Irfan, Muhammad; Cherian, Jabcob; Rahman, Abdul Aziz Abdul et al.

Article

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International Journal of Energy Economics and Policy

Provided in Cooperation with:
International Journal of Energy Economics and Policy (IJEEP)

Reference: Irfan, Muhammad/Cherian, Jabcob et. al. (2022). Measuring the impact of air pollutants on ecological footprint, Forest Area and Cropland. In: International Journal of Energy Economics and Policy 12 (1), S. 444 - 452.
https://econjournals.com/index.php/ijeep/article/download/12631/6632.
doi:10.32479/ijeep.12631.

International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2022, 12(1), 444-452.

Measuring the Impact of Air Pollutants on Ecological Footprint, Forest Area and Cropland

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Received: 15 September 2021 **Accepted:** 26 December 2021 **DOI:** https://doi.org/10.32479/ijeep.12631

ABSTRACT

The purpose of this study is to investigate the impact of air pollutants including carbon dioxide emissions (CO_2), Nitrogen oxides (NOx) and nitrous oxide (NO_2) over the period 1975 to 2020 on ecological footprint, Forest area and cropland. The study used GDP and trade openness as control variable in establishing the long run and short relationship between air pollutants and ecological footprint and its sub-components. The study used Johannsson co-integration and error correction model co-integrating relationship and elasticities. The study found that there exist at least three cointegrating equations for ecological footprint and forest area while four cointegrating equation for cropland. The results shows that model CO_2, NO_2 and TOP reduces the pressure on EF in long run while NOx and GDP damage the EF by utilizing more natural resources during production of goods and services. However, CO_2 concentration increases as forest area increases while NOx damage the cropland. The ECM shows that speed of adjustment is 90% for forest area and 50% and 40% for EF and cropland respectively. Carbon overdose is mainly caused by fossil fuel burning and forest destruction, which continuously accumulates as a result of industrialization. The study found that pollutants, such as CO_2, NO_2 and NOx also potential to damage ecosystems and only clean air is a desirable policy option for green economy.

Keywords: Air Pollutants, Ecological Footprint, Atmospheric Gases, Co-integrating Regressions, Error Correction Model
JEL Classifications: Q01, Q53, Q57

1. INTRODUCTION

Environmental pollution refers to the chemical process in which certain biological and physical components in the atmosphere are changed from the natural beauty of air to hazardous contamination. There are several types of environmental pollution, including (i) soil pollutants caused mainly by poor agricultural practices and industrial waste disposal. (ii) air pollutants are mainly caused by industrial activities and transportation (Bhuiyan et el., 2018). Ozone, particulate matter Carbon dioxide (CO_2), Sulfur dioxide (SO_2), Nitrogen oxide (N_2O), Nitrous oxide (NOx) and lead are the most common air pollutants caused by disposal of industrial wastes in the water, septic systems, and illegal dumping of solid waste of mercury, phosphorus, and bacterial pollution. Methane (CH4) emissions are primarily associated with the transportation and production of natural gas, coal, and oil while NOx is linked with high use of pesticides and fertilizers in agricultural. Furthermore, housing construction is considered another potential source of environmental pollution that depletes forestry, wildlife activities, and various plant species (Lvovsky et al., 2000).

There are numerous unhygienic man-made activities that cause the toxicological effects of notorious pollutants, including (i) Massive population growth enabled by inadequacy of healthcare infrastructure, (ii) inappropriate sewage disposal caused by large drains in the water system, (iii) industrial wastes and pollution that generated new toxic air pollutants, (iv) radioactive waste due to contamination by unsustainable processes, etc., which have a significant impact on global environment (Wasi et al., 2013).

Due to rapid urbanization, industrialization, trade liberalization policies, and massive population expansion, the loss of ecosystems and biological diversity is one of the most critical challenges that are faced by planets. Kappelle et al. (1999) examined the possible impacts of climate change on biodiversity loss and argued that the relationship is complicated. Direct impacts of urbanization primarily consist of habitat loss and degradation, altered disturbance regimes, modified soils and other physical transformations caused by the expansion of urban areas. A major problem of rapid urban growth is changing land use patterns unevenly. It can also put added pressure on food supply systems and cause excess demand. The pressures of urban living may lead to crime and other consequences of social deprivation.

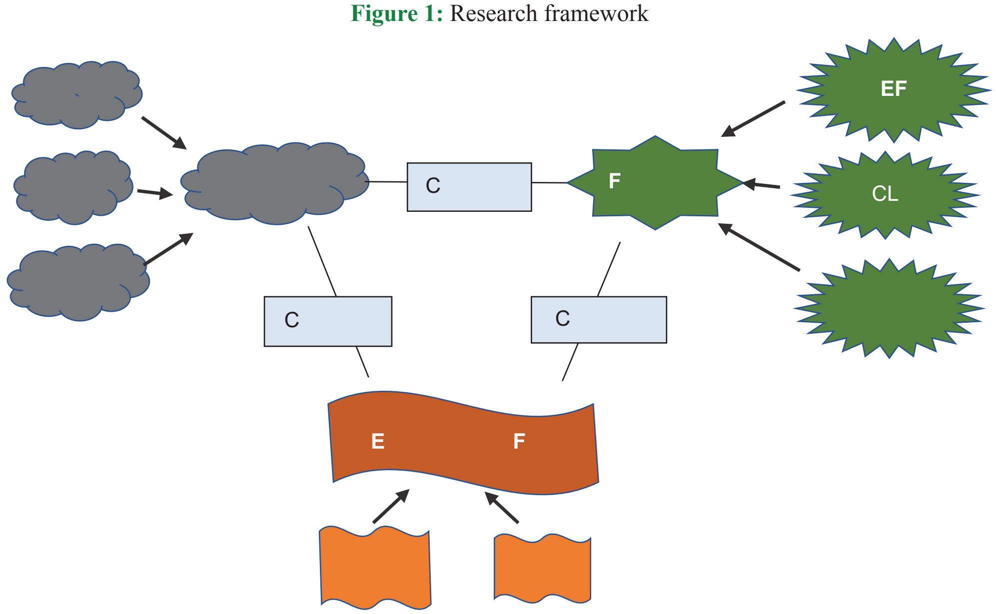
Socioeconomic and environmental changes are the main reasons for land use change (LUC). Rajpar et al. (2019) found that socio economic factors such as age, income, land ownership, farm inheritance by successors, social networks and lack of basic facilities are the main determinants of farmers' decisions to sell agricultural lands in Pakistan especially in rural areas. The consequence of LUC indicates that pressure on existing land worsen the ecological footprint as there are vast gaps between the acquired and actual output of agriculture produce, which suffers due to a lack of appropriate technology, use of inputs at improper times, unavailability of water, and inadequate education about insect pest control, which not only negatively affects the produce but also significantly reduces the amount of produce (Rahman et al., 2015).

Ecosystem processes operating within agricultural systems can provide some of the same supporting services described above, including pollination, pest control, and genetic diversity for future agricultural use, soil retention, and regulation of soil fertility, nutrient cycling and water. Each plant species absorbs different nutrients from the soil and releases certain substances in the soil. This method promotes the fertility of the soil, without using chemical fertilizers (Power, 2010). However, the excessive and unwisely use of fertilizer and synthetic chemicals for the control of insect pests harm the surrounding environment particularly water and soil. While nitrogen deposition influences species diversity and destroying some special species (Xiankai et al., 2008).

The inverted U-Shaped long-run relationship exist between carbon emissions and industrialization in Pakistan. Trade-induced energy pollutants confirm the existence of pollution haven hypothesis, which explains that sustainable efforts are needed to reduce carbon dioxide emissions through production of cleaner technologies. A cleaner production technology mix coupled with renewable energy for reducing carbon emissions could significantly alleviate the problem (Shahbaz et al., 2014).

As the world's economies become more integrated and the global economy subsequently grows, there is increasing concern regarding how such trends will affect the environment. In fact, the relationship between globalization and the environment has become quite contentious in policy circles. In part in response to these controversies, a burgeoning amount of academic attention has emerged that examines the globalization/environment nexus. Although there have been advances in the thinking about these relationships, significant challenges remain. The direct and indirect causality exist between pollutants, footprint and economic factors. As the size of economy grow, GDP increases and during production natural resource uses as input while residual releases in environment as pollutants (Figure 1). Over utilization of resources or resource degradation and on the other side pollution beyond threshold level creates problem. This article provides a critical taxonomy that will help scholars better understand the overwhelming literature on the subject and also outlines the key

Figure 1: Research framework



Source: Self extract

challenges that scholars and policy makers will face for a second wave of thinking on the subject. It was helpful to develop an interactive environmental model, and unlike previous studies, this study calculated the Cropland and Forest Land as sub-component of ecological footprint to establish a relationship with atmospheric gases such as CO_2, NO_2 and NOx, which is the relative weighting of environmental factors of Pakistan. This study makes a significant contribution by tracing the impact of environmental factors on species natural habitat, under which ecological footprint is used as an indicator in environmental literature, while forests are used to determine the impact of environmental factors on species natural habitats. In addition, the study used Cropland (for land use land change), which is relatively more pronounced than other environmental factors that are less explored in environmental literature.

The above discussion supported the strong relationship between socioeconomic, biological, and environmental factors around Pakistan. In this study, carbon dioxide, Nitrogen Oxide, Nitrus Oxide concentrations were examined in conjunction with growth factors that simultaneously affected ecosystems and ecological footprint in Pakistan from 1975 to 2020. The study has a following sub-objectives i.e.

- To identify the relationship between air pollutant levels and ecological footprints of the country.
- By observing the effect of air pollutants and growth factors on forest area and cropland.
- By using the unit root test, Co-integration test, and error correction model, these objectives will be achieved.

2. MATERIALS AND METHODS

In the study, the dynamic impact of tropospheric ozone such as CO_2, N_2O and NOx concentrations on ecological footprint, forest area and Cropland investigated by using annual observations for the period of 1975-2020. The data is obtained from World Development Indicator and Global Footprint Networks (GFN). For the study, ecological footprint is measured in hectares per person, forest area in 1000 ha/capita, cropland is measured in 1000/ha. NO_2, NOx, and CO_2 are caused mainly by burning fossil fuels and forest depletion and agriculture fertilizers are measured in parts per million. Since the data of EF is available upto 2017, therefore study used trend calibration for appropriate value for year 2018, 2019 and 2020. The forest area is used as a proxy for the storage of carbon and enable us to estimate how much carbon has been emitted due to deforestation. Moreover, two growth factors were used as intervening variables between environmental indicators and atmospheric gases i.e. Gross Domestic Product and Trade openness. Both variables affected simultaneously the ecological footprint, Cropland, forest area and also the greenhouse gases. The nature and description of variables are explained in Table 1.

When variables are independent and have time series data, they usually followed a non-stationary property or follows a trend (Granger, 1981), and in case of absence of dependency, regression of independent variables gives spurious result (R-square is less then D-Watson). In order to obtain robust and unbiased estimates for long run or short run relationship, the first step is to check the presence of unit root through ADF test. The next step is to confirm the level when series become stationary for further analysis. When all series are stationary at level i.e. I(0) and become non-stationary at first difference i.e. I(I) Johansson's Co-integration test is the appropriate test and if series follows mixed order of integration, Auto Regressive Distributed Lag (ARDL) would be the suitable method of analysis.

2.1. Co-integration

Let we assume that Yt is group of separate time series variables, and all variables are nonstationary time series in nature.

$$y_1 = \left(y_{11}, y_{12,} \cdots y_{1t}\right) \tag{1a}$$

$$y_2 = \left(y_{21}, y_{22,} \cdots y_{2t}\right) \tag{1b}$$

$$y_3 = \left(y_{31}, y_{32,} \cdots y_{3t}\right) \tag{1c}$$

Cointegration means that y_1, y_2, and y_3 are cab be combined in such a way that there linear combination is stationary as suggested by Johansen and Juselius (1990), and B in equation 2 is the cointegrating vector.

$$\beta Y_t = \beta_1 y_{11} + \beta_2 y_{2t} + \beta_3 y_{3t} \sim I\left(0\right) \tag{2}$$

The null hypothesis in Johansen's method for the maximum likelihood is; Ho: there is no cointegration against the alternative that there exist at least one cointegration equation. The null hypothesis of non-co-integration among variables is rejected when the estimated likelihood test statistic exceeds its critical value. The eigen-value (lambda), trace statistics (r) enable us to find either the variables in vector are co-integrated in one or more long run relationships.

If series are co-integrated of order I(I), trace test indicates a unique co-integrating vector of order 1 and shows that series possess long run relationship. For more than one co-integration equation, the study used likelihood ratio test to identify number of co-integrated vectors such as "r". The multivariate co-integration methodology as proposed by Johansen (1988) and Johansen and Juselius (1990) is expressed as

$$EF_t = \pi_0 + \sum_{T=1}^{K} \pi_i (EF)_{t-1} + \mu_t \tag{3}$$

The study used three distinct equation for establishing the long run relationship between EF and air pollutants (CO_2, NO_2, NOx), CL and FA with air pollutants (CO_2, NO_2, NOx). While GDP and TOP is used as control variables in each model. The models for environmental factors for maintaining the ecological balance is as follow.

Table 1: List of Variables and Description

Variables time (1975-2020)	Symbol	Measurement	Data source
Dependent Variable			
Ecological Foot Print	EF	Hector/person	Global Footprint Network (data.footprintnetwork.org)
Forest area	FA	1000 ha	Global Footprint Network (data.footprintnetwork.org)
Crop land	CL	Total Crop land	Global Footprint Network (data.footprintnetwork.org)
Independent variables			
Carbon dioxide Emission	CO_2	Parts/million	Global Footprint Network (data.footprintnetwork.org)
Nitrogen oxide emission	NO_2	Parts/million	Global Footprint Network (data.footprintnetwork.org)
Nitrous Oxide	NOx	Parts/million in volume	Global Footprint Network (data.footprintnetwork.org)
Control variables			
Gross domestic product	GDP	In USD Pu	World Development Indicators
Trade Openness	TOP	Export + import/GDP	World Development Indicators

Model 1: Relationship between ecological foot print and atmospheric gases

$$(EF)\ t = (CO_2, NO_2, NOx, GDP, TOP) \quad (4)$$

Model 2: Relationship between forest area and atmospheric gases

$$(FA)\ t = (CO_2, NO_2, NOx, GDP, TOP) \quad (5)$$

Model 3: Relationship between Cropland and atmospheric gases

$$(CL)\ t = (CO_2, NO_2, NOx, GDP, TOP) \quad (6)$$

2.2. Error Correction Model (ECM)

When the series come stationary at I (1), then regressions at first differences loses the long-run relationship. To obtain the short run relationship, the regressors should be at level. Error Correction Model (ECM) incorporates variables both in their levels and first differences because ECM captures the short-run disequilibrium situations as well as the long-run equilibrium adjustments between variables. ECM term having negative sign and value between "0 and 1" indicates convergence of model towards long-run equilibrium and shows how much percentage adjustment takes place every year

The ECM for model 1 is as follows;

$$D(EF)_t = \beta_0 + \beta_1 D(CO2)_t + \beta_2 D(NO2)_t + \beta_3 D(NOx)_t + \beta_4 D(GDP)_t + \beta_5 D(TOP)_t + \varepsilon \quad (7)$$

Where D is the first difference and t is time span from 1975-2020, and ε is the error correction term or speed of adjustment coefficient. The coefficients β_0 to β_0 be the short run elasticities

The model for forest area and atmospheric gases are as follows

$$D(FA)_t = \beta_0 + \beta_1 D(CO2)_t + \beta_2 D(NO2)_t + \beta_3 D(NOx)_t + \beta_4 D(GDP)_t + \beta_5 D(TOP)_t + \varepsilon \quad (8)$$

The model for cropland and atmospheric gases are as follows

$$D(CL)_t = \beta_0 + \beta_1 D(CO2)_t + \beta_2 D(NO2)_t + \beta_3 D(NOx)_t + \beta_4 D(GDP)_t + \beta_5 D(TOP)_t + \varepsilon \quad (9)$$

The carbon emission contributes 60% of the Ecological foot print, burning of fossil fuel through utilization of natural resources increase pressure on ecological footprint. The Nitrogen Dioxide (NO_2) comes from burning of fuel used in transportation such as emission from car, truck, busses and power plant. More the emission in air, more will be the pressure on ecological footprint. Nitrous Oxide releases in air when chemical reaction of fertilizer takes place in agriculture fields. The common myth prevails in farmers that more will be the fertilizer more will be the output. Therefore, farmer use excess fertilizer that have two negative outcomes, first it increase the nitrous oxide emission in air and second it decrease the soil fertility and hence it adversely affect the ecological footprint. The GDP and trade openness directly damage the environment by utilizing more resources. The study not only consider ecological footprint to establish the short run and long run relationship with atmospheric gasses but also dig-out the relationship in detail by adding two subcomponent of ecological footprint such as forest area and cropland. The reduction in forest area and marginal change in cropland put more pressure on ecological footprint

3. RESULTS

Descriptive statistics and correlation results represented in Table 2. The study used ADF test to check that study variables are stationary at level or first difference. Table 3 represent the result of ADF test and it shows that all variables are non-stationary at level and also at constant and trend. The ADF value does not fall in the acceptance region as calculated value is less than tabulated value. However the ADF test at first difference i.e., I(1) shows that study variables proves that no-unit root exist at first difference. Since all variables are of same order i.e., I(1) therefore as proposed by Johansen and Juselius (1990) co-integration methodology help us to estimate the long-run and short run elasticities.

The results of Johansen's test for ecological footprint model (model 1) are present in Table 4. The test statistics of no co-integration equation (r = 0) among model variables is rejected as trace statistics value (230.057) is greater than 5% significant value (95.75). This proves that at least one co-integration equation exists between model 1 variables. The trace statistics for $r \leq 1$, $r \leq 2$, and $r \leq 3$ are also rejected in favor of general hypothesis ($r > 1$) and other null hypothesis such as $r > 1$, $r > 2$ and $r > 3$ found that each trace statistics are greater than 95% critical value. The rejection of null hypothesis enables us to conclude that there exist

Table 2: Descriptive statistics and Correlation matrix

	EF	CL	FA	CO_2	NO_2	NOx	GDP	TOP
Mean	0.756	0.169	0.051	97167.240	36587.590	32013.610	121	13.3
Maximum	0.912	0.204	0.062	208570	70115	56880	258	28
Minimum	0.611	0.130	0.041	22838.080	15041.850	10963.240	31.9	2.23
Std. Dev.	0.086	0.020	0.007	55300.260	16140.840	15208.390	67.9	8.13
Skewness	−0.251	−0.346	−0.038	0.451	0.302	0.076	0.511	0.191
Observations	46	46	46	46	46	46	46	46

*GDP and TOP are in billion US dollar

Table 3: ADF test

Variables	Level		First Difference	
	Constant	Constant + Trend	Constant	Constant + Trend
Ecological Footprint	−1.677636	−1.81515	−7.5759*	−7.682313*
Forest Area	−1.397865	−1.685384	−6.255354*	−6.205797
Crop land	−2.239974	−3.521917	−8.990244*	−8.917712*
CO_2	4.125633	−0.33407	−4.486894*	−5.740896*
NO_2	1.121882	−1.898147	−7.141573*	−7.518379*
Ag NO_2	−0.032934	−2.840738	−7.234072*	−7.187748*
GDP	1.036543	−1.604069	−3.842848*	−3.143913
TOP	0.065063	−2.623592	−6.471629*	−6.461342*

*shows 0.01 P values

four co-integration relationship between model-1 variables EF, CO_2, NO_2, NOx GDP and TOP. In case of Max-Eigen statistics, the hypothesis and acceptance/rejection decision criteria is same like trace statistics. Table 4 shows that there exist 4 co-integration equation between variables of model 1 E-max values for r ≤ 1, r ≤ 2, and r ≤ 3 is rejected at 5% confidence level.

The trace and Eigenvalue statistics confirm that there exists a long run relationship among ecological footprint and atmospheric gases along with control variables (GDP and TOP). The normalized co-integration equation of model 1 is in Table 5. The long run elasticities of CO_2, NO_2, NOx, GDP and TOP are −0.825, −2.43, 2.17, 1.62 and −0.84. The elasticities shows that one percent increase in GDP increase the pressure on EF by 1.68, while 1% increase in TOP decrease the pressure on EF by 0.84. The results are according to the prevailing situation as in TOP, import share is more than export share. However, the CO_2 and NO_2 decrease the pressure on EF while NOx through agriculture fertilizer increases the pressure on EF.

Table 6 present the vector co-integration results of Model-2 that explain the relationship between cropland with atmospheric gases and control variables. The test statistics of no co-integration equation (r = 0) among model variables is rejected as trace statistics value (238.40) is greater than 5% significant value (95.75). This proves that at least one co-integration equation exists between model 1 variables. The trace statistics for r ≤ 1, r ≤ 2, and r ≤ 3 are also rejected in favor of general hypothesis (r > 1) and other null hypothesis such as r > 1, r > 2 and r > 3 found that each trace statistics are greater than 95% critical value. The rejection of null hypothesis enables us to conclude that there exist four co-integration relationship between model-2 variables CL, CO_2, NO_2, NOx GDP and TOP. In case of Max-Eigen statistics, the hypothesis and acceptance/rejection decision criteria is same like trace statistics. Table 4 shows that there exist 4 co-integration equation between variables of model 1 E-max values for r ≤ 1, r ≤ 2, and r ≤ 3 is rejected at 5% confidence level.

The trace and Eigenvalue statistics confirm in Table 7 that there exists a long run relationship among ecological footprint and atmospheric gases along with control variables (GDP and TOP). The normalized co-integration equation of model 1 is in Table 7. The long run elasticities of CO_2, NO_2, NOx, GDP and TOP are 0.1429, −0.227, 0.001, 0.07 and −0.168. The elasticities shows that one percent increase in cropland area will increase the CO_2 value by 0.14 unit as cutting of crop will increase the CO_2 concentration in air. The relationship of GDP with cropland is positive as increase in cropland will contribute the GDP by 0.07. The elasticity value is very low and this proves that share of agriculture and especially cropland in total GDP is nominal. While 1% increase in TOP reduces the cropland area as we import more agriculture products from abroad.

Table 8 present the vector co-integration results of Model-3 that explain the relationship between forest area with atmospheric gases and control variables. The test statistics of no co-integration equation (r = 0) among model variables is rejected as trace statistics value (88.97) is greater than 5% significant value (95.75). This proves that at least one co-integration equation exists between model 1 variables. The trace statistics for r ≤ 1, r ≤ 2, r ≤ 3 and r ≤ 4 are also rejected in favor of general hypothesis (r > 1) and other null hypothesis such as r > 1, r > 2, r > 3 and r > 4 found that each trace statistics are greater than 95% critical value. The rejection of null hypothesis enables us to conclude that there exist five co-integration relationship between model-2 variables FA, CO_2, NO_2, NOx GDP and TOP. In case of Max-Eigen statistics, the hypothesis and acceptance/rejection decision criteria is same like trace statistics. Table 8 shows that there exist 5 co-integration equation between variables of model 1 E-max values for r ≤ 1, r ≤ 2, r ≤ 3 and r ≤ 4 is rejected at 5% confidence level.

The trace and Eigenvalue statistics confirm that there exists a long run relationship among forest area and atmospheric gases along with control variables (GDP and TOP). The normalized co-integration equation of model 1 is in Table 9. The long run elasticities of CO_2, NO_2, NOx, GDP and TOP are −0.79, 0.239, −0.60, 1.10 and −0.124 respectively. The elasticities shows that one percent increase in forest area will decrease the CO_2 value by 0.79 unit as forest is the biggest source of storing carbon dioxide. The relationship of GDP with forest area is positive as increase in forest area will contribute the GDP by 1.10 and it is more elastic. However, forest area has negative relation with TOP.

Table 4: Johansen's test for multiple Co-integration vectors Co-integration test for Ecological Footprints

H0 Trace	Eigenvalue	Test Statistics Trace	0.05 Critical Value	Probability**
r = 0*	r > 0	230.0574	95.75366	0.0000
r ≤ 1*	r > 1	147.8293	69.81889	0.0000
r ≤ 2*	r > 2	81.21549	47.85613	0.0000
r ≤ 3*	r > 3	33.59288	29.79707	0.0174
r ≤ 4	r > 4	7.843757	15.49471	0.4823
r ≤ 5	r > 5	0.004392	3.841466	0.9463
A max values	**A max values**			
r = 0*	r > 0	82.22811	40.07757	0.0000
r ≤ 1*	r > 1	66.61380	33.87687	0.0000
r ≤ 2*	r > 2	47.62261	27.58434	0.0000
r ≤ 3*	r > 3	25.74913	21.13162	0.0104
r ≤ 4	r > 4	7.839364	14.26460	0.3952
r ≤ 5	r > 5	0.004392	3.841466	0.9463

Table 5: Normalize Co-integration coefficient (SE in parenthesis): Log likelihood 823.3290

Variable	EF	CO_2	NO_2	NOx	GDP	TOP
Co-integration	1.000000	−0.825120	−2.430046	2.171288	1.628218	0.840316
SE		(0.34687)	(0.35681)	(0.32045)	(0.28237)	(0.08722)

Table 6: Johansen's test for multiple co-integration vectors co-integration test for CropLand

H0 Trace	Eigenvalue	Trace Statistics	0.05 Critical Value	Probability**
r = 0*	r > 0	238.4020	95.75366	0.0000
r ≤ 1*	r > 1	154.3688	69.81889	0.0000
r ≤ 2*	r > 2	85.77265	47.85613	0.0000
r ≤ 3*	r > 3	41.93164	29.79707	0.0013
r ≤ 4	r > 4	9.140426	15.49471	0.3526
r ≤ 5	r > 5	0.512743	3.841466	0.4740
A max values	**A max values**			
r = 0*	r > 0	84.03315	40.07757	0.0000
r ≤ 1*	r > 1	68.59616	33.87687	0.0000
r ≤ 2*	r > 2	43.84101	27.58434	0.0002
r ≤ 3*	r > 3	32.79122	21.13162	0.0008
r ≤ 4	r > 4	8.627682	14.26460	0.3185
r ≤ 5	r > 5	0.512743	3.841466	0.4740

Table 7: Normalize Co-integration coefficient (SE in parenthesis): Log likelihood 804.4669

Variable	CROPLAND	CO_2	NO_2	NOx	GDP	TOP
Co-integration	1.000000	0.142976	−0.227503	0.001398	0.070286	−0.168965
SE		(0.10550)	(0.13570)	(0.12033)	(0.08934)	(0.03404)

Table 8: Johansen's test for multiple co-integration vectors co-integration test i.e., Forest Land

H0 Trace	Eigenvalue	Test Statistics Trace	0.05 Critical Value	Probability**
r = 0*	r > 0	234.6713	95.75366	0.0000
r ≤ 1*	r > 1	145.6989	69.81889	0.0000
r ≤ 2*	r > 2	79.16985	47.85613	0.0000
r ≤ 3*	r > 3	35.34101	29.79707	0.0104
r ≤ 4	r > 4	16.32443	15.49471	0.0374
r ≤ 5	r > 5	1.392891	3.841466	0.2379
A max values	**A max values**			
r = 0*	r > 0	88.97246	40.07757	0.0000
r ≤ 1*	r > 1	66.52902	33.87687	0.0000
r ≤ 2*	r > 2	43.82884	27.58434	0.0002
r ≤ 3*	r > 3	19.01658	21.13162	0.0963
r ≤ 4	r > 4	14.93154	14.26460	0.0392
r ≤ 5	r > 5	1.392891	3.841466	0.2379

Table 10 present the stability of the model that model has the capacity to restore equilibrium if there is in shock in the economy. This means that system has the capability to converge or it diverge from the equilibrium. The study used error correction model

Table 9: Normalize Co-integration coefficient (SE in parenthesis): Log likelihood 808.6408

Variable	Forest Land	CO_2	NO_2	NOx	GDP	TOP
Co-integration	1.000000	−0.790311	0.239461	−0.607053	1.104905	−0.124906
SE		(0.12731)	(0.17049)	(0.14989)	(0.09263)	(0.04673)

Table 10: Short Run Error Correction Model for Ecological Footprints, Cropland and Forest Land

Variable	Model 1 (EF)	Model 2 (Crop Land)	Model 3 (Forest Land)
C	0.000453	0.006028**	0.009997
D (CO_2)	0.585097***	0.745123***	0.039584
D (NO_2)	0.121437*	0.183402**	−0.030253
D (NOx)	0.047169*	0.036100*	0.115134
D (GDP)	−0.677735*	−1.186437**	−0.552067
D (TOP)	0.035488*	0.091412**	0.078169
ECM	−0.500748**	−0.902961***	−0.402724***
R^2	0.400980	0.526500	0.307876
Adjusted R^2	0.306398	0.451737	0.198593
F-statistics	4.239493	7.042243	2.817237

*, **, *** 1, 5 and 10% significance level respectively

(ECM) to check the short run deviation and convergence from equilibrium. The ECM shows the speed of adjustment of variables in study models over the period of time. The ECM of Model 1 shows that 50% disequilibrium on ecological footprint is due to the variables of CO_2, NO_2, NOx, GDP and TOP. This means that every year 50% adjustment takes place and this shows the moderate speed of adjustment. The long run speed of adjustment is 42% which is less than the moderate level. The variables such as CO_2 is significant for ecological footprint at 1 percent confidence level while GDP is significant at 10% level.

The speed of adjustment for crop land is 90%, which is very high and this because of two variables that are significant at 5% confidence level such as CO_2 and GDP. The ECM for forest area is 40% which is less than moderate level. The long run speed of adjustment is 34%.

4. DISCUSSION OF RESULTS

Each country has a goal to attain a high GDP per capita growth however the process of reaching high growth rate through trade openness, technology transfer, foreign direct investment, urbanization and industrialization leads in contamination of air, water, land, etc. Hence, worsening of environmental quality, ecological footprints including forest area and crop land leading to an augmentation in the use of the conventional type of energy in main economic operations. Energy consumption is, however, a sparing factor in the production of goods and services but, as a result of dangerous emissions of Sulphur dioxide (SO2), carbon dioxide (CO_2), nitrogen oxide (NO_2), Nitrous oxide (NOx), and many other gases in the air, this has an adverse impact on the environmental quality. Pollutant emissions increase GHG output, with hazardous consequences and an imminent threat to climate change and ecological imbalance (Shahbaz et al., 2019).

The difficulties of the balance between economic development and the conservation of the global environment are facing both developed and developing countries. Greenhouse gases raise the global temperature, most research conclude that CO_2 is the major fault behind the rising degradation of the ecosystem (Zhang et al., 2017). The population expansion in southern Asia has led to a considerable increase in the number of cars utilized and the urbanization and their contribution to regional air pollution. The concentration of Sulphur dioxide, carbon dioxide, nitrogen oxides, nitrous oxide and other pollutants in the atmosphere in the past several decades has been steadily growing because of the above-mentioned reasons. In addition, since 1990, greenhouse gas emissions in this region have grown by around 3.3% (Khwaja et al., 2012). Trade also depends on the relative quantity of economic factor resources and so the comparative advantage of the trade-related environmental consequences depends on trade and economic environmental policy (Copeland and Taylor, 2004). However, trade openness has been observed to have a detrimental impact on the environment when the country is shifting toward cleaner technology to manufacture products and services or when limitations on foreign investment are reduced by the transfer of new technologies onto emerging countries (Liddle, 2015).

Quantifying degradation of the environment in terms of greenhouse gases alone does not reflect a wide knowledge of environmental problems arising out of a variety of economic activities. For example, the composition of all greenhouse gas emissions has shifted from conventionally described as mostly nitrogen and Sulphur to more carbon and smoke intense in the current age (Ulucak and Bilgili, 2018). The quality of environment is thus not suitable for assessing the real dynamics of the environmental welfare, solely by the emissions of these contaminants. In contrast, the Ecological Footprints proposed by Rees (1992) and then modified by Wackernagel and Rees (1998), simply assesses the quality of the environment from several points of view. The EF takes into account both human demand for environmental resources and the appropriate environmental capabilities in order to satisfy them and absorb waste created during the process (Wackernagel et al., 2004). This is particularly necessary in order to ensure environmental sustainability which needs the capacity of the environment to exceed the appropriate human demand. EFP is thus a more relevant measure of environmental sustainability that can be used to evaluate environmental quality completely (Bagliani et al., 2008).

An array of several environmental indicators is developed to calculate a specific index, which is the unique element in the EF. The EF is hence comprehensive in that it reflects a broad range of different environmental characteristics, which account for the overall environmental condition (Costanza, 2000). In addition, deteriorating the environment is described as a multidimensional phenomenon including numerous factors that are directly and indirectly responsible for environmental degradation. The EF is therefore useful in measuring environment quality as EFP also takes account of the indirect influence on the environment of economic activities, which, if environmental quality is only assessed in emissions, are generally neglected (McDonald and Patterson, 2004).

5. CONCLUSION

Pakistan was studied to identify the key environmental pollutants and growth factors that contributed to diminishing forest area and increasing pressure on ecological footprint for the study period of 1975-2020. A variety of indicators were used in order to track ecological footprint, forest area and cropland. The tropospheric and stratospheric ozone gases CO_2, NO_2 and NOx along with two control variables such as GDP and TOP taken into account as factors of robustness. In this study, the co-integration equations of each model and ECM for stability has been checked and suggest the following policy implications.

Pakistan unit root tests conclude that ecological footprint, forest area and cropland according to the random walk hypothesis, are non-stationary, and are stabilized at their first difference. Based on the results, the variables affect by the numerous environmental and growth factors are limitable through sustainable policy instruments for ecological conservation across the countries.

Over time, environmental indicators and specific growth factors fluctuate, whereas they remain stable at first differences. Due to the numerous reforms for limiting the atmospheric pollutants, climatic factors, and stable growth patterns undertaken, these variables diverge from their steady state conditions.

Pakistan co-integrating estimators show that tropospheric ozone CO_2, NO_2 and NOx negatively affect the ecological footprint whereas GDP directly influence the ecological footprint. The results emphasize the need to limit the NOx emissions in order to prevent from the Cropland loss across. Forest area is badly affected by the NO_2 emissions and greenhouse gas. The results indicate that forest areas are one of the potential habitat areas for the various species; therefore, policies should be devised for the protection of the habitats to balance ecological footprint.

In order to preserve our natural base, we need to redraft our policies so that there is no tropospheric ozone depletion, carbon dioxide emissions and nitrogen oxide emissions respectively. As a result, CO_2 emissions, and GHG emissions play a large role in influencing forest area and ecological footprint while economic growth undermine the forest area. Cropland is affected by mass NOx emission through fertilizer. It is essential to re-define agriculture air pollution policies in terms of conserving natural environment and green economy.

It is argued in WHO (2003) that there are several approaches a society can take to reduce exposure to air pollutants. For example, we could adopt air quality guidelines and standards for outdoor improvements to minimize health risks, educating the general public about the risks of exposure to air pollutants, and using market-driven instruments such as taxes on polluting industries and firms etc. Such information is helpful to reduce human exposure to air pollutants and minimize their risks at the same time.

Lastly, improving physical infrastructure and natural systems will help reduce environmental hazards for long-term development (UN, 2015). This study examined the impact of carbon, nitrogen and nitrox emissions on EF and its component separately since carbon emissions are a major cause of global warming. Carbon overdose is mainly caused by fossil fuel burning and forest destruction, which continuously accumulates as a result of industrialization. The study found that pollutants, such as NO_2 and NOx also potential to damage ecosystems and biological diversity. As a result of unsustainable environmental reforms in a region, the pollutants are amplified by specific growth factors, such as GDP and trade. For the countries long-term viability, only clean air is a desirable policy option.

The developed countries are less vulnerable to climate change because they are better equipped to manage climatic changes as compared to developing countries (Wijaya, 2014). There is an important threat of climate change on food security to developing countries, especially crops/staple foods/crops that suffer from significant drought, heatwaves, and other extreme weather events that cost the agricultural value-added across the globe (Bhuiyan et al., 2018). People in the poor countries have experienced gradual increases in sea level, strong cyclones, longer and warmer days, heavier rainfall, and longer and stronger heat waves as a direct result of human-induced climate change. Mitigated policies and adaptation to climate change are therefore desirable policy options to reduce environmental threats episodes of global greenhouse gas emissions (Vidal, 2013).

It is important for the Pakistan to adopt certain sustainable policies to mitigate climate change effect on various economic factors, including biodiversity loss, ecosystem disturbance, agricultural productivity loss, soil erosion, and many socio-economic and environmental factors that directly affect economies with low climate change adaptation plans.

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