1.173]	−0.078 [−0.647]	3.084* [11.541]	2.408* [9.026]	2.579* [10.579]
GDPS	-	-	-	−0.225* [−9.271]	−0.162* [−6.722]	−0.174* [−7.504]
URB	1.687* [9.855]	2.070* [8.956]	1.882* [12.069]	1.662* [9.524]	2.046* [10.449]	1.888* [12.005]

Note: The dependent variable is the log of Ecological Footprint (EF) as global hectare; GDP = log of real GDP per capita; URB = log of urbanization rate. Figures in [.] are *t*-statistiques. The asterisk * denotes statistical significance at 5% level.

and urbanization using the ARDL approach. As a robustness check, we also employ the Fully Modified OLS (FMOLS) and the Dynamic OLS (DOLS) estimators. Both techniques account for the possible endogeneity of the variables and perform better in small samples. The results are portrayed in Table 8. The coefficient associated with real GDP per capita is negative and significant in ARDL estimates. This outcome signifies that per capita income is negatively associated with environmental sustainability by lowering ecological footprint. Specifically, keeping other things constant, a one percent increase in real per capita income leads to about 0.35 percent decrease in ecological footprint.

With regard to urbanization, the results reveal a positive and significant coefficient in all estimations implying that urbanization causes greater ecological degradation in Cote d'Ivoire. Other things remain the same, a one percent increase in urbanization is evidenced to rise the ecological footprint by 1.7% percent. This outcome confirms that the current pace of urbanization is not favorable for Cote d'Ivoire in consideration of the environment. This is not shocking because urbanization is associated with higher energy demand and related ecological resources (wood, charcoal, and biomass), increased anthropogenic activities and deforestation. The impact of all of this is known to diminish the biocapacity and rise the ecological footprint. This part of the empirical findings is comparable with the works of Iheonu et al. (2021), Baajike et al. (2022), Li et al. (2022), Mignamissi and Djeufack (2022), Aladejare (2023), and Opuala et al. (2023), who all discovered that urbanization worsens environmental degradation in African countries. However, our urbanization result opposes to the results found by Keho (2015), Aladejare (2022), Kwakwa et al. (2023), and Otim et al. (2023) who found that urbanization improves environmental quality. It also contradicts with Asane-Otoo (2015), Dimnwobi et al. (2021) and Afriyie et al. (2023) who discovered that urbanization has no significant influence on environmental degradation. Our finding demonstrates that the impact of urbanization on the environment depends upon the proxy used to measure environmental degradation.

We check the robustness of the findings by re-estimating the model with the squared term of GDP. The estimation reveals two key findings. First, it can be witnessed that the sign and magnitude of the coefficient of urbanization are consistent with those of the initial model. Hence, this similarity can be considered as proof of the robustness of our findings across model specifications. Urbanization is associated with ecological degradation. Second, the findings are consistent with the EKC hypothesis which postulates that although economic growth at first worsens environmental degradation, it goes on to improve it later on. This piece of the empirical evidence resonates with the conclusions of Bah et al. (2020), Espoir and Sunge (2021), Baajike et al. (2022), and Li et al. (2022).

To complement the analysis of the relationship between ecological footprint, economic growth and urbanization, we further examine the direction of causality using the Granger causality test. In the presence of a long-run relationship, Granger causality test requires the inclusion of a lagged error-correction term within a Vector Error-Correction Model (VECM). **Table 9** provides the results of causality tests. The results show that both real GDP per capita and urbanization cause environmental degradation in the long-run. In the short-run, only real GDP per capita causes environmental degradation. Besides, urbanization causes economic growth in the short-run. The finding of the positive stimulating long-run

Table 9. Granger-causality test results.

Dependent variable	Explanatory variables			
	ΔEF	ΔGDP	ΔURB	ECT_{t-1}
ΔEF	-	22.869* (0.000)	4.002 (0.405)	−0.812* [−4.473]
ΔGDP	5.099 (0.277)	-	14.901* (0.005)	−0.122 [−1.247]
ΔURB	3.061 (0.547)	3.556 (0.469)	-	0.001 [0.107]

Note: Statistics for ΔEF, ΔGDP and ΔURB are Chi^2 with *p-values* in parentheses. Statistics for ECT_{t-1} are coefficients of adjustment, with *t*-statistics in brackets. The optimal lag length was 4 according to the AIC. The asterisk * denotes statistical significance at 5% levels.

causal effect of urbanization on ecological footprint is supportive of the urban environmental transition theory.

5. Conclusion and Policy Implications

This research was designed to explore the impact of urbanization on the environment in Cote d'Ivoire. Previous studies mostly focused on carbon emissions, which is an aspect of the environmental degradation. Instead, this study uses ecological footprint as a comprehensive measure of environmental degradation. Autoregressive distributed lag-bound testing approach to cointegration was used to analyze the long-run relationship between real GDP per capita, urbanization and ecological footprint and VECM model was used for causal analysis. Employing time series data spanning from 1970 to 2021, results disclose that there is a long-run connection between per capita income, urbanization and ecological footprint. The core finding of this research reveals that urbanization is a significantly contributing factor to the environmental degradation in Cote d'Ivoire by increasing ecological footprint. This suggests that urbanization takes place at the expense of environment through heavy ecological resource consumption. In many African countries including Cote d'Ivoire, urbanization is associated with higher demand for energy, increased anthropogenic activities and conversion of land surface to urban usage. These activities are known to reduce the biocapacity and worsen the ecological footprint. Besides, the results demonstrate an inverted U-shaped relationship between real GDP per capita and ecological, in support of the EKC hypothesis. This means that economic development could contribute to environmental sustainability in Cote d'Ivoire. The causality results divulge a one-way causal relationship running from urbanization to ecological footprint in the long run and from real per capita income to ecological footprint in the short and long run.

Overall, the results of this research underscore the role of urbanization in degrading the environment in Cote d'Ivoire. Considering the economic and urban population growth in Cote d'Ivoire, decelerating the speed of urbanization is not a viable policy to reduce its detrimental effects on the environment. Government can mitigate negative environmental effects through planned and organized urbanization. In many urban areas, several housing estates are not approved by the government. This leads to massive destruction of forests far from the eyes of the government. The study suggests introducing eco-friendly practices and green energies into urban planning that will design the safe accommodation of increased urbanization with environmental sustainability. In addition, government should promote renewable and cleaner energy sources along with enhanced green technologies and innovation in research and development. In this regard, efforts should emphasize the use of solar and biomass, which are potentially abundant in African countries. The government should also implement initiatives encompassing conservation and restoration of forests as well as biodiversity conservation. The control of existing classified forests and national parks and reserves by the Forest Development Corporation (SODEFOR) and the Ivorian Parks and Reserves Office (OIPR) must be reinforced within a strengthened forest governance framework. The human resources and means for intervention of these entities should be increased. Undoubtedly, all these initiatives will require large budgets that are beyond the current financial capacity of the country. Alternatively, introduction of carbon tax and other environmental taxes to deter highly environmentally damaging anthropogenic and industrial activities could contribute to reducing ecological degradation.

This study suffers from certain limitations. First of all, findings from this study may vary across econometric approaches. For instance, we have used a linear specification assuming the effects of urbanization and income to be symmetric. This assumption implies that increase and decrease in income have the same effect on ecological footprint. Such an assumption could be questionable if ecological footprint responds differently to income increase and decrease. Another potential caveat of this study is that the findings may be plagued with variable-omission bias. Some excluded potential variables can also influence ecological footprint in Cote d'Ivoire. One such variable may be quality of institutions. It has been shown in the empirical literature that low institutions undermine the effectiveness of environmental policies in developing countries. Moreover, globalization was found to mitigate the influence of urbanization on environmental degradation. Therefore, further study can build on the current study by investigating the roles of globalization and institutional quality in shaping the relationship between urbanization and environmental degradation. We intend to examine these issues in future research.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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