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# The Impact of Deforestation on Environment in Pakistan

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## Abstract

Forests are among the fundamental ecosystems that regulate and impact a region's temperature, climate, and carbon dioxide emissions. Growing urbanization and industrialization caused substantial increases in forest degradation, which raised the average surface temperature of the world. Numerous catastrophes have occurred in recent decades as a result of excessive and unregulated forest destruction. The purpose of this study is to examine the impact of deforestation on Pakistan's ecology between 1990 and 2021. We employ the Autoregressive Distributive Lag (ARDL) technique for this. The findings demonstrate that the depletion of forests has exacerbated Pakistan's environmental degradation. This finding suggests that deforestation contributes to both short-term and long-term environmental damage when all other factors are kept constant. On the other hand, it is determined that urbanization has improved its environmental sustainability over the long and short terms. GDP and GDP squared (GDP2) have a positive and negative effect on $CO_2$, respectively. In other words, greater economic growth can aid in improving environmental performance once the examined nations have attained a particular level of economic development. We conclude that deforestation is important factor for environmental degradation in Pakistan.

**Keywords:** Deforestation, Urbanization, Environmental degradation, Pakistan

## Introduction

Environmental degradation (EDE) is a significant global threat that is drawing the interest of scholars and decision-makers. Compared to unemployment or terrorism, the dehumanizing impacts of environmental deterioration are more thought-provoking. Floods, abnormal rainfall patterns, glacier melting, rising sea levels, rising ocean temperatures, declining labor force productivity, decreased agricultural production, and wiped-out species are all signs of environmental deterioration. Degradation of the environment is largely driven by climate change, which is largely caused by greenhouse gas emissions, of which carbon dioxide emissions are a major contributor. CO2 emissions account for over 75% of worldwide GHG emissions, according to British Petroleum Statistics (BP-Statistics, 2021).

United Nations has prioritized the implementation of Sustainable Development Goal 15, which calls for the conservation of terrestrial ecosystems, the adoption of sustainable forest management practices, the fight against desertification, the implementation of land reform, and the halting of biodiversity loss (Amjad et al., 2021; Balsalobre-Lorente et al., 2024). Achieving this goal will need prompt financial resource mobilization in addition to national law and international cooperation. Globally, 4.7 million hectares of forests have been lost annually on average in the ten years since 2010. The rates of deforestation are far higher (OWID, 2023). This statistic indicates that deforestation will be a serious threat to both developed and developing countries in the future. According to Global Forest Watch (2023), in 2010, there were 648 kha of trees in Pakistan, making up 0.74 percent of the total land area and misplaced 49 hectares of tree cover in 2022, which is equal to 19.3 kilotons of CO2 emissions. The preservation of forests is essential to achieving the Sustainable Development Goals (SDGs), reducing the negative effects of greenhouse gas emissions (GHGs), and mitigating climate change (Lin and Ullah, 2024a). Despite being robust to climatic challenges and sometimes seen as having a high societal value of natural capital, the forest sector has suffered greatly over the last 20 years. Forests provide a multitude of products, services, and uses. The main forest products include fuelwood, fodder, timber, and non-timber forest products (Sun et al., 2024). The main functions of the forests are biodiversity, climate change mitigation, ecotourism, and continuous water flow. Pakistan's present forestland is grossly inadequate when taking into account the country's susceptibility to various climate concerns. Pakistan may not be able to achieve one of the Millennium Development Goals (MDGs) set forth by the World Bank, which is to increase the amount of forest land by 2.5–6% by 2015. Due to environmental deterioration, Pakistan has recently seen significant natural catastrophes, including floods in 2010 and 2011. These disasters are expected to become more frequent in the years to come.

The UN Secretary-General expressed grave concerns about the frequency of disasters and the lack of a disaster management framework after visiting regions impacted by flooding and speaking with internally displaced people (IDPs). Pakistan's natural ecosystem and biodiversity are under greater risk due to altered environmental circumstances brought about by industrialization, urbanization, population development, and increased agricultural land usage. Without doing a thorough investigation, it is impossible to determine the critical elements involved in restoring ecological quality. Because trees are an important source of biodiversity, reducing flood damage and mitigating the negative consequences of climate change can help people maintain their livelihoods. With only 5.45% of its land covered by forests, Pakistan has less level of forestland (World Bank, 2018). The fast growing population and the high demand for a variety of products and services are putting a lot of strain on Pakistan's forest ecosystems (Xie et al., 2023). Higher temperatures in the northern part of Pakistan are also thought to be primarily caused by rising rates of deforestation, which accelerates the melting of

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glaciers and results in summer flooding. Deforestation must be used as an indicator of environmental deterioration in this study due to these factors.

Pakistan boasted rich mangrove forests on its southern border, enormous timber forests in its north, and majestic coniferous forests in its west (Shahbaz et al., 2007). Pakistan's population has increased from 37 million in 1947, when it was divided from India, to 180 million now, which has led to a significant loss of forests (Stanton, 2003). In order to save their lives, over a million Afghans fled Afghanistan when the Soviet Union invaded it in 1979. They sought safety in Pakistan and frequently settled in makeshift settlements cut out of once wooded terrain (Turk, 2011).

Logging without permission is the main cause of deforestation. Estimates of the amount of illicit wood harvested in Pakistan are based on the quantity of wood consumed and the overall amount of wood collected from state forests. Four times as much wood was unlawfully collected as was legitimately harvested, according to the documentation. According to Humphreys (2016), illegal logging is seen as a significant component of the subterranean economy. Forests in Khyber Pakhtunkhwa and Kashmir are susceptible to terrorist organizations' illicit timber harvesting. It is illegal to carry lumber between Afghanistan and Pakistan. After being smuggled out of Pakistan, the lumber is returned to Pakistan with the claim that it is duty-free Afghan timber. The timber is carried to Karachi and then to the Gulf States after being smuggled into Pakistan (Nizami, 2013).

Pakistan has made an effort to combat the "Timber Mafia," which refers to organizations or people that unlawfully cut down trees and resell them for profit without a permit. Following Bangladesh's split in 1971, Pakistan's green cover decreased to fewer than 5% from 7% at the time of independence. As of 2015, the World Bank's calculation of Pakistan's forest cover as a percentage of land cover was 1.91 (Kurosaki, 2009). Over the last 25 years, Pakistan's forest cover percentage increased from 3.28 in 1990 to 1.91 in 2015.

Pakistan is currently at a crucial juncture, with about 2–5% of its forest cover remaining. Islamabad is one of the verdant capitals that is experiencing destruction because to the existence of Margalla Hills National Park. Only twisted yellow sapwood that is ankle-high is left behind when bare lots and arborous regions are being cut down (Adil and Dehlavi, 2011). One approach for determining the quantity of illegal wood is game models, which are also used to inform policy choices aimed at curbing illicit forest activity. The subterranean market economy includes the illicit logging industry. Figure 1 illustrates that the worldwide underground market economy uses $1.81 trillion, of which $7 billion is utilized for illicit logging. Pakistan makes around $6.53 billion in contributions to the underground market economy, which includes $782 million for illegal logging. According to Nazir and Olabisi (2017), the above statistics are based on yearly illegal wood harvesting.

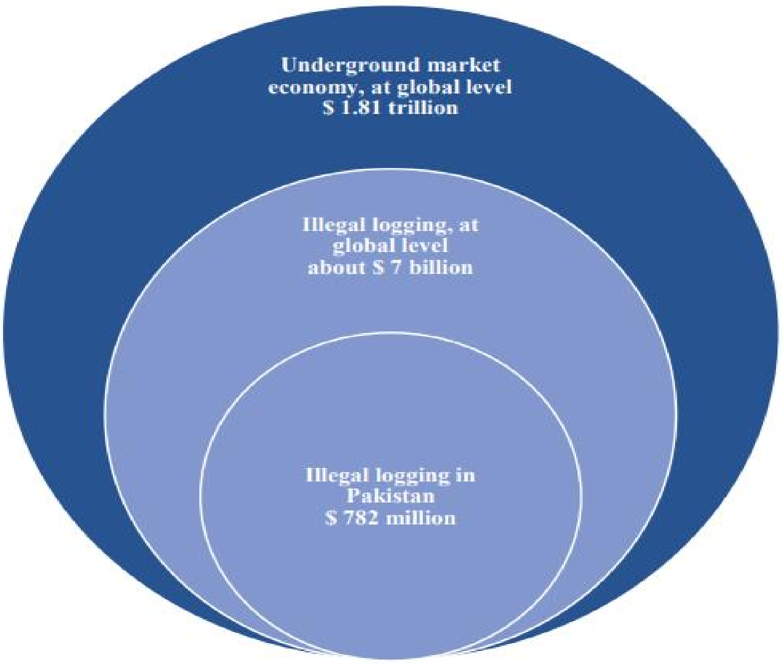


**Fig. 1: Underground market economy**

**Status of Deforestation in Pakistan**

In Pakistan, the government owns the majority of the forest. There are two types of forests: private (not state-owned) and public (owned by the state). Reserve and protected woods make up public forests, whereas Guzara forest is the primary part of private forests. These classifications are used to identify the sorts of woods and the rights of the people. According to Sahide and Giessen (2015), the proportion of production and protection forests is 27% and 72%, respectively.

**Concerns of Deforestation in Past & Present**

There is an alarming disparity between the rate of supply and demand. Here is a study on the use of wood in the past and present. In 1993, the supply of wood was only 18 percent, but by 2013, it had increased to a quarter of the average consumption (Wood, 2013). A significant amount of timber has been removed from public forests in various locations as a result of illegal logging. According to the Theory of Himalayan Environmental Degradation (THED), the mountain ecosystem in the Himalayan area is under more pressure as a result of human growth. Urbanization is another concern, since more rural areas are being turned into cities, making the supply of wood incompatible with the demand (Blaiki, 2013).

The failure of the government to establish an appropriate institutional framework for forest management has resulted in a reduction in the area covered by forests. Another important cause for the decline in the quantity of the owing to the proximity of private forest contractors and forest officials, which facilitated illegal logging activities (Barnes, 2010; Ali & Audi, 2016).

The Environmental Kuznets curve (EKC) hypothesis may be used to investigate the relationship between environmental deterioration and economic growth (EG) (Audi & Ali, 2017; Jahanger et al., 2022, Jahanger et al., 2023a, Jahanger et al., 2023b; Audi et al., 2025). According to the findings of the EKC hypothesis, environmental harm gradually declines as per capita income rises when a particular threshold is achieved. The following explains how the environment affects income: During the first phase, nations use antiquated technology to industrialize significantly, harming the environment while

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simultaneously promoting economic growth. The negative environmental consequences of EG, however, lessen and the atmosphere returns to its pre-development state at a particular economic level. But, as it might have an even bigger impact on the environment above a specific financial threshold, there are certain exceptions to this pattern and link. Instead of the more typical U-shaped curve, the EKC curve in this instance is N-shaped. This study aims to provide a comprehensive policy agenda for attaining sustainable development by examining the relationship between deforestation and environmental deterioration.

## Literature Review

An efficient economy and a sustainable society both depend on a nation's capacity to maintain a clean, pleasant, and healthy environment. This is because only such an ecosystem can provide the environment in which people must participate in economic and social activities, as well as the natural resources for social and economic usage, including human beings (Quynh et al., 2022; Khalid & Abdul, 2025). Environmental circumstances can be made worse by a variety of poisons that are either naturally occurring or the result of human activities. The ozone layer, which shields life on Earth from ultraviolet radiation, might be destroyed by the production of harmful substances into the atmosphere, like CO2.

Therefore, by trapping heat inside the earth's borders, CO2 emissions led to global warming, disturb the climatic circle, harm the health of humans and other biological species, and deteriorate the quality of the entire ecosystem. Additionally, the earth heats overall due to carbon dioxide emissions from a second thick layer that block solar radiation from ascending too far into the sky (Ikram et al., 2020; Sadiq et al., 2022a; Rasasi, 2025). Global temperatures are expected to rise sharply. Global warming and other CO2 effects impact all the weather system, ecology, and the quality of natural resources including water, food, minerals, soil, and trees. A country is therefore unlikely to achieve sustainable growth, as high bio-production, protected water, productive labor, and rich land are all necessary for sustained economic development. Reducing EDE can lessen the effects of environmental deterioration (Ao et al., 2019; Sadiq et al., 2023; Kumar & Wu, 2025).

Both industrialized and developing nations are concerned about the current high levels of pollution in the world. In addition to burning fossil fuels and industrial pollutants, human activity also releases sulfur dioxide, nitrogen oxides, and carbon dioxide into the atmosphere. CO2 is the primary source of EDE among other pollutants, making up more than 70% of worldwide emissions. According to CO2 and GHG emissions, the BRICS economies were among the top seven in the world in 2014. When fossil fuels like coal, gas, and oil are burned, a chemical called carbon is released into the atmosphere. It then releases CO2 by combining with ambient oxygen. International initiatives to decrease CO2 have a theoretical foundation thanks to the expanding scholarly interest and in-depth examinations on the influences of CO2 on climate change. In order to support future global sustainable socioeconomic growth, it is crucial to have a realistic understanding of how the intricate relationship between wealth and innovation impacts the environment, particularly in developing economies like the BRICS. Estimates of greenhouse gas emissions vary by economy and location since they depend on a nation's policies toward socioeconomic growth and climatic change. Economic aspects are mentioned as being extremely essential sources of information to assess and increase the legitimacy of international development pledges. Because the variation in surface global warming depends on worldwide emissions, developing economies play a critical role in the global climate equation. In 2013, pollution from various sources caused more than 729,000 deaths in China. However, approximately 546,700 people died in India in 2015 as a result of pollution from open burning, brick production, the use of industrial and thermal coal, home biomass, and transportation. Despite global efforts and pledges over the last three decades, the excessive dependence on fossil fuels seems to be a major

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barrier keeping developing economies from taking the lead in global governance on reducing CO2.

**Economic growth and environment degradation**

EKC can explain the relationship between EG and EDE. Based on changes in the natural biosphere to contaminated concentration a number of proxy factors can be used to describe EDE. For example, CO2 emissions sulfur dioxide emissions, total suspended particulate matter, nitrous oxide, methane emissions and water waste (Haisheng et al. 2005). According to many studies (Cetin 2018; Sinha and Shahbaz 2018; Al-Masri & Ibrahim, 2025), the EKC framework mostly uses CO2 emissions.

Several investigations have already been conducted to assess the reliability of EKC. For example, Ozatac et al. (2017) looked at the EKC hypothesis for Turkey using factors including energy consumption, trade, urbanization, and financial growth. The study's findings supported the EKC for Turkey. In their study, Katircioğlu and Taşpinar (2017) investigated the EKC hypothesis by considering financial development as a moderating variable and verified that the EKC hypothesis existed in Turkey. The findings indicated that financial development had a short-term, negative moderating effect on carbon dioxide emissions, indicating that environmental management measures were effective. Similarly Isik et al. (2019) used the augmented mean group (AMG) technique of estimate and the common correlated effects (CCE) procedures to try to verify the EKC hypothesis for the 50 states of the United States. Only 14 of the 50 states had EKC validated by the estimate results. Other studies were also carried out using other EKC framework variables in various locations, including capital, labor, energy, energy prices, etc. (Katircioglu and Celebi 2018; Hanvoravongchai & Paweenawat, 2025). The literature in this research is organized according to the several research streams on agriculture, forestry, and renewable energy that are currently accessible inside the EKC framework. EKC studies in the context of forestry are elaborated in the first strand of the literature, while the agriculture sector is

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covered in the second. Examining earlier research on the EKC hypothesis for renewable energy consumption is the third fold of the literature.

The initial phase of EKC research created both EG and CO2 emission using basic EKC models, and it used the EKC framework to analyze the relationship between the two variables. without any contributing factors, the effects it has on the environment (Grossman and Krueger, 1995). An inverted U-shaped connection between EG and CO2 was proposed by earlier research (Gani, 2012; Grossman and Krueger, 1991; Ekins, 1997) that examined the relationship between the two utilizing the EKC analytical approach. After that, researchers began examining real EKC studies (Dinda, 2004; Stern, 2004). In this groundbreaking study, they found an inverted U-shaped link between EG and CO2. According to the empirical EKC hypothesis, there is a positive correlation between EQ and EG, but this association only persists until a certain level of secured income is reached (Selden and Song, 1994; Panayotou, 1993). In other words, until a certain income turning point, CO2 emissions and income increase together. The pollution increases then flattens and finally reverses (Dinda, 2004).

Scale, composition, and technological effects are the three primary ways that economic growth impacts environmental quality, according to Grossman and Krueger (1991). These hypotheses are further supported by this conduct. Therefore, it is believed that processes pertaining to size, composition, and technological consequences cause environmental contamination. The public thus often demands more environmental regulations as an economy expands. According to the EKC system, this idea represents the shift from primary (agricultural output) to secondary (industry) and ultimately tertiary (third-sector) production. A combination of composition, size, and technical influences may have contributed to the inverted U-shaped EKC (Panayotou, 1993). The emergence of outdated and ineffective businesses during a society's formative years before industrialization leads to pollution and serious consequences. After commercial manufacturing, the economy shifts to the services sector, where composition effects demonstrate the expansion of the economy in less polluting industries. Technical effects: As income levels rise, industrial output gradually declines and is finally replaced by higher-tech, service-oriented businesses (Hussen, 200; Alvi & Mudassar, 2025). This trend suggests that if the composition of the product changes, pollutant levels shouldn't rise in unison with EG (Vukina et al., 1999). In other words, during the first phase of EG, environmental pollution levels increase until they hit a specific threshold, at which point economic pollution levels decline.

According to Brock and Taylor (2005), the EKC shows the proportional strength of the technology and scale impacts since highly developed and efficient production economic systems contribute to reduced pollution (Dinda, 2004). According to this theory, because of the technological impact, nations may develop and replace more polluting technologies with cleaner ones in their production processes (Hussen, 2005). According to this theory, economies would advance farther in order to prevent the energy sector from becoming technologically outdated. This suggests that the demand for a cleaner environment is more elastic than unity, which is consistent with higher scale returns (Lorente & Álvarez-Herránz, 2016). When the relationship between EG and pollution is examined, the technical influence is the key element that raises EQ (Andreoni and Levinson, 2001). Lastly, Hettige et al. (2000) pointed out that as pollution would not stop increasing until environmental restrictions were reinforced, the impact of improved technology performance and knowledge dissemination on the atmosphere is also included in the technical effect.

**Deforestation and Environmental Quality**

Global climate change has put people and environment at risk in current era owing to a number of issues, including water scarcity, droughts, rising ocean levels, fierce fires and destructive waves (Durbin & Filer, 2021; Hussain & Khan, 2022; Jin and Huang, 2023). Assessing the degree of EDE brought on by this climate issue is crucial in this regard. The majority of investigators' ecological degradation metrics typically focus on various secretory and environmental quality indicators. In terms of ecological management, these issues are usually considered demand-side factors. For a more accurate assessment of eco-friendliness, Siche et al. (2010) recommend using environmental quality as a demand-side measure of environmental parameters. The ability of a nation or area to maintain the standard of living for its citizens is assessed by the environmental quality.

The decrease in biocapacity is caused by the loss of natural resources and global climate change (Porro & Gia, 2021; Sarfraz et al., 2022). Because they absorb carbon dioxide and release oxygen, preserve biodiversity, and support a variety of biological processes, forests are essential for controlling the climate. Deforestation, particularly on a broad scale, substantially impairs these functions (Diaz & Weber, 2020; He et al., 2024). Deforestation also causes many plant and animal species to lose their habitat, which lowers biodiversity. Deforestation also affects local weather patterns, changes the water cycle, and causes soil erosion, all of which have an influence on the ecosystem that is far-reaching (Emodi, 2019; Li et al., 2023). Deforestation is also fuelled by economic factors, such as the need for resources, agriculture, and lumber, which can result in unsustainable practices. This typically happens in underdeveloped nations when reducing poverty and promoting economic growth may take precedence over environmental preservation. Forest degradation can worsen inequality and upend local populations who rely on forests for their livelihoods (Sohag et al., 2023). Additionally, earlier research has examined the possible contribution of forests to mitigating the effects of climate change (Thuy et al. 2014). Numerous studies have considered forest loss to be a contributing factor to environmental deterioration (Benedek 2013). These studies generally agree that there is a substantial correlation between economic expansion and deforestation. Bandyopadhyay (1992) and Lantz (2002) are two studies that do not support the EKC hypothesis for deforestation in the context of EKC.

Forests are a vital resource for ecosystem conservation and economic provisioning (Schulz et al., 2023). The world's indigenous and rural communities are increasingly reliant on forest resources. Similar to this, a large number of families in developing nations rely mostly on forest resources to meet their energy and subsistence demands (Anwar et al., 2021). However, an excessive dependence on trees leads to their destruction and deterioration, which significantly worsens the state of the ecosystem (L. J. Sun et al., 2023). The sustainability of the earth is under unprecedented threat from pollution that causes EDE (Sun et al., 2022). The results of the study show that deforestation has been linked to rising temperatures and extreme weather occurrences both locally and worldwide. Comparably, Arshad et al. (2020) examined a panel of South and Southeast Asian countries from 1990 to 2014 to determine the effects of economic growth, urbanization, and deforestation on EDE. Their results showed a U-shaped relationship between CO2 emissions and economic development in middle- and high-income countries. Furthermore, urbanization and deforestation raise CO2 emissions, which hinder environmental sustainability.

Amazon rainforests are one of the largest carbon sinks in the world, and because of widespread deforestation, the ecology and climate are in danger, creating vulnerability and insecurity (Gatti et al., 2021). The Amazon region's environmental quality is harmed by deforestation brought on by carbon sinks. Furthermore, Cary and Bekun (2021) concentrated on a number of political and economic elements that affect deforestation patterns, such as land use, GDP per capita, and democracy. Additionally, Denning (2021) pointed out that the southeast Amazon's capacity to absorb carbon dioxide has been diminished by deforestation and rising world temperatures, presenting a threat to future climate change.

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## Urbanization and Environmental Degradation

The proportion of a nation's population that lives in urban areas is referred to as urbanization. In developing and poor nations, the rate of urbanization varies, but generally speaking, rising urbanization is thought to be a major contributor to environmental deterioration through excessive CO2 emissions (Okunola et al. 2018). The majority of earlier research has been on how urbanization affects the environment through CO2 emissions (Wang et al. 2015). Katircioğlu and Katircioğlu (2018) refuted the presence of EKC in Turkey and came to the conclusion that the use of fossil fuels and urbanization are the main causes of rising CO2 emissions.

Wu et al. (2016) shown that there is a clear correlation between the rate of urbanization and energy intensity, which raises CO2 emissions. According to Wang et al. (2015), socioeconomic policies that address urban planning concerns are a major factor in reducing CO2 emissions. An increasing amount of research points to the impact of URB on EDE (Bereitschaft and Debbage, 2013). According to Yin et al. (2015), urbanization has an impact on both individual consumption patterns and patterns of energy usage. According to Fang et al. (2015), fewer separated urban patterns result in lower CO2 emissions.

There is not many research on how urbanization affects environmental quality. Research by Luo et al. (2018) examined the effects of urbanization in China by analyzing data spanning ten years, from 2005 to 2014. Results showed that urbanization, which is expected to continue to rise by 2020, is the primary source of the rising eco-pressure in mid-western regions. Due to significant grain production, the central area has seen the most environmental impact. Due to the presence of the chemical and energy sectors, eco-pressure was lower in the western areas. According to the report, upgrading technology will also lessen environmental strain in China's midwestern areas. Urbanization has been shown to be one of the key factors influencing environmental quality (Charfeddine, 2017).

Furthermore, Hassan et al. (2019) used the ARDL technique to show how Pakistan's environmental quality was affected by economic growth, urbanization, and natural resources during a 45-year span, from 1970 to 2014. The study's findings show how Pakistan's natural resources enhance the quality of the nation's environment.

The findings also show that there is a two-way causal relationship between environmental quality and natural resources. They said that industrialization, a byproduct of urbanization, is to blame for the depletion of natural resources. Rashid et al. (2018) expressed concern that environmental degradation is greater than national norms, which are predicted to rise further as a result of urbanization. Environmental deterioration is influenced by a variety of demographic and socioeconomic factors. In present study, we investigate the effect of deforestation and urbanization on environmental degradation and community.

## Research Methodology

### Theoretical Framework

There are theoretically strong connections between the ecosystem's condition and the decline of forests. In order to maintain ecological balance and provide ecosystem services, forests are essential. Biocapacity is enhanced by carbon sequestration, habitat availability, and control of water (Wu et al., 2022). The loss of forests reduces biocapacity, which affects the environment's ability to support human requirements. Because of habitat degradation and deforestation increases the ecological footprint (Chervier et al., 2024). Long-term environmental sustainability is hindered by their negative impacts on biodiversity loss, water shortages, climate change, and agricultural productivity. The quality of the environment is also continuously deteriorating (Barbosa et al., 2023). The accumulation of pollution from businesses and factories is posing an increasing threat to both human and animal existence. Addressing forest depletion is crucial for advancing environmental sustainability, safeguarding ecosystems, and preserving human well-being (VanderWilde et al., 2023). To better understand the theoretical relationships between these two fields, education and communication are essential. By drawing these connections, people may take action to lessen forest loss and enhance environmental quality by better understanding how their actions impact the ecosystem.

Recycling, reducing waste, and optimizing resource use are ways that farmers and businesses may prioritize resource efficiency. This lessens pollution, protects natural resources, and lessens the negative environmental impacts of economic activity (Raza and Lin, 2022). Shifts in agricultural structural trends might be advantageous for agroforestry, precision agriculture, and other sustainable farming methods. According to Amoako et al. (2022), these methods preserve biodiversity, cut down on water use, protect soil health, use less chemicals, and support environmental sustainability. We may transition to a circular economic model by implementing structural changes. This approach decreases waste production and reliance on raw materials while mitigating the environmental impacts of resource extraction and disposal (Wu and Ding, 2021).

**Model of the study**

$EDE = f(DEF, URB, GDP, GDP^2)$ . . . . . . . . . . . . . (1)

where

EDE = Environmental degradation

DEF = Deforestation

URB = Urbanization

GDP = GDP is the proxy of Economic growth (EG)

**Econometric Model**

In accordance with Pesaran et al. (2001), we employ the Autoregressive Distributed Lag (ARDL) model as follows to examine the immediate and long-term impacts of agricultural production, forests, and renewable energy consumption on carbon dioxide emissions:

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$\Delta CO_{2t} = \beta_0 + \beta_1 CO^2_{t-1} + \beta_2 DEF_{t-1} + \beta_3 URB_{t-1} + \beta_4 EG_{t-1} + \sum_{k=1}^{n} \delta_{1k} CO^2_{t-k} + \sum_{k=0}^{n} \delta_{2k} DEF_{t-k} + \sum_{k=1}^{n} \delta_{3k} URB_{t-k} + \sum_{k=0}^{n} \delta_{4k} EG_{t-k} + \varepsilon_t$ . . . . . . . . . . . (2)

where εt is the error term and Δ is the difference operator. The constant term is β0. The long-term coefficients are β1, β2, and β3. Error correction dynamics are represented by δ1, δ2, δ3, and δ4. To ascertain if there is cointegration between variables, the ARDL model employs the Wald test (F-statistics). In contrast to the alternative hypothesis, which holds that there is cointegration between variables, the null hypothesis asserts that there is no cointegration. The critical values of F-statistics and two different kinds of bounds—a lower limit and an upper bound—are presented by Pesaran et al. (2001). The absence of long-term cointegration between variables is shown if the Wald test results are below the lower bound. On the other hand, a long-term cointegration of variables is indicated if the test statistics are greater than the upper bound. An inconclusive result is shown if the F-statistic is within the boundaries. We choose the ideal lag lengths using the Schwarz Bayesian Criteria (SBC).

Other well-known cointegration models are employed in the literature for various situations. For example, the cointegration approach developed by Engle and Granger (1987) may be applied to two variables that have the same order of integration, or I(1). Second, the cointegration approaches developed by Johansen (1990) are only useful when the data is big and all of the series have the same integration order. Researchers were encouraged to develop new methods that address the variables with distinct series of integration, such as a blend of I(0) and I(1), due to the limitations of current approaches, which require that all series be integrated at the same level. In order to address the problem, Pesaran et al. (2001) finally introduce the Autoregressive Distributed Lag (ARDL) cointegration model. The variables with stationarity can be handled using the ARDL technique using a combination of I(0) and I(1). For a small sample size, this model is excellent and yields trustworthy findings (Ghatak and Siddiki, 2001). Furthermore, endogenity is one of the main problems during estimates. By adding delays and making the model dynamic, as in Pesaran et al. (2001), this endogenity issue can be resolved. The Johansen and Engle-Granger cointegration techniques cannot employ distinct variable lags. Nonetheless, the ARDL model may make use of various variable delays (Ozturk and Acaravci, 2011). For this reason, we investigate the cointegration of CO2 emissions, deforestation, urbanization, and economic growth for Pakistan using the ARDL estimate approach.

**Selection of Variable and Data Source**

We use time series data for Pakistan from 1970 to 2021 to investigate the link between DEF, EG, URB and EDE (CO2). Through an analysis of environmental quality indicators, the present study provides insights into ways for attaining a sustainable future. Nonetheless, it is well known that structural change and forest loss may have a major effect on the ecological quality of the world. The parameters and data sources are introduced in detail here.

**Dependent Variable**

CO2 emissions, a stand-in for environmental deterioration, are the dependent variable. Carbon emissions per capita is a measure of CO2 emissions. The World Development Indicator is the source of the data (WDI, 2023). The majority of studies quantify environmental deterioration using proxies such carbon dioxide emissions. Because the pertinent data is easily accessible, carbon dioxide is the indication of choice for environmental researchers. However, there are many different ways that environmental contamination affects ecosystems; measuring pollution in terms of CO2, which only provides information on air pollution, is inaccurate. Evaluation of environmental sustainability is limited by the use of CO2 as an impurity (Ali et al., 2023). Consequently, scientists have looked for alternative indicators that may be used to measure ecological degradation in a broader sense. Initially, ecological footprints—a more complete measure of environmental contamination than CO2 emissions—were employed by academics to do this (Rees, 1992). Suppose that the ecological footprint of a country is greater than its biocapacity. If this is the case, it means that the country has an EDE and that pollution levels are higher than what the environment can sustain.

### Independent Variables

The independent variables of our study is as given below.

### Deforestation

Forest rents as a percentage of GDP are used to quantify the deforestation variable. In both developed and developing nations, economic considerations like as mining, infrastructural development, logging and timber industries, agricultural growth, and poverty alleviation are the main causes of deforestation (Zhao et al., 2024). While the logging and wood companies take advantage of precious resources, the conversion of forests to agricultural land produces food and generates cash. Nonetheless, it is important to acknowledge the long-term negative consequences of deforestation, such as climate change, biodiversity loss, and environmental degradation (Jin and Song, 2023).

### Economic Growth (GDP)

The analysis substitutes EG for the more significant GDP per capita variable in the EDE literature (Ramzan et al., 2023). GDP is calculated as GDP per capita (constant 2015 US dollars). EG is defined as the economy's long-term expansion that has both positive and negative effects on environmental quality (Kakar et al., 2023). Innovation, technical advancements, and the adoption of greener technologies may be associated with economic growth, even if resource consumption is often connected to it (Zhang et al., 2024).

### Urbanization

We use the percentage of people who live in cities as a proxy for the degree of urbanization. Numerous studies have demonstrated that as the urban population grows and the development of public and private transportation systems pick up speed, environmental pollution will rise. Industrial activity is concentrated in

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these places (Wang and Lin, 2023). In addition to generating economies of scale, URB presents chances to lower pollution and make better use of energy (Nut¸a ˘ et al., 2024). Therefore, it is not clear how urbanization affects environmental deterioration. These datasets are all converted to logarithmic formats.

### Data Source

The influence of urbanization, economic expansion, and deforestation on environmental deterioration in Pakistan between 1990 and 2021 is examined in this paper. Data on CO2 emissions, forest rents as a percentage of GDP, GDP per capita, and the share of the population living in cities were gathered for this analysis from World Development Indicators (World Bank, 2023).

### Results and Discussion

This study uses time series autoregressive distributive leg (ARDL) regression to investigate the diverse effects of urbanization, economic expansion, and deforestation on environmental deterioration. The results of Pakistan are explained in this chapter.

**Table 1: Descriptive Statistics**

| | $LnCO_2$ | LnGDP | LnDEF | LnURB |
|---|---|---|---|---|
| Mean | -0.554988 | 25.546362 | -1.458373 | 1.223563 |
| Median | -0.444809 | 25.733648 | -1.529799 | 1.346785 |
| Maximum | -0.002011 | 26.084464 | -0.025677 | 1.711342 |
| Minimum | -1.195706 | 24.047332 | -2.348771 | 0.574672 |
| Std. Dev. | 0.352969 | 0.648292 | 0.457456 | 0.281474 |
| Skewness | -0.386092 | -0.239748 | 1.177551 | -0.59732 |
| Kurtosis | 1.896574 | 1.894621 | 5.256786 | 2.409831 |
| Jarque-Bera | 3.788250 | 2.975245 | 22.187643 | 3.792465 |
| Probability | 0.143489 | 0.217464 | 0.000001 | 0.152842 |

Table 1 displays the descriptive data that were looked at in the first phase of the investigation. This table provides a summary of the dataset's attributes. All variables undergo a natural log transformation to lessen heteroskedasticity. There is a negative derived mean of the lagged values for CO2 and DEF, but a positive calculated mean for GDP and URB. The mean of GDP is the greatest, while the mean of DEF is the lowest, in relation to the other variables. Kurtosis study shows that DEF has larger tails whereas CO2, GDP and URB have smaller tails since their values are below the crucial point. All variables were left-skewed, according to skewness analysis, with the exception of DEF, which was right-skewed. For four variables—CO2 emissions, deforestation, economic growth, and urbanization—this study presents Jarque-Bera test statistics. These variables are all normally distributed, as indicated by their p-values being larger than 0.05.

**Table 2: Tests for Unit Roots**

| Variables | Augmented Dickey-Fuller (ADF) | | Phillip Perron (PP) | |
|---|---|---|---|---|
| | I(0) | I(1) | I(0) | I(1) |
| Ln CO2 | -0.5286 | -6.4865 | -0.5243 | -6.5329 |
| | (-2.935/.863) | (_2.921/0.000) | (-2.916/0.823) | (-2.919/0.000) |
| LnDEF | -2.8654 | -3.9683 | -2.8452 | -9.2953 |
| | (-2.937/0.060) | (-2.921/0.003) | (-2.915/0.059) | (2.911/0.000) |
| LnURB | -0.7847 | -4.8952 | -0.8496 | -3.8494 |
| | (-2.925/0.815) | (2.834/0.000) | (2.917/0.733) | (2.911/0.003) |
| LnGDP | 0.2294 | -5.9785 | 0.1108 | -5.9763 |
| | (-2.946/0.968) | (-2.910/0.000) | (2.920/0.954) | (-2.922/0.000) |

Note: (t-stats/p-values)

In Step 2, we used the modified Dickey and Fuller (1979) and Phillips and Perron (1988) to confirm stationarity tests. Table 2 presents the results of these testing. These tests were carried out at the variable's level and initial difference. At the 5% level, the t-statistics for every variable were not statistically significant. This suggests that each of these variables is non-stationary and has unit roots. All

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variables, however, adhere to the I(1) integration order, and these parameters show t-statistics for the first difference that are statistically significant at 5%.

**Table 3: Bound Test**

| K | ------ | 1% | | 5% | | 10% | | p-value | |
|---|---|---|---|---|---|---|---|---|---|
| | | I(0) | I(1) | I(0) | I(1) | I(0) | I(1) | I(0) | I(1) |
| F | 4.978 | 3.609 | 5.275 | 2.52 | 3.853 | 2.044 | 3.25 | 0.001 | 0.013 |
| t | -4.44 | -2.663 | -4.420 | -1.956 | -3.639 | -1.609 | -3.249 | 0.000 | 0.008 |

Note: Lower and upper bounds are indicated by I(0) and I(1).

The stationarity test was followed by a bound test that evaluated the long-term cointegration relationship using the KS critical value (Pesaran and Shin, 1999). The results are shown in Table 3. Given that the bound test p-value is less than 0.05, the null hypothesis—that the variables are not cointegrated—may be rejected at 5% significance. Given this, a closer look at the traits of long-term partnerships seems relevant.

**Table 4: Diagnostic Tests**

| Diagnostic | p-value ($X^2$) | Outcome |
|---|---|---|
| Breusch-Godfrey LM | 0.49 | No serial autocorrelation |
| Breusch-Pagan-Godfrey | 0.56 | No heteroscedasticity |
| Ramsey RESET test | 0.74 | Model correctly specified |
| Jargue-Bera test | 0.68 | Normal distribution of residuals |

ARDL coefficients are evaluated using a variety of post-estimation tests to determine their stability and dependability (see Table 4).

Table 5 presents the results of the ARDL. According to the ARDL simulation results, the loss of forests has made Pakistan's EDE worse. According to this finding, deforestation contributes to EDE over the long and short terms by 0.243 percent and 0.083 percent, respectively, when all other factors are held constant. Put differently, it jeopardizes Pakistan's capacity to preserve a sustainable ecosystem. This outcome is not surprising considering that Pakistan's economic growth has compelled the nation to industrialize and promoted excessive depletion of its natural resources. Because an over-reliance on forest resources reduces their biocapacity and hinders regrowth, this process depletes forest resources and speeds up environmental damage. The primary goal of early development is profit maximization at the expense of the environment and forest resources in general. This stage is characterized by widespread deforestation, the overuse of production techniques that hurt the environment, and the clearance of forest areas to make way for additional agricultural and industrial operations. The study results support those of Aquilas et al. (2022), Amirnejad et al. (2021), and Barbosa et al. (2023), who discovered that the increasing demand for forest resources due to population growth and economic expansion is surpassing the world's ability to restore these resources. Because forest resources are being destroyed at an unsustainable rate, depletion and environmental problems result.

**Table 5: ARDL estimates based on environmental degradation ($CO_2$ emission)**

| Variable | Coefficient | p-value |
|---|---|---|
| **Long-run** | | |
| LnGDP | 0.495** | 0.003 |
| LnGDP2 | -0.381* | 0.083 |
| LnDEF | 0.243** | 0.039 |
| LnURB | -0.472** | 0.025 |
| Short run | | |
| LnGDP | 0.254* | 0.065 |
| LnGDP2 | -0.467* | 0.093 |
| LnDEF | 0.083** | 0.039 |
| LnURB | -0.423** | 0.018 |
| ECT-1 | -0.94*** | 0.000 |

Note: *** represents p<0.01, ** represents p<0.05 and *represents p<0.10

Furthermore, our hypothesis is that deforestation decreases carbon sequestration and releases stored carbon into the atmosphere, causing climate change is supported by the empirical study of Ayad et al. (2024). In addition to causing major economic harm including infrastructure devastation, fatalities, and disruption of livelihoods in impacted regions, it may alter weather patterns and increase the frequency and severity of natural catastrophes like landslides and floods.

GDP and GDP squared (GDP2) have a positive and negative effect on CO2, respectively. The results demonstrate that even if GDP2 is negative, the GDP coefficient is positive. In other words, greater EG can aid in improving environmental performance once the examined nations have attained a particular level of economic development. Growth's impact on CO2 emissions, in particular, demonstrates that economic development has a marginally beneficial effect at first, then a slow decline and eventual negative effect. Generally speaking, countries boost economic activity, commerce, and infrastructure in order to achieve rapid growth while minimizing their environmental impact. This leads to an increase in energy consumption, which deteriorates the environmental performance of the economies. In Pakistan, this outcome supports the EKC theory. These findings are similar to those of Haseeb et al. (2018) on the BRICS economies. However, our findings differ from those of Inglesi-Lotz & Dogan (2018) for Sub-Saharan African nations. It is possible to justify the EKC hypothesis by pointing out that these countries utilize fewer harmful materials in their power consumption processes, which improves environmental consequences.

Urban regions often draw investment in renewable energy and green technology, which boosts economic growth, creates jobs, and lessens reliance on fossil fuels. Further contributing to economic success and good environment, urbanization also encourages innovation and information sharing, which advances eco-friendly applies and the growth of sustainable businesses (Tang and Hu, 2023).

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To illustrate the rate at which equilibrium is restored, the dynamic model's ECT value fluctuates between 0 and 1. Therefore, if it is not positive and significant, ECT assesses the pace at which the system approaches equilibrium. The model designates a statistically significant negative ECT. This suggests that the long-term divergence will equalize at a rate of 0.94.

## Conclusion and Recommendations

### Conclusion

The current study uses time series data from 1970 to 2021 and ARDL technique to experimentally investigate how urbanization, economic expansion, and deforestation affect Pakistan's environmental sustainability (CO2). The fact-based conclusions of this study show that urbanization has improved environmental quality whereas deforestation and economic expansion have exacerbated environmental deterioration. The results show that the EKC is supported by strong evidence. In the quadratic form, GDP contains two statistically significant coefficients: a positive coefficient and a negative coefficient. This finding shows an inverted U-shaped EKC for Pakistan. In order to create a more sustainable future, this article suggests policy proposals for reducing pollution using robust regulatory mechanisms.

### Recommendations

Given the results of the study, the following policy suggestions are put forth: In order to meet the Sustainable Development Goals, the Pakistani government has to act on the empirical conclusions of this study. The formation of green belts and statewide afforestation initiatives are critically needed in addition to protecting the state's current forests. Adopting renewable and alternative energy sources is crucial in light of rising energy consumption, as opposed to depending only on conventional sources to satisfy energy demands. Governments should provide local residents with alternate energy sources including solar energy, liquefied petroleum gas (LPG), piped natural gas, and micro-hydroelectric power plants in

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order to lessen the strain on natural trees and substitute firewood in highland habitats. The country's declining and limited forest resources make it unable to meet the nation's increasing demand for forest products, which far outstrips its current sustainable domestic supply. To create a clear implementation route, the Federal Government of Pakistan must also amend current environmental regulations and approve pertinent legislation. Reducing the timber mafia, disciplining government organizations such as the Metropolitan Development Authority (MDA), and offering alternate energy sources to the local populace are the primary goals of this strategy. These initiatives will eventually assist Pakistan in achieving the climate goals outlined in the National Climate Change Policy 2021 agenda. Pakistan passed environmental protection law in 1997 and an ordinance in 2005, yet there are still many shortcomings. This research fills the gap in the scope of forest protection and management systems caused by the merging of the Ministries of Forestry and Environment. Regulations pertaining to environmental protection must be reexamined in light of management techniques and human activities.

In addition, our study has shown that economic growth might accelerate environmental degradation. Therefore, economic efforts that encourage growth while minimizing environmental harm should be given top attention by governments and other authorities. In addition, the country relies on investment, not green investment. Accordingly, the research recommends that the country give priority to environmentally friendly initiatives and increase public knowledge of the possibilities for green investment. As public understanding of green investment principles increases, economic growth may continue without negatively impacting the environment. At the same time, the government need to promote the use of green inventions and technology that help separate environmental damage from economic growth. In order to find and spread cleaner, more sustainable technologies across a range of industries, including industry, energy, and agriculture, Pakistan needs do research and development.

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