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# Wavelet Quantile Evidence on Urbanisation, Human Capital and Economic Growth Impacts on Nigeria's Ecological Footprint

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## ABSTRACT

*In light of growing uncertainties in the climate, it is crucial to identify what is causing environmental pressure in Nigeria. This study explores dynamic links between urbanisation, human capital accumulation economic growth and the nation's ecological footprint (EF) from 1961 to 2020. Employing Wavelet Quantile Correlation (WQC) and Quantile-on-Quantile Granger Causality (QQGC) approaches, we capture both frequency-specific and distribution-specific dependencies neglected by linear techniques. WQC results indicate that rising urban population, expanding human capital and GDP growth dampen EF in the short- and medium-term, yet predominantly amplify EF over longer horizons; negative correlations persist for lower quantiles (0.1–0.5), highlighting heterogeneous vulnerabilities. QQGC confirms significant bidirectional causality across all quantile pairs, underscoring pervasive interdependence irrespective of economic or ecological states. Policy simulations suggest that integrating environmental education into all schooling levels, promoting renewable energy within rapidly growing cities, and decoupling growth from fossil-fuel dependence are critical for sustaining long-run environmental gains. Our evidence supports context-specific, time-phased interventions that align Nigeria's urban transition and human capital strategy with its 2050 net-zero commitment. By revealing quantile-dependent effects, the study enriches environmental Kuznets literature and offers nuanced guidance for green development planning strategies.*

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| Highlights: | Contribution to the field statement: |
| --- | --- |
| - Urbanisation lowers Nigeria's ecological footprint in the short-medium term but magnifies it long-term, per wavelet–quantile results.<br>- Rising human capital trims footprint at lower quantiles yet drives higher-quantile, long-horizon ecological pressure.<br>- Quantile-on-quantile causality confirms the bidirectional influence between urbanisation, human capital, GDP and the ecological footprint across every quantile pair.<br>- Policy simulation reveals renewable-energy urban growth and environmental education can decouple these drivers from Nigeria's rising footprint by 2050. | Applying Wavelet Quantile Correlation and Quantile-on-Quantile Causality to Nigeria's 1961–2020 dataset, this study pioneers frequency- and distribution-sensitive evidence that urbanisation, human capital and growth alternately mitigate or magnify ecological footprints across temporal–quantile regimes. By integrating education-centred policy simulations, it reframes environmental Kuznets expectations, enriching urban sustainability economics and methodology scholarship. |

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## 1. Introduction

At present, the global economy is characterized by different uncertainties, such as wars (physical and trade), political and economic instabilities, and climate change. Among all these concerns, climate change is at the forefront of discussions. This is because its impact is being felt globally. The discussion centred on climate change is that the way humans use their resources should not lead to the degradation of the environment. Climate change has caused frequent and severe heat waves, droughts, floods, wildfires, and storms, leading to loss of life, displacement, economic damage, and food insecurity. These problems have made environmental sustainability a major point of discussion, and this is emphasized by the United Nations (UN) Sustainable Development Goals (SDGs). Environmental sustainability is the ability to meet present needs without jeopardizing the chances of future generations from meeting their needs (UN, 1987). Therefore, due to the importance of climate change, it is essential to continually investigate the major drivers of environmental sustainability or factors that can degrade the environment.

From previous studies, different factors can affect the quality of the environment either positively or negatively, such as economic growth, urbanization, human capital, geopolitical risk, population, financial development, policy uncertainties, foreign direct investment (FDI), stringent environmental policies, and globalization (Ahmed et al., 2022; Ibrahim et al., 2023; Kamal et al., 2021; Luo & Sun, 2024; Zou et al., 2025). This study focuses on how urbanization, human capital, and economic growth influence ecological footprint. Urbanization refers to the movement of people from rural to urban areas because of the inherent economic benefits in urban areas. According to Humbal et al. (2023), in the nineteenth century, just 15% of people on earth lived in cities. The twentieth century saw a drastic shift in the situation, with the 1950s seeing a sharp increase in the pace of urban population growth. Half of the world's population is expected to live in cities sixty years from now. Furthermore, it is anticipated that 86% of industrialized nations and 64% of emerging nations will be urbanized by 2050. Urbanization is being driven by diverse social, economic, and ecological variables. Also, industrialization, employment possibilities, population increase, social concerns, and modernization were further factors that promoted urbanization. It is crucial to note that unchecked urbanization has several detrimental impacts on the global biosphere, such as increasing air pollution, slum expansion, environmental degradation, land insecurity, and problems with water and sanitation. However, when used responsibly, it has several positive effects, such as enhanced infrastructure and technology, first-rate medical and educational facilities, more substantial communication and transportation, and higher living standards. Therefore, further research is required to fully understand the dual impact of urbanization on the environment.

Human capital is also one of the factors that can contribute to economic expansion and a sustainable environment. Human capital refers to the skills, knowledge, experience, and training that individuals have, which helps them to be more productive. It is also essential to state that access to quality healthcare and individuals being in good health condition are determinants of human capital. According to Samans et al. (2017), almost no other aspect can determine a country's long–term prosperity more than how it develops its human capital. They defined 'human capital' as the abilities and knowledge that people have that allow them to provide value to the global economy. Formal education and skill development are not the only factors that determine human capital. It may be improved over the course of a person's lifetime, increasing with use and decreasing with inactivity. Samans et al. (2017) and Sarkodie et al. (2020) further argued that being educated makes individuals more socially conscious and, as a result, more ecologically conscious. Education is a fundamental component of human capital. Therefore, the argument above shows that human capital is a necessary factor in achieving environmental sustainability.

Urbanization and human capital are key components of economic progress. At the same time, economic growth is a major factor that either drives environmental quality or degrades the environment. Economic growth simply means there is an increase in the production of goods and services, which can have a significant positive impact on employment levels, income, and living standards (Boussaidi & Hakimi, 2025). On the other hand, if this expansion is not controlled sustainably, the quality of the environment may suffer. Thus, it is important to promote sustainable practices to achieve a balance between economic expansion and environmental protection.

There are different ways in which environmental quality is measured, including using the level of greenhouse gases (GHGs). Rather than using GHGs such as carbon dioxide emissions ($CO_2$) to proxy for environmental quality, this research used ecological footprint. Anthropogenic activities' effects on grazing land, the ocean, agricultural lands, forest products, infrastructure (built–up land), and carbon footprint are measured by ecological footprint. The amount of land and water required to create commodities and absorb waste is measured in global hectares (Ahmed & Wang, 2019). According to current research, ecological footprints are a comprehensive and cumulative measure of how human activity affects the ecosystem (Charfeddine, 2017; Destek et al., 2018). In simple terms, ecological footprint measures how much nature is needed by people to support their way of living. A high ecological footprint is detrimental to the environment, while a low ecological footprint is beneficial.

Therefore, this research investigates the impact of urbanization (UPOP), human capital (HUMC), and economic growth (GDPR) on ecological footprint (ECOL) in Nigeria from 1961 to 2020 using methods such as the Wavelet Quantile Correlation (WQC) (Kumar & Padakandla, 2022), and the Quantile–on–Quantile Granger Causality analysis (QQGC) (Adebayo & Özkan, 2024). The WQC investigates the relationship between variables, taking into account both frequency scales and quantile dependency. This is more advantageous when compared to linear techniques. On the other hand, compared to the Granger Causality (GC) and Quantile Granger Causality (QGC) approaches, QQGC allows for a more detailed study of causation by examining causality from the quantiles of an independent variable to the quantiles of a dependent variable. Furthermore, the Quantile ADF proposed by Adebayo & Özkan (2024) is employed to test for data stationarity. This is more advanced than the traditional unit root tests, such as ADF and PP. The methods employed are some of the contributions made to existing literature. In addition, urbanization is included in this research because urbanization levels are increasing rapidly in Nigeria. In addition, it is essential to state that Nigeria is the most populous country in Africa, with a population of more than 200 million people (World Bank, 2025). Nigeria also aims to achieve net–zero by 2050. Sarkodie et al. (2020) stated that the inconsistencies that can be found across different economic variables and the degradation of the environment could be due to the absence of human capital as a moderating variable. This means the role of human capital in achieving environmental quality cannot be neglected.

## 2. Literature Review

Udemba (2020) used Nigeria as a case study to examine the interconnection between GDPR and ECOL. Using Nigeria is motivated by the fact that the nation's economy mostly depends on fossil fuels. According to the results of the Granger Causality (GC) and Autoregressive Distributed Lag (ARDL) methods, the *scale effect* theory is confirmed. This means that GDPR and ECOL are growing at the same rate. Likewise, using the same methodology for the Nigerian economy, Dada et al. (2022) found that while GDPR contributes to the degradation of the environment, HUMC and URB reduce ECOL. According to Akadiri et al. (2025), concerns over Nigeria's environmental sustainability have been raised by the country's drive for economic expansion, especially in light of the consequences of resource reliance, urbanization, and foreign direct investment (FDI). Results show that environmental quality continuously deteriorates by economic expansion across all quantiles, with the impacts getting worse with time. Urbanization and FDI both have detrimental ecological effects, especially at medium and high quantiles. Obekpa et al. (2025) argued that the total ECOL increases because of population growth and economic expansion.

Nathaniel (2021) argued that in addition to being the most developed and urbanized nation in Africa, South Africa is the biggest emitter of $CO_2$. Long–term results indicate that although HUMC supports environmental sustainability, urbanization and economic expansion raise ECOL. In addition, the relationship between urbanization and HUMC lessens environmental deterioration. The methods used include ARDL, FMOLS, DOLS, and CCR. In Brazil and China, employing the QARDL approach, Tiwari et al. (2022) established that GDPR increases ECOL, while HUMC reduces it. Furthermore, adopting the dynamic ARDL and KRLS methods, Zhou et al. (2022) found a contradictory result regarding HUMC and that is, HUMC increases ECOL in Pakistan. In addition, GDPR drives ECOL, while urbanization undermines it. In GCC economies, Amer et al. (2022) showed how urbanization decreases ECOL and how GDPR & HUMC increase ECOL using the FGLS technique. In G–11 economies, Mehmood (2024) opined that urbanization and GDPR increase ECOL.

In recent studies, Degirmenci et al. (2025) established that URB contributes to ecological sustainability in Brazil, while it harms the environment in China. It was also found that HUMC spurs the sustainability of the environment. In BRICS economies, Liu et al. (2025) argued that the availability of natural resources and growth in the economy both increase ECOL. In addition, the study suggests a causal feedback link between HUMC, URB, and ECOL. Tunio et al. (2025) confirmed that economic expansion exacerbates environmental deterioration over time while reducing it in the short run. Also, URB has been identified as a major contributor to long-term environmental deterioration, highlighting the necessity of focused governmental responses. According to the study of Mohamed et al. (2025), GDPR and URB increase ECOL for the Somalian economy.

Conclusively, the literature, shows that GDPR (Economic Growth) leads to ecological degradation, while the impact of URB (Urbanization) and HUMC (Human Capital) on the environment can be both positive and negative. Therefore, further research is required due to the inconsistent outcomes.

**Table 1:** Literature Review Summary.

| **Author(s)** | **Year** | **Country(ies)** | **Methods** | **Outcome** |
|---|---|---|---|---|
| Udemba (2020) | 1981–2018 | Nigeria | ARDL & Granger Causality | GDPR (+) |
| Nathaniel (2021) | 1970–2016 | South Africa | ARDL, FMOLS, DOLS & CCR | URB (+), GDPR (+), HUMC (–) |
| Zhou et al. (2022) | 1980–2018 | Pakistan | Dynamic ARDL & KRLS | HUMC (+), GDPR (+), URB (–) |
| Dada et al. (2022) | 1970–2017 | Nigeria | ARDL & Granger Causality | URB (–), HUMC (–), GDPR (+) |
| Tiwari et al. (2022) | 1971Q1–2017Q4 | Brazil & China | QARDL | GDPR (+), HUMC (–) |
| Amer et al. (2022) | 1995–2017 | GCC | FGLS | URB (–), GDPR (+), HUMC (+) |
| Mehmood (2024) | 1990–2020 | G–11 | CS–ARDL | URB (+), GDPR (+) |
| Akadiri et al. (2025) | 1970–2022 | Nigeria | Wavelets Quantile Regression | URB (+), GDPR (+) |
| Obekpa et al. (2025) | 1981–2020 | Nigeria | Quantile Regression & KRLS | GDPR (+) |
| Degirmenci et al. (2025) | 1991–2019 | E–7 | AMG | URB (+), URB (–), HUMC (–) |
| Liu et al. (2025) | 1992–2016 | BRICS | AMG, PMG, CCEMG, FMOLS & DOLS | GDPR (+) |
| Tunio et al. (2025) | 1970–2022 | 34 High-Income European and Asian | VECM | GDPR (+), URB (+) |
| Mohamed et al. (2025) | 1990–2020 | Somalia | ARDL, FMOLS & CCR | GDPR (+), URB (+) |

***Note:*** *(+) denotes positive association; (–) denotes negative association.*

## 3. Data, Theoretical Framework, and Methodology

### 3.1 Data and Sources

The data employed in this research (1961–2020) and their sources are as follows: Ecological Footprint (global hectares per capita) (ECOL), which is the dependent variable, is used as a proxy for environmental progress, and its source is the g. The independent variables include Urban Population (% of total population) (UPOP), a proxy for urbanization, Index of Human Capital Per Person (HUMC), and Gross Domestic Product (constant 2015 US$) (GDPR), which is a proxy for economic expansion. UPOP and GDPR data sources are (the World Bank, 2024), while the HUMC data source is from (Feenstra et al., 2015). It is important to note that the data period stopped in 2020 because of limited data availability.

### 3.2 Theoretical Framework

#### 3.2.1 Theories of Urbanization

The theoretical framework that links urbanization to ecological quality includes the Ecological Modernization Theory (EMT), Environmental Transition Theory (ETT), and Compact City Theory (CTT). According to the EMT, emissions increase as urban areas become more developed and then decrease after a specific degree of modernization is reached (Mol & Spaargaren, 2000). Examining urbanization from another perspective, ETT proposes that the impact of urbanization differs at different phases of development (Jacobi et al., 2010). Lastly, CCT asserts that urbanization can positively contribute to ecological progress due to an improvement in public infrastructure, such as hospitals, schools, water and electricity supply, and public transportation (Burton, 2000; Sadorsky, 2014).

#### 3.2.2 Environmental Kuznets Curve

The EKC hypothesis, posited by Grossman & Krueger (1991), argues that economic growth can be grouped into three (3) phases. The initial phase is the *scale effect*, which is related to the early stages of economic growth and is marked by high competitiveness. During this stage, governments are more concerned with economic performance than with ecological performance. This stage is primarily linked to developing countries that want to be like industrialized nations, and to accomplish this, competitive economic growth is implemented, which has a negative impact on the environment. The *technological expansion effect stage* is the second phase. The shift from the scale effect to a more enlightened stage is what defines this stage when people will begin to understand how their activities affect the environment and their health and will begin to advocate for a high–quality environment. The final stage is the *composite effect stage.* At this point, a complete understanding of the necessity of excellent environmental quality and clean economic operations is observed and implemented. Most economic operations will be more sophisticated, with cutting–edge technology that will ensure both economic and environmental sustainability. Service sectors and R&D activities will drive economic progress.

### 3.3 Methodology

The Quantile ADF (QADF) test proposed by Adebayo & Özkan (2024) was carried out as a preliminary assessment to test for stationarity conditions. Once the stationarity results have been obtained, we proceed to adopt the next method, which is the Wavelet Quantile Correlation (WQC) proposed by (Kumar & Padakandla, 2022). According to previous empirical research, the connections between variables can change over time. Nonetheless, the classic Quantile Regression (QR) technique does not account for the potential of separate impacts of the independent variable on the conditional quantiles of the dependent variable over several temporal dimensions. To solve this restriction, the WQC technique was adopted. In addition, for results confirmation and robustness check, the Quantile on Quantile Granger Causality (QQGC) proposed by Adebayo & Özkan (2024) was adopted. Compared to the Granger Causality (GC) and Quantile Granger Causality (QGC) approaches, QQGC allows for a more detailed study of causation by examining causality from the quantiles of an independent variable to the quantiles of a dependent variable.

## 4. Results and Discussions

### 4.1 Descriptive Statistics

The first preliminary investigation carried out is the descriptive statistics. We found an unequal distribution in the dataset for the majority of the variables since their mean values surpassed the values of the standard deviation. In addition, ECOL and UPOP are skewed to the left (negatively skewed), while GDPR and HUMC are skewed to the right (positively skewed). Aside from ECOL, all other variables exhibit non–normal distribution because the p-values are less than 5%.

**Table 2**: Descriptive Statistics.

| | ECOL | GDPR | HUMC | UPOP |
|---|---|---|---|---|
| Mean | 0.001261 | 2.810756 | 0.034534 | 0.363637 |
| Median | 0.002163 | 2.797440 | 0.022652 | 0.369119 |
| Maximum | 0.023713 | 2.926920 | 0.073959 | 0.429534 |
| Minimum | –0.026550 | 2.700024 | 0.015279 | 0.297930 |
| Std. Dev. | 0.010096 | 0.065298 | 0.020197 | 0.040755 |
| Skewness | –0.106260 | 0.351242 | 0.698096 | –0.054668 |
| Kurtosis | 2.718179 | 2.194047 | 1.928865 | 1.686894 |
| Jarque–Bera | 1.245875 | 11.43042 | 30.96683 | 17.36201 |
| Probability | 0.536366 | 0.003295* | 0.000000* | 0.000170* |

* denotes < p–value of 1%

### 4.2 Nonlinearity Test

To examine the series' nonlinear patterns, Broock et al. (1996) nonlinearity test is adopted. As shown in Table 3, the results of nonlinearity tests confirm the presence of nonlinearity in each variable under examination, demonstrating that the quantile-based technique is appropriate for this study.

**Table 3**: Result of the Nonlinearity Test.

| | ECOL | GDPR | HUMC | UPOP |
|---|---|---|---|---|
| DIM2 | 0.176495* | 0.202384* | 0.205072* | 0.208327* |
| DIM3 | 0.291713* | 0.342204* | 0.346645* | 0.353975* |
| DIM4 | 0.365823* | 0.439496* | 0.445041* | 0.456302* |
| DIM5 | 0.412253* | 0.507715* | 0.513889* | 0.528617* |
| DIM6 | 0.440993* | 0.555877* | 0.562402* | 0.580003* |

* denotes < p–value of 1%.

### 4.3 Stationary Test

The QADF test, proposed by Adebayo & Özkan (2024), was performed to investigate the data's stationarity over different quantiles. Unlike traditional ADF and PP tests, which presume consistent distributional features across the whole range, the QADF test takes into account probable distributional changes at different points within the distribution. This method adds to a more thorough knowledge of the data characteristics (Adebayo & Özkan, 2024). Figure 1 shows that all the variables are stationary at the level.

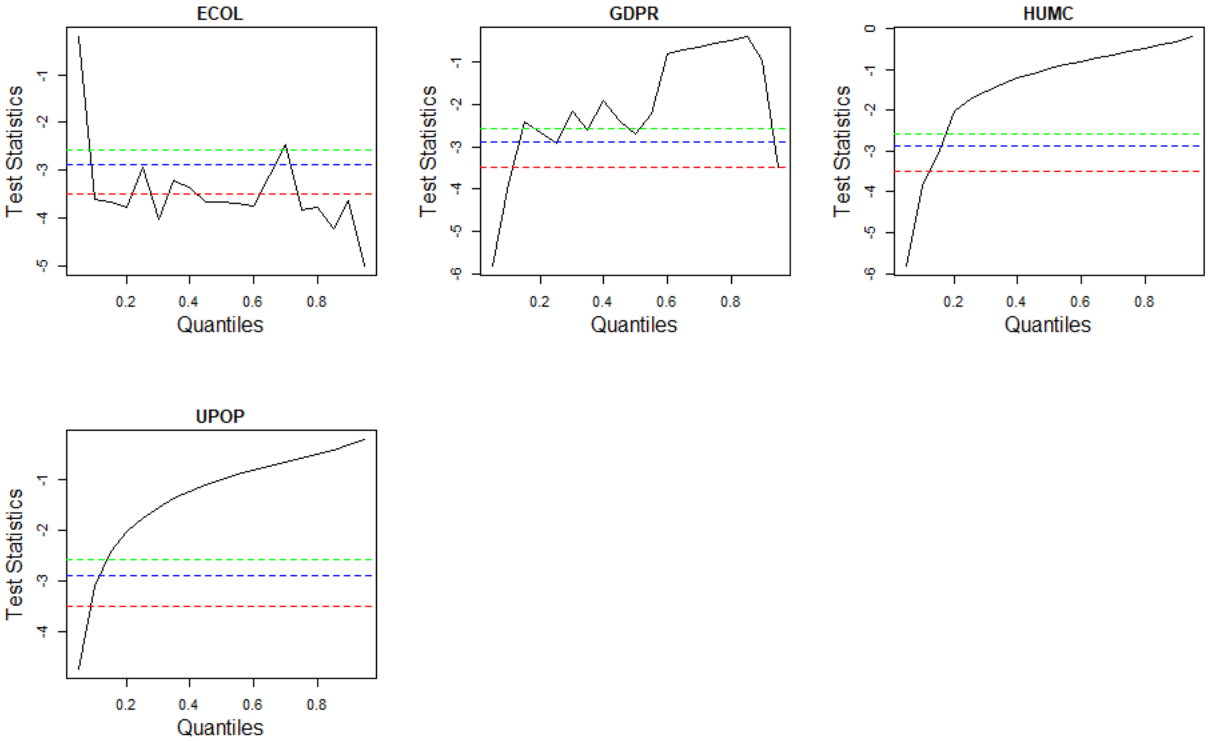


**Figure 1**. Quantile ADF Unit Root Test.

### 4.4 Wavelet Quantile Correlation (WQC)

The WQC is a reliable method for dealing with difficulties involving patterns that are tail–dependent. This approach fully investigates the relationship between variables, taking into account both frequency scales and quantile dependency. Figures 2, 3 & 4 depict the asymmetric behaviour between GDPR, HUMC, UPOP, and ECOL over various periods and quantiles. The Y–axis displays the distinct periods, namely short, medium, and long term, while the X–axis displays the various quantiles (0.1–0.9).

The outcome of the WQC analysis shows that the relationship between GDPR, HUMC, UPOP, and ECOL in the short and medium term is negative. However, in the long run, the association is mainly positive, although, between the quantiles 0.1 and 0.5, there exists a negative link.

The negative short-run and positive long-term association between GDPR and ECOL can be justified. Nigeria's short–term ecological footprint reduction with initial GDP growth may be explained by a move away from traditional, highly resource-intensive practices and toward somewhat more efficient, albeit still basic, technologies and consumption patterns linked to the country's early phases of industrialization and urbanization. This outcome corresponds with the study of Wang et al. (2022) for 166 economies. However, Nigeria's dominant resource extraction (particularly oil), weak environmental regulations and enforcement, rapid population growth that increases demand for consumption, and an economic development trajectory that has historically placed expansion above environmental sustainability are likely the main causes of the country's overwhelming long-term trend of growing ecological footprint. This corresponds to the studies of (Dada et al., 2022; Udemba, 2020). It is important to note that the EKC is not confirmed in this research. This is because the short and medium-term results are negative, while the long-run result is positive.

Secondly, the relationship between HUMC and ECOL in the short and medium term is negative, and this corresponds to the study of (Dada et al., 2022; Nathaniel, 2021; Tiwari et al., 2022). However, in the long run, the association is mainly positive. This means the approach of using human capital to solve the environmental crisis in Nigeria is not sustainable. The outcome of this research is justifiable. As human capital develops, which involves the development of skills, knowledge, education, and experience, it should lead to better choices, which should contribute to ecological quality. However, this is not always the case in the real world. Human capital could develop, and yet people can still live below the poverty line. Therefore, their actions will be centred on making use of the resources around them to survive, and this includes the use of fossils. This positive association in the long run corresponds to the studies of (Akadiri et al., 2025; Amer et al., 2022; Mehmood, 2024; Zhou et al., 2022).

Lastly, the negative short-run association (Amer et al., 2022; Dada et al., 2022) between UPOP and ECOL in Nigeria could be attributed to initial efficiency gains from urbanization, such as improved infrastructure use, shared public services, and more compact living, which reduces per capita resource use. However, a long-term positive link is predicted to emerge as urban populations grow, increasing energy use, transportation use, waste output, and pressure on natural resources. Over time, rapid urban growth can outrun sustainable planning and infrastructure development, resulting in a bigger environmental impact. This aligns with the studies of (Akadiri et al., 2025; Mehmood, 2024; Nathaniel, 2021).

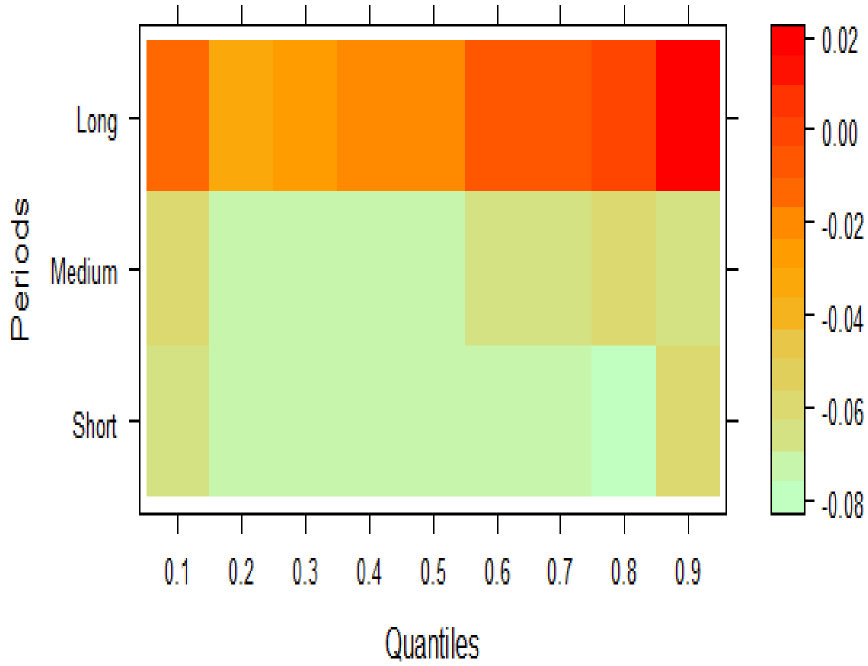


**Figure 2**. The impact of GDPR on ECOL.

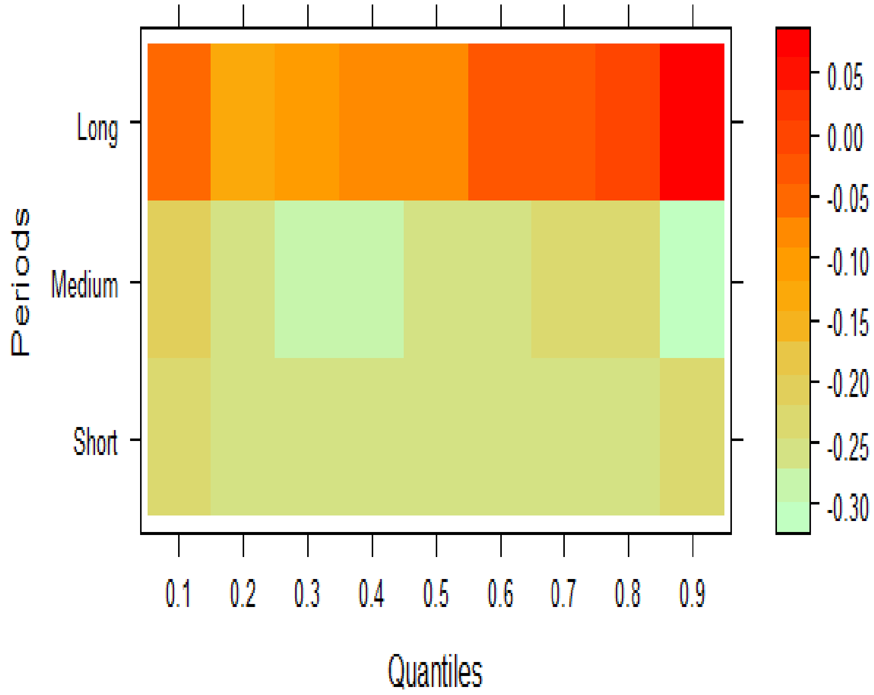


**Figure 3**. The impact of HUMC on ECOL.

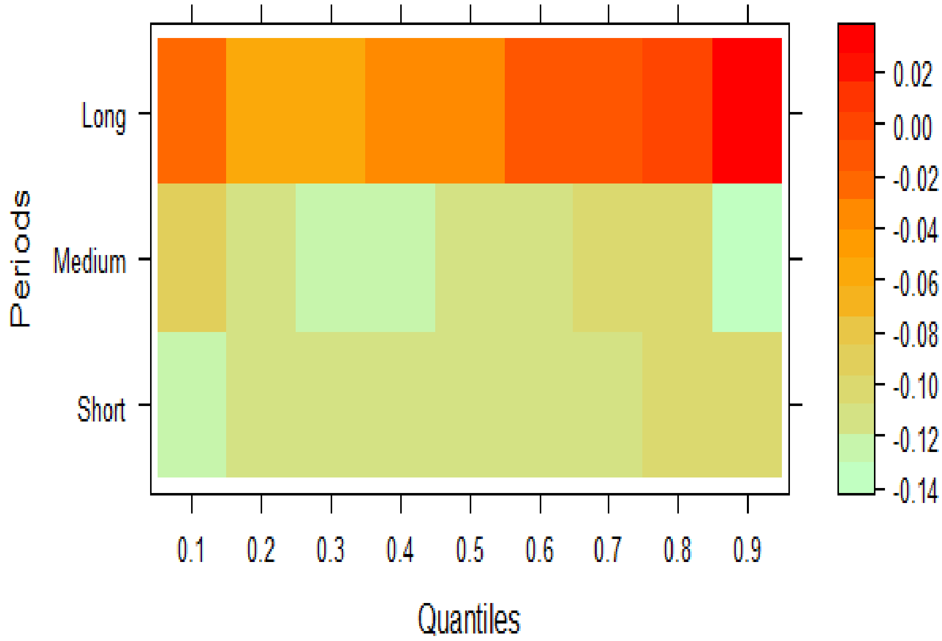


**Figure 4**. The impact of UPOP on ECOL.

### 4.5 Quantile–on–Quantile Granger Causality Analysis (QQGC)

The QQGC results in Figures 5, 6, & 7 revealed that UPOP, HUMC, and GDPR all have a substantial impact on ECOL across all quantiles. This can be seen in the orange and red colours with asterisks.

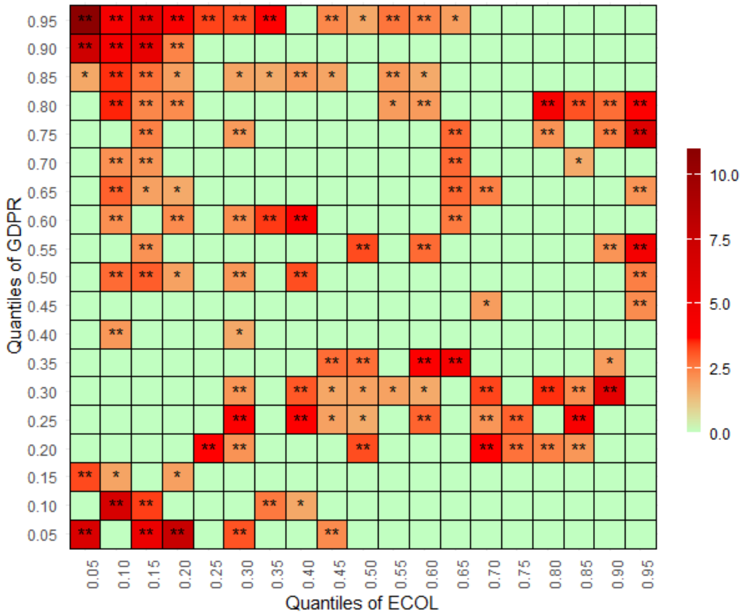


**Figure 5**. Causality from GDPR to ECOL.

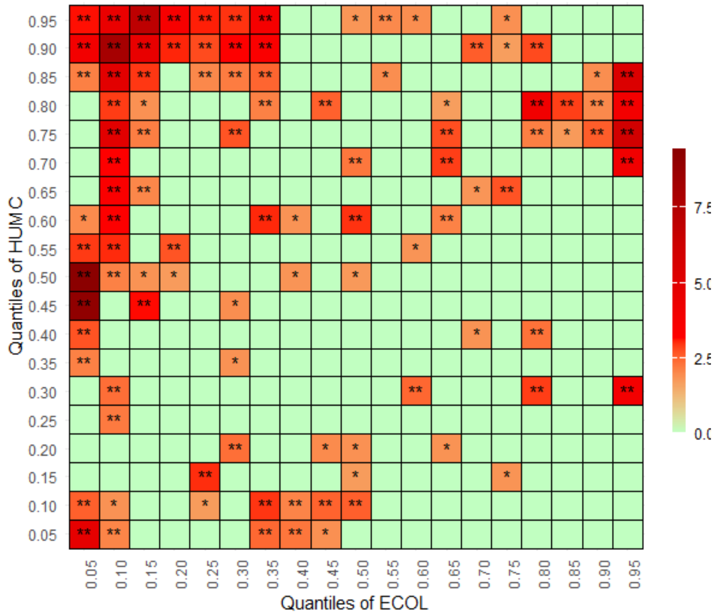


**Figure 6**. Causality from HUMC to ECOL.

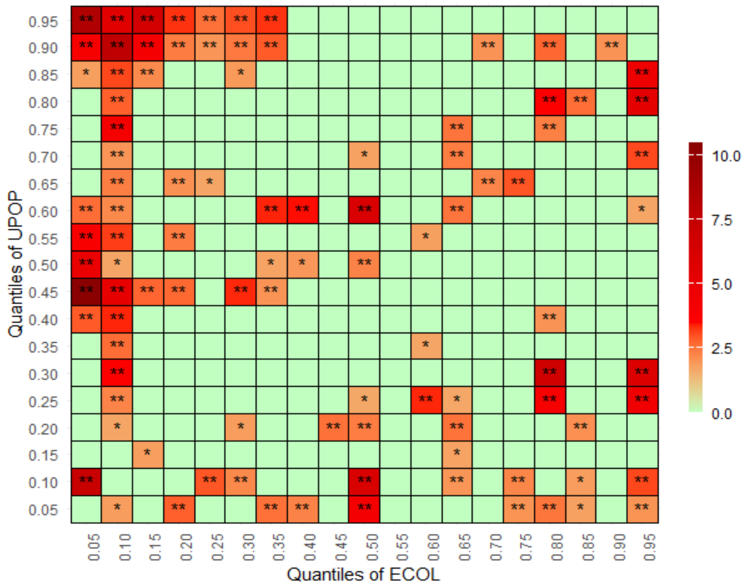


**Figure 7**. Causality from UPOP to ECOL.

## 5. Conclusion and Recommendations

This study investigates how urbanization, human capital, and economic growth affect ecological footprint from 1961–2020 using the Wavelet Quantile Correlation (WQC), and the Quantile–on–Quantile Granger Causality analysis (QQGC) methods. The WQC outcomes show that urban population, human capital, and economic growth reduce the ecological footprint in the short and medium term, while in the long term, the findings are predominantly positive. However, within the quantiles 0.1 and 0.5, there exists a negative link. In addition, the QQGC confirms the WQC across all quantiles.

The study recommends the following: (1) To strike a balance between HUMC and ECOL, and guarantee long–term environmental preservation, it is essential to incorporate environmental education into all educational levels, encouraging green innovation, and coordinating human capital development with sustainability objectives. (2) To manage urban growth without adding to ecological pressure, boosting the use of renewable energy, investing in green infrastructure, enforcing environmental legislation, and promoting sustainable urban planning is crucial. (3) Decoupling

economic growth from ecological decline also entails the adoption of clean energy sources, mixed with stringent environmental policies to discourage the use of unclean energy.
The study has some limitations, such as, it only focuses on Nigeria. Other studies can use a group of other countries or individual countries and investigate similar research questions. In addition, other econometric methods can be adopted for more robust findings.

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**Data availability statement**
The authors confirm that the data supporting the findings of this study are available within the article, and data is available upon request.

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Oluwatoyin Abidemi Somoye, Abraham Ayobamiji, and Toluwalope Seyi Akinwande all contributed equally to the writing – original draft preparation and writing – review & editing of the manuscript. All authors have read and approved the final version of the article.

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**Abbreviations:**

| | |
|---|---|
| ADF: | Augmented Dickey Fuller |
| AMG: | Augmented Mean Group |
| ARDL: | Autoregressive Distributed Lag |
| CCEMG: | Common Correlated Effects Mean Group |
| CCR: | Canonical Cointegrating Regression |
| CCT: | Compact City Theory |
| DOLS: | Dynamic Ordinary Least Squares |
| EKC: | Environmental Kuznets Curve |
| EMT: | Ecological Modernization Theory |
| ETT: | Environmental Transition Theory |
| FGLS: | Feasible Generalized Least Squares |
| FMOLS: | Fully Modified Ordinary Least Squares |
| KRLS: | Kernel–based Regularized Least Squares |
| NARDL: | Non–linear ARDL |
| PMG: | Pooled Mean Group |
| PP: | Phillips Perron |
| QADF: | Quantile Augmented Dickey Fuller |
| QARDL: | Quantile Autoregressive Distributed Lag |

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