International Journal of Social Science Archives

ISSN: 2707-8892

Available at www.ijssa.com

International Journal of Social Science Archives, December, 2023, 6(3), 1-19

Sustainable Environmental Management: Assessing the Interplay of Climate Change, Socio-Economic Factors and Ecosystem Vitality at the National Level

Noman Arshed[a*], Uzma Hanif[b], Muhammad Umar[c]

[a]Assistant Professor, Department of Economics, University of Education, Lahore, Pakistan. [b]Assistant Professor, Department of Economics, Forman Christian College University, Lahore, Pakistan. [c]Assistant Director Fisheries, Government of Punjab, Pakistan.

[*]**Email:** noman.arshed@ue.edu.pk

***Abstract*:** This study explores the intricate relationships between climate change vulnerability, renewable energy adoption, economic growth dynamics, population density, environmental expenditures, and regulatory quality, examining their collective impact on biodiversity and ecosystem vitality. Employing dynamic panel data estimates, our research underscores that escalating climate change vulnerability exerts a detrimental influence on both biodiversity and ecosystem vitality, underscoring the urgent imperative to address climate vulnerabilities. Furthermore, we reveal a non-linear relationship between economic growth and biodiversity/ecosystem vitality, emphasizing the need for balanced development to avoid negative consequences on biodiversity. High population density emerges as a negative factor affecting biodiversity and ecosystem vitality, while government investments in environmental protection and robust regulatory frameworks play pivotal roles in enhancing both. The study offers vital policy insights, advocating for sustainable environmental management strategies that prioritize climate resilience, responsible energy transitions, and well-structured policies to safeguard our natural ecosystems.

Keywords: Economics of Biodiversity, Ecological Economics, Sustainable Development, Cross Country Analysis

1.Introduction

The adverse consequences of climate change on complex ecosystem as well as habitat have emerged as major issues of environmental economics, attracted the attraction of researchers to address them. Climate change vulnerability, renewable energy production, economic development, population density pressure, increasing environmental expenditures, regulatory quality and their interaction impact on complex ecosystems, habitat conservation as well as ecosystem viability have become urgent research problems, need to be investigated to frame evidence-based policy implications for the stakeholders (EPA, 2022; Malhi et al., 2020). With increasing understanding of environmental degradation and struggle of economies for sustainable development, across the globe, it has become imperative to probe these factors, their interplay and function/s in determining the natural landscape. Climate change, resulting in unrestricting anthropogenic activities such as fossil fuels burning and deforestation, is evident by spatiotemporal variations in the rainfall and snowfall patterns, and an increase in ferocity and frequency of extreme weather events e.g., firenadoes, cyclones, hurricanes, heatwaves, landslide etc., across the world (Climate Action, n.d.; Malhi et al., 2020; Shivanna, 2022). These changes jeopardized the Earth's ecosystem and natural habitat, posed challenges to delicate balance of life on the Planet. Climate change and its resulting environmental stresses are causing loss of biodiversity, destruction of natural habitat, and reduced ecosystem vigour, to name a few concerns of this beast. To address these complex issues, it is crucial to unfold the responsible factors and their interplay that adversely affect the environment of our planet. Therefore, this study aims to provide an evidence-based analysis by taking a variety of factors into account. First, climate change vulnerability, a chief metric that reveals a regions' susceptibility to the environmental degradation along with other adverse impacts to almost all spheres of life, particularly ecosystem degradation and habitat loss. Secondly, exploiting renewable energy sources that play an important role as they have proved sustainable alternative to fossil fuel use with capacity to minimize the adverse consequences of climate change.

Furter, the study will also probe the quadratic impact of GDP and enveloping economic development, as both can be associated either positively or negatively as reported by Environmental Kuznet Curve (Stern, 2004) and Load Capacity curve (Pata & Tanriover, 2023). It will also take population density into account that considers high concentration of population and its resulting stress/s on natural resources as well as on habitat.

Environmental expenditures are defined as financial resources allocated for environmental protection and conservation, whereas regulatory quality referred to the effectiveness of the set of rules and regulations developed for environmental protection. These two factors are chief culprit in determining the paths and levels of a country's commitment for environmental protection.

The study's utmost objective is to recommend evidence-based policy instruments that will guide to develop a balance between economic development and environmental conservation. The outcome of the study will lead towards designing sustainable policies that will ensure health of the complex ecosystem, and habitat in the long term along with vitality of the environment by understanding their multifaceted relationship and also trade-offs between these many factors. Climate change, economic growth, population density, renewable energy, environmental expenditures and regulatory quality along with their interaction will be considered in determining the health of the ecosystems and habitats. The study is driven by dire and urgent need to conserve the environment ensure biodiversity and to secure a robust and resilient ecosystem for sustainable futures.

2. Literature Review

Climate change vulnerability is a chief culprit affecting ecosystems as well as habitats. Climate change vulnerable places are more likely to encounter with loss of biodiversity, habitat degradation, and reduced ecosystem services (IPCC, 2014). Continuously increasing temperatures, extreme weather events and rise in sea level all are consequences of climate change that directly impact ecosystems. Exposing them to further disturbances (Bellard et al., 2012). These disturbances can untimely affect the vitality of ecosystems.

Vulnerability to climate change may affect biodiversity and ecosystem vitality significantly (García-Palacios et al., 2018; Shivanna, 2022). Increasing temperatures have forced animals and plants to migrate to higher elevations or latitudes, with far-reaching consequences for ecosystems. The relationship of temperature and biodiversity is highly complex, whereas the importance of biodiversity to sustain ecosystem functions increase with ambient environmental warming (Climate Action, n.d.; García et al., 2018; Waldock et al., 2018). Consequently, it affects the terrestrial ecosystem carbon services, ecosystem service value, economic development, ecosystem functions and human activities. Plant diversity in response to change in precipitation are relatively strong at regional levels, in particular dryland regions (Korell et al., 2021; Xiang et al., 2019).

A rise in sea level posed serious threats of the survival of seventeen percent of the United States federally protected species. Rising sea level can submerge and erode habitats, increase salinity levels of underground water, crumble coastal plant communities, and affecting biodiversity and overall ecosystem vitality (Dixon et al., 2023; Saving Oceans Blog, 2020). Climate change can ignite the ferocity of extreme events such as cyclones, hurricanes droughts, floods, and wildfires. Thus, these events may bring significant changes in biodiversity and ecosystem vitality, including loss of endangered species, habitat destruction, and undesired changes in ecosystem functions (Malhi et al., 2020; Waldock et al., 2018; Weiskopf et al., 2020). Drought is considered as major physical stress to terrestrial ecosystems. Biodiversity as well as ecosystem vitality potentially hurt by sever and frequent onset of droughts caused by spatial-temporal variations in the precipitation patterns (Xiang et al., 2019). Highlands' fragile biodiversity and ecosystem may further adversely affect Glacial Lake Outbursts Floods (Chettri et al., 2023).

For devising effective adaptation as well as mitigation policies and practices, it is imperative to investigate the potential impact/s of climate change on the health of biodiversity and ecosystem vitality. For improvement of deteriorating environmental quality, mitigation strategies to counter climate change, and protecting withering ecosystem; exploiting renewable energy sources is considered a key strategy across the world (Bashir et al., 2023).

Adoption of renewable energy technologies is suggested by researchers to bring down fatal greenhouse gas emissions, control increasing temperature and also paly an indispensable role in ecosystem resilience (Deshuai et al., 2022; Gasparatos et al., 2017; Łukasiewicz et al., 2022; Niebuhr et al., 2022). For the purpose of overall sustainability, renewable energy projects may possibly reduce the adverse environmental impacts than traditional fossil fuel infrastructure (Aslam et al., 2021), but it may lead to increase in mining threats for metals that are required in renewable energy projects (Sonter et al., 2020, 2023). Overall, transitioning to renewable energy positively affect the health and vitality of ecosystems. Renewable energy production does not affect the environment adversely, it fosters a stringer ecosystem as it is Clean (Marsh, 2023). Green economic growth is vitalizing through clean energy (renewable energy), that strengthens the theory of improving environmental quality via green technological innovations (Wei et al., 2023).

The placement of renewable energy sources can impact biodiversity, as the construction of these sources may threaten plant life and wildlife (Marsh, 2023). Wind turbines, a common form of renewable energy, can kill airborne animals like birds and bats, including many protected species, which can have consequences across the food chain and ecosystems (Millar, 2022).

Protecting biota while navigating the complexities surrounding the transition to renewable energy will require sharing knowledge between energy experts, wildlife experts, policymakers, and resource managers (Tulloch et al., 2016). Developing wind energy in the right locations and using appropriate technologies can help minimize its impact on biodiversity, potentially eliminating the conflict between clean energy and biodiversity (Millar, 2022).

Overall, the literature suggests that while renewable energy transition can negatively impact biodiversity and ecosystem vitality, it also offers significant potential for positive contributions to environmental quality and green economic growth.

The relationship between economic growth (GDP) and environmental outcomes is complex. The Environmental Kuznets Curve (EKC) hypothesis suggests an inverted U-shaped relationship between GDP per capita and environmental degradation (Stern, 2004). In the early stages of economic development, environmental degradation tends to increase, but there is potential for environmental improvement beyond a certain income level. However, this relationship is influenced by various factors, including technology and regulatory quality, which can mediate the environmental impact of economic growth.

More than half of the global GDP, about $44 trillion, relies to some extent on nature, and the decline in biodiversity could take a toll on wealth creation from nature itself (Hoffmann, 2022; Russo, 2020; Struder, 2023; World Bank, 2021). GDP fails to address the negative impacts of externalities such as climate change and inequalities. GDP does not consider the effects of production and consumption on the environment in economic evaluations or market mechanisms. A higher GDP per capita generally indicates a higher rate of per capita CO_2 emissions (Acheampong & Opoku, 2023; Adetunji, 2021; Bove, 2021; Dang et al., 2020).

Biodiversity represents value for many industries and service providers who are essential contributors to the engine of economic growth. Protecting biota while navigating the complexities surrounding GDP will require sharing knowledge between economic experts and wildlife experts, as well as policymakers and resource managers (Brezac, 2020; Hoffmann, 2022; WeConservePA, 2023). We need to reset the relationship between humans and nature and shift biodiversity to the focal point of companies, the economy, governments, scientists, and every individual to shift towards an "inclusive" measure of economic success (Adetunji, 2021; Lewsey, n.d.; Ouyang et al., 2020).

Higher population density can lead to increased resource consumption and habitat fragmentation, which may adversely affect ecosystems (Seto et al., 2012). However, population density can also drive urbanization and technological innovation, which may reduce per capita resource consumption and pollution emissions (Sorel et al., 2023). Therefore, the impact of population density on ecosystems depends on various contextual factors (Schuyler et al., 2021).

There is some evidence that species richness for many taxonomic groups is often highest in areas with high human population density (HPD) (Chown et al., 2003; Evans et al., 2007; Luck, 2007). Greater population density has also been associated with greater functional richness (Mortelliti & Brehm, 2020). While as population density increases, so does the threat to biodiversity (Luck, 2007). Habitat fragmentation and inter-patch distance may positively or negatively affect population density, depending on the direction of both effects (Tischendorf et al., 2005). Human population density adjacent to protected areas is the most significant and consistent predictor of alien and invasive species richness (Spear et al., 2013).

Investment in environmental protection and conservation is a critical factor in preserving ecosystems and habitat quality. Studies indicate that higher environmental expenditures are associated with reduced environmental degradation (Damania et al., 2003). These investments can support the implementation of policies and projects aimed at conserving biodiversity and ecosystem services, thus contributing to ecosystem vitality.

Biodiversity and nature are as critical as climate change for determining humanity's long-term prospects, but until now, they have played a relatively minor role in sustainable investing (Attwell, 2023). However, demand for investment solutions and products to facilitate capital allocation to nature themes is growing(Attwell, 2023). Investor groups, such as Finance for Biodiversity, with over $21 trillion in assets under management, advocate for integrating nature considerations into financial institutions' investment policies and engagement strategies(Attwell, 2023).

Biodiversity finance includes funding for direct actions to protect biodiversity and funding related to various economic sectors, such as agriculture, fisheries, tourism, and forestry (OECD, 2020). There is a need to increase biodiversity finance and develop a common framework to assess and track private finance for biodiversity(OECD, 2020). InVEST (Integrated Valuation of Ecosystem Services and Tradeoffs) models are used to map and value natural goods and services that sustain and fulfil human life (Stanford University, 2023). It enables decision-makers to assess quantified tradeoffs associated with alternative management choices and to identify areas where investment in natural capital can enhance human development and conservation (Stanford University, 2023).

Current funding for biodiversity comes mainly from governments, but this may change as corporations and investors recognize the importance of preserving biodiversity for sustainable economic growth (Graaf & Reinders, 2023). Private sector investments in preserving global biodiversity need to triple by 2030 to meet the sustainability standards of a landmark UN agreement (Morgan Stanley, 2023).

There is an association between environmental health, ecosystem vitality, and human well-being (Folayan et al., 2020). Better ecosystem vitality, including biodiversity and habitat, can offer protection against environmentally communicable diseases through the rational use of resources, healthy life choices, and preventive health practices (Folayan et al., 2020). The most vocal companies on biodiversity topics are often concentrated in sectors associated with a negative environmental impact, such as utilities, materials, and energy(Graaf & Reinders, 2023). Interest in biodiversity credits is rising as another way for companies to bolster their nature footprint(Attwell, 2023). Despite the importance of biodiversity and nature, they remain a long way behind climate factors regarding integration into investment strategies and policies (Attwell, 2023). However, there are opportunities for investors and financial advisors to engage with biodiversity, such as screening companies with known negative impacts on nature in their operations or supply chains (Attwell, 2023).

Regulatory quality, which reflects the effectiveness of environmental policies and regulations, is pivotal in mitigating environmental degradation. Countries with strong regulatory quality tend to have better environmental outcomes (Fredriksson et al., 2005). Effective set of rules and regulations could pave the way towards sustainable resource use as well as habitat protection, thus positively impact ecosystem health.

Regulatory quality, referred to as the governments' ability to devise and implement sound policy instruments and sound set of rules, is considered vital in conserving and enhancing the health of ecosystem services (EPI, 2020). It is a key ingredient to ensure sustainable development not at the cost of health and resilience of ecosystems. The Ecosystem Vitality promoting policy objective measures how well countries are able to preserve, protect, and enhance ecosystems and the services they provide to the economy. It holds 60% share in the total Environmental Performance Index (EPI) score and comprises seven sub-categories highlighting issues, including Biodiversity and habitat, Ecosystem Services, Fisheries, Climate Change, Pollution Emissions, Agriculture, and Water Resources (EPI, 2020).

Biodiversity and climate change are inextricably linked, and institutions are crucial in addressing these challenges. Sustainable finance initiatives, such as the Biodiversity-Sensitive Areas Screening Metrics, enable investors to identify companies with physical assets in areas of high biodiversity relevance, promoting investments that support biodiversity and ecosystem vitality (MSCI, 2023).

Regulatory quality of institutions support biodiversity and ecosystem vitality can lead to substantial economic benefits. Biodiversity underpins economic activity through agriculture, forestry, fisheries products, stable natural hydrological cycles, fertile soils, a balanced climate, and numerous other vital ecosystem services (WeConservePA, 2023). The higher diversity of ecosystem is linked with more stability, productivity, and resilience which benefits human well-being and supporting sustainable economic development. Ensuring regulatory quality that supports biodiversity and ecosystem vitality can be challenging, but it also presents opportunities for governments, businesses, and civil society collaboration. Integrating nature considerations into financial institutions' investment policies and engagement strategies, as advocated by investor groups like Finance for Biodiversity, can help drive positive change and promote sustainable development (MSCI, 2023).

In summary, contemporary research in environmental economics highlights the intricate connections between climate change vulnerability, renewable energy adoption, GDP, population density, environmental expenditures, and regulatory quality, and their combined influence on ecosystem and habitat preservation and ecosystem vitality. These theoretical links underscore the need for a holistic understanding of these variables to formulate policies that promote sustainable development while safeguarding our natural environment.

3.Methods

Table 1 reports the variables used in this study and its sources. The variables BIOD and ECOS are dependent variables, while all others are independent variables in which LGDP is used in quadratic form to account for the Environmental Kuznets Curve hypothesis as discussed in literature (Adeel-Farooq et al., 2023; Jain et al., 2023).

The data is collected for 57 countries from which the data for at least 10 years is available between 1995 to 2022, making total of 1071 observations in unbalanced panel data.

Table 1: Variables and Data Sources

Names (Symbol)	Definition (Units)	Sources
Ecosystem and Habitat (BIOD)	Index of biodiversity and habitat.	Environmental Performance Index
Ecosystem Vitality (ECOS)	Index of Ecosystem vitality excluding the component of biodiversity & and habitat	Environmental Performance Index
Climate Change Vulnerability (VULN)	Index of items which represent the negative impact propensity of human societies by climate change	Notre Dame Global Adaptation Index
Renewable Energy (RENE)	Renewable / clean energy as a	World Development Indicators

	percent of total energy consumption	
Economic Activity (GDP)	Real GDP per capita in US$	World Development Indicators
Population Density (PD)	Population per unit area.	World Development Indicators
Environmental Expenditures (ENVEXP)	Government expenditures on environment related matters % of total expenditures	International Monetary Fund
Regulatory Quality (RQ)	Index between -2.5 to 2.5 represents the perceptions of the government ability to implement sound policies and regulations that promote private sector development.	Worldwide Governance Indicators

$$BIOD_{it} = \alpha_0 + \alpha_1 VULN_{it} + \alpha_2 RENE_{it} + \alpha_3 LGDP_{it} + \alpha_4 LGDP_{it}^2 + \alpha_5 PD_{it} + \alpha_6 ENVEXP_{it} + \alpha_7 RQ_{it} + \varepsilon_{it} \quad --(1)$$

$$ECOS_{it} = \alpha_0 + \alpha_1 VULN_{it} + \alpha_2 RENE_{it} + \alpha_3 LGDP_{it} + \alpha_4 LGDP_{it}^2 + \alpha_5 PD_{it} + \alpha_6 ENVEXP_{it} + \alpha_7 RQ_{it} + \varepsilon_{it} \quad --(2)$$

Equations 1 and 2 represent the estimation models which this study has adapted. Since the data is changing across countries and years, and the number of years exceeds 18 per country on average, this study has adapted dynamic panel data models (Arshed et al., 2018). Further preliminary normality tests showed that the data is not normal, necessitating the use of Panel Quantile ARDL model with PMG specification. PMG specification estimates long run homogenous estimates while providing short run heterogenous estimates (Blackburne & Frank, 2007). Thus, this hybrid estimation setup helps control from cross sectional heteroskedasticity, time series autocorrelation and non-normality of the data (Arshed et al., 2022; Ul-Durar et al., 2023).

4. Results and Discussions

This study puts forward that the ecosystem and habitat (BIOD) and ecosystem vitality, excluding BIOD (ECOS), are important factors to be considered in the country's environment. This study proposes climate change vulnerability (VULN), renewable energy consumption (RENE), Size of the economy (GDP), population density (PD), environmental expenditures (ENVEXP) and regulatory quality (RQ). Table 2, with descriptive statistics, shows that all the variables are non-normally distributed as the Shapiro Wilk test is significant.

Table 2: Descriptive Statistics

Stats	**BIOD**	**ECOS**	**VULN**	**RENE**	**LGDP**	**PD**	**ENVEXP**	**RQ**
Mean	41.72	29.39	0.45	30.55	8.37	328.96	0.59	-0.03
Median	41.91	28.05	0.44	19.08	8.26	65.99	0.57	-0.15
Sd	22.61	16.30	0.09	30.67	1.49	1598.2	0.57	0.99
skewness	0.06	1.18	0.26	0.77	0.12	9.09	12.53	0.09
kurtosis	2.05	6.22	2.35	2.20	2.13	92.70	317.38	2.35
S-Wilk	11.15	13.98	10.14	16.17	12.30	22.99	14.84	9.68
prob	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 3: Correlation Analysis

	BIOD	ECOS	VULN	RENE	LGDP	PD	ENVEXP	RQ
BIOD	1.00							
ECOS	-0.11	1.00						
VULN	-0.56	0.13	1.00					
RENE	-0.03	-0.14	0.16	1.00				
LGDP	0.43	-0.18	-0.82	-0.19	1.00			
PD	-0.25	-0.18	0.08	-0.23	0.15	1.00		
ENVEXP	0.34	-0.04	-0.28	-0.18	0.40	-0.06	1.00	
RQ	0.46	-0.21	-0.73	-0.17	0.88	0.19	0.37	1.00

Table 3 provides the correlation of the variables, here we can see that the first two columns show the correlation of dependent variables with independent variables, where the majority had negative associations owing to the need to find their effects. While other pairwise correlations are under 0.9, indicating no hint of multicollinearity. Figure 1 shows a positive association of GDP with ecosystem vitality. Figure 2 shows negative association of climate change vulnerability with ecosystem vitality.

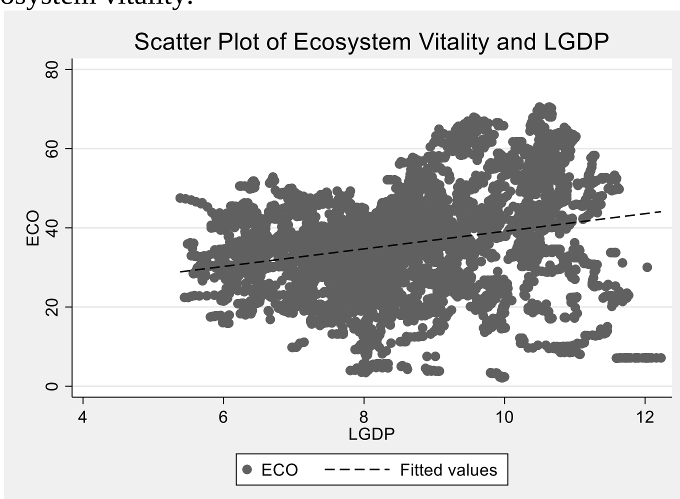

Figure 1: Ecosystem Vitality and Economic Activity

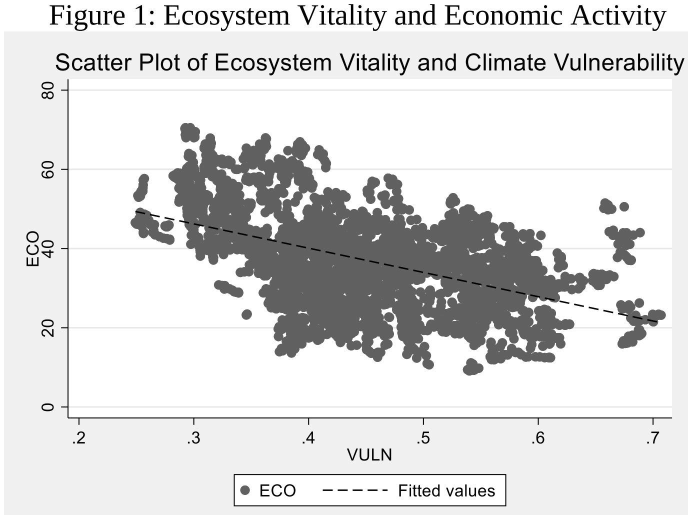

Figure 2: Ecosystem Vitality and Climate Change Vulnerability

Figure 3 shows almost no association between renewable energy and ecosystem vitality. Figure 4 shows positive association between environmental expenditures on ecosystem vitality. Regulatory quality show positive association in figure 5 while population density shows negative association in figure 6.

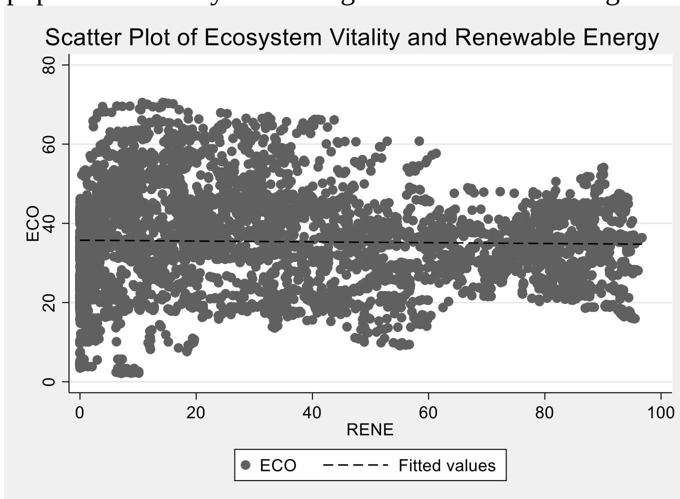

Figure 3: Ecosystem Vitality and Renewable Energy

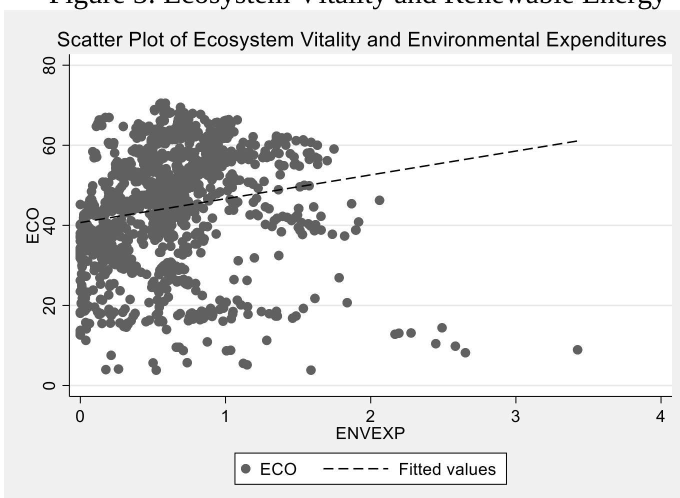

Figure 4: Ecosystem Vitality and Environmental Expenditures

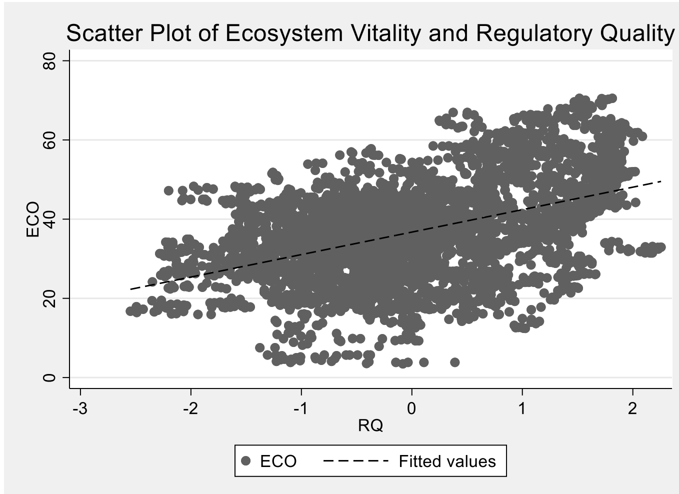

Figure 5: Ecosystem Vitality and Regulatory Quality

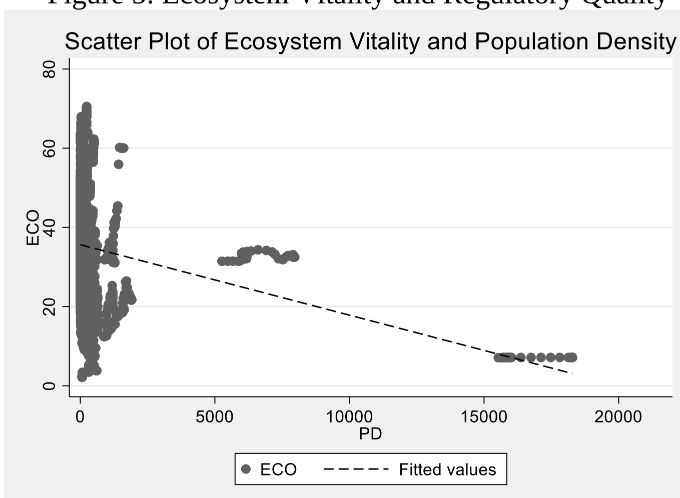

Figure 6: Ecosystem Vitality and Population Density

Table 4: Long Run Panel Quantile ARDL estimates

	BIOD	**ECOS**
VULN	-159.11 (0.00)	-98.57 (0.00)
RENE	-0.009 (0.85)	-0.01 (0.67)
LGDP	33.44 (0.00)	14.21 (0.00)
$LGDP^2$	-2.09 (0.00)	-0.91 (0.00)
PD	-0.004 (0.00)	-0.002 (0.00)
ENVEXP	12.46 (0.00)	5.83 (0.00)
RQ	6.63 (0.00)	5.19 (0.00)
Const.	-22.52 (0.68)	25.86 (0.34)
	Regression Estimates	
Obs.	1071	1071
R squared	0.23	0.31

Wald test	38.82 (0.00)	66.41 (0.00)

The set of variables in the equation 1 and 2 are tested for presence of cointegration using Pedroni test (Pedroni, 2008). For both cases the significance confirmed that there is a long run cointegrated relation in the model. While both residuals of long run models

Table 4 provides the long run estimates of panel quantile regression for the model of BIOD and ECOS. Using sample size of 1071 both models are overall fit as determined by the significant Wald tests. In both models, the similar independent variables are able to explain the changes in BIOD and ECOS by 23% and 31% respectively.

The results showed that increase in climate change vulnerability leads to decrease in biodiversity (BIOD) and ecosystem vitality (ECOS) by 159.11% and 98.57% respectively. These results are similar to (Shivanna, 2022; Weiskopf et al., 2020; Yoshikawa et al., 2023).

Renewable energy has shown insignificant effect on both BIOD and ECOS in long run. A study by (Franklin, 2022) showed that renewable energy can have negligible effect on biodiversity.

GDP and GDP^2 had shown positive and negative effect respectively in both models tracing a ∩ shaped effect on BIOD and ECOS. It iterates that increase in GDP initially assists in increasing BIOD and ECOS but this positive effect diminishes to a point that further increase in GDP lead to a decreasing BIOD and ECOS effect. These results are depicting the outcome of Load Capacity Curve (Adebayo et al., 2022; Guloglu et al., 2023; Huang et al., 2023; Pata & Tanriover, 2023) whereby a high increase in economic activity will overburden the ecosystem.

Population density has shown negative effect on BIOD and ECOS by 0.004% and 0.002% respectively. The studies by (Luck, 2007; Mehring et al., 2020) have confirmed that increase in population density is threat to biodiversity.

Government expenditures on environment play a supportive role in increasing BIOD and ECOS by 12.46% and 5.86% respectively in long run. (OECD, 2020)

Regulatory quality also increases BIOD and ECOS by 6.63% and 5.19% respectively in long run. Similar outcome was concluded by one IUCN study (Kristina, 2008) and a study in China by (Ma & Xu, 2022).

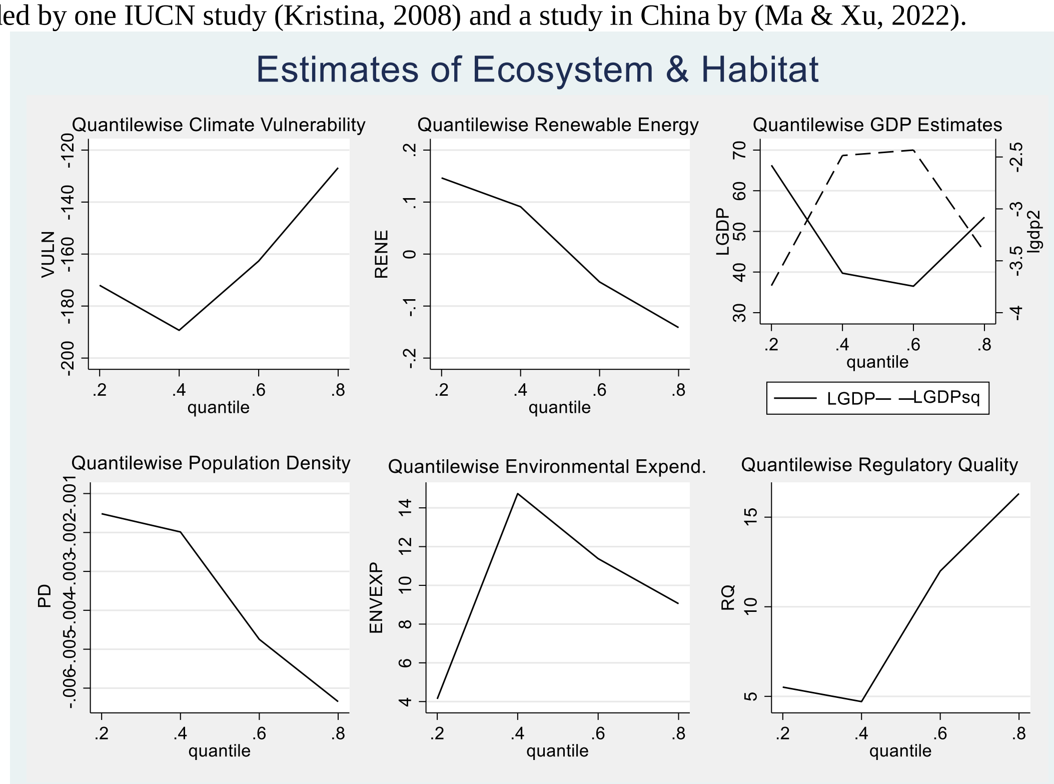

Figure 7: Quantile wise estimates of BIOD model

Figure 7 plots the long run coefficients generated from quantile regression against 20, 40, 60 and 80 percentiles for BIOD model. Each graph shows the effect of independent variable for the change in the percentile position of dependent variable. In the first window, there is a U shaped pattern of effect of VULN against BIOD. In the second window, RENE shown decrease in effects pattern against BIOD. In the third window, LGDP show a U shaped pattern of effects while $LGDP^2$ show a ∩ shaped pattern of effects against BIOD. In the fourth window, there is a decrease in effects pattern of PD against BIOD. In fifth window, there is ∩ shaped pattern of effects of ENVEXP against BIOD. Lastly in sixth window, there is increase in effects of RQ against BIOD.

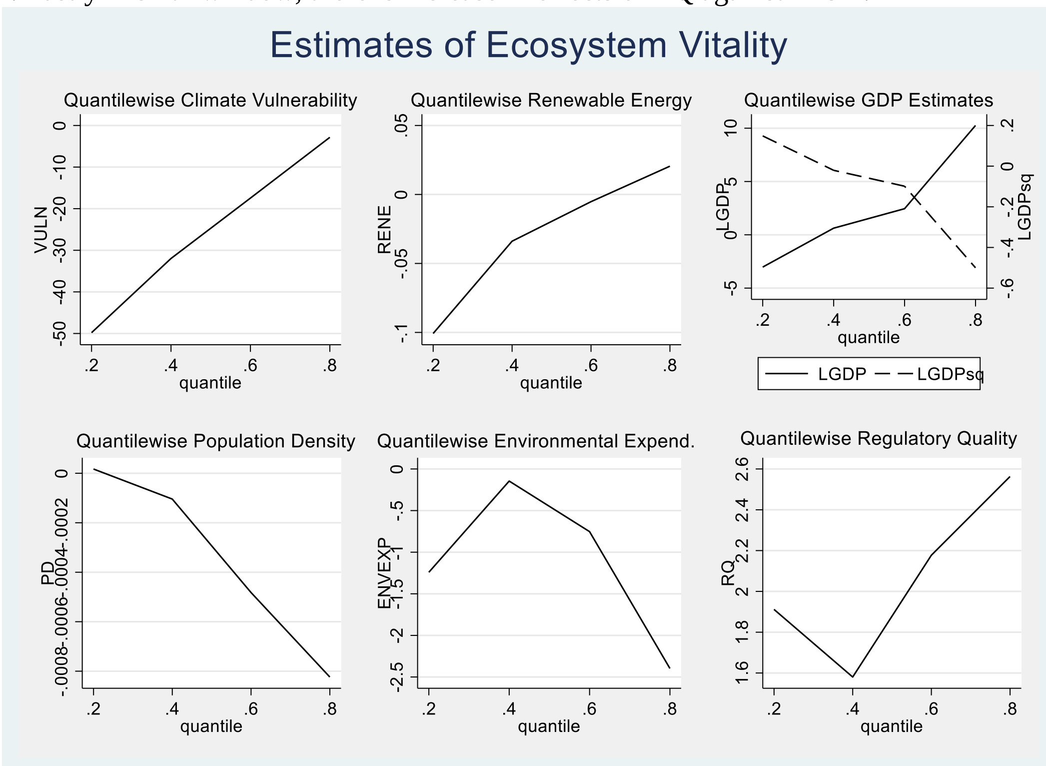

Figure 8: Quantilewise estimates of ECOS model

Figure 8 plots the long run coefficients generated from quantile regression against 20, 40, 60 and 80 percentiles for ECOS model. In the first window, there is a increasing pattern of effect of VULN against ECOS. In the second window, RENE shown increase in effects pattern against ECOS. In the third window, LGDP show an increase in pattern of effects while $LGDP^2$ show a decrease in pattern of effects against ECOS. In the fourth window, there is a decrease in effects pattern of PD against ECOS. In fifth window, there is ∩ shaped pattern of effects of ENVEXP against ECOS. Lastly in sixth window, there is increase in effects of RQ against ECOS.

Table 5: Short Run Estimates of Pane Quantile ARDL

	ΔBIOD	ΔECOS
ΔVULN	11.14 (0.04)	-4.79 (0.50)
ΔRENE	0.006 (0.55)	0.02 (0.12)
ΔLGDP	-6.52 (0.03)	5.28 (0.17)
$\Delta LGDP^2$	0.33 (0.04)	-0.29 (0.17)
ΔPD	-0.001 (0.09)	0.001 (0.19)
ΔENVEXP	-0.004 (0.97)	0.06 (0.68)
ΔRQ	0.10 (0.48)	0.04 (0.83)
ECM_{-1}	-0.003 (0.00)	-0.008 (0.00)
Const.	0.21 (0.00)	-0.05 (0.00)
Obs.	1014	1014
R squared	0.01	0.01
Wald test	3.03 (0.00)	2.45 (0.01)

Table 5 shows the overall long run estimates for BIOD and ECOS variables while countrywise estimates are reported in appendix. Here we can see that in the short run only variables in BIOD model are significant while the convergence coefficient is negative and significant showing that there is a convergence in the model for any intervention in terms of independent variables.

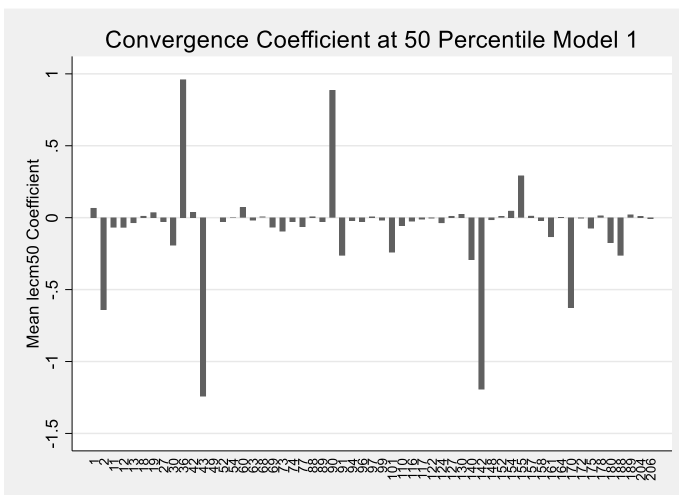

Figure 9: Country Wise Convergence Coefficient for BIOD model

Figure 9 shows the plot of convergence coefficient of the country wise estimates from BIOD short run model. Here we can see that few countries have shown positive convergence coefficient indicating that the long run model do not converge in those countries.

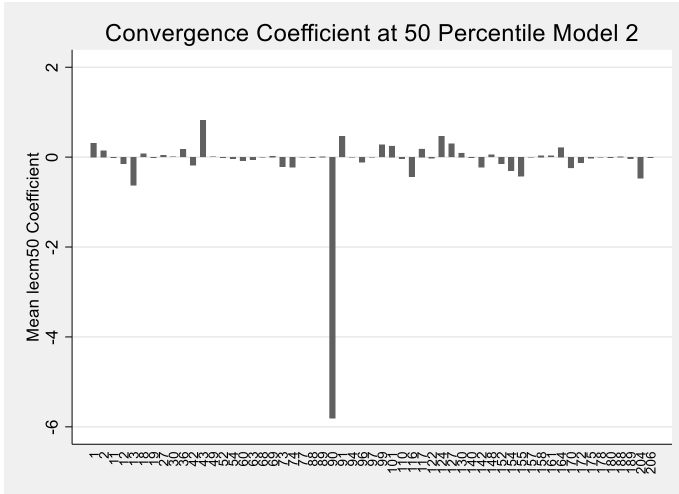

Figure 10: Country wise Convergence Coefficient for ECOS model

Figure 10 shows the plot of the convergence coefficient of the country wise estimates from ECOS short-run model. Here we can see that few countries have shown a positive convergence coefficient, indicating that the long run model does not converge in those countries.

5.Conclusion and Policy Implications

The panel median-based regression analysis conducted in this study has shed light on the climate change vulnerability, renewable energy, economic growth (measured by GDP and its quadratic effect), population density, environmental expenditures, and regulatory quality, and their collective impact on biodiversity (BIOD) and ecosystem vitality (ECOS) relationship. The findings draw from the analysis are valuable in exploring the environmental consequences of human activities.

This study has explored the critical consequence of environment change that is depreciating biodiversity and ecosystem vitality. The analysis significantly connected the climate change vulnerability with the ecosystem indicators (BIOD and ECOS) used in the study. The outcomes are confirming the outcomes of (Shivanna, 2022; Weiskopf et al., 2020; Yoshikawa et al., 2023), where they highlighted that climate vulnerability would manifest in different forms in the economy. The selected sample of the study supported no effect of renewable energy development in preservation of biodiversity. Franklin (2022) iterated this notion that renewable energy helps in reducing carbon emissions but they do not have any contribution in preserving biodiversity.

The quantile analysis showed a ∩-shaped GDP and BIOD and ECOS relationship. According to this GDP increase from low to high would improve BIOD and ECOS as economies would be above to afford social projects, but there is a diminishing effect that leads to decreasing effect after a threshold. This pattern of effects supports the Load Capacity Curve Hypothesis Curve (Adebayo et al., 2022; Guloglu et al., 2023; Huang et al., 2023). This indicates that economic activity tends to become overburdening. There is need to find a balance between economic activity and ecosystem and intervene appropriately so that growth can be achieved without harming the environment.

For the case of controlling variables, increase in population density have also shown harming effects as discussed in literature by (Luck, 2007; Mehring et al., 2020). They point out that sustainable urban planning must be included to mitigate the biodiversity loss. Other indicators like government environmental expenditures and regulations are beneficial for biodiversity. Thus, these must be included in the environmental policies. OECD (2020), Kristina (2008), and Ma and Xu (2022) also highlighted these well-structured environmental policies and ecological conservation investments must be deployed.

Conclusively, the following are some policy directives extracted from this study. Climate change vulnerability at the national level must be abated. Environmental harm that disturbs the climate must be reduced. Even though renewable energy is fruitful for abating environmental harm, it is lacking ability to restore the biodiversity loss.

Policymakers must develop renewable energy infrastructure by incorporating indigenous knowledge so that infrastructure change do not disturb the biodiversity. The environment and growth trade-off like Load Capacity Curve discussed in many studies must be taken care of. Population management in urban setup in important so that urban growth do not substitute the habitat diversity. Environmental protection investments along with strict regulatory measures are needed to support biodiversity as pointed out by OECD and IUCN studies.

References

Acheampong, A. O., & Opoku, E. E. O. (2023). Environmental degradation and economic growth: Investigating linkages and potential pathways. *Energy Economics*, *123*, 106734.

Adebayo, T. S., Pata, U. K., & Akadiri, S. S. (2022). A comparison of CO2 emissions, load capacity factor, and ecological footprint for Thailand's environmental sustainability. *Environment, Development and Sustainability*. https://doi.org/10.1007/s10668-022-02810-9

Adeel-Farooq, R. M., Raji, J. O., & Qamri, G. M. (2023). Does financial development influence the overall natural environment? An environmental performance index (EPI) based insight from the ASEAN countries. *Environment, Development and Sustainability*, *25*(6), 5123–5139. https://doi.org/10.1007/s10668-022-02258-x

Adetunji, J. (2021, December 13). *GDP ignores the enviroment: Why it's time for more sustainable growth metric*. The Conversation. https://theconversation.com/gdp-ignores-the-environment-why-its-time-for-a-more-sustainable-growth-metric-170820

Arshed, N., Anwar, A., Kousar, N., & Bukhari, S. (2018). Education enrollment and income inequality: A case of SAARC economies. *Social Indicators Research*, *140*, 1211–1224.

Arshed, N., Nasir, S., & Saeed, M. I. (2022). Impact of the External Debt on Standard of Living: A Case of Asian Countries. *Social Indicators Research*, *163*(1), 321–340. https://doi.org/10.1007/s11205-022-02906-9

Aslam, B., Zafar, A., Khalil, U., & Azam, U. (2021). Seismic activity prediction of the northern part of Pakistan from novel machine learning technique. *Journal of Seismology*, *25*(2), 639–652.

Attwell, W. (2023, October 26). Comment: Why biodiversity is about to go mainstream in ESG investing. *Reuters*. https://www.reuters.com/sustainability/land-use-biodiversity/comment-why-biodiversity-is-about-go-mainstream-esg-investing-2023-10-26/

Bashir, M. A., Dengfeng, Z., Amin, F., Mentel, G., Raza, S. A., & Bashir, M. F. (2023). Transition to greener electricity and resource use impact on environmental quality: Policy based study from OECD countries. *Utilities Policy*, *81*, 101518. https://doi.org/10.1016/j.jup.2023.101518

Bellard, C., Bertelsmeier, C., Leadley, P., Thuiller, W., & Courchamp, F. (2012). Impacts of climate change on the future of biodiversity. *Ecology Letters*, *15*(4), 365–377. https://doi.org/10.1111/j.1461-0248.2011.01736.x

Blackburne, E. F., & Frank, M. W. (2007). Estimation of nonstationary heterogeneous panels. *Stata Journal*, *7*(2), 197–208.

Bove, T. (2021, January 7). *How GDP negatively affects climate change policy*. Earth.Org. https://earth.org/gdp-climate-change/

Brezac, A. (2020). *Biodiversity and economic growth: A fusional relationship* (Investment Acumen: Axa Investment Managers' Research Review, p. 73).

Chettri, N., Adhikari, B., Chaudhary, S., & Wangchuk, K. (2023). Changing discourses in the third pole: A systematic review of climate change impact on biodiversity in the Hindu Kush Himalaya. *Ecological Indicators*, *155*, 111046. https://doi.org/10.1016/j.ecolind.2023.111046

Chown, S. L., Rensberg, B. J. V., Gaston, K. J., Rodrigues, A. S. L., & Jaarsveld, A. S. V. (2003). Energy, species richness and human population size: Conservation implications at a national scale. *Ecological Applications*, *13*(5), 1233–1241.

Climate Action. (n.d.). *Biodiversity- our strongest natural defense against cliamte change*. United Nations. https://www.un.org/en/climatechange/science/climate-issues/biodiversity

Damania, R., Fredriksson, P. G., & List, J. A. (2003). Trade liberalization, corruption, and environmental policy formation: Theory and evidence. *Journal of Environmental Economics and Management*, *46*(3), 490–512.

Dang, H. H., Fu, H., & Serajuddin, U. (2020, January 14). *Does GDP growth necissitate environmental degradation?* World Bank Blogs. https://blogs.worldbank.org/opendata/does-gdp-growth-necessitate-environmental-degradation

Deshuai, M., Hui, L., & Ullah, S. (2022). Pro-environmental behavior–Renewable energy transitions nexus: Exploring the role of higher education and information and communications technology diffusion. *Frontiers in Psychology*, *13*, 1010627. https://doi.org/10.3389/fpsyg.2022.1010627

Dixon, O., Gammal, J., Clark, D., Ellis, J. I., & Pilditch, C. A. (2023). Estimating Effects of Sea Level Rise on Benthic Biodiversity and Ecosystem Functioning in a Large Meso-Tidal Coastal Lagoon. *Biology*, *12*(1), Article 1. https://doi.org/10.3390/biology12010105

EPA. (2022, December 13). *Climate Chante Impacts on Ecosystems*. United States Environmental Protection Agency. https://www.epa.gov/climateimpacts/climate-change-impacts-ecosystems

EPI. (2020). *Ecosystem Vitality*. Environmental Performance Index. https://epi.yale.edu/epi-results/2020/component/eco

Evans, K. L., Greenwood, J. J. D., & Gaston, K. J. (2007). The Positive Correlation between Avian Species Richness and Human Population Density in Britain Is Not Attributable to Sampling Bias. *Global Ecology and Biogeography*, *16*(3), 300–304.

Folayan, M. O., El Tantawi, M., Schroth, R. J., Kemoli, A. M., Gaffar, B., Amalia, R., & Feldens, C. A. (2020). Association Between Environmental Health, Ecosystem Vitality, and Early Childhood Caries. *Frontiers in Pediatrics*, *8*, 196. https://doi.org/10.3389/fped.2020.00196

Franklin, P. (2022, January 31). *Expanding renewable energy need not hinder conservation of biodiversity*. Department of Plant Sciences. https://www.plantsciences.ucdavis.edu/news/expanding-renewable-energy-need-not-hinder-conservation-biodiversity

Fredriksson, P. G., Neumayer, E., Damania, R., & Gates, S. (2005). Environmentalism, democracy, and pollution control. *Journal of Environmental Economics and Management*, *49*(2), 343–365.

García, F. C., Bestion, E., Warfield, R., & Yvon-Durocher, G. (2018). Changes in temperature alter the relationship between biodiversity and ecosystem functioning. *Proceedings of the National Academy of Sciences*, *115*(43), 10989–10994. https://doi.org/10.1073/pnas.1805518115

García-Palacios, P., Gross, N., Gaitán, J., & Maestre, F. T. (2018). Climate mediates the biodiversity–ecosystem stability relationship globally. *Proceedings of the National Academy of Sciences*, *115*(33), 8400–8405.

Gasparatos, A., Doll, C. N. H., Esteban, M., Ahmed, A., & Olang, T. A. (2017). Renewable energy and biodiversity: Implications for transitioning to a Green Economy. *Renewable and Sustainable Energy Reviews*, *70*, 161–184. https://doi.org/10.1016/j.rser.2016.08.030

Graaf, K. D., & Reinders, S. (2023, April 20). *Unlocking hudden investment opportunities in biodiversity*. Goldman Sachs.https://www.gsam.com/content/gsam/global/en/market-insights/gsam-insights/perspectives/2023/biodiversity-investment-opportunities.html

Guloglu, B., Emre Caglar, A., & Korkut Pata, U. (2023). Analyzing the determinants of the load capacity factor in OECD countries: Evidence from advanced quantile panel data methods. *Gondwana Research*, *118*, 92–104.

Hoffmann, L. (2022, March 4). *Biodiversity and Economy—An Underestimated Relationship*. United Nations Unieversity. https://flores.unu.edu/en/news/news/biodiversity-and-economy-an-underestimated-relationship.html

Huang, Y., Villanthenkodath, M. A., & Haseeb, M. (2023). The nexus between eco-friendly technology and environmental degradation in India: Does the N or inverted N-shape load capacity curve (LCC) hypothesis hold?. In *Natural Resources Forum*. Blackwell Publishing.

IPCC. (2014). *Climate Change 2014: Impacts, Adaptation, and Vulnerability*. The Intergovernmetnal Panel for Climate Change. https://www.ipcc.ch/report/ar5/wg2/

Jain, M., Jain, T., & Jain, P. (2023). Revisiting the nexus between economic growth and environment health: An empirical study on 180 nations. *Environmental Science and Pollution Research*.

Korell, L., Auge, H., Chase, J. M., Harpole, W. S., & Knight, T. M. (2021). Responses of plant diversity to precipitation change are strongest at local spatial scales and in drylands. *Nature Communications, 12*.

Kristina, M. G. (2008). *Regulatory and Governance Gaps in the International Regime for the Conservation and Sustainable Use of Marine Biodiversity in Areas beyond National Jurisdiction* (IUCN Environmental Policy and Law Papers Online – Marine Series No. 1). IUCN.

Lewsey, F. (n.d.). *Desgupta Review: Nature's value must be at the heart of economics*. University of Cambridge. https://www.cam.ac.uk/stories/dasguptareview

Luck, G. W. (2007). A review of the relationships between human population density and biodiversity. *Biological Reviews*, *82*(4), 607–645. https://doi.org/10.1111/j.1469-185X.2007.00028.x

Łukasiewicz, K., Pietrzak, P., Kraciuk, J., Kacperska, E., & Cieciora, M. (2022). Sustainable Energy Development—A Systematic Literature Review. *Energies*, *15*(21), Article 21.

Ma, X., & Xu, J. (2022). Impact of Environmental Regulation on High-Quality Economic Development. *Frontiers in Environmental Science*, *10*. https://www.frontiersin.org/articles/10.3389/fenvs.2022.896892

Malhi, Y., Franklin, J., Seddon, N., Solan, M., Turner, M. G., Field, C. B., & Knowlton, N. (2020). Climate change and ecosystems: Threats, opportunities and solutions. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *375*(1794), 20190104. https://doi.org/10.1098/rstb.2019.0104

Marsh, J. (2023, March 17). *How renewable energy impacts biodiversity*. Endangered.Co. https://www.endangered.org/how-renewable-energy-impacts-biodiversity/

Mehring, M., Mehlhaus, N., Ott, E., & Hummel, D. (2020). A systematic review of biodiversity and demographic change: A misinterpreted relationship? *Ambio*, *49*(7), 1297–1312. https://doi.org/10.1007/s13280-019-01276-w

Millar, A. (2022, March 22). *The impact of with turbines on biodiversity and how to minimize it*. NS Energy. https://www.nsenergybusiness.com/features/the-impact-of-wind-turbines-on-biodiversity-and-how-to-minimise-it/

Morgan Stanley. (2023, May 19). *How investing can protect global biodiversity*. Morgan Stanley. https://www.morganstanley.com/ideas/biodiversity-investing-rising-importance

Mortelliti, A., & Brehm, A. M. (2020). Environmental heterogeneity and population density affect the functional diversity of personality traits in small mammal populations. *Proceedings of the Royal Society B: Biological Sciences*, *287*(1940), 20201713. https://doi.org/10.1098/rspb.2020.1713

MSCI. (2023). *WHy biodiversity matters*. https://www.msci.com/our-solutions/climate-investing/biodiversity-sustainable-finance

Niebuhr, B. B., Sant'Ana, D., Panzacchi, M., van Moorter, B., Sandström, P., Morato, R. G., & Skarin, A. (2022). Renewable energy infrastructure impacts biodiversity beyond the area it occupies. *Proceedings of the National Academy of Sciences*, *119*(48), e2208815119. https://doi.org/10.1073/pnas.2208815119

OECD. (2020). *A comprehesive overview of global biodiversity finance*. https://www.oecd.org/environment/resources/biodiversity/report-a-comprehensive-overview-of-global-biodiversity-finance.pdf

Ouyang, Z., Song, C., Zheng, H., Polasky, S., Xiao, Y., Bateman, I. J., Liu, J., Ruckelshaus, M., Shi, F., Xiao, Y., Xu, W., Zou, Z., & Daily, G. C. (2020). Using gross ecosystem product (GEP) to value nature in decision making. *Proceedings of the National Academy of Sciences*, *117*(25), 14593–14601. https://doi.org/10.1073/pnas.1911439117

Pata, U. K., & Tanriover, B. (2023). Is the Load Capacity Curve Hypothesis Valid for the Top Ten Tourism Destinations? *Sustainability*, *15*(2), 960. https://doi.org/10.3390/su15020960

Pedroni, P. (2008). *Nonstationary panel data*. Notes for IMF Course.

Russo, A. (2020, January 19). *Https://www.weforum.org/press/2020/01/half-of-world-s-gdp-moderately-or-highly-dependent-on-nature-says-new-report/*. World Economic Forum.

Saving Oceans Blog. (2020, October 21). *Sea Level Rise, and the Impacts on Biodiversity*. Saving Oceans Org. https://savingoceans.org/blog/f/sea-level-rise-and-the-impacts-on-biodiversity

Schuyler, Q., Wilcox, C., Lawson, T. J., Ranatunga, R. R. M. K. P., Hu, C.-S., Global Plastics Project Partners, & Hardesty, B. D. (2021). Human Population Density is a Poor Predictor of Debris in the Environment. *Frontiers in Environmental Science*, *9*. https://www.frontiersin.org/articles/10.3389/fenvs.2021.583454

Seto, K. C., Güneralp, B., & Hutyra, L. R. (2012). Global forecasts of urban expansion to 2030 and direct impacts on biodiversity and carbon pools. *Proceedings of the National Academy of Sciences*, *109*(40), 16083–16088. https://doi.org/10.1073/pnas.1211658109

Shivanna, K. R. (2022). Climate change and its impact on biodiversity and human welfare. *Proceedings of the Indian National Science Academy. Part A, Physical Sciences*, *88*(2), 160–171.

Sonter, L. J., Dade, M. C., Watson, J. E. M., & Valenta, R. K. (2020). Renewable energy production will exacerbate mining threats to biodiversity. *Nature Communications*, *11*(1), Article 1. https://doi.org/10.1038/s41467-020-17928-5

Sonter, L. J., Maron, M., Bull, J. W., Giljum, S., Luckeneder, S., Maus, V., McDonald-Madden, E., Northey, S. A., Sánchez, L. E., Valenta, R., Visconti, P., Werner, T. T., & Watson, J. E. M. (2023). How to fuel an energy transition with ecologically responsible mining. *Proceedings of the National Academy of Sciences*, *120*(35), e2307006120. https://doi.org/10.1073/pnas.2307006120

Sorel, M. H., Murdoch, A. R., Zabel, R. W., Kamphaus, C. M., Buhle, E. R., Scheuerell, M. D., & Converse, S. J. (2023). Effects of population density and environmental conditions on life-history prevalence in a migratory fish. *Ecology and Evolution*, *13*(5), e10087. https://doi.org/10.1002/ece3.10087

Spear, D., Foxcroft, L. C., Bezuidenhout, H., & McGeoch, M. A. (2013). Human population density explains alien species richness in protected areas. *Biological Conservation*, *159*, 137–147.

Stanford University. (2023). *InVEST*. Natrual Capital Project Stanford University.

Stern, D. I. (2004). The Rise and Fall of the Environmental Kuznets Curve. *World Development*, *32*(8), 1419–1439. https://doi.org/10.1016/j.worlddev.2004.03.004

Struder, N. (2023, January 26). *Half of Global GDP relies on nature- but it's being wiped out. Here's the business case for investing in biodiversity*. Fortune. https://fortune.com/2023/01/26/half-global-gdp-environment-nature-business-case-for-investing-biodiversity-nick-studer/

Tischendorf, L., Grez, A., Zaviezo, T., & Fahrig, L. (2005). Mechanisms Affecting Population Density in Fragmented Habitat. *Ecology and Society*, *10*(1). https://www.jstor.org/stable/26267703

Tulloch, A. I. T., Pichancourt, J.-B., Gosper, C. R., Sanders, A., & Chadès, I. (2016). Fire management strategies to maintain species population processes in a fragmented landscape of fire-interval extremes. *Ecological Applications*, *26*(7), 2175–2189. https://doi.org/10.1002/eap.1362

Ul-Durar, S., Arshed, N., Anwar, A., Sharif, A., & Lin, W. (2023). How does economic complexity affect natural resource extraction in resource rich countries? *Resources Policy*, *86*, 104214.

Waldock, C., Dornelas, M., & Bates, A. E. (2018). Temperature-Driven Biodiversity Change: Disentangling Space and Time. *Bioscience*, *68*(11), 873. https://doi.org/10.1093/biosci/biy096

WeConservePA. (2023). *Economic Benefits of Biodiversity*. https://library.weconservepa.org/guides/95-economic-benefits-of-biodiversity

Wei, S., Jiandong, W., & Saleem, H. (2023). The impact of renewable energy transition, green growth, green trade and green innovation on environmental quality: Evidence from top 10 green future countries. *Frontiers in Environmental Science*, *10*. https://www.frontiersin.org/articles/10.3389/fenvs.2022.1076859

Weiskopf, S. R., Rubenstein, M. A., Crozier, L. G., Gaichas, S., Griffis, R., Halofsky, J. E., Hyde, K. J. W., Morelli, T. L., Morisette, J. T., Muñoz, R. C., Pershing, A. J., Peterson, D. L., Poudel, R., Staudinger, M. D., Sutton-Grier, A. E., Thompson, L., Vose, J., Weltzin, J. F., & Whyte, K. P. (2020). Climate change effects on biodiversity, ecosystems, ecosystem services, and natural resource management in the United States. *Science of The Total Environment*, *733*, 137782. https://doi.org/10.1016/j.scitotenv.2020.137782

World Bank. (2021, July 1). *Protecting Nature Could Avert Global Economic Losses of $2.7 Trillion Per Year*. The World Bank. https://www.worldbank.org/en/news/press-release/2021/07/01/protecting-nature-could-avert-global-economic-losses-of-usd2-7-trillion-per-year

Xiang, J., Zhang, W., Song, X., & Li, J. (2019). Impacts of Precipitation and Temperature on Changes in the Terrestrial Ecosystem Pattern in the Yangtze River Economic Belt, China. *International Journal of Environmental Research and Public Health*, *16*(23), Article 23. https://doi.org/10.3390/ijerph16234872

Yoshikawa, T., Koide, D., Yokomizo, H., Kim, J. Y., & Kadoya, T. (2023). Assessing ecosystem vulnerability under severe uncertainty of global climate change. *Scientific Reports*, *13*, 5932.