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AGRIBUSINESS

The impact of agroecosystem on ecological footprint: Fresh evidence in the perspective of existing agriculture and green Pakistan

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ABSTRACT: *The focus of this research study investigated the impact of agroecosystem on the ecological footprint in Pakistan, using the time series data over the period from 1990 to 2019. The econometric methods of time series were employed to investigate the long-term association between an agroecosystem and ecological footprint. After performing the stationarity tests Johansen approach was employed. Results of the Johansen method imply that long-term co-integration exists between the exogenous and endogenous variables. Moreover, the ARDL model was performed and long-run results were validated by the bound testing approach. The elasticity of the short-run form of the ARDL model reveals that agricultural land, employment, energy consumption, fertilizer use, and biomass burned dry matter in agriculture have a positive relationship with the agroecosystem. In contrast in the log-run form of ARDL agricultural land, employment, energy consumption, fertilizer use in agriculture and temperature have a positive impact on ecological footprint. Results of the impulse response function revealed that employment and fertilizer use in agriculture have positive while energy consumption and livestock in number have a negative influence on the ecological footprint. Thus, rigorous practices of agriculture for higher production put extra pressure on the agroecosystem. As a result, the stability of the agroecosystem deteriorates and reduces. To minimize the ecological ecosystem, modern technology is required to reduce carbon emission, enhance greener production and improve the biocapacity of the land in the country. This study would help the researcher, planner, policymaker and academicians to provide a proper guideline and vision to provide sustainable food and environment.*

Key words: *agroecosystem, ecological footprint, sustainable agriculture, ARDL, and Pakistan.*

O impacto do agroecossistema na pegada ecológica: novas evidências para a perspectiva da agricultura verde existente no Paquistão

RESUMO: *O foco deste estudo é investigar o impacto do agroecossistema na pegada ecológica no Paquistão, usando os dados de séries temporais no período de 1990 a 2019. Os métodos econométricos de séries temporais foram empregados para investigar a associação de longo prazo entre um agroecossistema e a pegada ecológica. Após a realização dos testes de estacionaridade, a abordagem de Johansen foi empregada. Os resultados do método de Johansen implicam que existe cointegração de longo prazo entre as variáveis exógenas e endógenas. Além disso, o modelo ARDL foi realizado e os resultados de longo prazo foram validados pela abordagem de teste vinculado. A elasticidade da forma de curto prazo do modelo ARDL revela que terras agrícolas, emprego, consumo de energia, uso de fertilizantes e biomassa queimada na agricultura têm uma relação positiva com o agroecossistema. Em contraste, na forma log-run das terras agrícolas ARDL, o emprego, o consumo de energia, o uso de fertilizantes na agricultura e a temperatura têm um impacto positivo na pegada ecológica. Os resultados da função impulso resposta revelam que o emprego e o uso de fertilizantes na agricultura são positivos enquanto o consumo de energia e a pecuária em número têm uma influência negativa na pegada ecológica. Assim, práticas rigorosas de agricultura para maior produção colocam uma pressão extra sobre o agroecossistema. Como resultado, a estabilidade do agroecossistema se deteriora e reduz. Para minimizar o ecossistema ecológico, é necessária tecnologia moderna para reduzir a emissão de carbono, aumentar a produção mais verde e melhorar a biocapacidade da terra no país. Este estudo ajudaria o pesquisador, planejador, formulador de políticas e acadêmicos a ter uma orientação e visão adequadas para fornecer alimentos e meio ambiente sustentáveis.*

Palavras-chave: *agroecossistema, pegada ecológica, agricultura sustentável, ARDL e Paquistão.*

INTRODUCTION

The agriculture sector contributes to the global economy. It drives and supports the people of the entire world to procure food and plays a key role in the reduction of extreme poverty and the development of the rural part of the world. Therefore, globally, the development of the agriculture sector is highly important. This sector would enable the world to feed an anticipated 9.7 billion people by 2050

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(HLPE. 2016; FAO, 2011; WORLD BANK, 2020). Compared to the other sector of the world, growth in the agriculture sector is two to four times more effective in generating incomes for the extremely poor people. In the year 2016 it estimated that 65% of the workforce is engaged in the agricultural industry (WORLD BANK, 2020). The nexus between agriculture and economic growth has an inevitable relationship that has extreme importance and concern in the global economy. The share of global gross domestic product (GDP) shared was 4% in the year 2000 and it is still stable by 2020. However, it is almost 25% in some developing parts of the world. More importantly, agriculture value-added has been increased 68% between 2000 to 2018 around USD 3.4 trillion (WORLD BANK, 2020; FAO, 2020).

In recent times the usage of modern technology and industrialization is obligatory for the economic development of the country. The agricultural sector is not only procuring the food to the society but it drives to run agro-based industry. Inevitably, the agriculture sector does not take place a role in environmental damages. This means that agricultural operation has the quality to conserve the environment and prevent it from damages. However, as a result of the paradigm shift from the traditional agricultural sector to the industrial sector, this act is responsible for the deterioration of the environment (MAHMOOD et al., 2019; ULLAH et al., 2018). Despite this highly global significance of the agriculture sector, it consistently faces confronting challenges such as to fulfill the increasing demand for quality food, allocating and efficiently using natural resources, protecting biodiversity, enhancing the welfare of the society particularly extreme poor peoples of the developing economies. The other emerging challenge is climate change. This phenomenon significantly reduces crop yield and revenue, specifically in climate change in the sensitive region of the world including South Asia. Ironically, 25% of greenhouse gas emissions are caused due to agriculture, land use, and forestry. Therefore, adaptation strategies have to be introduced to overcome the issues of climate change (WORLD BANK, 2020; ALI et al., 2020).

An agroecosystem is the fundamental unit of agroecology and is composed of both abiotic and biotic components that interact with each other and the surrounding environment. The foremost purpose of agroecological sustainability is to supply balanced, secure and safe food for the entire living organism and create social value for human beings in society. In recent times, the agroecosystem was affected by the intrusion of anthropogenic activities such as deforestation and conversion of forest and orchard land into agriculture cultivable land. However, to produce more food for the increasing populations of the world, humans have exploited natural resources with extraordinary approaches. These approaches have put long-lasting ecological impacts, for instance, unprecedented invasion of pests, reduction in the fertility of the soil (RAJ et al. 2020; BANERJEE et al. 2020; JHARIYA et al. 2019a, b). The existing monoculture system of agriculture is highly vulnerable to climate change. In contrast, agroecosystem shows more robustness concerning climate change (MEENA et al. 2020). Therefore, climate-resilient agriculture practices and efficient usage of energy decrease the climate footprint of the agroecosystem (RAJ et al. 2020). The ecological footprint concerning the agroecosystem is a very crucial matter. On small scale, it reflects the concentration of GHG emissions, energy, inputs and outputs, and energy usage level, but on large scale, it addresses the assimilative capacity of the food production system for a country (BANERJEE et al., 2021). The environmental degradation on earth is caused due to the human beings activities. The environmental degradation issues such as the increase in temperature, irregular changes in climate, and consistent increase in the ozone layer (MEENA et al. 2018).

Many researchers for instance ULLAH et al. (2018), ALI et al. (2021), LONG et al. (2018), SARKODIE & OWUSU (2017), and JEBLI & YOUSSEF (2016) have established a relationship between agricultural development, operations, activities, and environmental degradation in different countries. Taking the basis that little and limited research work has been reported and added to the literature. However, a lack of literature in the same context is required to fill the gap. Therefore, in this scenario, fresh evidence is obligatory to examine the influences of agroecosystem on ecological footprint. This research examined the impact of the agroecosystem on the ecological footprint in Pakistan. The results of this paper would be stimulating and significant in the context of sustainable agriculture and green Pakistan. Moreover, this study would check the exogenous and endogenous variables both in the short and long-run in the case of Pakistan using the ARDL approach. Further, the impulse response functions analysis will be performed to check the impulse of agroecosystem variables on the ecological footprint. Segmentation of the paper is presented as follows. The next section is the review of the literature followed by methodology and results and discussions of the paper. The last part is the conclusion and policy implications of the study.

Review of literature

The previous researchers have performed the relationship between agricultural operation and environmental pollution and degradation. The most similar study was performed by ULLAH et al. (2018). This study tested the nexus between agricultural activities and carbon emissions. The results of the study revealed agricultural operation is the fundamental cause of environmental degradation and pollution. A similar study was conducted by LONG et al. (2018) in China. It was explored that agriculture has a significant impact on carbon emissions in China. Moreover, the other variable foreign direct investment increases emissions while innovation in the country decreases carbon emissions. In the same way, CHANDIO et al. (2019) studied the relationship between energy, growth, and environmental quality in the sector of agriculture. The analysis of the study concluded that energy usage and growth have a positive relationship impact on carbon emission. These results suggested that energy consumption and growth in the agricultural sector reduce the quality of the environment.

In contrast to previous findings, MAHMOOD et al. (2019) studied the impact of agricultural development and carbon emission in Saudi Arabia. Results of their study concluded that agricultural development has a negative impact on carbon emissions in the country. These results also have a conflict with the results of ALI et al. (2021). They tested the existing prevailing Indian agricultural ecosystem on carbon emissions over the period from 1990 to 2014. Their findings unveiled that agricultural operations and activities applied in agriculture are a valid source of environmental degradation and pollution in India. Further, they confirmed that in the agriculture ecosystem one-way causality exists between carbon emission and agricultural technology, pesticide, livestock, and animal manure applied to the soil. However, two-way causality was detected between carbon emission and the production of biomass-burned crop residues. These results confirmed that agricultural ecosystems have a robust effect on carbon emissions in the country. Furthermore, other studies such as LEITAO (2018) have reported similar findings. The author explored the relationship between agricultural productivity and carbon emissions using time series data in Portugal. Results of the study revealed that factors such as productivity of the land, labor in agricultural operation, and agricultural raw material exports enhance carbon emission. These results suggested agricultural activities components increase environmental degradation and pollution.

In addition, to the above studies, SARKODIE & OWUSU (2017) explored the nexus between crop and livestock production and carbon emission using the time series data over the time period of 1961 to 2012 in the case of Ghana. It was revealed that crop and livestock production release carbon dioxide emissions in the country. These results were supported by RAVINDRA et al. (2019). They examined the relationship between agricultural crop residues and air pollution in India, over the time span from 2003-04 to 2016-17. The analysis of the study supported the results of the (ULLAH et al., 2018; SARKODIE & OWUSU 2017). In a similar context, JEBLI & YOUSSEF (2016) analyzed the link between agriculture, economic growth and carbon dioxide emissions in Tunisia. They concluded that agriculture enhances the release of carbon emissions. They suggested that renewable energy should be in agriculture to reduce carbon emissions and enhance the growth of the sector.

Moreover, in support of the past studies' results which show that the agriculture sector is the major source of environmental deterioration, GOKMENOGLU & TASPINAR (2018) established the relationship between agricultural value, economic growth and energy consumption on carbon dioxide emissions. This study has taken the case of Pakistan over the time span of 1971-2014. It was explored that variables such as agricultural value-added have a positive impact on carbon emission in the country. In the same way, LIU et al. (2017) studied the presence of Environmental Kuznets Curves (EKC) in the panel data cases of 4 Association of Southeast Asian Nations (ASEAN) countries. They reported that EKC does not validate in the case of 4 ASEAN countries. Conversely, RAFIQ et al. (2015) had used panel data for 53 counties and confirmed the validity of EKC hypothesis in the context of agriculture. RIDZUAN et al. (2020) analyzed the impact of agriculture, renewable energy, and economic growth on carbon dioxide emissions in Malaysia for the period 1978 to 2016. They reported that livestock has a positive impact associated with carbon emissions but crops and fisheries have a decreasing impact on carbon emission in the country.

METHODOLOGY

The study focused on the nexus between the agroecosystem and ecological footprint of

Pakistan using various databases data of 1990-2019. Table 1 presents the depiction of all the variables and data sources in the study. The ecological footprint is treated as the dependent variable and measured in Global million hectares. This variable data was taken from a global footprint network advancing the science of sustainability (GFN, 2021). The ecological foot print presents the environmental limitations and degradation which is occurred due to human activities and operations. The ecological footprint is the combine all the value of cropland, built-up land, carbon dioxide emissions, forest, fishing, and grazing (MRABET & ALSAMARA 2017; CHARFEDDINE 2017; ULUCAK & BILGILI 2018). The independent variables are eight in number. These variables collectively represent the agroecosystem in Pakistan. The inclusion of all agroecosystem collectively has robust association with the ecological footprint. These variables were selected based on the theoretical support from the previous literature of research studies. For instance, past research studies show that land and employment in agriculture (LEITAO 2018) fertilizer, nutrient, biomass burned dry matter, livestock of stock, (ALI et al., 2020; ULLAH et al., 2018) energy consumption (RIDZUAN et al., 2020; CHANDIO et al., 2019), rainfall and temperature (ALI et al. 2020) determinants have an influence on the environmental quality. The agricultural land and employment in agriculture variables data were taken in 1000 Ha and 1000 person respectively. Both the variables fertilizer by nutrient and biomass burned dry matter were measured in tonnes. The energy consumption in agriculture and livestock number data was estimated in Tera joule and stock of livestock respectively. These variables' data were taken from food and agricultural organization statistics (FAO, 2021). The annual temperature and rainfall data were measured in ºC and mm respectively. The climate data platform of the climate watch website was retrieved for data collection (CWD, 2021).

The linking between an agroecosystem and ecological footprint was established using the time series model shown in equation 1. The logarithmic function was used to capture the results of the analysis. The logarithmic function model has more benefits such as log-transformation shrinks the data, reducing the sharpness of the data, enhancing the reliability of the data, and normalizing the data. The co-efficient of log-transformation are considered as direct elasticities in the model (NATHANIEL et al., 020, ULLAH & KHAN, 2020).

$$LnEFP_t = \beta_0 + \beta_1 LnAGL_t + \beta_2 LnEMA_t + \beta_3 LnENC_t + \beta_4 LnFRN_t$$
$$+ \beta_5 LnLSS_t + \beta_6 LnBMB_t + \beta_7 LnTMP_t + \beta_4 LnPRP_t + \varepsilon_t \quad (1)$$

Here in Equation 1 β presents the parameter, t shows the time period and ε is the error term of the regression model. Further, the LnEFP shows ecological footprint, LnAGL indicates agricultural land, LnEMA is employed in agriculture, LnENC is the energy consumption in agriculture, LnFRN signifies fertilizer by nutrients and LnLSS implies livestock number. Further, LnBMB indicates that biomass burned dry matter, LnTMP denotes temperature and LnPRP is the expression of precipitation in the model of this study.

The flow chart of the research methodology has been structured in figure 1. Following this flow chart initially, we have performed descriptive statistics, correlation analysis, and trend analysis of the study. After the basic task, we performed a stationary test also known as the unit root test. Based on the unit root results we have chosen our model for the study. The Johansen cointegration test was selected to test the long-run nexus between an agroecosystem and ecological footprint. The Johansen test is composed of Trace and Max-Eigenvalue tests (JOHANSEN, 1988); (JOHANSEN & JUSELIUS, 1990). Suppose these two results are not similar then the Max-Eigenvalue test results would be considered. The reason is Max-Eigenvalue has more power and credible results (JOHANSEN & JUSELIUS, 1990). The mathematical expression of both the Johansen tests are written as follow:

$$Johansen_{Tr}(V) = -K \sum_{g=V+1}^{h} \ln(1-\lambda_m) \quad (2)$$

$$Johansen_{Ma}(V+1) = -K \ln(1-\lambda_{V+1}) \quad (3)$$

According to Equations 2 & 3, K imply sample size and V signify vectors of cointegration. The λ indicates the value of them ordered. The eigenvalue matrix coefficient is shown with the symbol $\boldsymbol{\pi}$. The Johansen trace test (V) is tested to null hypothesis against the alternative. This means that H_0: rank $\boldsymbol{\pi} \leq V$ against H_1: rank $\boldsymbol{\pi} > V$. Johansen Max-Eigen value (V + 1) is incorporated here to test the hypothesis H_0: rank $\boldsymbol{\pi} \leq V$ against H_1: rank $\boldsymbol{\pi} = V + 1$.

In the next model in this study, we use the ARDL approach. Before performing this model bound test designed by PESARAN et al. (2001) was employed to examine the long-run relationship. The ARDL model has certain characteristics such as this model provide direct elasticities of the variables and it can be run irrespective of the integrated order I(0) or I(1). However, this approach is very much sensitive to lag-length criteria. Therefore, AIC criteria were chosen to determine the lag-length order PESARAN

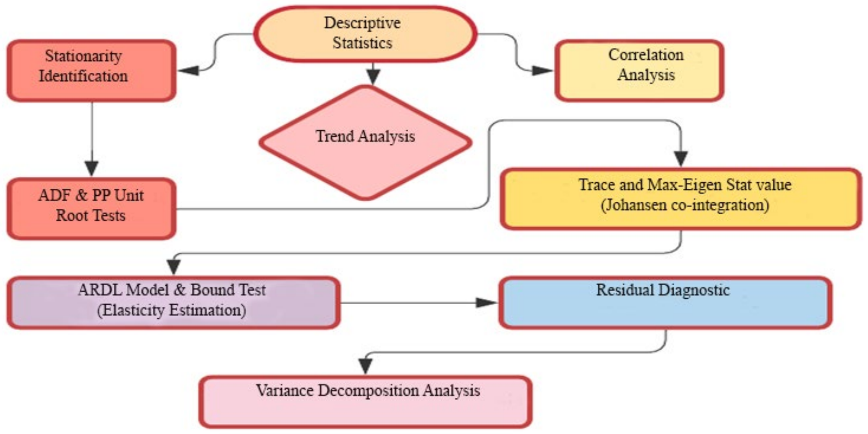

Figure 1 - Flow chart of research methodology.

et al. (2001). Further, the ECT term validates the speed of adjustment of the long-run stability of equilibrium. The ARDL model has the following mathematical specification in this study.

$$\begin{aligned}\Delta\ln(EFP)_t &= a_0 + \sum_{i=1}^{k} a_{1i}\Delta\ln(EFP)_{t-i} + \sum_{j=0}^{m} a_{2j}\Delta\ln AGL_{t-j} \\ &+ \sum_{k=0}^{n} a_{3k}\Delta\ln EMA_{t-k} + \sum_{1=0}^{o} a_{4l}\Delta\ln ENC_{t-k} + \sum_{m=0}^{p} a_{5m}\Delta\ln FRN_{t-m} \\ &+ \sum_{n=0}^{q} a_{6n}\Delta\ln LSS_{t-n} + \sum_{o=0}^{r} a_{6o}\Delta\ln BMB_{t-o} + \sum_{p=0}^{s} a_{6p}\Delta\ln TMP_{t-p} \\ &+ \sum_{q=0}^{t} a_{6q}\Delta\ln PRP_{t-q} + b_0\ln(EFP)_{t-1} + b_1\ln AGL_{t-1} \\ &+ b_2\ln EMA_{t-1} + b_3\ln ENC_{t-1} + b_4\ln FRN_{t-1} + b_5\ln LSS_{t-1} \\ &+ b_6\ln BMB_{t-1} + b_7\ln TMP_{t-1} + b_8\ln PRP_{t-1} + m_t\end{aligned} \tag{4}$$

In the above Equation 4 the difference operator is presented with Δ and α and β shows the short and long-run parameters respectively. While μ_t denotes error term which is a serially independent residual term. Furthermore, this model was econometrically cross-checked with the estimation of diagnostic statistics. The diagnostics statistics suggest the authenticity, normality, validity, and accuracy of the ARDL model specification in the study.

In the final part of the research methodology, we performed the impulse response function in the favour of Cholesky technique. This estimation has central recognition while estimation the causal analysis within a VAR system. This function can present accurate policy effectiveness analysis. In addition, the EFP reacts over time to the agroecosystem. The mathematical specification of the impulse response function is presented below in Equation 5.

$$\begin{aligned}LnEFP_t &= \alpha + \sum_{a=1}^{h}\beta_a LnAGL_{t-a} + \sum_{b=1}^{h}\gamma_b LnEMA_{t-b} \\ &+ \sum_{c=1}^{h}\delta_c LnENC_{t-c} + \sum_{d=1}^{h}\phi_d LnFRN_{t-d} + \sum_{e=1}^{h}\varphi_e LnLSS_{t-e} \\ &+ \sum_{f=1}^{h} h_f LnBMB_{t-f} + \sum_{g=1}^{h} 1_g LnTMP_{t-g} + \sum_{k=1}^{h} x_k LnPRP_{t-k} + \mu_{1t}\end{aligned} \tag{5}$$

The symbol μ shows the stochastic error term called impulses or innovation in the system.

RESULTS AND DISCUSSIONS

The correlation and descriptive statistics of the entire variables in the study are presented in table 1. Fascinatingly, all the independent variables display positive monotonically linkages with ecological footprint except precipitation. The provision of descriptive statistics reveals that the characteristics of all the variables are uniform, normal and balanced. This means that there is no outlier present in the data. Further, figure 2 portrays the trend analysis of the study.

After performing the preliminary analysis this study initiates formal time series analysis. First, we employed the unit root test. To examine the unit root integration, we used ADF and PP tests. The ADF and PP test results are presents in table 2. These results showed that all the variables are integrated

Table 1 - Correlation and descriptive statistics of the variables.

Variables	EFP	AGL	EMA	ENC	FRN	LSS	BMB	TMP	PRP
EFP	1.00	0.23	0.94	0.16	0.98	0.94	0.95	0.62	-0.06
AGL	0.23	1.00	0.15	-0.19	0.24	0.21	0.26	0.23	-0.37
EMA	0.94	0.15	1.00	0.01	0.92	0.95	0.92	0.58	0.02
ENC	0.16	-0.19	0.01	1.00	0.14	0.08	0.18	-0.14	0.44
FRN	0.98	0.24	0.92	0.14	1.00	0.95	0.93	0.62	-0.03
LSS	0.94	0.21	0.95	0.08	0.95	1.00	0.94	0.53	0.02
BMB	0.95	0.26	0.92	0.18	0.93	0.94	1.00	0.56	-0.04
TMP	0.62	0.23	0.58	-0.14	0.62	0.53	0.56	1.00	-0.35
PRP	-0.06	-0.37	0.02	0.44	-0.03	0.02	-0.04	-0.35	1.00
Mean	124.00	36150.17	19067.17	32796.29	3331468.00	55624995.00	6458828.00	20.50	26.40
Median	128.00	36153.50	18289.50	32859.08	3434003.00	49887500.00	6397005.00	20.59	26.75
Maximum	170.00	37003.00	24996.54	37417.90	4758868.00	87823000.00	7327529.00	21.41	35.27
Minimum	79.16	35206.00	13608.00	28645.80	1884133.00	35050016.00	5666375.00	19.44	15.98
Std. Dev.	26.31	566.16	3426.46	2287.95	876326.90	16721648.00	498805.80	0.45	4.83
Skewness	-0.19	-0.22	0.00	0.04	-0.07	0.44	0.23	-0.45	-0.26
Kurtosis	1.82	1.97	1.58	2.35	1.83	1.87	1.96	2.79	2.38
Jarque-Bera	1.92	1.57	2.52	0.54	1.74	2.57	1.62	1.08	0.82
Probability	0.38	0.46	0.28	0.76	0.42	0.28	0.44	0.58	0.66
Observations	30	30	30	30	30	30	30	30	30

Source: Author (s) calculation.

into order one. The unit root results directly us to apply the onwards models in the study. Based on the integrated order we therefore first check the long-run relationship by applying Johansen co-integration between an agroecosystem and ecological footprint in the case of Pakistan. The Johansen test outcome is given in table 3. The Johansen cointegration test consists of two further tests. First, the Max-Eigen value, and the other is Trace statistics. The Trace test has 5 co-integrated vectors and the Max-Eigen value has 4 co-integrated vectors. These results revealed that agroecosystem and ecological footprint has a long-term relationship.

This study used the ARDL approach to examine the short and long-run elasticity of agroecosystem on ecological footprint. To perform the ARDL model initially we check the Bound test approach for ARDL. This test has some characteristics such as lag length sensitivity and variables integrated order in the data. Relating to the Bound test ARDL model these concerns have been avoided and the smooth performance of the ARDL model was executed. As a result, the AIC criteria were chosen because of the lowest value among all the criteria presented in table 4. As a results, the best ARDL model was chosen having lag-length are ARDL (1, 0, 0, 0, 0, 0, 1, 1, 1). The AIC criteria have been shown in figure 4. Further, the ARDL bound test is valid because the F statistics value is within the lower and upper bound values table 5. The validity of the bound test shows that the ARDL model is dynamically stable and the long-run relationship is valid. The ARDL short and long-run relationship between agroecosystem and ecological footprint has been provided in table 6. The co-integrated form of the ARDL model shows the short-run relationship between an agroecosystem and ecological footprint. Moreover, all the variables are taken in the logarithmic form already, therefore all the co-efficient are treated as direct elasticity. This means that in the short-run form of the ARDL a model 1% increase in the agricultural land in Pakistan would enhance 0.21% ecological footprint in Pakistan. However, in the long run, this amount is a bit high which is 0.77%. Further, both in the short and long run the employment, energy consumption, and fertilizer use in agriculture have a significant impact on ecological footprint. This suggested that 1% increase in employment, energy consumption and fertilizer use in agriculture enhance 0.46%, 0.38% and 0.38% in short-run while 0.55%, 0.38% and 0.52% ecological footprint in Pakistan respectively. Similarly, in the short-run biomass burned dry matter

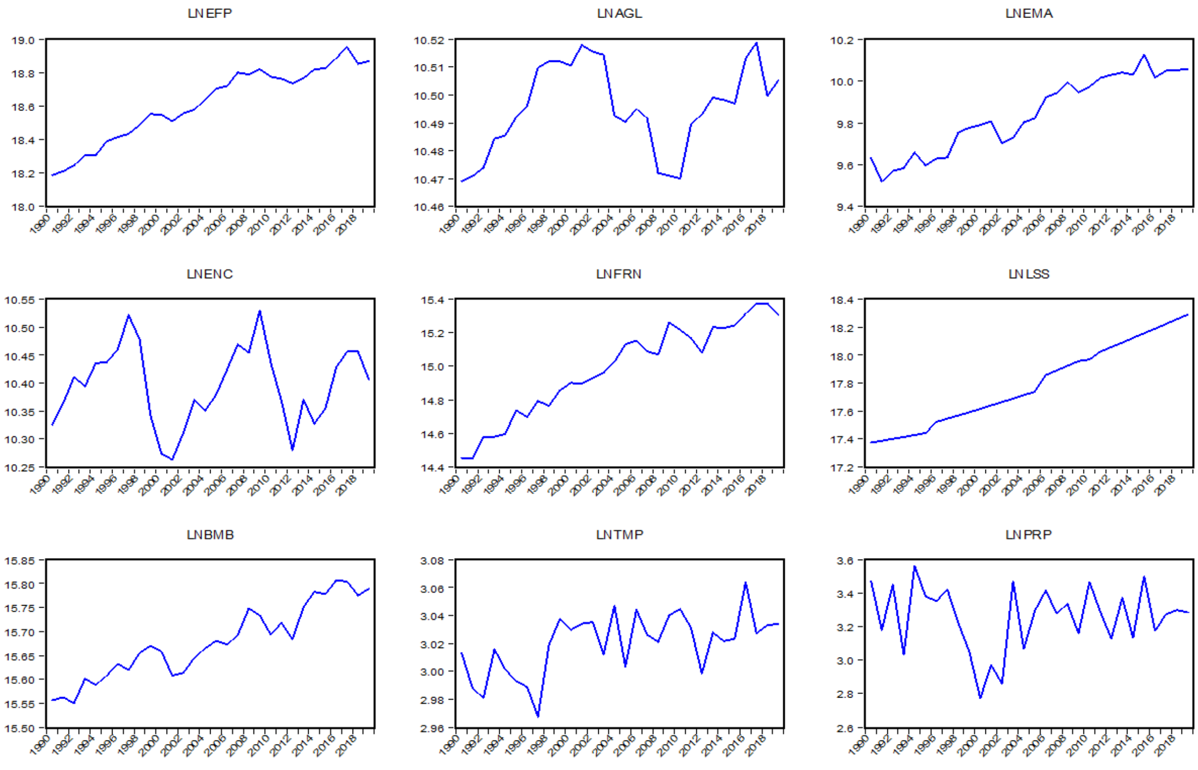

Figure 2 - Trend analysis of the study.

has a positive relationship and significant impact on the ecological footprint in Pakistan. In contrast, in the long run, the biomass burned dry matter has a negative influence on ecological footprint. Results of the short-run form of ARDL showed that temperature has a negative association with the ecological footprint. However, this nexus is the opposite in the long run of the ARDL model. The ARDL model stable in nature because the co-integrating equation in table 6 shows a significantly negative coefficient. This means that all the variables in the model dynamically move together.

To examine the validity, credibility, and stability of the ARDL model several diagnostic statistics were performed and their results are shown

Table 2 - Unit root tests.

Parameters	-------------------ADF Test------------------		--------------------PP Test--------------------		Results
	Level	1st Difference	Level	1st Difference	Integrated ~ I
EFP	-1.81(0.37)	-5.47(0.00***)	-1.91(0.32)	-5.47(0.00***)	Integrated ~ I
AGL	-2.06(0.26)	-4.75(0.00***)	-2.11(0.24)	-4.73(0.00***)	Integrated ~ I
EMA	-0.81(0.80)	-7.81(0.00***)	-0.50(0.88)	-9.86(0.00***)	Integrated ~ I
ENC	-3.083(0.14)	-4.34(0.00***)	-2.72(0.28)	-4.57(0.00***)	Integrated ~ I
FRN	-2.21(0.21)	-4.94(0.00***)	-2.48(0.13)	-8.19(0.00***)	Integrated ~ I
LSS	0.97(1.00)	-5.31(0.00***)	1.13(1.00)	-5.33(0.00***)	Integrated ~ I
BMB	-1.12(0.69)	-6.12(0.00***)	-1.12(0.69)	-6.12(0.00***)	Integrated ~ I
TMP	-3.42(0.12)	-8.66(0.00***)	-3.46(0.22)	15.28(0.00***)	Integrated ~ I
PRP	-5.08(0.21)	-11.77(0.00***)	-5.13(0.13)	-12.08(0.00***)	Integrated ~ I

Table 3 - Outcomes of Johansen co-integration.

H_0 Vs H_1	E	T	C.V 5%	P	Co-integrating Equations
H_0: V= 0 Vs H_1: V = 1	1.00	547.66	197.37	0.00	None *
H_0: V ≤ 1 Vs H_1: V = 2	0.98	283.73	159.53	0.00	At most 1 *
H_0: V ≤ 2 Vs H_1: V = 3	0.86	174.02	125.62	0.00	At most 2 *
H_0: $V \leq 3$ Vs H_1: $V = 4$	0.80	118.47	95.75	0.00	At most 3 *
H_0: $V \leq 4$ Vs H_1: $V = 5$	0.69	72.88	69.82	0.03	At most 4 *
------Max-Eigen Statistic------					
H_0: $V= 0$ Vs H_1: $V = 1$	1.00	263.94	58.43	0.00	None *
H_0: $V \leq 1$ Vs H_1: $V = 2$	0.98	109.71	52.36	0.00	At most 1 *
H_0: $V \leq 2$ Vs H_1: $V = 3$	0.86	55.55	46.23	0.00	At most 2 *
H_0: $V \leq 3$ Vs H_1: $V = 4$	0.80	45.58	40.08	0.01	At most 3 *

Note: E stands for Eigenvalue, T stands for Trace statistics, and C.V present critical value. Statistical significance. *, ** 1% & 5% level of significance.
Source: Author(s) calculation.

in table 7. These results showed that based on χ2 RESET, CUSUM, and JB test, the ARDL model is authentic, stable, and normal, and consistent with model specification. Moreover, χ2 LM and χ2 ARCH support the model concerning autocorrelation and heteroscedasticity problems. This implies that the ARDL model does not suffer from these issues.

The next type of analysis we performed in this study is known as the impulse response function. The results of this function are presented in figure 3. This revealed that how the endogenous variable treated exogenous variables in the model. This function detects the influence of one variable over other variables in the system. The impact of agricultural land has a negative impact on ecological footprint up to the 7th period of the horizon and after that, it diverges its position from negative to positive. The most influential impact has been found in the impulse of fertilizer and employment in agriculture on ecological footprint. This suggested that throughout the entire period these variables' course of the horizon is positive. Conversely, livestock in number and energy consumption has a negative relationship with the ecological footprint. The biomass burned dry matter has on and off negative and positive relationship with the ecological footprint. Further, temperature shows a positive impact on the ecological footprint in the case of Pakistan.

The stability situation of the VAR model and the goodness of impulse response function was

Table 4 - Specification of the ARDL model.

Model	LR	AIC*	SBC	HQ	Adj R^2	Specification
1	76.94	-4.41	-3.80	-4.22	0.99	ARDL(1, 0, 0, 0, 0, 0, 1, 1, 1)
2	77.71	-4.39	-3.73	-4.19	0.99	ARDL(1, 0, 0, 0, 1, 0, 1, 1, 1)
3	76.65	-4.39	-3.78	-4.20	0.99	ARDL(1, 0, 0, 0, 1, 0, 1, 1, 0)
4	77.35	-4.37	-3.71	-4.16	0.99	ARDL(1, 1, 0, 0, 0, 0, 1, 1, 1)
5	78.19	-4.36	-3.65	-4.14	0.99	ARDL(1, 1, 0, 0, 1, 0, 1, 1, 1)
6	77.12	-4.35	-3.69	-4.15	0.99	ARDL(1, 0, 0, 0, 0, 1, 1, 1, 1)
7	78.10	-4.35	-3.64	-4.13	0.99	ARDL(1, 0, 0, 1, 1, 0, 1, 1, 1)
8	77.02	-4.35	-3.69	-4.14	0.99	ARDL(1, 0, 0, 1, 0, 0, 1, 1, 1)
9	76.99	-4.34	-3.68	-4.14	0.99	ARDL(1, 0, 1, 0, 1, 0, 1, 1, 0)
10	76.95	-4.34	-3.68	-4.13	0.99	ARDL(1, 0, 1, 0, 0, 0, 1, 1, 1)

Table 5 - Bounds test for co-integration analysis.

Critical value (Pesaran et al., 2001)	Lower Bound value I(0)	Upper Bound value I(1)
10%	1.85	2.85
5%	2.11	3.15
1%	2.62	3.77
Critical value (Narayan, 2004)		
10%	1.75	3.66
5%	2.11	4.32
1%	2.99	5.98
F-statistic = 1.35, K = 8		

Source: Author(s) calculation.

examined using the AR root model. Based on the AR root diagram model if inverse roots of AR characteristic polynomial are less than 1 or located in the unit circle, the model is considered stable. Figure 4 shows that all the inverse roots of the AR characteristic polynomial are inside the unit circle. Further, all the dots should have been inside the circle on the inverse roots graph. This implies that impulse responses are good.

Table 6 - Outcomes of the ARDL model.

Variable	Co-efficient	Std. Error	t-Statistic	Prob.
Co-integrating form				
D(LnAGL)	0.21	0.43	0.49	0.63
D(LnEMA)	0.46	0.10	4.49	0.00*
D(LnENC)	0.38	0.10	3.88	0.00*
D(LnFRN)	0.38	0.06	6.44	0.00*
D(LnLSS)	-0.08	0.12	-0.68	0.50
D(LnBMB)	0.52	0.14	3.60	0.00*
D(LnTMP)	-0.07	0.19	-0.40	0.70
D(LnPRP)	-0.06	0.02	-2.95	0.01**
Cointegrating Eq (-1)	-0.90	0.14	-6.22	0.00*
Long-run coefficients				
LnAGL	0.77	0.51	1.50	0.15
LnEMA	0.55	0.14	3.88	0.00*
LnENC	0.38	0.14	2.71	0.02**
LnFRN	0.52	0.10	5.46	0.00*
LnLSS	-0.14	0.11	-1.28	0.22
LnBMB	-0.06	0.35	-0.19	0.85
LnTMP	1.30	0.59	2.21	0.04**
LnPRP	-0.01	0.08	-0.11	0.91
Constant	-7.00	6.15	-1.14	0.27
Log-likelihood (LogL) (76.94)				
Akaike Information Criteria (AIC) (-4.41)				
Schwartz Information Criteria (SIC) (-3.80)				
Hannan-Quinn Criteria (HQ) (-4.22)				
Adjusted R^2 (0.99)				
ARDL model specification: (1, 0, 0, 0, 0, 0, 1, 1, 1)				

Note: Statistical significance. * indicate 1% & ** shows 5% level of significance.

Table 7 - Results of diagnostic tests.

Test type				
ARCH Test	χ^2-statistic	Value (0.01)	*df* (1)	P-value (0.91)
Ramsey RESET Test	F-statistic	Value (1.80)	*df* (1,15)	P-value (0.19)
Breusch–Godfrey Serial Correlation LM Test	χ^2-statistic	Value (3.29)	*df* (2)	P-value (0.19)
Jarque–Bera Test	F-statistic	Value (10.11)		P-value (0.15)

Source: Author(s) calculation.

Generally, ecosystem and agricultural sustainability have both mutual interrelationships. Ecological system has massive contribution in agricultural production, which is required for human. However, with the increasing population this huge contribution to agriculture results in deterioration of ecological system (DALE & POLASKY, 2007). The positive aspects of the of the ecological system refers to ecosystem services. Agriculture operations is dependent on land use. Therefore, changes in land due to agriculture activities has substantial impact on ecosystem services. On one hand ecosystem increase crop productivity due to augmentation of pollination in crop and minimize floods frequent occurrence

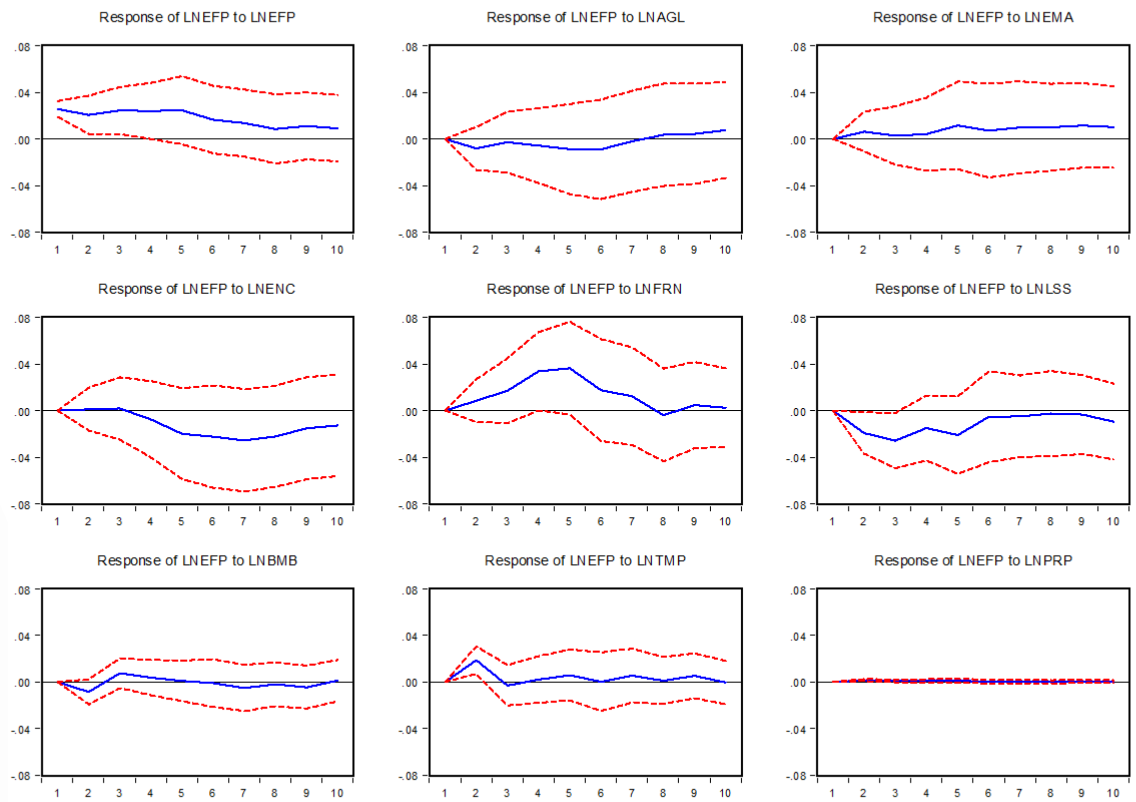

Figure 3 - Response to Cholesky one S.D. Innovations ± 2 S.E

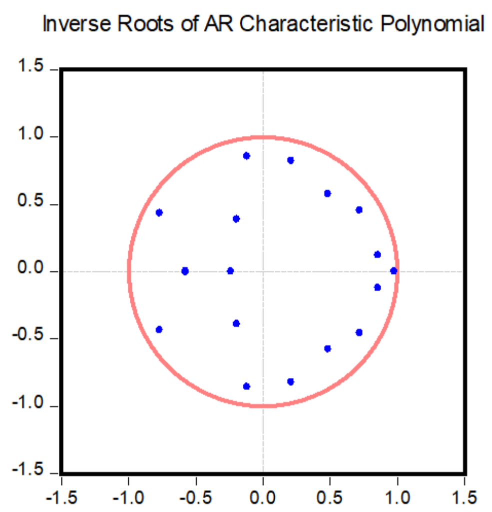

Figure 4 - Inverse root of AR characteristic polynomial.

chance due to forestation. Conversely, agriculture operations have positive and negative impact on ecosystem services. However, this study is mainly concern with the negatives impacts of agricultural practices on ecological system (ZHANG et al. 2007). Results of the study suggested that agroecosystem activities in Pakistan such as agricultural land, employment in agriculture, energy consumption, and fertilizer application enhance ecological foot print in Pakistan. It is common practice that these agricultural activities enhanced crop productivity but at the cost of environment burden. Moreover, crop burning residues is the malpractice which needs government immediate attentions to stop the deterioration of environment.

CONCLUSIONS AND POLICY IMPLICATION

This study focuses on the nexus between an agroecosystem and ecological footprint in Pakistan. The study uses modern econometric techniques such as Johansen, ARDL and impulse response function approaches. Before conducting formal analysis stationarity problem was avoided and ADF and PP tests were performed. The Johansen tests cleared there is a long-run relationship between an agroecosystem and ecological footprint. Moreover, these results were endorsed by the bound testing approach of the ARDL model. The results of the short and long-run elasticity of the ARDL model show that agricultural land, employment, energy consumption, fertilizer use and biomass burned dry matter in agriculture have a positive relationship with agroecosystem. Moreover, in the log-run form of ARDL agricultural land, employment, energy consumption, fertilizer use in agriculture and temperature have a positive impact on ecological footprint. Similar, results were detected using the impulse response function that employment and fertilizer use in agriculture have positive while energy consumption and livestock in number have a negative influence on the ecological footprint. The diagnostics and inverse AR tests alternatively showed that the stability and functional form of the ARDL and impulse response function are correct respectively.

Based on the above results several policy implications emerged. These results suggested that rigorous practices of agriculture mean extensive agriculture farming for more productivity and production deteriorate the environment and natural resources. Therefore, more chemicals and fertilizers are used for higher production. Therefore, instead of inorganic, the usage of organic fertilizer has to be used. Special attention needs for livestock raising so that it provides more manure with the added meat, milk, etc. The zero tillage should be used to reduce the usage of high energy consumption in agriculture. The scope and concept of green products should be introduced in the country and policy should be made to introduce a modern technology for low carbon emission. This study would help the researcher, planner, policymaker and academicians to provide a proper guideline and vision to provide sustainable food and environment.

DECLARATION OF CONFLICT OF INTEREST

The authors declare no conflict of interest. The founding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

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AUTHORS' CONTRIBUTIONS

Arif Ullah designed, collected the data and performed analyses. Arif Ullah, Shijia Kang and Sultan Salem prepared the draft of the manuscript. All authors critically revised the manuscript and approved of the final version.

REFERENCES

ALI, U. et al. Determinants of farmers 'choice adaptation strategies to climate change: evidence from Khyber Pakhtunkhwa Pakistan.

Pakistan Journal of Agricultural Sciences, v.57, n.3, p.941-951, 2020. Available from: <http://www.pakjas.com.pk>. Accessed: Dec. 22, 2021. doi: 10.21162/PAKJAS/20.

ALI, B. et al. Does the prevailing Indian agricultural ecosystem cause carbon dioxide emission? A consent towards risk reduction. **Environmental Science and Pollution Research**, v.28, n.4, p.4691-4703, 2021. Available from: <https://doi.org/10.1007/s11356-020-10848-3>. Accessed: Dec. 22, 2021. doi: 10.1007/s11356-020-10848-3.

BANERJEE, A, et al. Environmental and sustainable development through forestry and other resources. **Apple Academic Press Inc.**, CRC Press- a Tayler and Francis Group. p.422, 2020. Available from: <https://doi.org/10.1201/9780429276026>. Accessed: Dec. 22, 2021. doi: 10.1201/9780429276026.

BANERJEE, A. et al. Agroecological footprints management for sustainable food system, **Springer Singapore Pte. Limited**. 2021. Available from: <https://doi.org/10.1007/978-981-15-9496-0_1>. Accessed: Dec. 22, 2021. doi: 10.1007/978-981-15-9496-0_1.

CHANDIO, A. A, et al. Does energy-growth and environment quality matter for agriculture sector in Pakistan or not? An Application of Cointegration Approach. **Energies**, v.12, n.10, p.1879, 2019. Available from: <https://doi.org/10.3390/en12101879>. Accessed: Dec. 22, 2021. doi: 10.3390/en12101879.

CWD. 2021. **Climate watch data**. Available from: <https://www.climatewatchdata.org/ghg-emissions?end_year=2017&start_year=1990>. Accessed: Dec. 22, 2021.

DALE, V. H.; Polasky, S. Measures of the effects of agricultural practices on ecosystem services. **Ecological Economics**, v.64, n.2, p.286–296, 2007. Available from: <https://doi.org/10.1016/j.ecolecon.2007.05.009>. Accessed: Dec. 22, 2021. doi: 10.1016/j.ecolecon.2007.05.009.

FAO. Food Agriculture Organization. **World Food and Agriculture**. 2011. Rome. Available from: <https://www.fao.org/news/story/en/item/117492/icode/>. Accessed: Jun. 28, 2021.

FAO. Food Agriculture Organization. **World Food and Agriculture - Statistical Yearbook**. 2020. Rome. Available from: <https://doi.org/10.4060/cb1329en>. Accessed: Jun. 28, 2021. doi: 10.4060/cb1329en.

FAO. Food Agriculture Organization. **Food and Agriculture Organization of the United Nations Statistical Database**. 2021. Rome. Available from: <https://www.fao.org/faostat/en/#data>. Accessed: Jun. 28, 2021.

GFN. **Global footprint network advancing the science of sustainability**. 2021. Available from: <https://www.footprintnetwork.org/our-work/ecological-footprint/>. Accessed: Dec. 22, 2021.

GOKMENOGLU, K. K.; TASPINAR, N. Testing the agriculture-induced EKC hypothesis: the case of Pakistan. **Environmental Science and Pollution Research**, v.25, n.23, p.22829–22841, 2018. Available from: <https://doi.org/10.1007/s11356-018-2330-6>. Accessed: Dec. 22, 2021. doi: 10.1007/s11356-018-2330-6.

HLPE. High level panel of Experts. **Sustainable agricultural development for food security and nutrition: what roles for livestock?** A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security, Rome. 2016. Available from: <http://www.fao.org/3/a-i5795e.pdf>. Accessed: Dec. 22, 2021.

JHARIYA, M. K, et al. **Sustainable agriculture, forest and environmental management**. Springer Nature, Singapore, p.606. 2019a. Available from: <https://doi.org/10.1007/978-981-13-6830-1>. Accessed: Dec. 22, 2021. doi: 10.1007/978-981-13-6830-1.

JHARIYA, M. K, et al. Agroforestry and climate change: issues and challenges. Apple Academic Press Inc., CRC Press-a Tayler and Francis Group, p.335. 2019b. Available from: <https://doi.org/10.1201/9780429057274>. Accessed: Dec. 22, 2021. doi: 10.1201/9780429057274.

JEBLI, M. B., YOUSSEF, S. B. Renewable energy consumption and agriculture: evidence for cointegration and Granger causality for Tunisian economy. **International Journal of Sustainable Development & World Ecology**, v.24, n.2, p.149–158, 2016. Available from: <https://doi.org/10.1080/13504509.2016.1196467>. Accessed: Dec. 22, 2021. doi: 10.1080/13504509.2016.1196467.

JOHANSEN, S. Statistical and hypothesis testing of cointegration vector. **Journal of Economic Dynamics and Control**, v.12, n.2-3, p.231–254, 1988. Available from: <https://doi.org/10.1016/0165-1889(88)90041-3>. Accessed: Dec. 22, 2021. doi: 10.1016/0165-1889(88)90041-3.

JOHANSEN, S.; JUSELIUS, K. Maximum likelihood estimation and inference on cointegration–with application to the demand for money. **Oxford Bulletin of Economics and statistics**, v.52, n.2, p.169–210, 1990. Available from: <https://doi.org/10.1111/j.1468-0084.1990.mp52002003.x>. Accessed: Dec. 22, 2021. doi: 10.1111/j.1468-0084.1990.mp52002003.x.

LEITAO, N. C. The relationship between carbon dioxide emissions and Portuguese agriculture productivity. **Studies in Agriculture Economics**, v.120, n.3, p.143–149, 2018. Available from: <http://hdl.handle.net/10400.15/2554>. Accessed: Dec. 22, 2021. doi: 10.7896/j.1812.

LIU, X., et al. The impact of renewable energy and agriculture on carbon dioxide emissions: Investigating the environmental Kuznets curve in four selected ASEAN countries. **Journal of Cleaner Production**, v.164, p.1239–1247, 2017. Available from: <https://doi.org/10.1016/j.jclepro.2017.07.086>. Accessed: Dec. 22, 2021. doi: 10.1016/j.jclepro.2017.07.086.

LONG, X., et al. The influencing factors of CO_2 emission intensity of Chinese agriculture from 1997 to 2014. **Environmental Science and Pollution Research**, v.25, n.13, p.13093–13101, 2018. Available from: <https://doi.org/10.1007/s11356-018-1549-6>. Accessed: Dec. 22, 2021. doi: 10.1007/s11356-018-1549-6.

MEENA, R. S., et al. Response and interaction of Bradyrhizobium japonicum and Arbuscular mycorrhizal fungi in the soybean rhizosphere: a review. **Plant Growth Regulation**, v.84, n.4, p.207–223, 2018. Available from: <https://doi.org/10.1007/s10725-017-0334-8>. Accessed: Dec. 22, 2021. doi: 10.1007/s10725-017-0334-8.

MEENA, R. S. et al. Long term impacts of topsoil depth and amendments on soil physical and hydrological properties of an Alfisol in Central Ohio, USA. **Geoderma**, v.363, p.1141164, 2020. Available from: <https://doi.org/10.1016/j.geoderma.2019.114164>. Accessed: Dec. 22, 2021. doi: 10.1016/j.geoderma.2019.114164.

MAHMOOD, H. et al. Agriculture development and CO_2 emissions nexus in Saudi Arabia. **PloS one**, v.14, n.12, p.e0225865. 2019. Available from: <https://doi.org/10.1371/journal.pone.0225865>. Accessed: Dec. 22, 2021. doi: 10.1371/journal.pone.0225865.

NATHANIEL, S. et al. Energy consumption, FDI, and urbanization linkage in coastal Mediterranean countries: reassessing the pollution haven hypothesis. **Environmental Science and Pollution Research**, v.27, n.28, p.35474–35487, 2020. Available from: <https://doi.org/10.1007/s11356-020-09521-6>. Accessed: Dec. 22, 2021. doi: 10.1007/s11356-020-09521-6.

NARAYAN, P. **Reformulating critical values for the bounds F-statistics approach to cointegration: an application to the tourism demand model for Fiji**, v.2. n.4. 2004. Monash University, Melbourne. Available from: <https://bridges.monash.edu/ndownloader/files/8628229>. Accessed: Dec. 22, 2021.

PESARAN, M. H. et al. Bounds testing approaches to the analysis of level relationships. **Journal of Applied Economics**, v.16, n.3, p.289–326, 2001. Available from: <https://doi.org/10.1002/jae.616>. Accessed: Dec. 22, 2021. doi: 10.1002/jae.616.

RAFIQ, S. et al. Agriculture, trade openness and emissions: an empirical analysis and policy options. **Australian Journal of Agricultural and Resource Economics**, v.60, n.3, p.348–365, 2015. Available from: <https://doi.org/10.1111/1467-8489.12131>. Accessed: Dec. 22, 2021. doi: 10.1111/1467-8489.12131.

RAJ, A. et al. Climate change and agroforestry systems: adaptation and mitigation strategies. **Apple Academic Press Inc.**, CRC Press-a Tayler and Francis Group, p.383. 2020. Available from: <https://doi.org/10.1201/9780429286759>. Accessed: Dec. 22, 2021. doi: 10.1201/9780429286759.

RIDZUAN, N. H. A. M. et al. Effects of agriculture, renewable energy, and economic growth on carbon dioxide emissions: Evidence of the environmental Kuznets curve. **Resources, Conservation and Recycling**, v.160, p.104879, 2020. Available from: <https://www.researchgate.net/publication/341147108_Effects_of_agriculture_renewable_energy_and_economic_growth_on_carbon_dioxide_emissions_Evidence_of_the_environmental_Kuznets_curve>. Accessed: Dec. 22, 2021.

SARKODIE, S. A., OWUSU, P. A. The relationship between carbon dioxide, crop and food production index in Ghana: By estimating the long-run elasticities and variance decomposition. **Environmental Engineering Research**, v.22, n.2, p.193–202, 2017. Available from: <https://doi.org/10.4491/eer.2016.135>. Accessed: Dec. 22, 2021. doi: 10.4491/eer.2016.135.

ULLAH A, et al. Does agricultural ecosystem cause environmental pollution in Pakistan? Promise and menace. **Environmental Science and Pollution Research**, v.25, n.14, p.13938–1395, 2018. Available from: <https://doi.org/10.1007/s11356-018-1530-4>. Accessed: Dec. 22, 2021. doi: 10.1007/s11356-018-1530-4.

ULLAH, A., KHAN, D. Testing environmental Kuznets curve hypothesis in the presence of green revolution: a cointegration analysis for Pakistan. **Environmental Science and Pollution Research**, 2020. Available from: <https://doi.org/10.1007/s11356-020-07648-0>. Accessed: Dec. 22, 2021. doi: 10.1007/s11356-020-07648-0.

WORLD BANK 2020. **Agriculture and Food**. The world bank. Available from: <https://www.worldbank.org/en/topic/agriculture/overview>. Accessed: Dec. 22, 2021.

ZHANG, W. et al. Ecosystem services and dis-services to agriculture. **Ecological Economics**, v.64, n.2 p.253-260, 2007. Available from: <https://doi.org/10.1016/j.ecolecon.2007.02.024>. Accessed: Dec. 22, 2021. doi: 10.1016/j.ecolecon.2007.02.024.