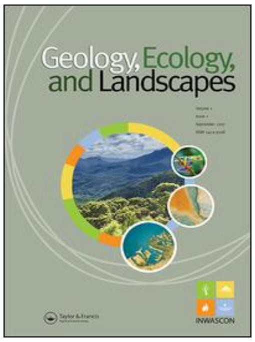

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RESEARCH ARTICLE

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Contemporary changes of greenhouse gases emission from the agricultural sector in the EU-27

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ABSTRACT

The agricultural sector is the second contributor to the worldwide emissions of greenhouse gases (GHGs), as it is responsible for 13.5% of GHG emissions. The main aim of this research is to track GHG emission from the agricultural sector in the EU-27 between 1990 and 2016 in order to determine trends and changes of emission on a country scale. To achieve the study goal, data were collected from the Organization for Economic Co-operation and Development (OECD) website, followed by the application of the Simple Linear Regression Model (SLRM). The obtained results showed that most of the EU-27 countries witnessed a significant reduction of GHG emissions from the agricultural sector, except for Iceland and Spain. Interestingly, the highest reduction conducted by the United Kingdom was followed by Germany and France, where the reduction reached 385.27; 226.72 and 294.92 tons of CO_2-equivalent per year, respectively. Thus, we can conclude that most EU countries significantly reduced GHG emissions to the atmosphere.

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Carbon dioxide (CO_2); climate change; land use; methane (CH_4); EU

1. Introduction

Nowadays, climate change has become one of the challenging issues humanity is facing, where greenhouse gases (GHGs) of anthropogenic origin are considered to be the main responsible factor for this disaster (Arora et al., 2018; Hongguang, Weidong, Xiaomei, & Zhipeng, 2012; Majumder, Islam, & Hossain, 2019; Mohammed, Mousavi, Alsafadi, & Bramdeo, 2019). The main damaging role of GHGs can be summarized by retaining infrared radiation in the Earth's atmosphere which caused a rise in the average of the Earth's temperature.

GHGs are mainly composed of 76% carbon dioxide (CO_2), 16% methane (CH_4); 6% nitrous oxide (N_2O); and 2% combination of hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride (SF6) (Intergovernmental Panel on Climate Change (IPCC), 2013; Arora et al. (2018); Rafiq, Rasheed, Arslan, Tallat, & Siddique, 2018). Interestingly, the Intergovernmental Panel on Climate Change (IPCC) (2013) estimated the increased concentration of CO_2, CH_4, and N_2O from 1750 to 2012 by 41.07%; 163.21% and 42.29%, respectively. There were many reasons behind this rapid increase of GHGs such as fossil fuel consumption, deforestation, and land use changes (Scott et al., 2018). Generally, energy sectors are responsible for more than 66.5% of GHG, while 13.5% of the GHG originated from agricultural sector (Herzog, 2005). Interestingly, 20% of CO_2; 70% of CH_4 and 90% of N_2O in the atmosphere were released from different activities in the agricultural sector (Cole et al., 1997; Yousefi, Damghani, & Khoramivafa, 2016). Moreover, Oertel, Matschullat, Zurba, Zimmermann, and Erasmi (2016) reported that 35% of CO_2; 47% of CH_4 and 53% of N_2O of the total agricultural GHGs originated from the soil.

Globally, a set of measures and many international agreements (i.e., Kyoto Protocol 1997) had been taken to reduce emissions of GHG all over the world, where the developed countries asked to minimize their emission by 25% to 40% before 2020. Thus, the UK launched the concept of low-carbon economy in 2003 and was since followed by Germany, Japan and the United States (Zi & Zhenyao, 2011).

In the recent decades, many researchers all around the world have studied the relation between the agricultural sector and GHG emission. McCarl and Schneider (2001) argued that interdependencies of crop and livestock management could play a significant role in GHG mitigation in the United States. Similarly, Burney, Davis, and Lobell (2010) recommended investing in crop production and yield improvement as a good strategy for reducing future GHG emissions. Tubiello et al. (2013) detected an increase in GHGs from the agricultural sector by 1.1% each year from 2000 to 2010 all around the world.

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The EU-27 countries are members of the United Nations Framework Convention on Climate Change (UNFCCC) where they committed to keep the net emissions by 10% increase beyond 1990 levels (i.e., Kyoto Protocol commitment). Thus, the aim of this paper is to track GHG emissions from the agricultural sector in the EU-27 between 1990 and 2016 in order to determine trends and changes of emission at a country level. Accordingly, the question being addressed is "what is the trend of GHG emission in the EU-27 between 1990 and 2016?"

2. Methods

The Simple Linear Regression Model (SLRM) can be defined as follows:

$$\mathbf{Y} = \beta + \alpha\mathbf{X}$$

where: Y: dependent variable, X: independent variable, ß; α: regression coefficients This model has been applied to estimate the GHG emission trend for 27 years (i.e., between 1990–2016), depending on secondary data collected from the Organization for Economic Co-operation and Development (OECD) website (https://stats.oecd.org/), for the EU-27.

Meanwhile, statistical analysis was performed for each country using Excel STAT software. The analysis included central tendency (mean), dispersion (standard deviation and coefficient of variation), and distribution (skewness and kurtosis).

3. Results

3.1. Statistical analysis of GHG emissions for the EU-27

The statistical analysis of GHG emissions for the EU-27 shows that France has the highest emission, while Iceland has the lowest emission in the studied time series as can be seen in Figure 1. Low coefficient of variation CV% was recorded in all the studied countries, while kurtosis values range from 8.2 to −1.7, associated with skewed values which range between 2.9 and −0.6, as can be seen in Table 1.

3.2. Trends of GHG emissions for the EU-27

Trends analysis of GHG emissions showed that most of the EU-27 countries witnessed a significant reduction of GHG emissions from the agricultural sector, except for Iceland and Spain, as can be seen in Table 2. Interestingly, the highest reduction conducted by the United Kingdom was followed by Germany and France, where the reduction reached 385.27; 226.72 and 294.92 tons of CO_2-equivalent per year, respectively. Iceland and Spain also recorded a reduction that was not of significance, where the reduction reached 0.3633 and 21.112 tons of CO_2-equivalent per year, respectively. Figure 2 illustrates the change of GHG emissions in the agricultural sector in 1990 and 2016, where most countries have significant reduction, while Figure 3 demonstrates emission changes from each country between 1990 and 2016.

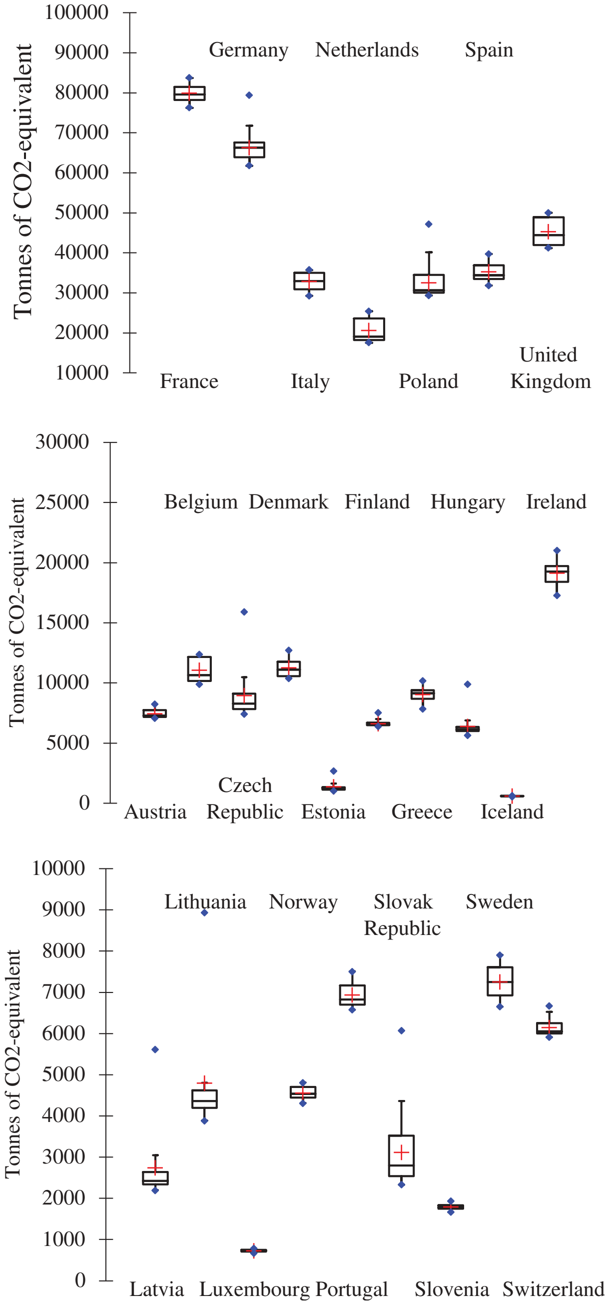

Figure 1. Boxplot analysis of GHGs emissions for the EU-27.

4. Discussion

Generally, agriculture is one of the main sectors that contributed significantly in the total GHG emission and many other environmental impacts such as global warming, soil acidification, air pollution and water quality (Leip et al., 2015). At a global scale, Tubiello et al. (2013) reported a yearly increase of average emission by 1.6% per year from 1961 to 2010,

Table 1. Statistical analysis of GHG emissions for the EU-27.

Statistic	Mini	Max	Mean	SD (n)	CV	Sk	Ku
Austria	7062.8	8225.1	7447.9	356.8	0.0	0.7	−0.7
Belgium	9897.1	12,362.6	11,056.8	959.4	0.1	0.2	−1.7
Czech Republic	7411.9	15,898.1	8938.4	1943.2	0.2	2.3	4.7
Denmark	10,385.8	12,710.8	11,255.5	738.4	0.1	0.5	−1.1
Estonia	1021.5	2664.8	1354.3	413.3	0.3	2.2	3.7
Finland	6375.3	7525.5	6605.9	241.3	0.0	2.2	5.3
Greece	7846.0	10,163.7	9028.0	595.5	0.1	−0.2	−0.2
Hungary	5635.7	9878.2	6396.0	855.4	0.1	2.9	8.2
Iceland	543.7	628.6	585.4	18.9	0.0	−0.2	0.2
Ireland	17,267.2	21,027.2	19,125.6	995.7	0.1	0.0	−0.8
Latvia	2197.5	5612.3	2744.8	838.0	0.3	2.5	5.2
Lithuania	3883.5	8934.7	4800.3	1269.1	0.3	2.5	5.1
Luxembourg	674.8	783.8	728.1	29.7	0.0	−0.1	−1.1
Norway	4310.3	4808.8	4558.4	146.0	0.0	0.0	−1.2
Portugal	6578.4	7506.9	6940.1	267.4	0.0	0.4	−1.2
Slovak Republic	2334.9	6068.4	3117.4	881.5	0.3	1.9	3.2
Slovenia	1666.5	1933.1	1792.9	69.3	0.0	0.3	−0.4
Sweden	6653.5	7905.0	7256.1	366.0	0.1	0.1	−1.2
Switzerland	5912.3	6672.3	6144.7	214.9	0.0	1.2	0.1
France	76,245.2	83,727.1	79,872.2	2170.1	0.0	0.1	−1.1
Germany	61,771.8	79,398.0	66,240.7	3459.4	0.1	2.0	5.3
Italy	29,242.6	35,728.7	32,853.0	2142.5	0.1	−0.2	−1.4
Netherlands	17,547.8	25,378.6	20,589.2	2795.2	0.1	0.6	−1.3
New Zealand	34,476.8	40,161.2	37,776.8	1729.0	0.0	−0.6	−0.8
Poland	29,354.2	47,155.6	32,457.0	3926.4	0.1	2.1	5.0
Spain	31,843.1	39,712.8	35,243.4	2297.1	0.1	0.4	−1.0
United Kingdom	41,225.8	50,000.6	45,270.1	3205.5	0.1	0.2	−1.6

SD: Standard deviation; CV: Coefficient of variation; Sk: Skewness (Pearson); Ku: Kurtosis.

Table 2. Trends analysis of GHG emissions for the EU-27.

Country	Regressions Model	Trend	α	R^2	Sig.
Austria	y = −40.084x + 87.736	-	−40.084	0.7657	**
Belgium	y = −115.08x + 241.568	-	−115.08	0.8729	**
Czech Republic	y = −180.91x + 371.292	-	−180.91	0.5258	**
Denmark	y = −91.302x + 194.133	-	−91.302	0.9275	**
Estonia	y = −28.772x + 58.984	-	−28.772	0.294	**
Finland	y = −20.855x + 48.379	-	−20.855	0.4531	**
France	y = −226.72x + 533.991	-	−226.72	0.6621	**
Germany	y = −294.92x + 656.957	-	−294.92	0.4409	**
Greece	y = −71.967x + 153.178	-	−71.967	0.8859	**
Hungary	y = −44.828x + 96.187	-	−44.828	0.1666	**
Iceland	y = −0.3633x + 1313	-	−0.3633	0.0224	-
Ireland	y = −89.786x + 198.967	-	−89.786	0.4933	**
Italy	y = −264.89x + 563.43	-	−264.89	0.9273	**
Latvia	y = −57.765x + 118.447	-	−57.765	0.2883	**
Lithuania	y = −93.325x + 191.730	-	−93.325	0.3281	**
Luxembourg	y = −2.3017x + 5338.5	-	−2.3017	0.365	**
Netherlands	y = −324.19x + 669.940	-	−324.19	0.816	**
Norway	y = −16.36x + 37.328	-	−16.36	0.7619	**
Poland	y = −384.32x + 802.259	-	−384.32	0.5812	**
Portugal	y = −25.193x + 57.401	-	−25.193	0.5384	**
Slovak Republic	y = −90.79x + 184.969	-	−90.79	0.6435	**
Slovenia	y = −6.1503x + 14.112	-	−6.1503	0.4776	**
Spain	y = −21.112x + 77.532	-	−21.112	0.0051	-
Sweden	y = −38.568x + 84.508	-	−38.568	0.6737	**
Switzerland	y = −20.975x + 48.158	-	−20.975	0.578	**
United Kingdom	y = −385.27x + 816.956	-	−385.27	0.8764	**

** significant at confidence level of 99%

reaching 4.6 $GtCO_2$ per year in 2010. However, more than 42% of EU lands are used for agricultural practices, revealing the role of the agricultural system, practice, and productions in the carbon cycle and other GHG emission. In 2003, the contribution of the agricultural sector in Europe reached 11% of the total emission (Freibauer, 2003), where the emission can be divided into many sectors such as agricultural soils and livestock sectors. GHG emission from EU soils varies from 0.7 Mg ha-1 per year CO_2-equivalents on sandy arable soils to 25 Mg on organic soils (Freibauer, 2003). On the other hand, Freibauer, Rounsevell, Smith, and Verhagen (2004) reported that European soils can sequester up to 16–19 Mt C per year, which is less than 2% of the equivalent to 2% of European anthropogenic emissions. However, Ciais et al. (2010) highlighted that, due to intensifying agriculture in Eastern Europe as well as western Europe, N_2O emissions will become the main source of concern for the impact of European

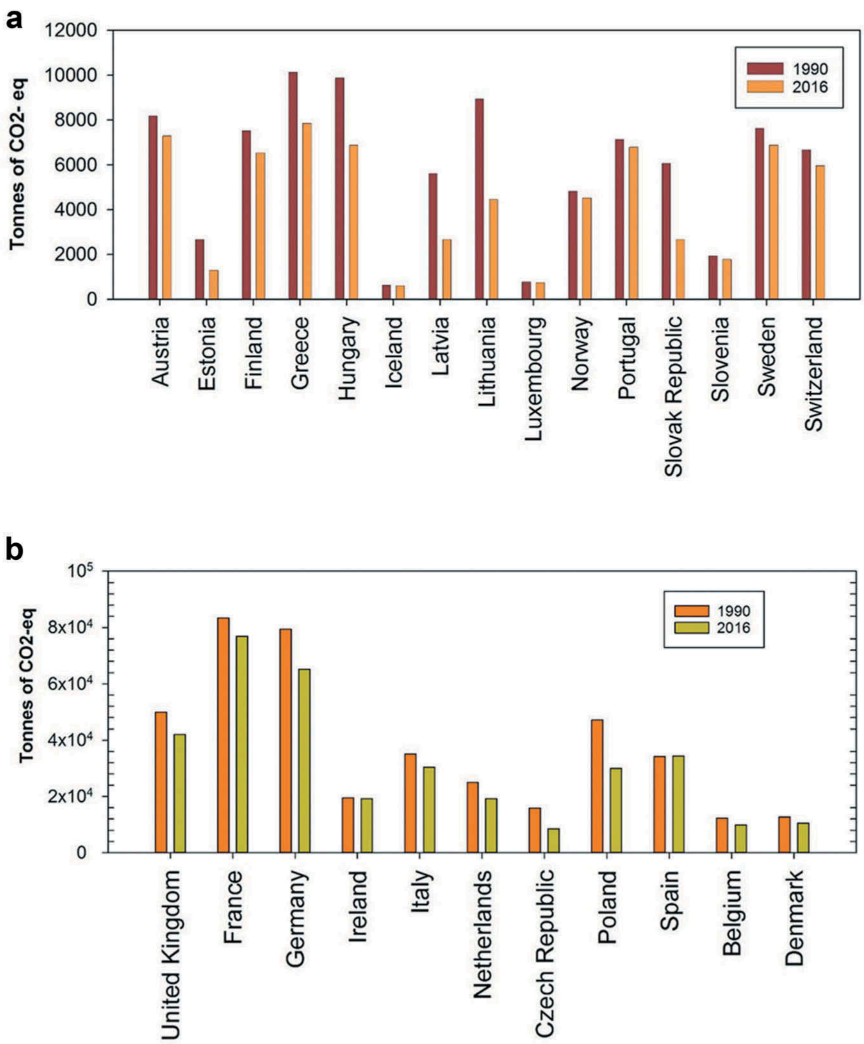

Figure 2. GHGs emission from the agricultural sector in 1990 and 2016 for the EU-27.

agriculture on climate. Interestingly, livestock production systems occupied around 65% of the European Union's agricultural land (Leip et al., 2015), where the EU-27 members produce 26%, 13%, 22% of the world's milk, beef, pork (Lesschen, Van den Berg, Westhoek, Witzke, & Oenema, 2011); and the dairy sector has the highest GHG emission in the EU-27, followed by the beef sector.

Hence, Verge, De Kimpe, and Desjardins (2007) expected the worldwide total GHG emissions from the agricultural sector to increase by about 50%. Our analyses reveal a negative trend of GHG emission from the agricultural sector in most of the EU-27 countries (Table 2, Figure 2), which can be explained by the impact of the Common Agricultural Policy (CAP) reform, where agricultural inputs were optimized: between 1990 and 2000, N_2O emissions decreased from 74 to 73 Tg CO_2 equivalent (Verge et al., 2007).

Even though each of the EU-27 countries has its own regulations and policies related to the agricultural sector and energy management, GHG emissions can be driven from the same sources (Davíðsdóttir & Agnarsson, 2010). Consequently, many reasons could explain the results of Tables 1 and 2. For example, in France, nuclear power is the main supplier of energy, thus the total GHG emissions are low, but having a large agricultural sector, the reduction of GHGs from this sector was essential for policy-makers for achieving a significant total accumulated reduction in 2020 (De Cara & Jayet, 2000). Similarly, the agricultural sector in Germany contributed by 52% and 34% to the total N_2O and CH_4 emissions in Germany. However, launching the climate protection program in Germany led to reducing CO_2 emissions by 25% (Flessa et al., 2002), which supports our obtained results in Table 2 and Figure 2. On the contrary, emissions from the agricultural sector in Iceland were relatively high due to land use, land use changes and forestry (LULUCF), which significantly contributed to GHG emission (Davíðsdóttir & Agnarsson, 2010). In Spain, the Ministry of Agriculture indicated a steady increase of CO_2 emission due to increased population associated with expands of different demands (Vargas-Amelin & Pindado, 2014).

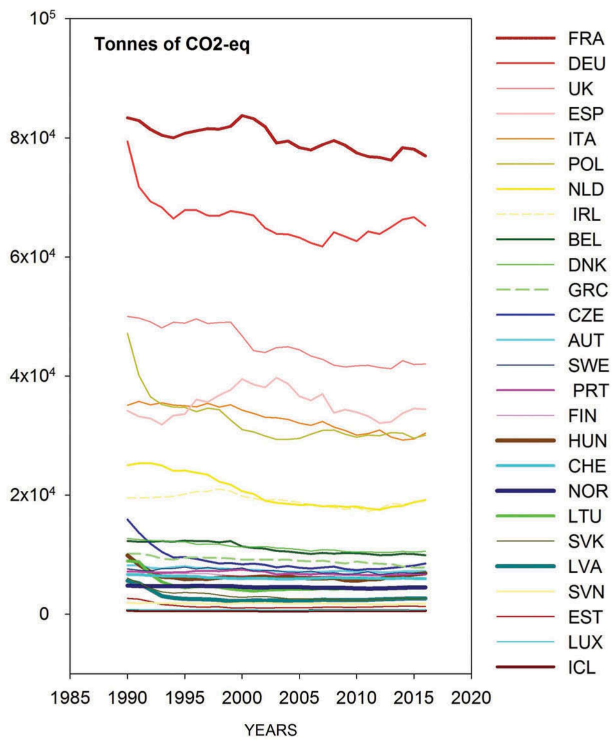

Figure 3. Changes of GHGs emission from the agricultural sector for each country within the EU-27.

5. Concluding

In this research, we track the contribution of the agricultural sector to GHG emission in the EU-27 countries. The obtained results showed that most countries applied policies to reduce the GHG emission. As a result, most countries showed a significant reduction between 1990 and 2016.

In addition, more specific and detailed studies shall be conducted in the future to measure GHGs from different agricultural subsectors such as livestock production, crop production and soil ecosystem, as well as the forestry ecosystem and Land Uses and Land Cover Changes (LULCC) to come up with a list of actions for minimizing GHG emission in terms of climate change. In our cases, an important national project is responsible for measuring CO_2 originating from the soil under different land use schemes. Hence, effective GHG mitigation policies should be economically efficient, providing a balance between rapid human demand from different sectors and sustainability of land resources. Altogether, the reduction of GHGs in all sectors is one of the necessary steps to fight climate changes on a global scale and to insure sustainability of the Earth's resources.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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