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Assessing Forest Conservation Strategies for Biodiversity Restoration and Sustainable Development: A Comparative Analysis of Global Income Groups

Ocena strategii ochrony lasów pod kątem przywracania różnorodności biologicznej i zrównoważonego rozwoju: globalna analiza porównawcza

Rima H. Binsaeed*, Abdelmohsen A. Nassani, Khalid Zaman***, Zeeshan Arshad****, Mohamed Haffar*****, Dadang Yunus Lutfiansyah******, Kamalularifin Subari*******, Hailan Salamun********

*King Saud University,College of Business Administration, Department of Management, P.O. Box 71115, Riyadh, 11587, Saudi Arabia
E-mail: rbinasaeed@ksu.edu.sa
**King Saud University, College of Business Administration, Department of Management, P.O. Box 71115, Riyadh, 11587, Saudi Arabia
E-mail: Nassani@ksu.edu.sa
***The University of Haripur, Department of Economics, Haripur Khyber Pakhtunkhwa, Pakistan
E-mail (Corresponding Author): khalid_zaman786@yahoo.com
****Universidade de Aveiro, Department of Environment and Planning, CESAM /Centre for Environmental and Marine Studies, Campus Universitário de Santiago, 3810-193 Aveiro, Portugal
E-mail: Arshad@ua.pt
*****University of Birmingham, Birmingham Business School, Department of Management, Birmingham B15 2TT, UK
E-mail: m.haffar@bham.ac.uk
******Universitas Pendidikan Indonesia, Department of Community Education, 40154, Kota Bandung, Indonesia
E-mail: dadangyunus@upi.edu
*******Universiti Teknologi Malaysia (UTM), Faculty of Social Sciences & Humanities, Skudai 81310, Johor, Malaysia
E-mail: p-arifin@utm.my
********Malaysia Terengganu (UMT), Centre for Fundamental and Continuing Studies (PPAL), Department of Nationhood and Civilization, Universiti 21030 Kuala Nerus, Terengganu, Malaysia
E-mail: hailan@umt.edu.my

Abstract

The escalating rate of deforestation presents significant challenges to the global economy, including the loss of habitats for endangered species and a decline in biocapacity reserves. This situation also raises concerns about overcrowding and excessive production, which can undermine conservation efforts. Addressing this issue, Sustainable Development Goal 15 of the United Nations emphasizes managing forest resources, preventing habitat loss, combatting desertification, and expanding biodiversity reserves. Its contributions have played a pivotal role in wildlife conservation, mitigating rural-urban migration and preserving land resources. Given the relevance of this problem, this study examines the consequences of ongoing tropical deforestation on the loss of endangered species habitats while controlling for biocapacity reserves, urbanization, economic growth, and industrialization across a large sample of 159 nations, further categorized into low-, middle-, and high-income countries. The findings from cross-sectional and quantile regression analyses reveal that higher deforestation rates, increased rural-urban migration, and greater industrialization threaten endangered species habitats. Conversely, increased biocapacity reserves and economic growth contribute to wildlife restoration. Granger causality estimations highlight unidirectional relationships between deforestation and biodiversity loss (as well as biocapacity reserves), while deforestation and industrialization exhibit bidirectional causality. The results further indicate that sustained economic growth leads to deforestation, biocapacity reserves, and urbanization, while urbanization contributes to deforestation. This underscores the role of deforestation as the primary driver of habitat loss for endangered species and the depletion of biocapacity, thereby fostering mass production. Urbanization and economic growth are shown to be causally linked to deforestation across countries. The study underscores the urgent need to safeguard forest reserves against large-scale land conversion for infrastructure development, industrialization, and settlement of overpopulated urban areas, as these factors contribute to habitat degradation and biodiversity loss. Conserving, restoring, and promoting sustainable utilization of ecosystems are essential measures to address natural uncertainties and advance Sustainable development goals.

Key words: deforestation, biodiversity loss, biocapacity reserves, urbanization, industrialization, economic growth, quantile regression

Streszczenie

Rosnące tempo wylesiania stwarza poważne wyzwania dla gospodarki światowej, w tym groźbę utraty siedlisk zagrożonych gatunków i spadek rezerw pojemności biologicznej przyrody. Sytuacja ta budzi również obawy związane z przeludnieniem i nadmierną produkcją, co może zniweczyć wysiłki na rzecz ochrony przyrody. Odnosząc się do tej kwestii, Cel Zrównoważonego Rozwoju nr 15 Organizacji Narodów Zjednoczonych kładzie nacisk na zarządzanie zasobami leśnymi, zapobieganie utracie siedlisk, zwalczanie pustynnienia i poszerzanie rezerwatów różnorodności biologicznej. Jego realizacja odgrywa kluczową rolę w ochronie dzikiej przyrody, łagodzeniu migracji ze wsi do miast i ochronie zasobów gruntów. Biorąc pod uwagę znaczenie tego problemu, w niniejszym badaniu zbadano wpływ ciągłego wylesiania tropikalnego na utratę siedlisk zagrożonych gatunków, przy jednoczesnym kontrolowaniu rezerw pojemności biologicznego, urbanizacji, wzrostu gospodarczego i industrializacji na dużej próbie 159 krajów, podzielonych dalej na kategorie o niskim, krajach o średnich i wysokich dochodach. Wyniki analiz przekrojowych i regresji kwantylowej pokazują, że wyższe wskaźniki wylesiania, wzmożona migracja ze wsi do miast i większa industrializacja zagrażają siedliskom zagrożonych gatunków. I odwrotnie, zwiększone rezerwy pojemności biologicznej i wzrost gospodarczy przyczyniają się do odbudowy dzikiej fauny i flory. Szacunki przyczynowości Grangera uwydatniają jednokierunkowe związki między wylesianiem a utratą różnorodności biologicznej (a także rezerwami pojemności biologicznej), podczas gdy wylesianie i industrializacja wykazują dwukierunkową przyczynowość. Wyniki wskazują ponadto, że trwały wzrost gospodarczy prowadzi do wylesiania, rezerw pojemności biologicznych i urbanizacji, podczas gdy urbanizacja przyczynia się do wylesiania. Podkreśla to rolę wylesiania jako głównego czynnika powodującego utratę siedlisk zagrożonych gatunków i wyczerpywanie się pojemności biologicznej, co sprzyja masowej produkcji. Wykazano, że urbanizacja i wzrost gospodarczy są powiązane przyczynowo z wylesianiem w różnych krajach. Badanie podkreśla pilną potrzebę zabezpieczenia rezerwatów leśnych przed przekształcaniem gruntów na dużą skalę w celu rozwoju infrastruktury, industrializacji i zasiedlania przeludnionych obszarów miejskich, ponieważ czynniki te przyczyniają się do degradacji siedlisk i utraty różnorodności biologicznej. Ochrona, przywracanie i promowanie zrównoważonego wykorzystania ekosystemów to podstawowe środki pozwalające zaradzić naturalnym niepewnościom i osiągać zrównoważony rozwój.

Słowa kluczowe: wylesianie, utrata różnorodności biologicznej, rezerwy pojemności biologicznej, urbanizacja, industrializacja, wzrost gospodarczy, regresja kwantylowa

1. Introduction

Nature gives us attractiveness, sensitization, knowledge, cleansing, and comprehension to live a happy existence without harming humans and other animals. Over 75% of human activities affect the earth's surface, resulting in a large precursor of threatened wildlife habitats. The increasing pace of deforestation is mainly responsible for increasing ecological footprints and climate susceptibility. Rainforests are essential for supporting *life on land*, especially in areas where climate change is a threat. Land-use policy and restoration are critical for enhancing human and animal lives, reducing suffering, and lowering the economic risks associated with natural disasters worldwide (Chan et al., 2023). According to global statistics, over 1.6 billion people rely directly on forests to thrive. Forests provide a habitat for more than 80% of all terrestrial animals. The loss of arable land has had a negative impact on the environment, and its deterioration rate is about 30 to 35 times that of the past. More than 7000 valuable species and plants are subjected to wildlife trafficking worldwide. The need to restore sustainable rainforests is essential for safeguarding biodiversity loss (United Nations, 2021).

According to the Rainforest Alliance (2017) report, human activities on land are responsible for 35.8 million acres of deforestation per year, resulting in significant species loss. Deforestation has resulted in the extinction of endangered species habitats, which has reached a rate of roughly 100 species every day. It is essential to maintain the rare wildlife species' habitats by offering financial incentives to the rural population to restore the natural beauty, conserve forest resources, and protect biodiversity loss. The irresponsible harvesting of timber, unregulated tourism, and agricultural expansions endanger natural beauty and the loss of valuable species. Under the Endangered Species Act (ESA), which Congress passed in 1973, the Federal Ministry enlisted the protected species both nationally and internationally to avoid habitat destruction of endangered species (The National Wildlife Federation, 2021).The time has come to implement long-term plans to conserve endangered species, such as the creation of protected places for rare species for captive breeding and conservation laws and public awareness to prevent habitat degradation (Croteau et al., 2011). The recent report of WWF (2020) argued that the biocapacity deficit occurred with the ecological footprints exceeding the biocapacity of the area, which deteriorates the global resource conservation agenda. Alternatively, biocapacity reserves exist when the ecological reserves exceed the population footprints. Hence, trade cannot compensate for the biocapacity deficit; hence, it is equal to overshoot. According to Guo et al. (2017), enhancing biocapacity through regional planning can decrease ecological overshoot and pave the road for regional sustainability.

The World Bank (2021) provided the most recent statistics on endangered species, which revealed that fourteen nations throughout the world were home to more than 250 endangered species, including birds, fish, and mammals. The Indonesian economy is at the top of the list, with 517 endangered species, including 160 endangered birds, 166 endangered fish, and 191 endangered mammals. India has 413 endangered species, the United States has 382, Mexico and Brazil have 348, China has 305, Colombia has 283, Madagascar and Tanzania has 269, Peru has 224, the Philippines has 222, Malaysia has 221, Ecuador has 214, and South Africa has 205. Figure 1 depicts the global trend profile of several endangered species.

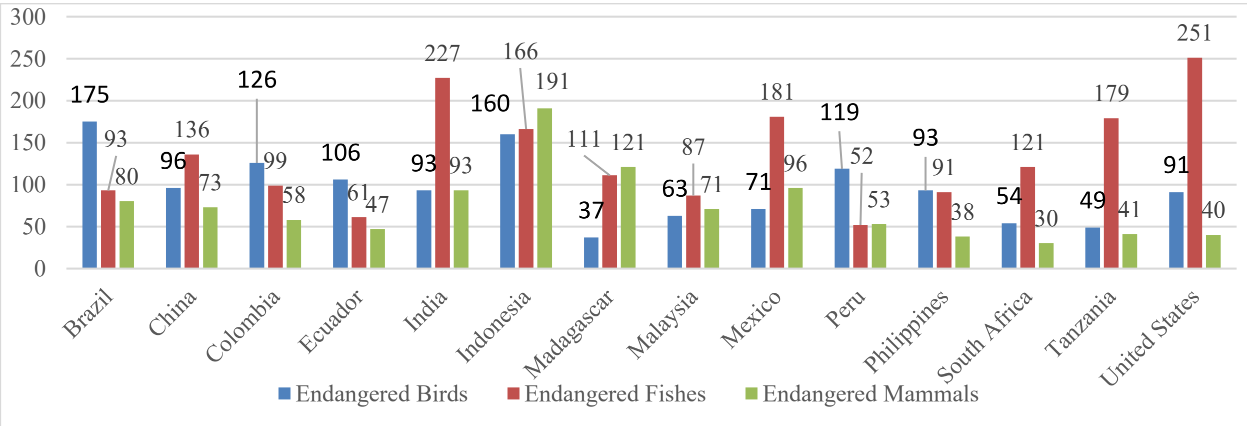

Figure 1. Endangered Species (> 200) in the World's 14 Countries (2018 estimates) (World Bank, 2021)

Forest rentals were employed as a substitution factor for deforestation in the study, whereas arable land hectares per person were used for biocapacity reserves. The natural logarithm of the total number of endangered species was used to examine the relationship between these three variables in a cross-section of fourteen nations worldwide. Figure 2 depicts the increase and decline of the aforementioned parameters in 2018.

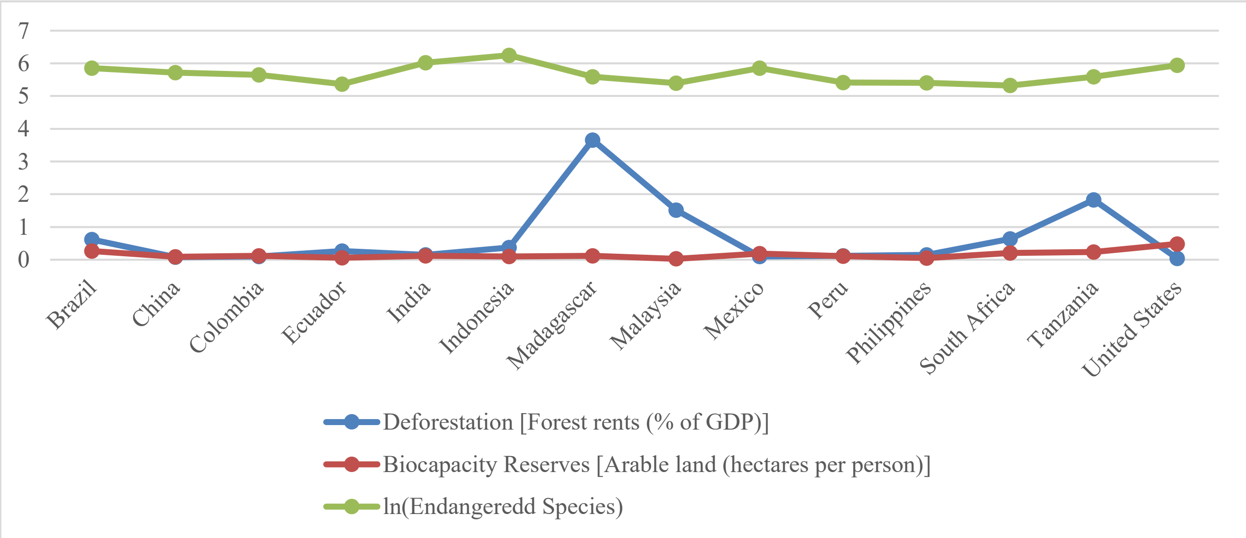

Figure 2. Endangered Species, Deforestation, and Biocapacity Reserves in the World's 14 Countries (2018 estimates) (World Bank, 2021)

Figure 2 shows that deforestation rates are higher in Madagascar, Malaysia, Tanzania, and South Africa, at 3.660 percent of GDP, 1.517 percent of GDP, 1.824 percent of GDP, and 0.640 percent of GDP. The United States, with 0.482 hectares per person, Brazil, with 0.266 hectares per person, South Africa, with 0.207 hectares per person, and Mexico, with 0.189 hectares per person, have slightly greater biocapacity reserves. The number of endangered species is larger than the rate of deforestation and biocapacity reserves, implying that increased deforestation and a growing biocapacity shortfall result in more biodiversity loss across countries.

It is clear from the data and discourse that endangered species habitat loss results from increased deforestation, growing rural-urban migration, colossal production, ongoing economic expansion, and a biocapacity deficit. As a result, the following research questions have surfaced, which must be addressed by extensive research on the subject. First, how much does deforestation contribute to biodiversity loss across countries? This is a complex matter, as the primary causes of deforestation include land conversion for agricultural growth and urban resettlement, and forest fires that threaten biodiversity in the Amazonian rainforest. As a result of increased deforestation throughout the world, endangered species are losing their habitat. Second, is there a risk of endangered species habitat loss due to a biocapacity deficit? The question suggests that human footprints on arable land deplete numerous valuable economic and environmental resources, putting future resource sustainability plans at risk. By exploiting arable land for commercial activity, ecological footprints produce a biocapacity deficit, resulting in further deforestation and biodiversity loss throughout the world. As a result, the scarcity of endangered species must be conserved through captive breeding and other species survival measures. Finally, has the economic transition from a rural to an urban had a negative impact on biodiversity loss? Economic transformations prioritizing urban infrastructure over rural infrastructure have resulted in increased urbanization and industrialization (Khan, 2023). Further, it resulted in increased deforestation, the extinction of valuable species, and the loss of their habitats, ultimately increasing biodiversity loss. Plans to preserve forest resources would be the ultimate solution to improving biocapacity reserves, which could be done by appropriate regional land-use policies and community engagement to maintain natural biodiversity levels.

The stated research questions enable the development of a set of study research objectives that provide a clear path to provide solid policy conclusions globally, i.e.,

i) To evaluate the influence of deforestation on endangered species habitat loss.
ii) To establish a link between biocapacity reserves and biodiversity decline in different nations.
iii) To investigate the impact of rapid urbanization and resource extraction on endangered species; and
iv) To determine the causal and inter-temporal links between the abovementioned factors over time.

The study used cross-sectional regression using a quantiles distribution technique to investigate the long-run association between the variables. On the other hand, the study employed the Granger causality technique and an innovation accounting matrix to examine causal inferences and inter-temporal estimates across nations. The mentioned statistical methodologies provide answers to the research questions, which aid in developing policy recommendations across nations.

2. Literature Review

Although there is a plethora of scientific work on the various factors of biodiversity loss, the conceptual understanding of the issue varies depending on the context themes and country peculiarities. The study divided the literature review into three different sub-sections, i.e.,

i) The first section evaluated the influence of deforestation on biodiversity loss.
ii) The second section established the link between biocapacity deficit and habitat loss of endangered species, and
iii) The final section investigated the impact of urbanization, industrialization, and economic growth on endangered species.

2.1. The Relationship between Deforestation and Biodiversity Loss

A substantial body of evidence identifies the direct link between deforestation and biodiversity loss; yet, the channel through which they are discussed varies depending on the country's features. Bhuiyan et al. (2017) analyzed data from 18 Asian nations from 2000 to 2014 to examine the possible association between climate change, habitat area, and biodiversity loss. According to the findings, climate change and energy demand both impact aquaculture and marine productivity. Furthermore, rapid population growth has reduced the possible habitat area of endangered species, while climate change, inbound FDI, and economic growth have all contributed to biodiversity loss. As a result, there is an urgent need to curb expanding population and climatic vulnerabilities, primarily responsible for forest damage and biodiversity loss. Zambrano-Monserrate et al. (2018) studied the causative factors of deforestation in five European nations from 1974 to 2013. In most situations, the data confirmed the ups and downs in the deforestation rate due to a rise in the country's growth per capita. Because of sustainable agricultural cultivation, agricultural exports do not contribute to deforestation. Investing in forest conservation projects to prevent biodiversity loss would promote long-term economic consequences and resource-based growth. Yue et al. (2020) investigated the link between forest biodiversity, food production, and resource price in globally aggregated data from 1970 to 2018. The findings show that the loss of forest biodiversity due to poor land-use planning has had a negative impact on environmental quality. Furthermore, increased food production is associated with increased carbon footprints due to high energy consumption. The price of resources is expected to promote forest ecological services and aid in improving environmental quality. The biodiversity hotspots require special attention to protect forest resources, which support the global food supply. Tsiantikoudis et al. (2019) used Bulgaria as a case study to examine the negative environmental externalities that result from increased deforestation-related carbon emissions in a country. The findings demonstrate that continuous economic expansion leads to increased deforestation-related carbon emissions, confirming the N-shaped link. The need for forest restoration is the ultimate solution for preventing biodiversity loss and helping to conserve the natural habitat of valuable species, all of which contribute to long-term economic growth and improved environmental air quality. Habibullah et al. (2021) analyzed biodiversity loss in the form of imperiled birds, fishes, and other animals due to susceptible climatic events by surveying an extensive panel data set of 115 nations. The findings confirmed that climatic events such as extreme temperature, precipitation, and natural disasters have a negative impact on the habitat loss of endangered species. In contrast, environmental governance indicators help reduce biodiversity loss and allow for the conservation of forest resources to protect endangered species. Ngwira and Watanbe (2019) presented some dismal statistics concerning deforestation in Malawi. Between 1991 and 2017, the forest area covered decreased considerably, from 66 percent to 47.6 percent. The household mainly employed wood for the brick fire, tobacco curing, and agricultural development to overcome poverty, address food issues, and meet population growth challenges. Deforestation is mainly ascribed to a lack of resources, a poor market system, and a lack of knowledge. There is a greater need to raise awareness and provide financial incentives to rural families about the importance of forest resource protection and provide them with alternative livelihood options to prevent biodiversity loss. Ajanaku and Collins (2021) examined a broad panel of Sub-Saharan African nations from 1990 to 2016 to assess the rise and fall in the deforestation rate due to continuing economic expansion. The findings validated the inverted U-shaped environmental Kuznets curve connection of deforestation, with a US$3,300 turning point. Furthermore, forest commerce, agricultural development, and rural population growth contribute to increased deforestation across countries. The necessity for population control techniques and adequate land-use plans to balance the rural population would assist in protecting forest resources and biodiversity loss. Zaman (2022) discovered an asymmetric link between deforestation, ecological footprints, fossil fuel use, and economic growth in Brazil's Amazonia. The findings reveal that increased deforestation in a nation is associated with adverse environmental effects such as climate vulnerability and carbon emissions. Ecological footprints deplete economic and natural resources, putting the forest resource conservation agenda at risk. Forest reservoirs must be kept safe to reduce carbon emissions, avoid climate vulnerability, and maintain forest biodiversity. The study developed the research hypothesis, which was based on previous literature, i.e.,

H1: Deforestation is expected to exacerbate biodiversity loss and hasten the extinction of threatened species.

2.2. The Relationship between Biocapacity Deficit and Endangered Species' Habitat Loss

Earlier research found a variety of factors that are associated with a lack of biocapacity. Environmental footprints (Eren et al., 2018), financial development (Omoke et al., 2020), commerce and inbound FDI (Ansari & Khan, 2021), natural resource exploitation (Lee et al., 2021), and urbanization and industrialization (Ahmed et al. 2022) are the primary determinants. A biocapacity deficit occurs when human demand on arable land exceeds its natural capacity for yield production, resulting in a resource shortfall. Aydin et al. (2022) analyzed data from 15 European nations from 1995 to 2016 to examine the ecological deficit of invasive species, including fisheries, crops, forest reservoirs, grazing areas, and economic growth. The findings show that the ecological balance is maintained alongside economic development; but, once the threshold level is exceeded, further economic expansion is associated with adverse environmental externalities, such as waste production and carbon pollution. As a result, ecological deficiency impaired nature's ability to protect biodiversity loss. The ecological balance is critical for achieving the resource conservation goal, so it is critical to build biocapacity reserves and minimize ecological footprints to protect biodiversity loss. Apaydin et al. (2021) studied the link between ecological footprints, globalization, and economic growth during 1980-2016 using a large panel of 130 nations. The findings reveal that sustained economic growth is the primary driver of ecological footprints; globalization is not mature enough to positively impact economic growth while also failing to reduce negative environmental externalities globally. Pata (2021) looked at the US economy as a case study, utilizing time-series data from 1980 to 2016 to analyze the channel via which economic complexity and globalization increase ecological footprints and worsen environmental quality. According to the findings, globalization and green energy sources in economic processes help boost biocapacity reserves and decrease ecological footprints. Furthermore, nonrenewable energy sources and economic complexity put the biocapacity shortfall in peril. The ecological balance is critical for reducing economic complexity and enhancing environmental quality, which aids in resource conservation by amassing green energy sources. Gabbi et al. (2021) highlighted the need to incorporate biocapacity reserves into the economic growth agenda, resulting in a growth process that is more responsive to the actual capacity of natural resources to support biodiversity. Ozcan et al. (2021) proposed that political and institutional considerations would likely promote long-term ecological balance, which helps to strengthen natural reserves by preserving invasive species and paving the path for biodiversity conservation. Ilbay et al. (2021) identified four significant indicators that most likely generate ecological footprints in Ecuador from 1961 to 2016. The findings reveal that a lack of biocapacity, enormous population expansion and economic growth contribute to ecological footprints. Furthermore, ecological footprints reduce biocapacity transporting invasive species, which must be supported via resolving ecological problems and implementing sustainable policies. Nathaniel (2021) examined the significant relationships between biocapacity, human capital development, economic growth, urbanization, and ecological footprints, for the G7 nations from 1980 to 2016. The findings reveal that a lack of biocapacity, continuous economic expansion, and urbanization pressure negatively influence environmental quality, as represented by ecological footprints. On the other hand, human capital formation is a positive factor that helps to improve ecological quality and suggests biocapacity reserves that help to avoid biodiversity loss. Chunling et al. (2021) stressed the importance of greenfield investment in the energy and technical innovation sectors in addressing environmental footprints. Furthermore, it is a time to re-correct trade liberalization policies and economic activities to strengthen biocapacity reserves, which aid in reducing ecological footprints.

The vast literature emphasized the importance of restoring invasive species' habitat loss and outlined several preventative measures for their survival, including appropriate land-use policies (Nagy-Reis et al., 2021), protective sites for habitat conservation (Mayani-Parás et al., 2021), control and management (Dueas et al., 2021), and reduction in climatic episodes (Wang et al., 2022). Considering the importance of the literature, the study developed a new hypothesis, i.e.,

H2: A biocapacity deficiency is expected to exacerbate invasive species biodiversity loss, resulting in adverse environmental consequences.

2.3. The Effects of Urbanization, Industrialization, and Economic Growth on Biodiversity Loss

Growth-specific factors are seen as negative factors that have harmed species extinction. Previous research has shown that increased urbanization, massive industry, and continued economic expansion produce a biocapacity deficit, which raises the likelihood of endangered species habitat loss. For instance, Xu et al. (2018) surveyed a new Jiangwan town in Shanghai, China, and gathered data on bird species to assess habitat loss of endangered species and land-use changes. According to the findings, significant rural-urban migration damaged forest resources, resulting in biodiversity loss. Proper land planning would aid in economic development by protecting biodiversity resources and forest reservoirs to support biodiversity. Pichler et al. (2021) analyzed data from five Southeast Asian nations from 1990 to 2016 to examine the causes of nation transitions from deforestation to reforestation. The findings suggest that extreme climate unpredictability creates negative environmental impacts, necessitating greater afforestation and reforestation to address the problem. Furthermore, land-use strategies and regional planning for decreasing deforestation are advocated to progress toward green development. According to Rastandeh and Jarchow (2021), an increase in biodiversity reserves tends to enhance the urban healthcare agenda.

However, surpassing the biocapacity varying capacity by its actual size increases the shortfall in biocapacity reserves, resulting in negative urban healthcare outcomes. The study proposed green space design for animal species habitat conservation, resulting in positive economic gain globally. Koslowski et al. (2020) used Europe as a case study to examine the relationship between biodiversity footprint, urbanization, and income. They discovered that continued economic expansion and massive urbanization are likely to increase the risk of biodiversity loss, making it critical to clean and green ecological footprints. Dorninger et al. (2021) concluded that the impact of industrialization and economic globalization limits economic growth by lowering land usage for resource protection. As the competitive world becomes a global village, it is critical to develop sustainable production and consumption scenarios; hence, applicable land-use regulations would be ideal for the long-term protection of biodiversity loss. Dandotiya and Sharma (2022) discovered that climatic vulnerability is the primary element that deteriorates the natural environment by causing damage to the terrestrial ecosystem. Climatic episodes are becoming more common for various reasons, including industrialization, transportation, urbanization, and massive population development, all of which intensify extreme temperature and weather occurrences. These characteristics harmed the habitat of many invasive species, which must be remedied via climate adaptability. Hermoso et al. (2022) stressed the need for increased climatic funding to mitigate climatic vulnerability that has harmed the bio-natural economy's carrying capacity. Furthermore, there is an urgent need to manage natural resources and develop efficient environmental regulations to save resources. Finally, involvement in stakeholder participation for biodiversity loss management is best for long-term biodiversity. Bastos Lima and Palme (2022) discussed the importance of expanding the bio-economy in conserving natural habitat loss of endangered species, increasing the importance of biodiversity preservation, improving regional collaboration to protect biodiversity, and safeguarding future resource conservation sustainability agenda. As a result, it is critical to allocate greater resources to the establishment of bio-economy infrastructure in order to provide social protection and resource conservation. Based on the discussion, the study hypothesizes the following statement, i.e.,

H3: It is likely that as the economy shifts from rural to urban, agricultural to industrialization, and economic growth to development, more land-use restrictions will be implemented to prevent invasive species biodiversity loss.

Following the findings of the literature analysis, the research drew the following conclusions, i.e.,

i) It was discovered that increasing deforestation leads to increased habitat loss for endangered species and that this loss has to be controlled by land-use policy. Due to deforestation's influence on species, including birds, fish, and mammals, information from these species was included as a response variable.

ii) Due to increased biocapacity deficits, biodiversity was negatively affected by ecological footprints. Maintaining biodiversity reserves is the best way to decrease ecological footprints and enhance biodiversity. As a result, biocapacity reserves were shown to be a reliable indicator of threatened species' habitat degradation.

iii) Massive rural-urban migration tends to need additional space for the development of metropolitan cities, which has a negative impact on land-use changes and the ability of invasive species to preserve their habitat. The need for regional land-use planning and the development of smart cities programs may assist in boosting the capacity of the bio-economy. As a result, the claimed relevance of the urbanization element in the resource conservation agenda must be employed as an explanatory variable in the study.

iv) The economic transition from agricultural surpluses to an accommodating industrial sector has overwhelmed the resource market, hampered the implementation of a sustainable ecological strategy. Increased demand for natural resources in industrial production necessitated greater exploitation of several valuable resources, both renewable and nonrenewable. Forest reserves are also shrinking due to increased industrialization; thus, it is essential to manufacture environmentally friendly products to save natural resources. As a result, industrialization is regarded as a contributing factor to biodiversity loss, and

v) Continued economic development promotes short-run economic profit at the expense of environmental degradation, including biodiversity loss and biocapacity deficiency. As a result, there is a higher need for continuous economic activity to achieve sustainable economic gain that supports the natural environment and contributes to deforestation reduction. Thus, the proposed modeling framework includes economic growth per capita to provide reasonable inferences.

The five points mentioned above demonstrate the significance of the subject matter, which was previously overlooked in biodiversity modeling in large cross-sectional nations due to limiting resource degradation factors (see Hassan et al., 2019; Lee et al., 2021; Tamburino & Bravo, 2021). As long as deforestation is allowed to continue, it will be at the forefront of efforts to protect forest resources via regional land-use planning. Previous research is subject to country-specific shocks (see Zaman, 2022, 2023; Nathaniel, 2021; Ahmed et al., 2022). However, the requirement to include a broader range of nations has enabled the results to be more broadly generalized (Aqib & Zaman, 2023).

3. Data and Methodological Framework

The study gathered data on habitat degradation for endangered species (designated by HLENDS), which included threatened bird, fish, and mammalian species, and used it as a response variable. For invasive species, statistics from 2018 are available from the World Bank's (2021) database. The cross-section of 159 nations was employed to make robust inferences throughout the empirical inquiry. The selection of a specific panel comprising 159 countries in is justified by the challenges associated with gathering comprehensive and reliable data from all countries, especially in regions with limited resources and infrastructure. Despite our dedicated efforts to source data from a diverse range of reliable sources, certain countries had to be excluded due to data unavailability. This decision was made to ensure the integrity and quality of the data used in our analysis. By acknowledging these limitations, we aimed to maintain the scholarly rigor of our research while providing valuable insights within the constraints of available data. Table-A in appendix shows the list of selected countries for estimation. Additionally, forest rents (as a percentage of GDP) are used as a proxy for deforestation (as denoted by DEFOR; data is for the year 2019), based on the proposition that a higher forest rental value implies a greater risk of deforestation, implying the need to stabilize forest rental prices in order to help countries reduce deforestation. Biocapacity deficiency is seen as a negative aspect of the natural environment since it results in increased deforestation; hence, balancing biocapacity reserves is critical for resource conservation. The research examined biocapacity reserves (hectares per person in 2018, designated by BIORES) as a potential factor in natural resource conservation across nations. Massive urbanization (percentage of the total population as of 2019 estimates, denoted by URBAN), increasing industrialization (constant 2015 US dollars, denoted by IND, data collected for the year 2019), and continued economic growth (GDP per capita of 2019, constant 2015 US dollars, denoted by GDPPC) are all incorporated into the biodiversity modeling that served as the study's controlled variables. The data is collected from the World Bank (2021) database.

The variables are chosen depending on the subject's relevance. Invasive species habitat loss is a severe challenge globally, necessitating national and regional cooperation to prevent biodiversity loss, which is growing due to increasing deforestation rates. The previous literature identified multiple causes of deforestation, including forest fires (Dos Reis et al., 2021), destruction of rainforest due to infrastructure expansion and agricultural value addition (Hoang & Kanemoto, 2021), climate extremes (Alves de Oliveira et al., 2021), land-use change (Girard et al., 2021), wood fuel (Mahushi et al., 2021), timber extraction (Blackman &Villalobos, 2021), illegal logging (Kleinschmit et al., 2021), and metropolitan area settlement (Solano et al., 2021). Thus, the negative externalities, along with deforestation, scared the globalized community to protect forest resources to leave a green and clean imprint. Furthermore, the research utilized biocapacity reserves as a potential factor of balancing biodiversity, which aids in the conservation of vulnerable species' habitats. The ecological footprint is the primary curative component that depletes biocapacity reserves, exploits bioeconomic resources, and creates a biocapacity deficit, eventually affecting invasive species negatively. Finally, the study used controlled variables, such as industrialization, urban population, and economic growth. It confirmed that economic expansion increases deforestation and habitat loss of invasive species (Bodo et al., 2021). Massive urbanization and industrialization required more land for city development and food challenges, eventually hampered global forest reservoirs (Zaman, 2022). Thus, the rationale to use the stated variables allow to investigate the long-run and causal relationships between the stated variables, which is presented in equation (1) for estimation, i.e.,

$$\ln(HLENDS) = \int \ln(DEFOR, BIORES, URBAN, GDPPC, IND) \tag{1}$$

Where, 'ln' shows natural logarithm, HLENDS shows habitat loss of endangered species, DEFOR shows deforestation, BIORES shows bioreserves, URBAN shows urbanization, GDPPC shows GDP per capita, and IND shows industrialization.

The theoretical expectations with the beta coefficients are shown in equation (2), i.e.,

$$\ln(HLENDS)_{i,t} = \beta_0 + \beta_1 \ln(DEFOR)_{i,t} + \beta_2 \ln(BIORES)_{i,t} + \beta_3 \ln(URBAN)_{i,t} + \beta_4 \ln(GDPPC)_{i,t} + \beta_5 \ln(IND)_{i,t} + \varepsilon_{i,t}$$

$$\therefore \frac{\partial \ln(HLENDS)}{\partial \ln(DEFOR)} > 0, \frac{\partial \ln(HLENDS)}{\partial \ln(BIORES)} < 0, \frac{\partial \ln(HLENDS)}{\partial \ln(URBAN)} > 0, \frac{\partial \ln(HLENDS)}{\partial \ln(GDPPC)} > 0, \frac{\partial \ln(HLENDS)}{\partial \ln(IND)} > 0 \tag{2}$$

Equation (2) indicates that increased deforestation, massive urbanization, unsustainable economic development, and increased industrialization are likely to have a detrimental effect on invasive species habitat conservation. On the other hand, increasing biocapacity reserves is expected to help maintain forest supplies and mitigate the threat of endangered species habitat loss.

3.1. Theoretical Framework

The study offered three alternative and reasonable theoretical connections for saving habitat loss and biodiversity fragmentation in order to create a habitat loss function, i.e.,

i) Valuing Sustainable Forestry (VSF):

It is said that increasing forest resources protects biodiversity loss and conserves invasive species' habitats, which benefits the country's bioeconomic resources. The net advantage is anticipated to be realized via the stabilization of forest rental values, which contributes to enhancing species variety and richness. Increased forest prices harmed the natural environment by encouraging agricultural expansion and infrastructural development, which resulted in deforestation and increased climate vulnerability. The VSF may be calculated as follows:

$$VSF = \sum(\frac{FRENTS}{GDP}) \tag{i}$$

Where VSF shows valuing sustainable forestation, FRENTS shows forest rents, and GDP shows gross domestic product.

The increase in forest rental value causes deforestation and habitat loss of endangered species, hence, it is further transformed into the following:

$$DEFOR = \frac{\%\Delta(HLENDS)}{HLENDS} \div \frac{\%\Delta(VSF)}{VSF} \tag{ii}$$

Where, Δ shows first difference, DEFOR shows deforestation, and HLENDS shows habitat loss of endangered species.

ii) **Valuing Biocapacity Reserves (VBIOR):** According to the VBIOR theory, a rise in ecological footprints tends to diminish biocapacity reserves, resulting in a deficit in ecosystem services, which eventually affects the concept of *valuing sustainable forestation*. Human imprints on arable land prompt greater deforestation as forest rental prices rise, resulting in habitat devastation and biodiversity loss. The ultimate solution for increasing ecological services is the balance of biocapacity reserves. The higher the arable land in hectares covered by forests, the more bioeconomic resources countries may employ to increase their foreign reserves via sustainable trade promotion policies and achieve competitive advantage in the globalized world through natural resource management. The VBIOR may be calculated as follows:

$$VBIOR = \sum(\frac{ALAND}{POP^n}) \tag{iii}$$

Where ALAND shows arable land and POP^n shows total population.

Increased human footprints on arable land tend to deplete biocapacity reserves, resulting in a loss of biological variety that must be protected via global forest resource valuation. Thus, equation (iii) was extended to include the estimation of biocapacity reserves, i.e.

$$BIORES = [\frac{\%\Delta(HLENDS)}{HLENDS} \div \frac{\%\Delta(VBIOR)}{VBIOR}] + VSF \tag{iv}$$

Where BIORES shows biocapacity reserves.

According to Equation (iv), a percentage change in VBIOR reduces habitat loss of endangered species, which helps to enhance VSF to manage a deficiency in biocapacity reserves.

iii) **Valuing Sustainable Economic Activities (VSEA):** It is stated that economic growth should continue by the environmental sustainability agenda, which includes protecting economic and natural resources for long-term economic development. Increased industrialization, rural migrant population relocation in metropolitan regions, and continued commercial activity contribute to increased distress in natural resources and services, resulting in increased deforestation, biodiversity loss, and biocapacity deficit. As a result, the three criteria mentioned above have been included in the VSEA framework, which is as follows:

$$VSEA = \sum(\frac{URBAN}{POP^n} + IND + GDPPC) \tag{v}$$

Where URBAN shows urban population, IND shows industrialization, and GDPPC shows GDP per capita.

The more VSEA factors there are, the greater the strain on ecosystem services, including increased deforestation, increased biodiversity loss, and an increase in biodiversity deficit. As a result, it is critical to developing green and clean economic policies that promote the management of biological resources across nations. The following is an extension of equation (v):

$$VSEA=[\frac{\%\Delta(HLENDS)}{HLENDS}\div\frac{\%\Delta(URBAN)}{URBAN}+\frac{\%\Delta(HLENDS)}{HLENDS}\div\frac{\%\Delta(IND)}{IND}+\frac{\%\Delta(HLENDS)}{HLENDS}\div\frac{\%\Delta(GDPPC)}{GDPPC}]+VSF+VBIOR \quad \text{(vi)}$$

Equation (vi) indicated that smart cities' urban initiatives, responsible production and consumption, and sustainable economic activities would almost certainly include the VSF and VBIOR to manage natural resources effectively.

The study developed the habitat loss function, which consists of the VSF, VBIOR, and VSEA components, for assessing the severity of habitat loss for endangered species across nations, i.e.,

Habitat Loss Function: The associated function indicated that continued tropical deforestation, biocapacity deficiency, and unsustainable economic activities had a detrimental effect on the species richness and biodiversity of the region. Thus, integrating these elements enables the formulation of a sustainable policy choice that both mitigate habitat loss and increases species richness, i.e.,

$$HLF=\int(VSF,VBIOR,VSEA)$$
$$\therefore\frac{\partial(HLF)}{\partial(VSF)}>0,\frac{\partial(HLF)}{\partial(VBIOR)}>0, and\frac{\partial(HLF)}{\partial(VSEA)}>0 \quad \text{(vii)}$$

Where, HLF shows habitat loss function.

Equation (vii) demonstrates that the habitat loss function includes the stated resource conservation elements that contribute to the richness and variety of biodiversity across nations.

3.2. Econometric Framework

The study used three different statistical techniques to analyze the habitat loss function, i.e.,

i) Cross-sectionalregressionapparatuses
ii) Grangercausality, and
iii) Innovationaccounting matrix

Figure 3 shows the econometric framework for ready reference.

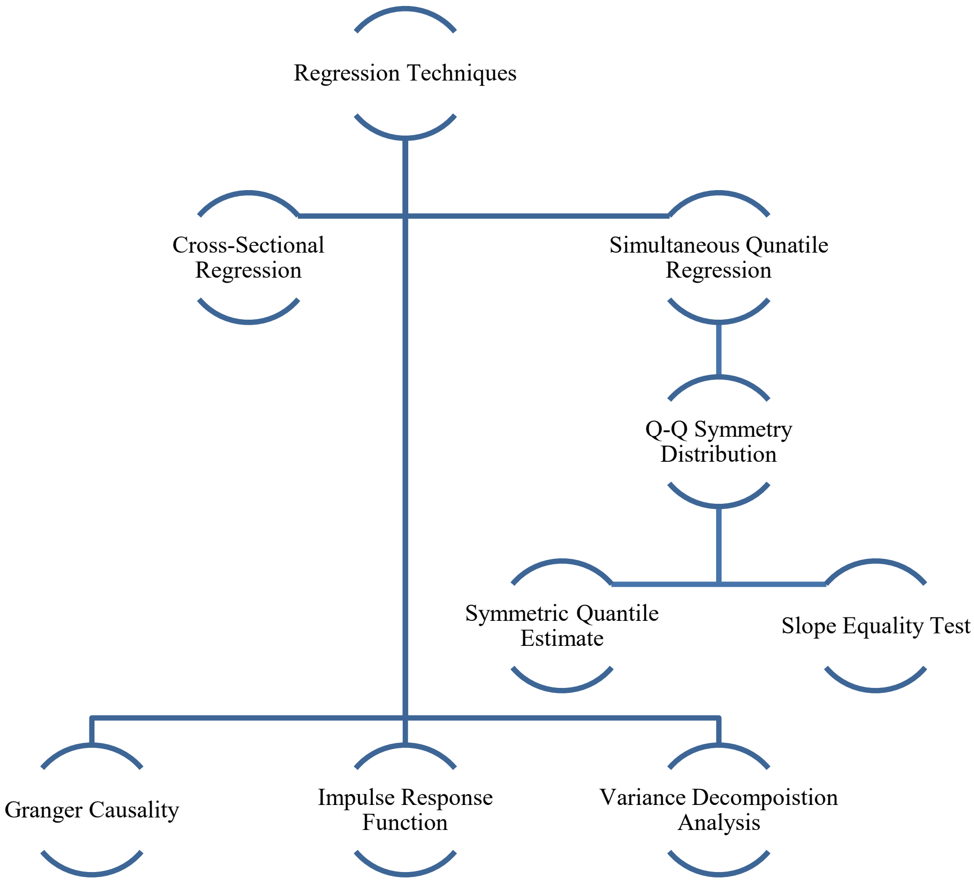

Figure 3. Econometric Framework (Authors extraction)

Cross-sectional regression enables the identification of potential covariates for the dependent variables and the prediction of the regression coefficients' predicted mean values (Zaman, 2023b). Although it may have autocorrelation and heteroskedasticity issues, it is widely used when the estimation procedure includes a large cross-section of countries and data are obtained at a one-point interval. Hence, it eliminates the majority of stochastic assumptions that impair the parameter estimates' reliability. Equation (2) is the empirical equation used to determine its value. Among the several disadvantages of cross-sectional regression, one significant disadvantage is that the candidate variables may exhibit distinct behaviors on the response variable at various quantiles of the distribution, which aids in correcting autocorrelation and heteroskedasticity difficulties. As a result, the study used simultaneous quantile regression to examine the coefficient estimates at the 25th, 50th, 75th, and 90th quantile distributions. Equation (3) depicts the quantiles distribution's regression equation, i.e.

$$\ln(HLENDS)_{0.25} = \tau_0 + \tau_1 \ln(DEFOR)_{0.25} + \tau_2 \ln(BIORES)_{0.25} + \tau_3 \ln(URBAN)_{0.25} + \tau_4 \ln(GDPPC)_{0.25} + \tau_5 \ln(IND)_{0.25} + \varepsilon_{0.25}$$

$$\vdots$$

$$\ln(HLENDS)50 = \tau_0 + \tau_1 \ln(DEFOR)_{0.50} + \tau_2 \ln(BIORES)_{0.50} + \tau_3 \ln(URBAN)_{0.50} + \tau_4 \ln(GDPPC)_{0.50} + \tau_5 \ln(IND)_{0.50} + \varepsilon_{0.50}$$

$$\vdots$$

$$\ln(HLENDS)_{0.75} = \tau_0 + \tau_1 \ln(DEFOR)_{0.75} + \tau_2 \ln(BIORES)_{0.75} + \tau_3 \ln(URBAN)_{0.75} + \tau_4 \ln(GDPPC)_{0.75} + \tau_5 \ln(IND)_{0.75} + \varepsilon_{0.75}$$

$$\vdots$$

$$\ln(HLENDS)_{0.90} = \tau_0 + \tau_1 \ln(DEFOR)_{0.90} + \tau_2 \ln(BIORES)_{0.90} + \tau_3 \ln(URBAN)_{0.90} + \tau_4 \ln(GDPPC)_{0.90} + \tau_5 \ln(IND)_{0.90} + \varepsilon_{0.90} \quad (3)$$

Based on equation (3), the study evaluates whether the slope of different quantiles is equal and symmetric. The Wald test is performed to check the null and alternative hypothesis and verified through chi-square statistics, i.e.,

i) SlopeEquality Test Hypothesis:

H_O: $\tau_{0.25} = \tau_{0.50}$ and $\tau_{0.50} = \tau_{0.75}$

H_A: $\tau_{0.25} \neq \tau_{0.50}$ and $\tau_{0.50} \neq \tau_{0.75}$

The rejection of the null hypothesis determined by statistically insignificant chi-square statistics would imply that the stated quantiles estimate not equal each other; hence, the deviation among the quantiles estimates served the robust inferences.

ii) SymmetricQuantiles Test Hypothesis

H_O: $\tau_{0.25} = \tau_{0.75}$

H_A: $\tau_{0.25} \neq \tau_{0.75}$

Accepting the alternative hypothesis determined by statistically insignificant chi-square statistics confirmed that the stated quantiles would not equal each other and accompanied the symmetric relationship between the variables in the quantiles distribution.

After estimating the coefficient by simultaneous quantile regression, the study evaluated the cross-sectional Granger causality test by F-statistics. The four possible causation inferences can be exhibited during the variables, i.e.,

i) Unidirectional Causality

The unidirectional causality can be found between the candidate variables but not confirmed the other way around, i.e.,

- Deforestation, biodiversity reserves, industrialization, economic growth, and urbanization Granger cause habitat loss of endangered species.

ii) Reverse Causality

The reverse causality can be found between the candidate variables contrary to the above unidirectional causality estimates, i.e.,

- Habitat loss of endangered species Granger cause deforestation, biodiversity reserves, industrialization, economic growth, and urbanization.

iii) Bidirectional Causality

The causality moves from both directions between the variables to support the feedback hypothesis, i.e.,

- Deforestation, biodiversity reserves, industrialization, economic growth, and urbanization Granger cause habitat loss of endangered species.

- Habitat loss of endangered species Granger cause deforestation, biodiversity reserves, industrialization, economic growth, and urbanization.

iv) No Causality

The causality relationship neither supported either one-way and reverse linkages or bidirectional; hence, it is likely to exhibit a flat relationship between the variables, although it may be highly correlated in the regression apparatus. The VAR framework is best depicted the Granger causality inferences shown in Equation (4), i.e.,

$$
\begin{bmatrix} \ln(HLENDS)_{i,t} \\ \ln(DEFOR)_{i,t} \\ \ln(BIORES)_{i,t} \\ \ln(IND)_{i,t} \\ \ln(GDPPC)_{i,t} \\ \ln(URBAN)_{i,t} \end{bmatrix} = \begin{bmatrix} \tau_0 \\ \tau_1 \\ \tau_2 \\ \tau_3 \\ \tau_4 \\ \tau_5 \end{bmatrix} + \sum_{i=1}^{p} \begin{bmatrix} \sigma_{11t}\sigma_{12t}\sigma_{13t}\sigma_{14t}\sigma_{15t} \\ \sigma_{21t}\sigma_{22t}\sigma_{23t}\sigma_{24t}\sigma_{25t} \\ \sigma_{31t}\sigma_{32t}\sigma_{33t}\sigma_{34t}\sigma_{35t} \\ \sigma_{41t}\sigma_{42t}\sigma_{43t}\sigma_{44t}\sigma_{45t} \\ \sigma_{51t}\sigma_{52t}\sigma_{53t}\sigma_{54t}\sigma_{55t} \\ \sigma_{61t}\sigma_{62t}\sigma_{63t}\sigma_{64t}\sigma_{65t} \end{bmatrix} \times \begin{bmatrix} \ln(HLENDS)_{t-i} \\ \ln(DEFOR)_{t-i} \\ \ln(BIORES)_{t-i} \\ \ln(IND)_{t-i} \\ \ln(GDPPC)_{t-i} \\ \ln(URBAN)_{t-i} \end{bmatrix}
$$

$$
+ \sum_{j=p+1}^{d\max} \begin{bmatrix} \theta_{11j}\theta_{12j}\theta_{13j}\theta_{14j}\theta_{15j} \\ \theta_{21j}\theta_{22j}\theta_{23j}\theta_{24j}\theta_{25j} \\ \theta_{31j}\theta_{32j}\theta_{33j}\theta_{34j}\theta_{35j} \\ \theta_{41j}\theta_{42j}\theta_{43j}\theta_{44j}\theta_{45j} \\ \theta_{51j}\theta_{52j}\theta_{53j}\theta_{54j}\theta_{55j} \\ \theta_{61j}\theta_{62j}\theta_{63j}\theta_{64j}\theta_{65j} \end{bmatrix} \times \begin{bmatrix} \ln(HLENDS)_{t-j} \\ \ln(DEFOR)_{t-j} \\ \ln(BIORES)_{t-j} \\ \ln(IND)_{t-j} \\ \ln(GDPPC)_{t-j} \\ \ln(URBAN)_{t-j} \end{bmatrix} + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \\ \varepsilon_4 \\ \varepsilon_5 \\ \varepsilon_6 \end{bmatrix} \quad (4)
$$

Equation (4) is simplified by using VAR(2) model testing Granger causality for multivariate system, i.e.,

$$
HLENDS_t = c_1 + \sum_{i=1}^{2} \beta_1 HLENDS_{t-i} + \sum_{i=1}^{2} \beta_2 DEFOR_{t-i} + \sum_{i=1}^{2} \beta_3 BIORES_{t-i} + \sum_{i=1}^{2} \beta_4 IND_{t-i} + \sum_{i=1}^{2} \beta_5 GDPPC_{t-i} + \sum_{i=1}^{2} \beta_6 URBAN_{t-i} + \varepsilon_{HLENDS}
$$

$$
DEFOR_t = c_1 + \sum_{i=1}^{2} \beta_1 DEFOR_{t-i} + \sum_{i=1}^{2} \beta_2 HLENDS_{t-i} + \sum_{i=1}^{2} \beta_3 BIORES_{t-i} + \sum_{i=1}^{2} \beta_4 IND_{t-i} + \sum_{i=1}^{2} \beta_5 GDPPC_{t-i} + \sum_{i=1}^{2} \beta_6 URBAN_{t-i} + \varepsilon_{DEFOR}
$$

$$
BIORES_t = c_1 + \sum_{i=1}^{2} \beta_1 BIORES_{t-i} + \sum_{i=1}^{2} \beta_2 DEFOR_{t-i} + \sum_{i=1}^{2} \beta_3 HLENDS_{t-i} + \sum_{i=1}^{2} \beta_4 IND_{t-i} + \sum_{i=1}^{2} \beta_5 GDPPC_{t-i} + \sum_{i=1}^{2} \beta_6 URBAN_{t-i} + \varepsilon_{BIORES}
$$

$$
IND_t = c_1 + \sum_{i=1}^{2} \beta_1 IND_{t-i} + \sum_{i=1}^{2} \beta_2 DEFOR_{t-i} + \sum_{i=1}^{2} \beta_3 BIORES_{t-i} + \sum_{i=1}^{2} \beta_4 HLENDS_{t-i} + \sum_{i=1}^{2} \beta_5 GDPPC_{t-i} + \sum_{i=1}^{2} \beta_6 URBAN_{t-i} + \varepsilon_{IND}
$$

$$GDPPC_t = c_1 + \sum_{i=1}^{2} \beta_1 GDPPC_{t-i} + \sum_{i=1}^{2} \beta_2 DEFOR_{t-i} + \sum_{i=1}^{2} \beta_3 BIORES_{t-i} + \sum_{i=1}^{2} \beta_4 IND_{t-i} + \sum_{i=1}^{2} \beta_5 HLENDS_{t-i} + \sum_{i=1}^{2} \beta_6 URBAN_{t-i} + \varepsilon_{GDPPC}$$

$$URBAN_t = c_1 + \sum_{i=1}^{2} \beta_1 URBAN_{t-i} + \sum_{i=1}^{2} \beta_2 DEFOR_{t-i} + \sum_{i=1}^{2} \beta_3 BIORES_{t-i} + \sum_{i=1}^{2} \beta_4 IND_{t-i} + \sum_{i=1}^{2} \beta_5 GDPPC_{t-i} + \sum_{i=1}^{2} \beta_6 HLENDS_{t-i} + \varepsilon_{URBAN} \quad (5)$$

Finally, the study used an innovation accounting matrix composed of an impulse response function (IRF) and variance decomposition analysis (VDA). Both strategies enable assessing the connection between variables across a specified time frame. The study assessed and forecasted the link between the factors during the following decade. The IRF estimates indicated the direction of the variables across a time horizon, whereas the VDA technique indicated the magnitude of the exogenous shocks to the explanatory variables over time. VAR (p) may be used to estimate the forecast error variance, i.e.

$$\begin{aligned}
&Var(\sigma(HLENDS, DEFOR) = Var(E[\sigma \perp DEFOR]) + E[Var(\sigma \perp DEFOR)] \\
&\Rightarrow Var(E[\sigma \perp DEFOR]) \leq Var(\sigma[HLENDS, DEFOR)] \\
&Var(\sigma(HLENDS, BIORES) = Var(E[\sigma \perp BIORES]) + E[Var(\sigma \perp BIORES)] \\
&\Rightarrow Var(E[\sigma \perp BIORES]) \leq Var(\sigma[HLENDS, BIORES)] \\
&Var(\sigma(HLENDS, IND) = Var(E[\sigma \perp IND]) + E[Var(\sigma \perp IND)] \\
&\Rightarrow Var(E[\sigma \perp IND]) \leq Var(\sigma[HLENDS, IND)] \\
&Var(\sigma(HLENDS, GDPPC) = Var(E[\sigma \perp GDPPC]) + E[Var(\sigma \perp GDPPC)] \\
&\Rightarrow Var(E[\sigma \perp GDPPC]) \leq Var(\sigma[HLENDS, GDPPC)] \\
&Var(\sigma(HLENDS, URBAN) = Var(E[\sigma \perp URBAN]) + E[Var(\sigma \perp URBAN)] \\
&\Rightarrow Var(E[\sigma \perp URBAN]) \leq Var(\sigma[HLENDS, URBAN)]
\end{aligned} \quad (6)$$

The mean sequre error (MSE) term is designed for the explanaotry variables, which is presente din equation (7), i.e.,

$$\begin{aligned}
MSE_\mu &= E_{HLENDS}[MSE_\mu(DEFOR)] \\
MSE_\mu &= E_{HLENDS}[MSE_\mu(BIORES)] \\
MSE_\mu &= E_{HLENDS}[MSE_\mu(IND)] \\
MSE_\mu &= E_{HLENDS}[MSE_\mu(GDPPC)] \\
MSE_\mu &= E_{HLENDS}[MSE_\mu(URBAN)]
\end{aligned} \quad (7)$$

Where, MSE shows mean square error.
The study established an anticipated time period of 2022 to 2030 to aid in policy analysis forecasting.

4. Results and Discussion

Table 1 summarizes the descriptive statistics for the factors examined. The average number of endangered species is 83.647, while the greatest and lowest numbers are 517 and 4, respectively. The higher dispersion of data values across cross-sectional nations is evident with a standard deviation of 81.835, a strongly skewed distribution, and a high kurtosis value. Deforestation has a maximum value of 12.431 percent of GDP and a mean value of 1.137 percent GDP. The arable land for hectares per person illustrates the biocapacity reserves, with a maximum reserve of 1.627 hectares per person and an average reserve of 0.211 hectares per person. On average, urbanization reached 59.281 percent of the total population, with a low of 12.366 percent. GDP per capita and industrialization are valued at an average of US$13291.021 and US$1.26E+11, respectively, among 159 cross-sectional nations. The trend analysis indicates the likelihood that deforestation and other related variables may result in habitat loss for endangered species across nations.

Table 1.Descriptive Statistics

Methods	HLENDS	DEFOR	BIORES	URBAN	GDPPC	IND
Mean	83.647	1.137	0.211	59.281	13291.021	1.26E+11
Maximum	517	12.431	1.627	100	104583.700	5.63E+12
Minimum	4	6.86E-05	0.001	13.366	278.319	53644287
Std. Dev.	81.835	1.973	0.223	21.977	18548.330	5.50E+11
Skewness	2.532	2.871	2.715	-0.208	2.307	8.194810
Kurtosis	10.483	12.628	13.795	2.112	8.717	75.36471
Observations	159	159	159	159	159	159

Note: HLENDS shows habitat loss of endangered species, DEFOR shows deforestation, BIORES shows biocapacity reserve, URBAN shows urbanization, GDPPC shows GDP per capita, and IND shows industrial value added.

Figure 4 depicts the quantile-quantile symmetric distribution of distance to locations below and above the median of the corresponding variables. It demonstrates that the natural logarithm of endangered species habitat loss has a distance to more than the median, but deforestation, bioreserves, and urbanization have a distance to points that are less than the median. GDP per capita and industrialization are both quite near the median line; hence, the observed deviations from the mean are relatively small. The higher divergence from the median line indicates the unpredictability of the variable series across cross-sections, which explains why the variables should be observed during the estimate.

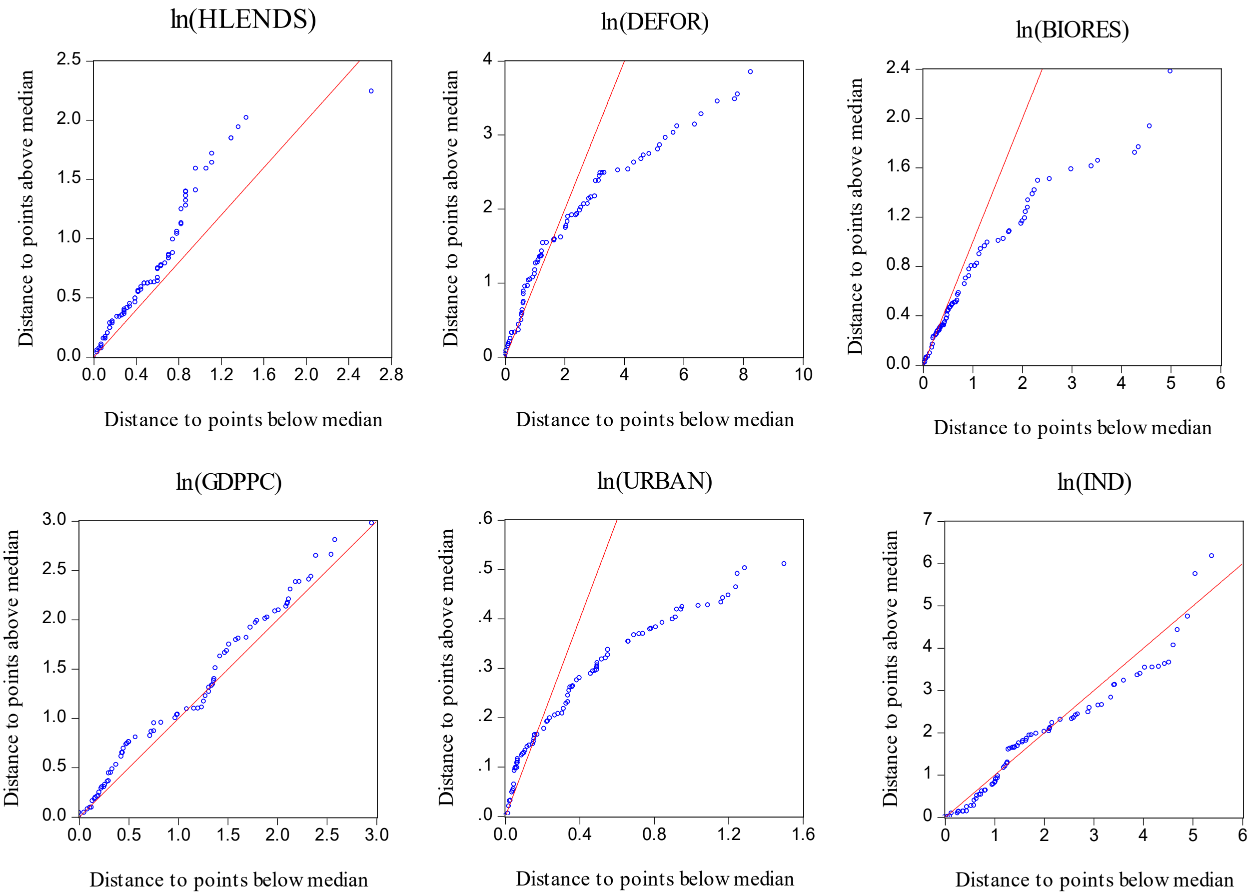

Figure 4. Quantile – Quantile (Q-Q) Symmetry Distribution (Author's estimation)
'ln' shows natural logarithm, ENDSP shows endangered species, DEFOR shows deforestation, BIORES shows biocapacity reserve, URBAN shows urbanization, GDPPC shows GDP per capita, and IND shows industrial value added.

Table 2 displays Pearson's correlation estimations, which reveal that deforestation and industrialization are the damaging factors affecting endangered species' habitats, with correlation coefficient values of $r = 0.218$ $p<0.005$ and $r = 0.391$ $p<0.000$, respectively. On the other hand, GDP per capita was inversely connected with threatened species habitat loss and deforestation, with correlation coefficient values of $r = -0.204$ $p<0.009$ and $r = -0.676$ $p<0.000$, respectively. It suggests that sustained economic expansion aids in reducing deforestation and the conservation of endangered species habitat. Urbanization and economic growth are critical factors adversely connected with biocapacity reserves with correlation coefficient values of $r = -0.148$ $p<0.062$ and $r = -0.187$ $p<0.017$, respectively. Finally, urbanization boosts industrialization and economic development while reducing biocapacity reserves across nations.

Table 2. Correlation Estimates

Variables	ln(HLENDS)	ln(DEFOR)	ln(BIORES)	ln(URBAN)	ln(GDPPC)	ln(IND)
ln(HLENDS)	1					
	-----					
ln(DEFOR)	0.218	1				
	(0.005)	-----				
ln(BIORES)	0.025	0.435	1			
	(0.750)	(0.000)	-----			
ln(URBAN)	3.96E-05	-0.462	-0.148	1		
	(0.999)	(0.000)	(0.062)	-----		
ln(GDPPC)	-0.204	-0.676	-0.187	0.694	1	
	(0.009)	(0.000)	(0.017)	(0.000)	-----	
ln(IND)	0.391	-0.299	0.117	0.419	0.478	1
	(0.000)	(0.000)	(0.138)	(0.000)	(0.000)	-----

Note: Small bracket shows probability value. 'ln' shows natural logarithm, HLENDS shows habitat loss of endangered species, DEFOR shows deforestation, BIODEF shows biocapacity deficit, URBAN shows urbanization, GDPPC shows GDP per capita, and IND shows industrial value added.

Table 3 provides partial and semi-partial correlations of endangered species in addition to Pearson's correlation coefficient estimations. The findings show that deforestation, urbanization, and industrialization have a positive link with endangered species habitat loss, implying that the aforementioned factors threaten endangered species' habitat loss. On the other side, biocapacity reserves and sustained economic development are inversely correlated with endangered species habitat degradation, indicating that both variables contribute to protecting endangered species habitat and improving biodiversity across nations.

Table 3. Partial and Semi Partial Correlations of ln(HLENDS)

Variables	Partial Correlation	Semi Partial Correlation	Square of Partial Correlation	Square of Semi Partial Correlation	Significance Value
Ln(DEFOR)	0.210	0.165	0.044	0.027	0.009
Ln(BIORES)	-0.255	-0.202	0.065	0.041	0.001
Ln(URBAN)	0.139	0.107	0.019	0.011	0.086
Ln(GDPPC)	-0.357	-0.292	0.127	0.085	0.000
Ln(IND)	0.596	0.566	0.355	0.321	0.000

Note: 'ln' shows natural logarithm, HLENDS shows habitat loss of endangered species, DEFOR shows deforestation, BIODEF shows biocapacity deficit, URBAN shows urbanization, GDPPC shows GDP per capita, and IND shows industrial value added.

Table 4 displays the cross-sectional regression estimates, which revealed that deforestation, urbanization, and industrialization all had a negative impact on the habitats of endangered species, with elasticity values of 0.077 percent, 0.264 percent, and 0.231 percent, respectively. On the other hand, Biocapacity reserves and GDP per capita, with elasticity estimates of -0.129 percent and -0.291 percent, respectively, help reduce the loss of habitat for endangered species. The findings are consistent with previous research. For instance, Negret et al. (2021) discovered that bird habitat loss is a cause of continuing tropical deforestation in Colombia, which was previously thought to be a bird-rich region. The habitat loss index was developed based on a country's evaluation of bird species' habitat loss. The research suggests that providing ecosystem services, such as bird habitat protection and decreased deforestation, will likely preserve a country's biodiversity and ecological function. Kouadio and Singh (2021) explored the probable reasons for deforestation in Côte d'Ivoire, including massive land clearance, trafficking, and reckless pesticides, which impacted the resource conservation goal. Habibullah et al. (2022) indicated that climate vulnerability exacerbated habitat loss of endangered species due to increased deforestation, intense weather, and natural catastrophe. According to Sganzerla et al. (2021), extensive urbanization exacerbates environmental and economic problems by causing an imbalance in resource management, increasing deforestation, harming biodiversity, and causing habitat loss for endangered species. According to Araujo et al. (2021), expanding industrialization production and a lack of resource conservation policies increase habitat loss of endangered species and biodiversity loss, which requires sustainable ecological knowledge to safeguard natural resources by limiting deforestation and irresponsible production and consumption.

Table 4. Overall Cross-Sectional Regression Estimates

Variables	Coefficient values	Stand error estimates	t-value	p-value	[95% Confidence Interval]	
ln(DEFOR)	0.077	0.029	2.660	0.009	0.020	0.134
ln(BIORES)	-0.149	0.046	-3.270	0.001	-0.239	-0.059
ln(URBAN)	0.264	0.153	1.730	0.086	-0.037	0.566
ln(GDPPC)	-0.291	0.061	-4.730	0.000	-0.412	-0.169
ln(IND)	0.231	0.025	9.170	0.000	0.181	0.281
Constant	0.027	0.643	0.040	0.967	-1.243	1.296
Mean dependent variable		4.094	SD dependent variable			0.795
R-squared		0.416	Number of observations			159
F-test		21.829	Prob> F			0.000
Akaikecriteria (AIC)		303.609	Bayesiancriteria (BIC)			322.022

Note: Dependent variable: ln(HLENDS). 'ln' shows natural logarithm, HLENDS shows endangered species, DEFOR shows deforestation, BIORES shows biocapacity reserves, URBAN shows urbanization, GDPPC shows GDP per capita, and IND shows industrial value added.

Table 5 presents the results of cross-sectional regression estimates for low-, middle-, and high-income countries, examining the relationship between various variables and habitat degradation for endangered species (represented by HLENDS).

Table 5. Cross-Sectional Regression Estimates for Low-, Middle-, and High-Income Countries

Variables	Low-IncomeCountries	Middle-IncomeCountries	High-IncomeCountries
ln(DEFOR)	0.109	0.083*	-0.245***
ln(BIORES)	-0.162*	-0.117***	0.368***
ln(URBAN)	0.356	0.188	-0.025
ln(GDPPC)	-0.176	-0.282**	-0.517
ln(IND)	0.268***	0.275***	0.550***
Constant	-2.030	-0.799	-5.012
Statistical Tests			
R^2	0.497	0.439	0.836
Adjusted R^2	0.443	0.396	0.778
F-statistics	9.301***	10.179***	14.376***

Note: Dependent variable is ln(HLENDS). *, **, and *** shows 10%, 5% and 1% significance level.

Regression analysis demonstrates a negative coefficient (-0.162) for biocapacity reserves (BIORES) in low-medium income countries, which is strongly connected with decreased habitat degradation for endangered species (HLENDS). The negative coefficient for biocapacity reserves suggests that increasing national parks, nature preserves, and other protected areas may decrease habitat deterioration for vulnerable species. This supports the idea that biocapacity reserves help endangered species survive by providing habitats and natural resources. Preserving biocapacity in well-managed protected areas protects biological systems from deforestation, habitat fragmentation, and overexploitation (Jain, 2023). Industrialization's positive coefficient (0.268) suggests a substantial and statistically significant relationship between habitat degradation and endangered species. Therefore, economically growing countries with critically endangered species are more likely to degrade their habitats (Raihan, 2023). Infrastructure building, urban growth, agricultural intensification, and resource extraction often cause habitat loss, pollution, and ecological disruption (Pröbstl et al., 2023). Industrialization increases habitat destruction for sensitive species. Economic growth may cost natural ecosystems and biodiversity. Industrialization harms endangered species' habitats via land conversion, pollution, plant cover loss, and biological processes (Chakraborty et al., 2023). These results emphasize the necessity for environmentally friendly, growth-promoting, sustainable development. Environmental legislation and sustainable land use, resource management, and conservation techniques are needed to mitigate industrialization's impact on endangered species habitats (Zehra et al. 2023).

In the case of middle-income countries, the positive coefficient for deforestation shows that endangered species' habitats degrade faster as deforestation rates grow. Fueled by logging, agricultural expansion, and infrastructure development, deforestation fragments ecosystems and destroys woody habitats (Albert et al., 2023). Deforestation is destroying endangered animal habitats. Deforestation disrupts ecosystems, fragments habitats, reduces biodiversity and increases sensitivity to environmental pressures (Faria et al., 2023). Succession plan remains viable for corporate benefits (Acheampong et al., 2023; Asgha, 2023). Industrialization's positive coefficient shows that developing economies and industrialization worsen endangered species habitats. Industrialization depletes natural resources, destroys habitats, and pollutes. It degrades ecosystems by altering landforms, introducing toxins, and disrupting biological processes. Urbanization, infrastructure development, intensive agriculture, and resource extraction may harm endangered species habitats (Akani, 2023). The negative coefficient for biocapacity reserves illustrates that protecting and managing endangered species' habitats reduces habitat degradation. Biocapacity reserves preserve natural resources and endangered animals. Large biocapacity reserves may protect vulnerable species' habitats (Jie et al., 2023). This research emphasizes the importance of protected areas, national parks, and other conservation areas for ecosystem preservation and biodiversity protection. Since economic growth has a negative coefficient, endangered species lose less habitat as middle-income countries develop – productivity and per capita income boost infrastructure, resource management, and environmental compliance, promoting sustainable development, economic growth, and ecologically friendly practices and policies may reduce habitat degradation. These findings show that we must emphasize sustainable development measures that support economic growth and environmental preservation (Hailiang et al., 2023).

In high-income countries, the negative coefficient for deforestation shows that more deforestation reduces habitat deterioration for sensitive species. Progressive conservation laws in high-income countries may explain this. High-income countries may have severe deforestation prohibitions and sustainable land use policies. Reforestation, afforestation, and sustainable forestry are examples (Sohag et al., 2023). Thus, the negative coefficient shows that high-income countries reduce deforestation's effects on endangered species habitats. The positive coefficient for biocapacity reserves shows that high-income countries with more protected areas and conservation activities have greater endangered species habitat degradation. Biocapacity reserves may be created to protect biodiversity and the environment. The positive coefficient may be because biocapacity reserves are concentrated in human-damaged regions. Thus, endangered species' remaining habitats are more likely to degrade (Mi et al. 2023). Industrialization's positive coefficient causes vulnerable species' habitat degradation. Industrialization involves intensive manufacturing, urbanization, and infrastructure. It demonstrates that industrialization may destroy habitats even in high-income countries with strict environmental regulations (Khan & Imran, 2023). Industrial activity may cause habitat loss, pollution, and ecological disruption, but less than in low- and middle-income countries (Albaity&Awad, 2023).

Simultaneous quantile regression estimates are shown in Table 6. The findings indicate that deforestation positively affects endangered species habitat loss at the 25th, 50th, and 75th quantile distributions. However, it becomes insignificantly explainable by the response variable at the 90th quantile distribution. Elasticity estimations are stronger at the 25th quantile (0.105 percent), 0.103 percent at the 50th, and 0.082 percent at the 75th quantile. At the 25th to 90th quantiles, biocapacity reserves have a negative relationship with endangered species habitat loss; however, the effect of improving endangered species biodiversity is more significant at the 25th quantile, i.e., -0.205 percent, followed by the 50th quantile, i.e., -0.127 percent, the 90th quantile, i.e., -0.125 percent, and the 75th quantile, i.e., -0.088 percent. Urbanization has a negative effect on endangered species habitat loss, with an elasticity of 0.378 percent at the 90th quantile distribution. Continued economic growth contributes to endangered species habitat conservation via land-use changes and sustainable infrastructure development. Economic development has a favorable effect on reducing biodiversity loss and enhancing conservation agendas at the 25th and 50th quantiles, with elasticity values of -0.374 percent and -0.201 percent, respectively. Finally, although there is a positive association between industrialization and biodiversity loss from the 25th to the 90th quantiles, the impact is more substantial at the 90th quantile with an elasticity value of 0.256 percent.

The stated findings are consistent with previous research, i.e.,

i) Continued tropical deforestation is the primary cause of habitat loss for endangered species, necessitating a biodiversity conservation agenda to sustain ecosystem services that aid in reducing human footprints in protected areas (Šorović, 2022; Kleemann et al., 2022; Alemu, 2022).

ii) A biocapacity deficit is another possible hazard to endangered species habitat loss since it results from increased ecological footprints on arable land, depleting biological resources. Human capital development contributes to the balance of natural resources and paves the road for environmental sustainability (Tamburino & Bravo, 2021; Ahmed et al., 2022). Economic growth exacerbates ecological imbalances, which must be addressed by introducing ecosystem services (Aydin et al., 2022;Niccolucci et al., 2021).

iii) Urbanization and industrialization have detrimental effects on ecological resources, resulting in increased biodiversity loss as urban metropolitan areas expand onto arable land. At the same time, growing populations exacerbate food security challenges, resulting in increased industrialization infrastructure globally. Urbanization and ecological footprints are moving in lockstep, resulting in the transformation of natural reserves into biocapacity deficits (Salman et al., 2022, Feng et al., 2021). Rapid industrialization increases air pollution and tends to increase the risk of climate change, necessitating conservation policies and land-use changes for managing forest reservoirs (Vergara et al., 2021;Bekabil, 2020), and

iv) Continued economic growth subsidized the endangered species habitat loss conservation agenda and made an economy's developmental agenda green and clean. Environmental stewardship contributes to the advancement of a sustainable resource agenda (Islam & Managi, 2019), which in turn contributes to the mitigation of climate uncertainty (Bhuiyan et al., 2018), hence advancing towards inclusive development (Sun et al., 2020). Promoting a bio-based economy is critical for resource management on economic, social, and environmental levels, as it helps minimize the ecological costs associated with growing forest harvest levels (Eyvindson et al., 2018).

Table 6. Simultaneous Quantile Regression Estimates

Dependent variable: ln(HLENDS)	**Coeffi-cientvalues**	**Standard error estimates**	**t-value**	**p-value**	**[95% Conf**	**Interval]**	**Sig**
			Q25 Estimates				
ln(DEFOR)	0.105	0.043	2.45	0.016	0.020	0.189	**
ln(BIORES)	-0.205	0.082	-2.50	0.014	-0.367	-0.043	**
ln(URBAN)	0.455	0.323	1.41	0.161	-0.184	1.094	
ln(GDPPC)	-0.374	0.126	-2.97	0.003	-0.623	-0.125	***
ln(IND)	0.223	0.052	4.29	0.000	0.120	0.326	***
Constant	-0.312	1.370	-0.23	0.820	-3.018	2.394	
			Q50 Estimates				
ln(DEFOR)	0.103	0.039	2.65	0.009	0.026	0.179	***
ln(BIORES)	-0.127	0.066	-1.94	0.055	-0.257	0.003	*
ln(URBAN)	0.235	0.211	1.11	0.268	-0.183	0.653	
ln(GDPPC)	-0.201	0.104	-1.92	0.057	-0.405	0.006	*
ln(IND)	0.211	0.041	5.16	0.000	0.130	0.292	***
Constant	-0.071	1.056	-0.07	0.946	-2.157	2.015	
			Q75 Estimates				
ln(DEFOR)	0.082	0.026	3.19	0.002	0.031	0.133	***
ln(BIORES)	-0.088	0.042	-2.09	0.039	-0.17	-0.005	**
ln(URBAN)	0.088	0.188	0.47	0.641	-0.284	0.460	
ln(GDPPC)	-0.136	0.093	-1.46	0.145	-0.319	0.047	
ln(IND)	0.221	0.030	7.46	0.000	0.163	0.280	***
Constant	0.181	0.614	0.30	0.768	-1.032	1.395	
			Q90 Estimates				
ln(DEFOR)	0.079	0.056	1.41	0.159	-0.032	0.190	
ln(BIORES)	-0.125	0.064	-1.95	0.053	-0.252	0.002	*
ln(URBAN)	0.378	0.205	1.84	0.067	-0.027	0.784	*
ln(GDPPC)	-0.253	0.167	-1.52	0.131	-0.583	0.076	
ln(IND)	0.256	0.032	7.90	0.000	0.192	0.320	***
Constant	-0.487	0.994	-0.49	0.625	-2.451	1.478	

Mean dependent var	4.094	SD dependent var	0.795
Pseudo R^2 of Q25	0.1751	Pseudo R^2 of Q50	0.2349
Pseudo R^2 of Q75	0.2988	Pseudo R^2 of Q90	0.3743
Breusch-Pagan / Cook-Weisberg test for heteroskedasticity Ho: Constant variance chi2(5) = 8.530 Prob > chi2 = 0.129			

Note: *** *p<0.01*, ** *p<0.05*, * *p<0.10*. 'ln' shows natural logarithm, ENDSP shows endangered species, DEFOR shows deforestation, BIORES shows biocapacity reserves, URBAN shows urbanization, GDPPC shows GDP per capita, and IND shows industrial value added.

The diagnostic test values in Table 7 demonstrate that the cross-sectional residual is normally distributed and free of autocorrelation and heteroskedasticity. Additionally, the model is functionally stable within a 5% confidence range (CI). As a result, the regression estimates are trustworthy and statistically valid.

Table 7. Diagnostic Test Estimates (Author's estimation)

DiagnosticTests	**SpecificTests**	**Test Statistics**	**Probability**	**Decision**
Normality Test	Jarque-Bera	2.198	0.333	Residualis normally distributed
Autocorrelation Test	Breusch-Godfrey Serial Correlation LM Test	0.394	0.675	No autocorrelation issue
Heteroskedasticity Test	Heteroskedasticity Test: ARCH	0.134	0.714	Residualis Homoscedastic
Model StabilityTests	CUSUM	Values fall in the con-fidence interval (CI)	p<0.05	Model is stable at 5% CI
	CUSUM Square	Values fall in the CI	p<0.05	

Figure 5 shows the model stability estimates by CUSUM and CUSUM square test and confirms that the estimated model falls within the 5% confidence interval; hence, the regression model is stable over time.

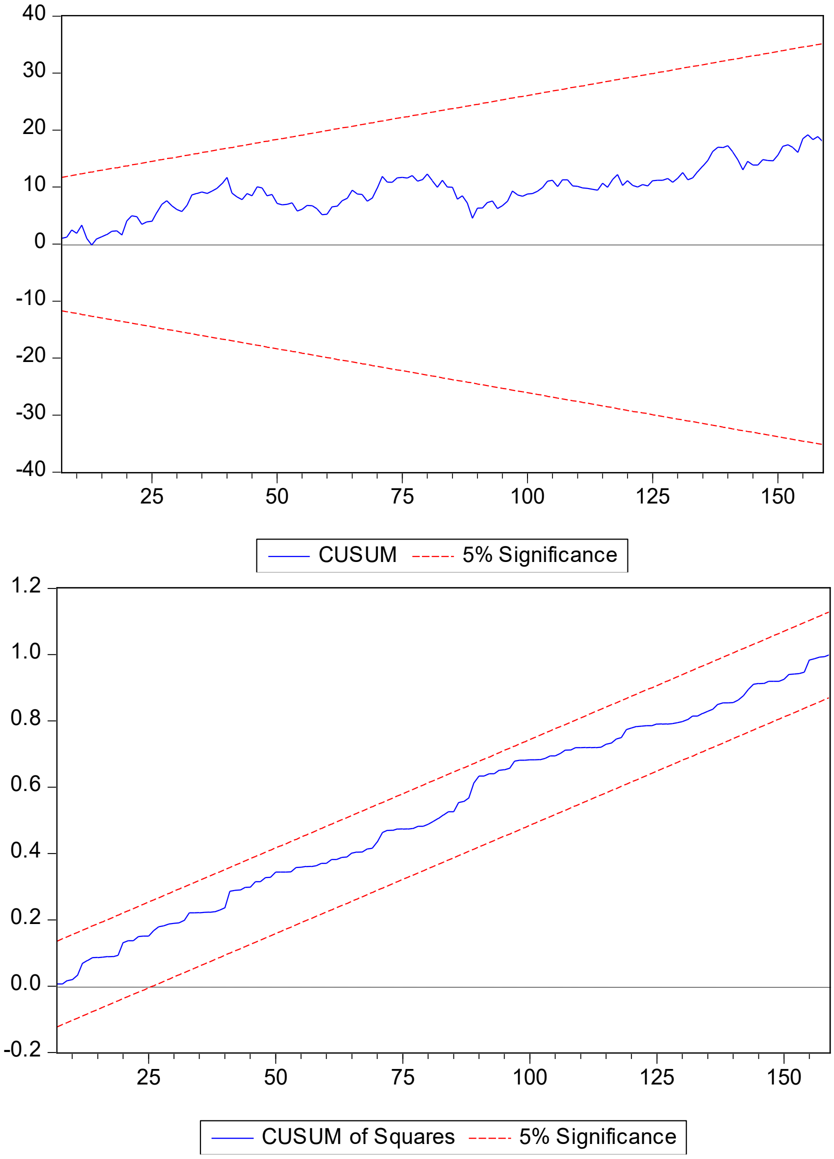

Figure 5. CUSUM and CUSUM Square Estimates (Author's estimation)

Table 8. Slope Equality Test Estimates (Author's estimation)

Test Summary		**Chi-Square-Statistic**	**Chi-Square degree of freedom**	**Prob.**
Wald Test		14.507	10	0.1511
Quantiles	Variable	Restriction Value	Std. Error	Prob.
	ln(DEFOR)	0.001	0.037	0.963
	ln(BIORES)	-0.077	0.062	0.211
	ln(URBAN)	0.220	0.191	0.249
	ln(GDPPC	-0.174	0.086	0.043
0.25, 0.5	ln(IND)	0.011	0.050	0.813
	ln(DEFOR)	0.020	0.036	0.579
	ln(BIORES)	-0.039	0.060	0.515
	ln(URBAN)	0.147	0.170	0.388
	ln(GDPPC)	-0.063	0.088	0.471
0.5, 0.75	ln(IND)	-0.010	0.034	0.773

'ln' shows natural logarithm, DEFOR shows deforestation, BIORES shows biocapacity reserves, URBAN shows urbanization, GDPPC shows GDP per capita, and IND shows industrial value added.

The estimates for the slope equality test are shown in Table 8. The null hypothesis asserts that the slope of the 25th quantile is equal to the slope of the 50th quantile. However, the alternative hypothesis asserts that the specified quantile distribution slopes are not equal. Another null hypothesis is that the slope of the 50th quantile equals the slope of the 75th quantile. The alternative hypothesis rejected the null hypothesis and demonstrated that the slopes of the two quantiles are not identical. To do this, the single Wald test is used, which calculates the chi-square statistics and confirms that the slopes of the various quantiles are not identical, indicating acceptance of the alternative hypothesis. The slope equality test established the validity of using quantile regression on the cross-sectional data set, indicating that the regression estimates are consistent and unbiased.

Table 9 displays the estimates of the symmetric quantiles distribution and determines whether the 25th and 75th quantiles have a symmetric connection with the provided variables. The Wald test restriction computed chi-square statistics revealed that the null hypothesis of asymmetric links between the stated quantiles is rejected against the alternative hypothesis of symmetric relationships, indicating that the quantile symmetric findings are solid and robust.

Table 9. Symmetric Quantiles Estimates (Author's estimation)

Test Summary		**Chi-Square-Statistic**	**Chi-Square degree of freedom**	**Prob.**
Wald Test		0.789	6	0.992
Quantiles	Variable	Restriction Value	Std. Error	Prob.
	ln(DEFOR)	-0.018	0.057	0.742
	ln(BIORES)	-0.038	0.096	0.689
	ln(URBAN)	0.073	0.288	0.800
	ln(GDPPC)	-0.110	0.132	0.405
	ln(IND)	0.021	0.063	0.730
0.25, 0.75	Constant	0.011	1.523	0.994

'ln' shows natural logarithm, ENDSP shows endangered species, DEFOR shows deforestation, BIORES shows biocapacity reserves, URBAN shows urbanization, GDPPC shows GDP per capita, and IND shows industrial value added.

Table 10 illustrates the Granger causality estimates and confirms that deforestation Granger causes habitat loss of endangered species and biocapacity deficit, whereas industrialization has a bidirectional connection. The result implies that continued tropical deforestation endangers biodiversity loss and causes a biocapacity deficit while it moves in tandem with industrialization, as deforestation accelerates industrialization and industrialization accelerates deforestation. As a result, the hypothesis of deforestation-caused habitat loss and deforestation-caused biocapacity deficit is validated across nations. Furthermore, there is unidirectional causation between urbanization and deforestation, confirming the urbanization-led deforestation hypothesis at a particular period. Economic growth Granger causes deforestation, biocapacity reserves, and urbanization, supporting the growth-led deforestation, growth-led biocapacity reserves, and growth-led urbanization hypotheses across nations.

The causation estimations aid in developing long-term sustainable strategies for preventing endangered species habitat loss and maintaining forest resources. According to Table 11, sustained tropical deforestation will reduce biodiversity loss in 2025 and 2028 but will have a different influence on biological capacity among nations in the succeeding years. Additionally, a rise in biocapacity reserves is anticipated to reduce biodiversity loss in 2024, 2028, and 2029 while not supporting the protection of endangered species habitats in the other years. Urbanization is predicted to wreak havoc on the natural habitats of endangered species by the year 2025; hence, smart city planning is critical for protecting invasive species' habitats. Economic growth in 2023, 2026, 2027, and 2030 is anticipated to support environmental services and biodiversity conservation. Finally, industrialization is projected to have a detrimental effect on natural flora and wildlife in 2023, 2025, 2026, and 2030.

Table 10. GrangerCausalityEstimates

Hypotheses	**F-statistics**	**Probability Value**	**Significance**	**Decision**
[ln(DEFOR) →ln(HLENDS)]$_{t-1}$	3.826	0.052	*	UnidirectionalCausality
[ln(DEFOR) →ln(BIORES)]$_{t-3}$	3.967	0.009	***	UnidirectionalCausality
[ln(URBAN) →ln(DEFOR)]$_{t-1}$	4.356	0.038	**	UnidirectionalCausality
[ln(GDPPC) →ln(DEFOR)]$_{t-1}$	5.498	0.020	**	UnidirectionalCausality
[ln(IND) ↔ln(DEFOR)]$_{t-1}$	2.919	0.089	*	BidirectionalCausality
[ln(DEFOR) ↔ln(IND)]$_{t-1}$	4.353	0.038	**	
[ln(GDPPC) →ln(BIORES)]$_{t-1}$	4.022	0.046	**	UnidirectionalCausality
[ln(GDPPC) →ln(URBAN)]$_{t-2}$	2.619	0.076	*	UnidirectionalCausality

Note: *** p<0.01, ** p<0.05, * p<0.10. → shows unidirectional, ↔ shows bidirectional, 't-1' shows first lag, t-2 shows second lag, and t-3 shows third lag, 'ln' shows natural logarithm, HLENDS shows habitat loss of endangered species, DEFOR shows deforestation, BIORES shows biocapacity reserves, URBAN shows urbanization, GDPPC shows GDP per capita, and IND shows industrial value added.

Table 11. IRF Estimates of ln(HLENDS)

Period	ln(HLENDS)	Ln(DEFOR)	ln(BIORES)	ln(URBAN)	ln(GDPPC)	ln(IND)
2022	0.797304	0	0	0	0	0
2023	0.003758	-0.114117	0.000690	-0.066077	-0.063688	0.054381
2024	-0.080772	-0.084680	0.057134	0.074110	-0.013780	-0.061018
2025	0.012600	0.003999	0.020587	0.026558	0.033450	0.006475
2026	0.010945	-0.004586	-0.014643	-0.024906	-0.022465	0.020478
2027	0.002598	-0.007823	-0.007359	-0.004961	-0.009321	-0.005875
2028	-0.000245	-0.002201	0.007327	0.002910	0.007794	-0.003281
2029	-0.001068	0.000590	0.003109	0.000676	0.000361	0.002246
2030	0.000838	-8.63E-05	-0.001137	-0.000246	-0.001513	0.000470
2031	0.000511	-0.000656	-0.000704	-9.47E-05	2.37E-05	-0.000398

Note: 'ln' shows natural logarithm, ENDSP shows endangered species, DEFOR shows deforestation, BIORES shows biocapacity reserves, URBAN shows urbanization, GDPPC shows GDP per capita, and IND shows industrial value added.

Finally, Table 12 summarizes the VDA estimates of endangered species habitat loss. It indicates that deforestation is projected to exert a greater variance on biodiversity loss than other factors, with a magnitude of 2.936 percent over the next ten years. Additionally, urbanization is anticipated to affect endangered species habitat loss by a factor of 1.622 percent. Industrialization, economic development, and biocapacity reserves are all anticipated to have a variance shock of 1.040 percent, 0.870 percent, and 0.581 percent on the natural habitats of endangered species, respectively. Forecasting estimates indicated that continued tropical deforestation, massive urbanization, and increasing industrialization undermined the United Nations Sustainable Development Agenda's number 15 goal of sustainable forest resources, protecting endangered species' habitat loss, designing smart cities, reducing ecological footprints on arable land, and practicing responsible consumption and production.

Table 12. Variance Decomposition Analysis of ln(HLENDS)

Period	S.E.	ln(HLENDS)	ln(DEFOR)	ln(BIORES)	ln(URBAN)	ln(GDPPC)	ln(IND)
2022	0.797304	100	0	0	0	0	0
2023	0.812472	96.30324	1.972801	7.21E-05	0.661427	0.614459	0.448003
2024	0.828538	93.55503	2.941614	0.475587	1.436091	0.618522	0.973157
2025	0.830024	93.24337	2.933411	0.535406	1.533330	0.778719	0.975761
2026	0.831168	93.00432	2.928390	0.564972	1.618908	0.849629	1.033777
2027	0.831329	92.96922	2.936109	0.572588	1.621841	0.861870	1.038369
2028	0.831412	92.95059	2.936222	0.580239	1.622741	0.870485	1.039719
2029	0.831422	92.94850	2.936201	0.581623	1.622767	0.870483	1.040423
2030	0.831425	92.94799	2.936183	0.581806	1.622765	0.870808	1.040448
2031	0.831426	92.94785	2.936239	0.581877	1.622764	0.870807	1.040469

Note: 'ln' shows natural logarithm, HLENDS shows habitat loss of endangered species, DEFOR shows deforestation, BIORES shows biocapacity reserves, URBAN shows urbanization, GDPPC shows GDP per capita, and IND shows industrial value added.

5. Conclusions and Policy Recommendations

The *life on land* topic was covered in the United Nations Sustainable Development Goal No. 15, which underlined the need to restore natural ecosystems by controlling deforestation, managing forest resources, combating desertification, protecting land degradation, and stopping biodiversity loss. Birds, fish, and other animals are becoming increasingly scarce, and their habitats are being impacted by the unsustainable use of terrestrial ecosystems worldwide. Endangered species' habitats must be protected and restored by reducing deforestation and creating biocapacity reserves. The study delves into the biological consequences of biodiversity loss linked to deforestation, biocapacity deficit, urbanization, industrialization, and sustained economic growth across a cross-sectional panel comprising 159 nations, further categorized into low-, middle-, and high-income countries. It would be beneficial to learn more about the progress made toward achieving the specific United Nations sustainable development goal. The quantile regression findings reveal that higher deforestation rates increase habitat loss of endangered species at various quantile (Q) distributions, i.e., Q25, Q50, Q75, and Q90. Land-use conversion for other purposes, such as urban area relocation and industrialization, increases biodiversity loss at different quantile distributions. The restoration of biocapacity reserves and sustained economic expansion aid in the recovery of wildlife species and the sustainable use of terrestrial ecosystems. The Granger causality estimates verified deforestation-induced biodiversity loss and biocapacity deficit, urbanization-induced deforestation, and economic growth-induced deforestation and urbanization. The bidirectional causality was found between deforestation and industrial value-added across countries. According to the IRF and VDA estimates, deforestation, urbanization, and industrialization are likely to be the most detrimental factors affecting the habitat loss of endangered species. On the other hand, expansion of biocapacity reserves and sustainable economic growth would be beneficial in restoring wildlife species over the next ten years. The following strategies are proposed to manage sustainable forest resources in order to assist restore the habitat of endangered species, i.e.,

i) The most effective way to safeguard wildlife by conserving habitat is to manage forest reserves sustainably. Human-made activities on land conversion for other uses resulted in significant destruction of forest land, responsible for devastating species loss. Agriculture growth and meeting the rising population's food security needs are two significant factors that destroy rainforests and create greater biodiversity loss. The following three policy agendas for sustaining forest resources and halting biodiversity loss are possible:
   - Improves rural people's livelihoods by providing financial incentives to repair and conserve forest resources.
   - Establish protected sites for endangered animals to procreate in captivity.
   - Enforcing international laws prohibiting the trade of endangered wildlife species.
   - Biodiversity conservation should be supported globally by stringent rules and regulations to protect endangered species and habitats, and
   - Raising public awareness about the conservation of endangered species' habitat degradation through a mass media campaign would aid in the transition to alternate land use plans.

ii) The development of metropolitan areas and the transformative shift toward industrialization are unfavorable factors regulating the sustainable use of terrestrial ecosystems. The massive rural-urban migration causes resource depletion in cities, resulting in the loss of rainforests to make way for metropolitan areas. Operational locations of industrialization have been located outside of cities, increasing deforestation due to establishing their manufacturing facilities while converting forests into highways and other infrastructure development, inflicting harm on biodiversity sustainability. The following potential corrective measures would be beneficial to resource conservation strategies, i.e.,
   - Reduced rural-urban migration and conserved forest resources via community development initiatives.
   - Utilized and expanded infertile land for the development of urban metropolises
   - Protect the natural habitats of endangered species by establishing protected areas.
   - Agriculture and industrial production should be strategically designed and technologically integrated so that manufacturing requires less arable land.
   - Projects of the Rainforest Alliance should be implemented to combat biodiversity loss and deforestation, and
   - To safeguard endangered species' habitat destruction through smart cities and industrial planning.

iii) Continued economic expansion and a biocapacity deficit, resulting in increased ecological footprints and rainforest destruction. The cost of economic development is biodiversity loss, which is not a viable basis for preventing future resource sustainability agendas. Over a year, human pressure on arable land usage grows, resulting in unavoidable habitat loss for endangered species. Maintaining and restoring forest resources is the ultimate option for enhancing biocapacity reserves and reducing ecological footprints. The following suggestions for halting biodiversity loss and enhancing biocapacity are conceivable, i.e.,
   - Sustainable regional land-use planning can reduce ecological overshoot while optimizing biocapacity reserves.
   - A sustainable way of living in terms of energy use, consumption, and production would reduce negative resource externalities and boost biocapacity stocks.
   - Increasing the productivity of land resources consistent with geographic and climatic circumstances.
   - Financial development is anticipated to play an influential role in investing in long-term agricultural production and livestock through mechanized farming methods and intercropping schemes, and
   - Reducing ecological footprints and developing biocapacity reserves by transforming fossil fuels throughout their life cycles to reduce carbon footprints.

The *life on land* agenda can be advanced efficiently when managing the sustainable use of ecosystems by reducing deforestation and halting habitat loss of endangered species. The agenda can be achieved through increasing biocapacity reserves, sustainable production, efficient land-use policies, and economic growth expansion. The optimization of economic and natural resources boosts reforestation projects, combats desertification, and prevents endangered species habitat loss, all of which are critical for accomplishing a global sustainable resource agenda.

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Appendix

Table A. List of Countries

Afghanistan	Brunei Darussalam	Czech Republic	Greece	Kuwait	Morocco	Qatar	Sweden
Albania	Bulgaria	Denmark	Guatemala	Kyrgyz Republic	Mozambique	Romania	Switzer-land
Algeria	Burkina Faso	Djibouti	Guinea	Lao PDR	Myanmar	Russian Fe-deration	Tajikistan
Angola	Burundi	Dominica	Guinea-Bissau	Latvia	Namibia	Rwanda	Tanzania
Argentina	Cabo Verde	Dominican Republic	Guyana	Lebanon	Nepal	Samoa	Timor-Leste
Armenia	Cambodia	Ecuador	Haiti	Lesotho	Netherlands	Sao Tome and Principe	Togo
Austria	Cameroon	Egypt, Arab Rep.	Honduras	Liberia	New Zealand	Saudi Arabia	Tonga
Azerbaijan	Canada	El Salvador	Hungary	Lithuania	Nicaragua	Senegal	Trinidad and Tobago
Bahamas, The	Central Afri-can Republic	Equatorial-Guinea	Iceland	Luxembourg	Niger	Serbia	Tunisia
Bahrain	Chad	Estonia	India	Madagascar	Nigeria	Seychelles	Turkey
Bangladesh	Chile	Eswatini	Indonesia	Malawi	North Macedonia	Sierra Leone	Turks and Caicos Islands
Belarus	China	Ethiopia	Iraq	Malaysia	Norway	Slovak Republic	Uganda
Belgium	Colombia	Fiji	Ireland	Maldives	Oman	Slovenia	Ukraine
Belize	Comoros	Finland	Israel	Mali	Pakistan	SouthAfrica	United Arab Emirates
Benin	Congo, Dem. Rep.	France	Italy	Mauritania	Panama	Spain	United States
Bhutan	Congo, Rep.	Gabon	Jamaica	Mauritius	Paraguay	Sri Lanka	Uruguay
Bolivia	Costa Rica	Gambia, The	Japan	Mexico	Peru	St. Lucia	Uzbekistan
Bosnia and Herzegovina	Coted'Ivoire	Georgia	Jordan	Moldova	Philippines	St. Vincent and the Grenadines	Vietnam
Botswana	Croatia	Germany	Kazakhstan	Mongolia	Poland	Sudan	Zambia
Brazil	Cyprus	Ghana	Kenya	Montenegro	Portugal	Suriname	**Total countries: 159**