The effects of environmental degradation on agriculture: Evidence from European countries

Duojiao tan

Accounting School, Hubei University of Economics, Wuhan, P. R. China

tanduojiao@hbue.edu.cn

Festus Fatai adedoyin

Department of Computing and Informatics,
Bournemouth University, UK
fadedoyin@bournemouth.ac.uk

Rafael alvarado

Carrera de Economía and Centro de Investigaciones Sociales y Económicas,

Universidad Nacional de Loja, Loja 110150, Ecuador.

jose.r.alvarado@unl.edu.ec

Muhammad ramzan

Faculty of International Trade and Economics, Shandong University of Finance and Economics,

Shandong, China.

ramzanmehar7@gmail.com

Md Safiullah kayesh

Department of Economics, University of Chittagong

Chattogram, Bangladesh

kayes.eco@cu.ac.bd

Muhammad Ibrahim Shah[1,2,*]

[1]Resource Economics and Environmental Sociology (REES), University of Alberta
Edmonton, Canada

[2]Alma mater Department of Economics, University of Dhaka, Bangladesh

mshah3@ualberta.ca

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[1]**Corresponding author**

Abstract

Currently, one of the most significant challenges of agricultural sector of an economy is to keep pace with the world's rapidly growing population in order to feed them. But continuous environmental degradation is posing serious threat to the agricultural production. The objective of this study is to look at how environmental degradation in the form of biodiversity loss, deforestation and agricultural emissions can affect agricultural production as well as cereal and vegetable production in 35 countries of Europe. The study utilizes Driscoll and Kraay estimator to understand the potential impacts of environmental degradation as well as other variables such as organic farming, renewable energy, political stability, e-governance, social progress and women empowerment on agriculture. The result reveals that biodiversity loss harms agricultural, cereal and vegetable production while forest area increase positively affect the cereal production and vegetable production. Agricultural emissions, on the other hand, does not significantly affect the three independent variables but it has a negative effect on cereal and positive impact on vegetable production. Renewable energy use, political stability and women empowerment all have positive and significant impacts on all the three dependent variables. E-governance significantly and positively affects agricultural and vegetable production and social progress has positive but insignificant effect on the dependent variables. Finally, the study provides crucial policy implications for the agricultural sector of Europe.

Keywords: Agriculture; Environment; Europe; Organic; Renewable

1.0 Introduction

To effectively restrict environmental consequences, there is broad consensus that stress should be directed not only at the appearance of environmental problems, but also at the larger socioeconomic drivers of those impacts, which are often overlooked (Pendrill, et, al., 2019; Liu et al., 2015; Kanemoto et al., 2014). Environmental degradation is primarily caused by the combustion of fossil fuels and biomass consumption, as well as drivers of land use such as water extraction and forestry in response to increased international demand (Pendrill, et, al., 2019; Davis and Caldeira, 2010). Deforestation, on the other hand, is a major source of biodiversity loss and anthropogenic greenhouse gas emissions (Pendrill, et, al., 2019; Kanemoto et al., 2014). Environmental deterioration, such as biodiversity loss and deforestation, has concerns for agriculture around the world (Rehman et al., 2020). As per facts, **a**n estimated 31% of the world's land area is covered by forest, which not only helps people survive and thrive by detoxifying air and water, but also employs a large portion of the population (Adams, 2012; WWF, 2021). Overall, forests provide livelihood and cultural integrity to 1.6 billion people worldwide, with 13.2 million directly employed in the forest sector. Meanwhile, forests are home to approximately 80% of the world's land-based species, as well as 80% of the world's terrestrial biodiversity, and are an important source of food, timber, fibre, medicine, and shelter (WWF, 2021). Correspondingly, forests play an essential role in pollution mitigation by sinking carbon, regulating the preventing global warming, water cycle and soil erosion. However, deforestation is jeopardising these benefits, and it is especially concerning in tropical rain forests, which are home to a large portion of the world's biodiversity (Matthews, et al., 2014).

The reduction in the number, biological communities, and genetic variability, as well as the variety of species in a given area, is referred to as biodiversity loss. It also refers to a decrease in biodiversity within a species, a specific geographic area, an ecosystem, or the entire earth, which is the basis of ecosystem goods and services ranging from food, medicines, and building materials, to climate regulation and clean water supplies (Sida, 2010). The loss of diversity of life can lead to a collapse in the natural cycle of the ecosystem (Arora, 2019). As a result, the poor, who frequently rely on such goods and services for basic survival or earnings, are directly influenced by environmental deterioration, and the loss of biodiversity (Vedeld, et al., 2007; Diaz et al., 2019).

Simultaneously, one of the most significant challenges is to keep pace of agricultural production to the world's rapidly growing population in order to feed the world. To achieve this, farmers uses fertilisers, and pesticides, as well as try to expand agricultural land, which has resulted in an increase in agricultural emissions (CH_4) of more than 60% over the last 40 years (Hofstra, & Vermeulen, 2016; Fróna, Szenderák, & Harangi-Rákos, 2019). As a result, agriculture production continues to suffer, demonstrating a symbiotic relationship between emissions and agricultural output. A high level of biodiversity, on the other hand, serves to strengthen ecological, social, and economic systems, reducing vulnerabilities to changes in the environment. For instance, a diverse farming base, as compared to monocultures, eliminates the risk of agricultural crop failures due to pests or diseases that affect most but not all crops. In this case, biodiversity helps to mitigate all these risks while also offering a crucial "safety net" for households during difficult times (Scherr, & McNeely, 2008).

On the other hand, agriculture is the world's leading source of greenhouse gas (GHG) emissions, accounting for more than 11% of total anthropogenic emissions from direct sources (Maraseni, & Qu, 2016). In addition, if we include emissions from agricultural input production, storage, packaging, and transportation, this figure further grows by 3-6 percent in global emissions. Meanwhile, if we take into account direct agricultural emissions, manure management accounts for 7% of methane (CH_4) emissions, rice production accounts for 11%, biomass burning accounts for 12% of CH_4 emissions, ruminants account for 32%, and soils account for 38% of nitrous oxide (N_2O) (Vermeulen et al., 2012; Bellarby et al., 2008). The velocity of agricultural emissions risen day by day due to the intensive use of energy in farm machinery and other related inputs. Although agriculture provides a primary source of income for nearly 86% of the world's rural population, it pollutes the environment and as a result it has affected itself (Van Pham & Smith, 2014). For instance, Arora (2019) demonstrated that if GHG emissions remain unchanged until 2100, crop yields will be reduced approximately by

45%, wheat yields by 50%, and rice yields by 30%. In this context, national policies must be aligned with sustainable development goals (SDGs) such as SDG-2.4, which stresses the importance of increasing productivity through sustainable food production systems and implementing resilient agricultural practices that help preserve ecosystems and strengthen capacity for environmental sustainability; SDG-12 also leads policies on responsible production and consumption.

In Europe, Agriculture is the leading sector of land user, occupies more than 40% land of the total territory of the EU-28, with agricultural holdings accounting for the remaining 9%. This territory is covered by the forest and other wooded land almost in the same proportion (Giannakis & Bruggeman, 2015; Monteleone, Cammerino, & Libutti, 2018). Therefore, agriculture has played a significant role in defining the landscape and continues to be a driving force in its transformation. As such, it is observed that agriculture is leading to transform a large portion of rural landscape in Europe. Meanwhile, as one of the main driving trends in this transformation is agricultural land use, while farmland marginalization, concentration, abandonment, intensification, and agricultural specialization, are the other factors (Monteleone et al., 2018; Paulo et al., 2016). In terms of consumption, the trend has frequently transitioned toward dairy products and animal origin, which have a high value added. Consequently, the tendency increased demand for feed crop production. In the European Union, livestock farming accounted for 66% of total land use and 40% of total global land use (Fróna, Szenderák, & Harangi-Rákos, 2019). However, due to the debt crisis in Mediterranean countries (Spain, Greece, Italy, Cyprus, and Portugal) over the last decade, this trend of agricultural farm has been steadily declining. Similarly, the number of farm holdings in Eastern European countries is declining at the fastest rate due to redistribution and privatisation of agricultural land as part of the restructuring process (Giannakis & Bruggeman, 2015). Despite this, agriculture continues to play an important economic role in many rural areas throughout Europe. In 2020, the EU-27's gross agricultural value added was 177.0 billion euros, accounting for 1.35 of Europe's GDP contribution. Agricultural income per annual work unit is estimated to be 27.2%, relatively higher than the 2010 index level (Eurostat, 2020). Agriculture employed 9.7 million people in Europe in 2016, demonstrating that agriculture remains a major employer in the EU (Eurostat, 2018). Furthermore, cereals are grown on approximately half of all farms in Europe, accounting for 1/4th of total crop production value and occupying the third largest area of total agriculture. In comparison to the rest of the world, this region produces 20% of all cereals, with 15% exported to other countries (FAO, 2016). Besides that, the EU produced fresh vegetables worth 34.5 billion euros in 2017. Two countries, Spain and Italy, produced two-fifths of the total vegetables production (Eurostat, 2019). In reality, agricultural activities such as slurry spreading, the use of carbon - based nitrogen fertilisers, and manure storage cause an estimated 94% of the total ammonia emissions in the EU (EEA, 2019). In addition, the sector consumed roughly half of all fresh water, putting significant strain on renewable water resources.

However, it is also undeniable that not only economic, but also political and social factors play a role on agricultural land usage and landscape. During the last decades, changes in EU agriculture also driven at farms level by the reforms of the common agricultural policy (CAP), resulting in landscape change. Subsidies to farmers are detached from production and addressed to a direct payment under the CAP framework in order to promote a market-oriented approach (Monteleone, Cammerino, & Libutti, 2018). Consequently, these farm level subsidies promote advanced sustainable agricultural practices such as renewable energy and organic produce, as well as helping to improve agricultural output without affecting the environment. Meanwhile, heightened environmental concerns were incorporated into a set of "good agricultural and environmental conditions" that control farmers' eligibility for EU subsidies. Furthermore, water and soil quality, landscape management, and soil carbon stock are all taken into account in this policy. The CAP has also been reoriented (from 2014-2020) to integrate rural development and environmental issues, which are mainly composed of a significant number of vital ingredients including certain rural development instruments and agro-environmental measures. In this new CAP, farmers will receive around 30% of the overall amount of resources if they take care of the following three categories (Monteleone, Cammerino, & Libutti, 2018). For instance, first, farmers must maintain permanent grassland on their properties. Second, they should devote significant resources to diversifying arable crops, and third, they must be accountable for allocating a minimum portion of the available agricultural land to “ecological focus area”. Despite this, many EU countries have launched online e-government services for farmers, which are based on an open source solution. To that purpose, the framework serves as a road map for installing e-government systems and services, which has yielded promising results due to its low cost and ease of implementation (Ntaliani, et. al, 2010). In practice, however, CAP reforms have made the agriculture sector more market-oriented, resulting in less protection for the sector. Farmers faced rapid increased market volatility as a result of this transition (Giannakis & Bruggeman, 2015). Meanwhile, many people are concerned that these rapid market changes have resulted in changes in land use, resulting in the expansion of agricultural operations in certain areas and the marginalisation and abandonment of agriculture in others. Consequently, agricultural land abandonment creates enormous environmental risks and economic cost in terms of natural capital and biodiversity loss, as well as malnutrition and job loss among agricultural workers (Navarro and Pereira, 2012; Alexiadis et al., 2013; Giannakis & Bruggeman, 2015; Pe'er, et. al., 2020). Furthermore, in 1988, the EU members adopted an international resolution recognising farming as a profession in which both men and women have equal employment opportunities. However, just about 30% of total farms in the EU are currently run by women, with just 4.9% of those under the age of 35 and 40% over the age of 65 (Franić, & Kovačićek, 2019; Balezentis, et. al., 2021). As a result, despite the current upward trend, the gender gap in farming exists, with the potential to widen in the future. These are crucial debates for the agricultural performance of EU countries, and they require a thorough investigation for solutions and policy formulation. To the best of our understanding, however, no study has quantified the potential shift in agriculture, cereal, and vegetable production in Europe as a result of deforestation, biodiversity loss, agricultural emissions, women empowerment, political stability, and e-governance changes. In this context, this study explores the effects of these explanatory factors on agriculture, as well as cereal and vegetable production, across European countries from 2009 to 2018. The figures 1, 2 and 3 describe the main three independent variables used in this study. Figure 1 illustrates the distribution among the countries of the red list index. Figure 2 illustrates the territorial distribution of the forest area. Finland and Sweden are the countries with the largest forest area. Finally, figure 3 shows the distribution among countries of agricultural emissions on average during the period analyzed.

<Insert Figure 1 here>

<Insert Figure 2 here>

<Insert Figure 3 here>

Accordingly, this study adds to the current literature in number of ways by examining the effects of deforestation, biodiversity loss, agricultural emissions, women empowerment, political stability, and e-governance on agriculture using a novel D-K estimator of fixed effect. First, the D-K estimator has an advantage over the OLS estimator in that it provides accurate information after adjusting for heteroskedastic and autocorrelated error structures in panel datasets. As we know that heteroscedasticity raises the variance of coefficient estimates and lowers p-values than they should be, which the OLS technique unable to detects. Therefore, the study will provide policy administrators with an in-depth insight of the selected determinants of European nations' agriculture, based on more robust empirical findings than prior studies. Second, the study also considered social progress, political stability and E-governance into account when determining the production performance of each sub-sector of agriculture, such as agriculture, cereals, vegetables, and fruits, each of which is distinctive in its own right. In this context, the study apprises European leaders through statistical conclusions about the efficacy of various economic, political, and social measures for agriculture in all associated countries. Furthermore, the study provides insight into the degree to which these policies have been instituted in Europe's agriculture sector, assisting in the formulation of corrective measures as needed, as well as policies to achieve the SDGs, particularly SDG target 2.5, which focuses on sustainable production and consumption.

The paper's reminder contents are organised as follows. The review of relevant published studies is outlined in the following section. The data and techniques utilised are detailed in Section 3. The findings and discussion are presented in Chapter 4, and the conclusion and policy pathway are discussed in Section 5.

2.0 Literature review

Since this study addressed the environmental degradation on agriculture as well other variables, we split this section into four subsections: (a) Environment and agriculture, (2) Renewable energy and agriculture, (3) Socio-political context and agriculture, and (4) Women empowerment, e-government and agriculture.

2.1 Environment and Agriculture

Our main objective is to investigate the effect of environmental degradation on agriculture production. Since different factors are responsible for environmental degradation, researchers have used several variables to quantify the degradation, and numerous studies have been conducted to determine the effect of environmental deterioration on agriculture. For example, Ayinde et al. (2011) examined the effect of climate change on agriculture productivity in Nigeria from 1981 to 2000 by using the Co-integration approach. The findings revealed that the temperature change has a detrimental impact on agriculture production, while rainfall has a positive effect. The studies propose agriculture-sensitive technologies to boost agricultural production. ~~For the similar county~~, Sulumbe et al. (2016) found that in Nigeria deforestation negatively affects agricultural production in both the short and long run, primarily due to soil erosion and the conversion of ~~converting~~ the arable land to less productive land.

Climate change is a well-recognised issue among policymakers in the current world. ~~A lot of~~ Thus, many studies have concentrated on the effect of climate change on agriculture. For example, Amponsah et al. (2015) ~~they~~ examined the effect of CO_2 concentration on cereal output of Ghana from 1962-2010 by using the autoregressive distributive lag model (ARDL) bounds test approach to co-integration. The findings revealed that CO_2 emissions have a significant negative effect on cereal output. Edoja et al. (2016) investigate the dynamic relationship between CO2 emissions and agriculture productivity in the case of Nigeria. They have found no any long-run relationship between these two variables in the Johanson cointegration test. However, they found a significant short-run negative relationship between CO_2 emissions and agriculture productivity in the VAR estimation. ~~Also for~~ In the case of Ghana, Asumadu-Sarkodie & Owusu (2016) examined the relationship between CO_2 and agriculture from 1961 to 2012 by using vector error correction and autoregressive distributive lag models. In this study, they did not consider the production of a particular crop as a variable but r~~ather~~ instead included various factors representative of the agriculture sector. The estimated result revealed the existence of a causal relationship between CO_2 emission and agriculture in both the short and long term. However, the intensity of this relationship gradually decreases. Akomolafe et al. (2021) incorporated various agriculture subsectors into the model to examine the effects of CO2 emissions on agriculture production in Nigeria from 1981 to 2014. Using VECM, the result shows that CO_2 positively impacts total agriculture production and other agriculture subsectors. For the particular agricultural yield, Rehman et al. (2020) attempted to explore the effect of CO_2 emission on maise crop production in Pakistan using the autoregressive distributive lag approach for the period of 1988 - 2017. They found a long-run positive association between CO_2 emission and maise production.

On the other hand, Salinger et al. (2005) examine the impact of climate change on agriculture productivity in the United States and Canada. According to their findings, an increase in CO_2 emissions can positively and negatively affect agricultural productivity, primarily due to the geographic variation of arable land in these two countries. In both cases, however, extreme weather changes adversely affect agricultural yield. Similarly, in the case of Tunesia, cereal and date production also decreased due to a rise in annual temperature (Ben Zaied & Ben Cheikh, 2015). However, they found the opposite result in the highland area.

2.2 Renewable energy and agriculture

Chandio et al. (2019) investigate the long-run effects of macroeconomic, energy, and demographic factors on the environmental quality in Pakistan by using the Co-integration and autoregressive distributive lag model (ARDL) approach. Their results indicate that environmental quality improves due to the increase in financial development and foreign direct investment, whereas increased economic growth and energy consumption in agriculture degrade the environmental quality. They argued for shift fossil fuels to renewable energy in order to improve the quality of the environment.

Liu et al. (2017) investigated the relationship of per capita renewable energy, agriculture, and CO_2 emission with output and non-renewable energy in BRICS countries in 1992 -2013 by utilising Panel co-integration. The findings revealed that per capita production and renewable energy are inversely related to CO_2 emission, while non-renewable energy and agriculture positively influence CO_2 emission. Moreover, they found unidirectional relationships from renewable energy to both CO_2 emission and non-renewable energy. Thus, the study suggests raising the use of renewable energy and strengthening agriculture management to mitigate the adverse effects of global warming.

Jebli & Youssef (2017) examined the short and long-run causal relationship between per capita renewable energy consumption, carbon dioxide emissions, real GDP, agricultural value-added, and arable land use in Morocco from 1980 to 2013. They used the autoregressive distributive lag (ARDL) and Granger causality approach to check the co-integration. They utilised two distinct models in this research: agricultural value-added and another for arable land usage.

They found that renewable energy consumption rises in the long run in proportion to economic growth, agricultural output, and arable land use. On the other hand, CO_2 emissions have a negative effect on the use of renewable energy.

Jebli and Youssef (2017) studied the association of per capita renewable energy consumption, agricultural value-added, CO2 emissions, and real GDP in five North African countries from 1980-2011 by using panel co-integration to identify the relationship among the variables. They found bidirectional causality between CO_2 emissions and agriculture and unidirectional causality running from renewable energy consumption to agriculture both in the short run and long run. The estimated result showed that both GDP and renewable consumption positively influence CO_2 emissions, whereas agriculture value-added contributes to CO_2 reduction. Their findings support that renewable energy consumption has a significant positive impact on agriculture production and environmental degradation.

2.3 Socio Political context and agriculture

There are several studies that have examined the effect of quality of institutions or corruption on agriculture. Anik et al.(2011), for example, examined the effect of corruption on farm-level efficiency during two distinct rice growing seasons in Bangladesh. They have collected data from 210 farmers and employed a stochastic frontier efficiency model. The findings exhibit that corruption costs may either increase or decrease efficiency, depending on the circumstance and context. In this connection, corruption is more encouraged in a controlled input market than in an open market, because in this case, bribe-paying farmers can acquire more inputs and operate more efficiently. Similarly, Anik & Bauer (2017) examined the impact of corruption in the agriculture sector of Bangladesh. The authors concentrated on the micro-level of the fertiliser market, where the sellers influence fertiliser price to make more profit. The findings showed that the sellers' profit is positively associated with the market restriction, while farm profit is adversely associated with the illegal financial transaction. Thus, the restriction in the market generates efficiency differences among the farms, and proper intervention can reduce corruption.

Sheikh & Mustafa (2018) examined the macroeconomic performance of agriculture in Pakistan from 1950 to 2010 by employing an autoregressive distributive lag model and error correction model. They have considered two political regimes such as democracy and dictatorship. They found that the overall macroeconomic performance under an autocratic system is better than a democratic system. It is hard to anticipate whether democracy or autocracy would be advantageous to Pakistan. However, they mentioned that persistent political regimes contribute to higher macroeconomic performance.

In a recent study, Abbas Drebee & Azam Abdul-Razak (2020) examined the short-run and long-run relationship between corruption and agriculture growth in Iraq from 2004 to 2019. Their estimated results revealed the existence of a long-run relationship between corruption and agriculture growth, where corruption significantly disrupted agriculture growth.

2.4 Women empowerment, e-government and agriculture

Available literature suggests that women's empowerment and the use of technology have a significant effect on agricultural output. Lee et al. (2017) examined the impact of agriculture extension programs on farmers' income and livelihoods. They analysed cross-sectional data of 1682 households using the propensity score matching (PSM) method. They found that when women have more access to modern technology and decision-making, this increases their monthly income and living standards. However, they have not found similar evidence in men's dominating farms. Thus, the findings indicate that increasing women farmers' access to modern technologies and farm management practices may improve the program beneficiaries' food security and dietary habits by increasing agriculture production.

Salazar et al. (2018) investigated the effect of a livestock transfer on Nicaragua's economically marginalised female farmers. They used double-difference estimation in conjunction with the propensity scoring method (PSM) on 1200 farmers. They also applied randomised control trials on treatment and control groups. Their findings bolster the argument that participation in this program improves farmer's food security by increasing earnings from agri-business. Moreover, this project also has a favorable impact on women's empowerment and gender equality in their households.

Diiro et al.(2018) examined women's empowerment in agriculture production in western Kenya. They applied the instrumental variable regression method to analyse cross-sectional data and found that empowering women improves grain production. Moreover, when women are empowered to work alongside men on co-owned farms, production improves. However, there is no indication that women's workload affects maise production. Although this study focused on maise production, the findings indicate that empowering women has a more substantial impact on reducing the gender gap and increasing agricultural output regardless of gender and ownership pattern of a farm.

On the other hand, Veeramacheneni & Vogel (2010) investigated the influence of information and communication technology on India's agriculture sector. The results revealed that investment in the Information and communication technology sector benefits agricultural output and exports.

Das et al.(2017) also examined the effect of information and communication technologies on the agriculture output of Bangladesh. They conducted a randomised survey on 1990 farmers and applied difference in differences analysis. According to the findings, rice (boro) output has increased more in ICT-based regions than in non-ICT- based service regions. According to Chhachhar et al. (2014), technology has brought positive changes in the agriculture sector in many countries, where mobile phones are vital in ensuring farmers get fair pricing. Moreover, farmers now get weather forecasts through mobile devices, and agriculture production increased significantly due to preventative measures.

3.0 Data and method

3.1Theoretical underpinning

The investigation of the link between environmental degradation and agriculture has caught the attention of economists, policy management, and the public at large. As a result, this study tends to examine this area in the context of the agricultural sector in 35 Europian countries during 2009-2018. The list of the countries is listed in appendix table A.1.

The main focus of this study is on how biodiversity loss, deforestation and agricultural GHG emission may affect the agricultural sector. Three dependent variables used in the study involve overall agricultural production, cereal production and vegetable and fruit primary production indices. We have selected cereal production as it accounts for 20% of world cereal production and vegetable and fruit primary production as Europe represents a big yet stable market for fresh fruit and vegetable. We report three maps for three dependent variables used in this study in figure 4, 5 and 6 respectively. Figure 4 illustrates the spatial distribution of agricultural production in the European countries that were included in the research. The map reports the average agricultural production during the analyzed period (2009-2018). We find that there is a heterogeneous behavior in agricultural production among the countries analyzed. Italy and Romania are the countries with the highest agricultural production.

<Insert Figure 4 here>

Figure 5 shows the distribution of cereal production in the average European countries during the period analyzed. The countries with the highest cereal production are France and Greece, while the countries with the lowest cereal production are Norway, Estonia, Latvia, Lithuania, and Slovakia.

<Insert Figure 5 here>

Figure 6 reports the distribution of the vegetables fruit primary production in the countries analyzed. The information represented on the map corresponds to the average of the variable during the analyzed period.

<Insert Figure 6 here>

Red List Index (RLI) will be used to proxy biodiversity loss. RLI of a species, according to IUCN, has values that range from 1 to 0. An RLI value of 1.0 equates to all species being categorised as Least Concern, and hence that none are expected to go extinct shortly. An RLI value of zero indicates that all species have gone Extinct (Butchart et al., 2005; Butchart et al., 2007). The data for deforestation and agricultural greenhouse gas emission comes from FAOSTAT. The reason for choosing agricultural GHG instead of overall GHG is that it indicates the sustainability of agricultural sector. The lesser the emission, the greater the possibility of sustainable agriculture. Therefore, improving agricultural sustainability may provide benefits to the agricultural sector by improving productivity. We selected these three indicators because most of the existing studies assess the effect of climate change or deforestation on agricultural production, not focusing much on the effects of biodiversity loss as well as how the emissions from agricultural sector can harm the agricultural sector itself.

Our study thus provides a critical understanding of how these three indicators can separately affect the agricultural sector of Europe which will allow us to provide more concrete policy directions for this region.

As much as these have adverse effects on agriculture, there are several variables, considered in this study, that could help in sustaining the agricultural produce. These include renewable energy, organic area, e-governance, women empowerment, and political and social progress. This is because increasing the use of renewable energy use in the agricultural sector could increase agricultural productivity (Karkacier et al, 2006), and produce less pollution in the environment while advancing to fight global warming.

However, the practice of organic area in agriculture is often posed as the solution, because it produced food with less harm to the ecosystem, plant and animal species, and human generally (McIntyre et al, 2009; De Schutter, 2010). Hence, the beneficial impact of the organic area in the agricultural sector in Europe assessed, as it is even regarded as a positive public image that it is commonly hyped as the paradigm for sustainable agriculture (Mercati 2016). Other important variable is e-governance index which measures the performance of rating of government relative to the use of telecommunication technology, and human capacity. The index ranges from 0 – 1, and a higher index means that the country is well versed with the use of technology (United Nation E-Government Survey). This survey is published once after two years, hence we interpolated the data to get a continuous time series indicator for this variable.

Other variables which could influence the agricultural sector of Europe involve women political empowerment, political and social progress. The data for women political empowerment comes from V-DEM, social progress is sourced from Social Progress Imperative and political stability and absence of violence comes from World Development Indicators. Table 1 summarizes the variables used in this study.

<Insert Table 1 here>

3.2 Estimation method

To get the purpose of research objectives of estimating the factors that influence the agricultural sector of Europe, this study proposes three distinct models and engages in the systematic estimation of panel data techniques in relations to the previous panel data studies (Shahbaz et al., 2016). The generalised econometric model is presented in the equation below. All variables were transformed into natural logarithms to control for outliers.

$$\ln Y_{it} = \beta_{\circ} + \beta_i X_{it} + \varepsilon_{it} \qquad [2]$$

Where i is the number of countries, and t is the number of years; ε_{it} is the random error components that are $\gamma_i + \mu_{it}$, that is country-specific endogeneity and *I.I.D* idiosyncratic error term is $\ln Y_{it}$ is the natural logarithm of the dependent variables (that is, Agriculture, Cereal, and Vegetable). $\beta_{\circ}$ is the constant value, X_{it} is the coefficient of explanatory variables (red list index, forest area, agricultural total emission, area under organic production, renewable energy consumption, political stability, social progress index, women political empowerment index, and e-governance development index. β_i is the coefficient of the explanatory variables. For red list index, organic area, renewable energy, political stability, social progress and women empowerment index, the value of $\beta > 0$.

This means that these variables are expected to contribute significantly to agriculture (Mushtaq et al., 2007; Sebri and Abid 2012; Jebli and Ben Youssef, 2017; Birkhaeuser et al., 1991; Ommani & Chizari, 2008; and Taragola & Van Lierde, 2010). Also, the emission from the agricultural sector is expected to have $\beta < 0$. However, the forest area can have either positive or negative impact on agriculture. To avoid potential bias and obtain robust estimates of the model, the study employed Driscoll and Kraay (1998) estimator. The motivation behind using Driscoll and Kraay (DK) estimator is that it provides a covariance estimate in the presence of heteroskedasticity, autocorrelation, and standard error of estimates that are more robust to cross-sectional and temporal dependence (Sarkodie and Strezov 2019).

4.0 Results and discussion

To examine the impact of the independent variables on total agricultural production, cereal production, and vegetable production, we used a sample of 350 observations for the European Union countries during 2009-2018. Various empirical investigations have estimated the impact of similar variables on agricultural production, highlighting the importance of political stability and the use of technology to improve yield in agriculture (Veeramacheneni et al., 2010; Sheikh & Mustafa, 2018). The variables defined in Table 2 report the descriptive statistics of the variables used in the econometric estimates. We report the mean, standard deviation, minimum values, maximum values, standard deviation, skewness, kurtosis and Jarque-Bera test. We find more significant variability in emissions from agriculture, renewable energy consumption, cereal production, and vegetable production among the data of interest. While, in the red list index, governance index, female empowerment index, and political stability, there is less variability between the European Union countries.

<Insert Table 2 here>

The degree of association between the variables constitutes a starting point in understanding the causal link between the variables. Table 3 (listed in the supplementary file) reports the partial correlation matrix between the variables. All variables are expressed in logarithms, where we use three measures of agricultural production as dependent variables. The independent variables include environmental, energy, technological, governance, and social progress variables. We found some interesting results that offer a preliminary look at the later econometric results. Except for some, the coefficients of the partial correlations between the independent variables are extremely small. Column 1 reports the principal coefficients of interest because it indicates the association between the independent variables and the dependent variable.

<Insert Table 3 here>

Table 4 reports the Chudik and Pesaran (2015) cross sectional dependence test to see if there is any cross sectional dependency between the series. We find that all the variables indicate significant level of cross sectional dependence.

<Insert Table 4 here>

Table 5 reports the Driscoll & Kraay (1998) regression; specifically, we report the coefficients, the p-value, and the fit of the model. In this regression, the dependent variable is the logarithm of agricultural production. The independent variables are the red list index, forest area, emissions from agriculture, area under organic agricultural production, renewable energy consumption, political stability, the e-governance index, the social progress index, and the political empowerment of women.

<Insert Table 5 here>

The results obtained in the regression can be organised in the following aspects. **First**, using a maximum of 3 lags, we find that the "within" fit of the model is close to 56% ($R^2 = 0.56$). The F test indicates that, jointly and simultaneously, the covariates have explanatory power for agricultural production because the p-value is zero. **Second**, the red list index has a positive and statistically significant effect on agricultural production, whose elasticity is high (3.66) compared to the rest of the elasticities of the model. This result implies that if the red list index increases, agricultural production also increases. In practice, an increase in the red list index means that the number of threatened species is low, which is beneficial in terms of biodiversity conservation and environmental sustainability. Some previous studies suggest the loss of biodiversity due to agricultural activity (Orsenigo et al., 2018; Crosti et al., 2020). However, the European Union countries apply various collective policies, which may explain why agricultural production in the European Union does not occur at the cost of the threat to biodiversity (Pizzi et al., 2020). The nexus between biodiversity and agriculture can be coherently analysed through the lens of the Sustainable Development Goals, in particular SDG 14 and 15. Both SDGs seek to conserve marine life and life in terrestrial ecosystems (Ntona et al., 2018; Tsani et al., 2020). Agricultural sustainability requires that increases in agricultural production result from innovation, modernisation and not the loss of biodiversity caused by the increase in the agricultural frontier.

Third, the impact of the forest area has a negative relationship with agricultural production; however, this coefficient is not statistically significant. This result means that the number of available hectares of forest area in the countries analysed has no impact on the amount of agriculture produced. In terms of sustainability, the result implies that the quantity of agricultural goods produced does not depend on the vegetation cover available to the European Union countries. The forestry policy of the members of the European Union is well coordinated, and the institutional levels of these countries are high (Orsi et al., 2020; Elomina & Pülzl, 2021). Consequently, joint actions at the level of the European community and the countries' level contribute to explaining the result obtained. Some recent empirical research has studied the impact of forest areas on agriculture with inconclusive results. For example, Zhao et al. (2019) point out that forest restoration increases the availability of water that is very necessary for agricultural activities. Sousa et al. (2019) point out that large-scale agricultural expansion that destroys the forest area decreases and modifies the configuration of the landscape and that forest conservation benefits agricultural production. It is logical to expect that reforestation and conservation policies will be beneficial in preventing soil erosion and maintaining agricultural yield and productivity (Sulumbe et al., 2016; Liu et al., 2020; Yang et al., 2020). One of the problems faced by several countries is that forest land becomes agricultural land, as indicated by Galinato & Galinato (2013). However, there is no evidence in the case of the European Union countries.

Fourth, we find that the elasticity of agricultural production concerning emissions from agriculture is negative and inelastic (-0.412). Furthermore, this elasticity is not statistically significant at a traditional significance level of 5%. In practice, this result means that agricultural production has no link to emissions from agriculture. Ahsan et al. (2020) use the cointegration method and find an elasticity of 0.20 (positive), which is the opposite of our research findings. Differences in environmental regulation between emerging and developed countries may justify the differences in results. The transmission mechanisms of polluting emissions to agricultural production are indirect. For example, an increase in emissions causes an impact on climate and temperature variability, damaging agricultural production in the long term (Salinger, 2005; Sivakumar et al., 2005; Asumadu-Sarkodie & Owusu, 2016; Abbas, 2020). **Fifth**, the cultivation of organic products has multiple advantages for agricultural and environmental sustainability. On the one hand, this type of agriculture uses fewer fertilisers with agrochemical compounds to contaminate the soil and water. Likewise, empirical studies suggest that people's health can improve when the consumption of organic products increases. Our research found that the area under organic production has a positive and significant impact on agricultural production. These results are consistent with the findings of Zanen et al. (2008), Ullah et al. (2008), and Aher et al. (2015). They find that the use of organic fertilisers significantly improves the capacity of agricultural soil. Despite the broad consensus of the benefits of organic agriculture, this activity is not without criticism, mainly due to the greater knowledge it requires, lack of suppliers of inputs, and costs per unit produced (Meemken & Qaim, 2018). In general, the environmental benefits of organic production are high, contributing to the sustainability of agricultural production (Smith et al., 2019).

Sixth, renewable energy consumption increases agricultural production because its coefficient is statistically significant at 5%. The elasticity of agricultural production concerning renewable energy consumption is close to 1. This result implies that changes in agricultural production are practically proportional to changes in renewable energy consumption. The empirical literature that relates to the consumption of energy from non-polluting sources and agricultural production is growing. For example, Jebli & Youssef (2019), among the results of interest, find that the consumption of non-hydroelectric renewable energy has a long-term relationship with agricultural land. The emergence of new technologies and globalisation facilitate the production of renewable energy that can be used in agriculture. Lefore et al. (2021) point out that solar energy has broad advantages for agriculture in terms of costs and productivity. It is logical to expect that the technology associated with renewable energy will significantly improve agricultural production (Milovanović, 2014). **Seventh**, the political stability of the countries can facilitate that the projects, programs, and policies on agriculture are permanent in time. We find that political stability has a positive and statistically significant impact on agricultural production, although this elasticity is extremely small. This result implies that credibility in the rule of law and the absence of a crisis affect the number of agricultural goods produced in the countries analysed. In the empirical literature, several arguments explain the nexus between the two variables. On the one hand, Mueller & Mueller (2016) point out that institutional reforms are necessary to improve the agricultural management model. On the contrary, the lack of political stability weakens the government's action in regulating agricultural activities (Astuti, 2021).

Eighth, the e-governance index can be understood as the government's ability to manage social interests using information and communication technologies. In the research context, we found that the e-governance index has a positive and significant impact. This result implies that online services, telecommunications infrastructure, and the human capital index contribute to increasing agricultural production. The mechanisms that convert the indicators measured by the e-governance index into better conditions for farmers are the ease of carrying out trade operations, speeding up the search for suppliers of agricultural inputs, and facilitating procedures, among others. Chhachhar et al. (2014) and Gupta et al. (2020) point out that technology enables farmers to seek solutions to problems, get agricultural advice, and acquire knowledge. In this sense, modern agriculture is strongly associated with technology, increasing productivity, and increasing the opportunities to reach markets (Das et al., 2016). **Ninth**, the social progress index positively affects agricultural production, although it is not statistically significant. This result means that the satisfaction of citizens' social and environmental needs is not associated with agricultural production decisions. **Finally**, we find that the political empowerment of women increases agricultural production with a significance level of 0.1%. In the particular case of agricultural activities, the fact that politics empower women implies that they can decide the management and regulation of agricultural policies. In the empirical literature, Lee et al. (2017) employs a matching method and finds that when women participate in political decisions in their environment, the level of agricultural income they receive improves. In this same direction, Salazar (2018) and Diiro et al. (2018) point out that women's empowerment improves associativity among farmers and increases agricultural production.

Agricultural policy on cereal production has received broad political and academic interest due to its contribution to food security (Sassi & Cardaci, 2013; Burcea & Dona, 2015). Table 4 also presents the results of the Driscoll-Kraay regression using cereal production as the dependent variable. The independent variables of the previous model are kept. A change in the results reported in the table 4 is about the differemce in the fit of the model of agriculture and cerral production model. Covariates explain 92% of the variations in cereal production. Another aspect that distinguishes the two models is the size of the coefficients and the sign of the estimators. In this model, the elasticity of the red list index decreases significantly concerning the first model. The forest area now has a positive impact, while in Table 4, the effect on agricultural production is negative. The effect of the forest area on cereal production is statistically significant, and now the impact of the area under organic production is not significant. The e-governance index loses importance compared to the previous regression.

The e-governance index can be used as an indirect variable for information and communication technologies that relate government to society, particularly farmers. Several investigations have shown the importance of technology to improve farmer outcomes, whether by increasing productivity, exports, or income (Matsumoto et al., 2013; Chhachhar et al., 2014; Das et al., 2016; Gupta et al., 2020). Lee et al. (2017) find that income increases when women use improved technology and receive advice in agricultural production processes. A similar result recently found by Dairo et al. (2018) highlights the importance of women's empowerment in agriculture. In model 3, the dependent variable is vegetable production, and the independent variables remain the same. The positive impact of political stability on agricultural production is small, although statistically significant. Anik and Bauer (2017) point out that corruption, associated with the lack of institutional quality, harms the maximisation of the social welfare of farmers. In this model, most of the covariates have a positive and statistically significant effect on vegetable production. An interesting result is that the social progress index has a non-significant impact on vegetable production. The result is explained because the social progress index includes calculation indicators related mainly to the urban population rather than agricultural activities. Another relevant result related to recent trends in agriculture is the positive impact of the organic production area on vegetable production. Seufert et al. (2012) and Meemken & Qaim (2018) highlight the importance of organic food production to promote long-term food security.

For robustness analysis, fixed effect regression is presented in table 6 which shows almost similar sign and significance level of table 5 for all the three dependent variables. This validates the robustness of this study.

<Insert Table 6 here>

5.0 **Conclusion and Policy Recommendations**

In this research, we address environmental degradation as one of the most urgent problems that today's society must solve and its relationship with agricultural production. We emphasise that the causes of environmental problems that affect agriculture and the economic and social drivers must be analyzed simultaneously to improve the efficiency of pro-environmental policies. The increase in demand for consumer goods in a context of high interdependence between countries causes an increase in the forms and types of environmental degradation. One of the forms of environmental degradation that are of most significant concern for the achievement of sustainable agriculture is the loss of biodiversity. The loss of biodiversity worries policymakers because forests contribute to water, air, and soil purification. In addition, they contribute to the provision of food to maintain the stability of the climate and stop soil erosion. The impact of the loss of biodiversity is not only reflected in the provision of ecosystem services and food. Still, it is also associated with the quality of life of the population that depends on agriculture. Policymakers and farmers face the tradeoff between environmental quality and food provision that requires expanding the agricultural frontier and the intensive use of fertilisers.

We highlight the importance of a deeper analysis of the nexus between agriculture and degradation in the search for the environmental sustainability of agricultural systems. We use data from the European Union countries to deepen the analysis of the nexus between agricultural production systems and environmental degradation. European countries are a relevant case study since this region is technology-intensive, environmental regulation is consolidating, and public awareness of the importance of the environment has improved. Although multiple factors can significantly impact agricultural production systems, in our research, we focused on examining the impact that comes from the loss of biodiversity, emissions from agriculture, deforestation, and some economic and social variables. There are several arguments for adding the covariates to the agricultural production and environmental degradation nexus analysis. For example, there is broad optimism about the adoption of renewable energy and the adoption of organic farming areas in reducing the negative impact of agriculture on the environment.

The application of the Driscoll and Kraay (1998) method allows us to obtain robust estimators in the presence of cross-sectional dependence and heteroskedasticity. The findings of this research can be synthesised in the following aspects. First, the red list index has a positive impact on agricultural production. This finding implies that improvements in agricultural productivity in the

European Union countries are not necessarily the result of the loss of biodiversity. The collective pro-environmental policies of the European Union should promote that the increase in agricultural productivity is based on innovation and avoid the expansion of the farming frontier that threatens biodiversity. The importance of maintaining the vegetation cover as a means of purifying water and air is of vital importance in a context of high production and consumption of cereals. Expanding organic growing areas can make a significant contribution to agricultural sustainability. As farmers use fewer pesticides harmful to the soil in the long term, soil fertility and food supply will be guaranteed. Those responsible for agricultural and environmental policies are challenged to design and implement procedures that reduce input costs and improve human capital endowments related to organic agriculture. The competitive prices of organic goods concerning traditional agricultural products will guarantee the permanence and consolidation in the market of these products. The production and consumption of renewable energy are some of the sectors where tax incentives can help to reduce the costs of organic production. Our findings reveal that renewable energy increases agricultural production, which is highly beneficial for farmers and reduces polluting gas emissions. Political stability contributes to agricultural production, evidencing the importance of the rule of law and respect for law and order so that agricultural policies achieve the expected effect. Policymakers can use e-governance to reduce costs, improve competitiveness, and promote the environmental responsibility of the agricultural system. In addition, they must strengthen the political empowerment of women to achieve more significant benefits in agriculture.

Having said this, we should also note some limitations of the study. Due to data unavialbility, we could not expand our country samples. Therefore, future studies should consider more groups of countries given the availability of data. They can also focus on expanding the analysis of the impact of environmental quality in agriculture, particularly concerning the effects of fiscal instruments on the production of agricultural goods with environmental responsibility.

Conflict of Interest

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Table 4: Chudik and Pesaran (2015) CSD test

Table 5. Results of Regression with Driscoll-Kraay standard errors

Table 6. Results of Regression with Fixed Effect

Table A.1. List of countries

E component

Table 3. Matrix of correlations