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RESEARCH PAPER

Long-term effects of some determinants in the agricultural sector on CO_2 emissions: Panel data analysis by income groups of world countries

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Abstract

Climate change is defined as one of the biggest problems of the third millennium. All countries in the world are striving to produce policies on this issue and achieve a common consensus. Regulations are being made in various sectors and efforts are continuing to adopt ecofriendly production techniques. Just as climate change affects all sectors, it is also affected by the production activities of the sectors. One of these sectors is the agricultural sector. Inputs and production techniques used in agriculture create direct environmental costs. The production techniques used by countries depending on their income level and development level contribute to the climate change process to a certain extent. In this research, the effects of the inputs used in agricultural production on CO_2 emissions according to the income levels of the countries of the world were investigated by panel data analysis. According to the results obtained, the effect of the arable land size of low and low-middle income group countries, the pesticides they use in agriculture, the animal fertilizers they use in agricultural production, the CO_2 level released from the energy they use in agriculture, and the effect of their agricultural nitrogen use on the total CO_2 level is statistically significant. While the effect of pesticide uses and the amount of nitrogen used in agriculture by middle-high income countries is statistically significant, it can be said that the amounts of pesticides used by high-income countries in agriculture, animal fertilizers used in agricultural production, the level of CO_2 released from the energy they use in agriculture and their use of agricultural nitrogen are statistically significant. While the results obtained reveal the relationship between the amount used and CO_2 emissions, they also indicate that the inputs used can be quality and environmentally friendly inputs. In classical suggestions, suggestions are made such as controlling input levels and preventing excessive use. However, the increasing world population and the resulting increase in nutritional needs emphasize the importance of optimal input use in agricultural production. It makes it important that qualitative, ecofriendly and effective inputs should be used rather than input usage possibilities and quantity-dimensional control.

Keywords

CO_2 emissions, Climate change, Agricultural inputs, Panel data analysis

Introduction

In the last few decades, the impact of climate change in many areas on Earth has become the center of international policies (IPCC 2007). It came to the fore at the United Nations COP15 Conference in 2009. One of the problems highlighted in the fifth assessment report of the United Nations Intergovernmental Panel on Climate Change (IPCC) is the severity of climate change. Both its impact on sectors such as agriculture and their effects on climate change have been noted (Pachauri 2014; Carter et al. 2018). Climate change causes a wide variety of problems. Its impact on agricultural production, combined with the increasing population and dense urbanization problems, is the main reason for the food supply security problem. This situation has become the most important event that humanity is worried about (Farajzadeh et al. 2022). Since the beginning of the 2000s, many uncontrollable natural disasters have occurred. These disasters occur as a result of climatic events. The disasters that occurred have revealed that all societies have an obligation to act together and have increased awareness (Ojo and Baiyegunhi 2021). For example, the Paris Agreement or COP21 stated that they aim to keep temperatures 1.5 °C below or 2 °C above the pre-industrial revolution level for greenhouse gas emission control (Fernandez and Daigneault 2016). In strategies to achieve the goals, COP21 encourages the use of renewable energy and recommends transferring various funds to less developed countries according to the development level of the countries. Finally, these recommendations were further emphasized at COP26 (United Nations 2018).

Anthropogenic greenhouse gas emissions continue in all sectors. The pace of industrialization around the world is leading to a continuous increase in greenhouse gas emissions and at the same time exacerbating environmental problems. Under the carbon neutrality policy, only about 5% of countries have achieved this target and extended it to 2070 (Chen et al. 2022). Maritime transportation, another sector, is one of the main reasons for this process. It alone is responsible for 3% of anthropogenic greenhouse gas emissions on a global scale (Watanabe and Cavalett 2022). Trade and the financial sector, which are important sectors, are also under long-term pressure in terms of carbon emissions. This is because they create high demand in terms of food and energy consumption. They can be seen as important sources of risk for air and water pollution (İmamoğlu 2019). The agricultural sector plays a major role in the emission of methane (CH_4) and carbon dioxide (CO_2), two important contributors to anthropogenic climate change. These emissions are caused by land use, fertilizers, pesticide use, animal waste and plant residues (Lynch and Garnett 2021).

As a result, climate change destroys all stages from production to consumption (Farajzadeh et al. 2022). It is estimated that climate change in the agricultural sector will reduce global food production by 0.5% in the 2020s and by 2.3% in the 2050s. The risk to food security can be described as high. The decline in food supply can lead to an average increase of 40% in prices for all food products, especially strategic products. These food price increases can lead to a reduction in the prosperity of low-income households and a decline in GDP at the social level (Calzadilla et al. 2013). At the macro level, an average 20% decline in value added is predicted in industrialised countries (Farajzadeh et al. 2022). Agriculture is one of the main causes of climate change. Although the agricultural sector has a major impact on the process of climate change, some of its characteristics distinguish it negatively from other sectors. These include low income levels in the sector, insufficient capital, structural problems of small farms, low technology levels, problems with infrastructure and low education levels (van Berkum 2015). However, it is quite strategic. This is because agriculture is a sector that produces biological inputs for renewable energy and other sectors that are part of alternative energy policies (Nowak et al. 2021). Its contribution to the economy is also considered important in terms of income, foreign exchange through foreign trade, rural development and investment (Draper et al. 2013; Prasada et al. 2022).

Carbon dioxide is the main component of greenhouse gasses (GHG) released into the atmosphere (Janardhan and Fesmire 2011). It is the cornerstone of global climate change. There is a constant interaction between agricultural production and CO_2 emissions (Stout 1990; USDA 2008; Snyder et al. 2009). Agricultural activities release carbon for reasons such as land use change, production, use of fossil fuels, use of synthetic fertilizers, use of pesticides, microbial decomposition and burning of plant residues (Jeffrey 2001; Hillier et al. 2011). Intensive agriculture and the increasing use of fertilizers over the last 30 years have led to more CO_2 emissions into the atmosphere. Increasing population pressure and the resulting need to increase food production are the cause of this increase. About 60% of the world's fertilizer demand is used for the production of wheat, a strategic product. According to countries, this demand comes from developing countries (FAO 2000). The global use of agricultural fertilizers increased from 30.5 million tons in 1961 to 102 million tons in 2002 (FAO 2008). Fertilizers containing nitrogen, phosphorus and potassium have different effects.

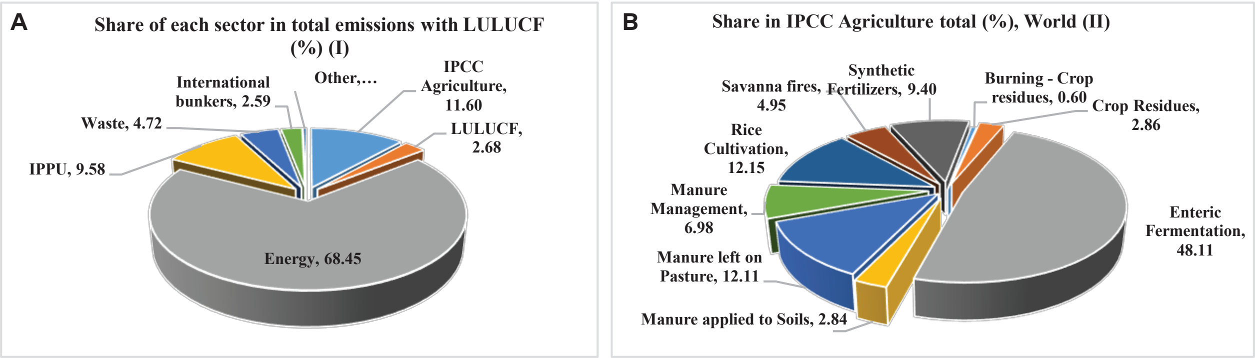

Figure 1. Share of sectors (**A**) and Agriculture Sector (**B**) in total greenhouse gas emissions (%).

However, the nitrogen used in agricultural production has a different property. As the nitrogen applied evaporates very quickly, very little of it is absorbed by the plants. The factors that determine this are soil temperature, soil properties and the amount of precipitation. Therefore, the effectiveness of fertilizers is more related to the application method and the quality of the fertilizer than to the quantity of fertilizer (Witney 1988; Manos et al. 2007). The use of pesticides, another pollutant in agriculture, is increasing rapidly worldwide. The reason for this is the increase in disease and pest populations as a result of intensive production with increasing demand and changing climatic conditions. In terms of its consequences, it represents a major environmental problem. It mixes not only with groundwater through leakage, but also with the atmosphere through evaporation. For this reason, it can be said to be one of the leading agricultural pollutants and contaminants (Lal 2004). In recent years, households have turned their attention in this direction due to climate awareness and sensitivity to access to healthy food. For this reason, the results of research and experience on these harmful substances are frequently exchanged. Regarding energy use in agriculture, it can be stated that the electricity used in irrigation causes CO_2 emissions due to the fossil fuels used to generate electricity and the fuels used in agricultural mechanization. Many factors that cause CO2 emissions are discussed in the literature. But there are very few studies on the agricultural sector that include inputs in agricultural production. Additionally, no study has been found based on income groups of world countries. This study examined the long-term impact of agricultural inputs on total CO_2 emissions. The World Bank has divided the countries into four groups. They can be divided into low-income countries, low-and middle-income countries, middle-and high-income countries and high-income countries. In this classification, the World Bank has formed the income groups of countries according to per capita GNP. The GNP per capita can directly represent the level of prosperity of the people in that country.

Material and method

The study examined the impact of agricultural inputs that are considered effective on the total CO_2 emissions of countries categorised by the World Bank into four income groups. Income groups by country; low-income countries, low-middle-income countries, middle-high income countries and high-income countries (World Bank 2023). These countries are listed in Table 1.

The research covers the years 2000–2020. Agricultural inputs whose impact on the total CO_2 content is examined are the size of arable land, the use of pesticides in agriculture, the use of animal manure in agriculture, the CO_2 content released by agricultural energy and the use of nitrogen in agriculture. The symbols and units for the variables analysed can be found in Table 2.

A panel data set covering the relevant years was created for the variables under investigation. After the panel data set was created, the functional relationship was defined in fully logarithmic form so that it could be interpreted proportionally. In the relationship defined in fully logarithmic form, all variables are arranged in units per thousand

Table 1. Distribution of countries according to income groups examined.

Contries Groups	Contries	Countries not included in the model due to lack of data
Low Income Group Countriesr	Burkina Faso, Central African Republic, Congo, Dem. Rep., Eritrea, Ethiopia, Gambia, The Guinea-Bissau, Madagascar, Mali, Mozambique, Malawi Niger, Syrian Arab Republic, Chad, Togo, Uganda.	Afghanistan, Burundi, Liberia, Korea, Dem. People's Rep., Rwanda, Sudan, Sierra Leone, Somalia, South Sudan, Yemen Rep.
Low-Middle Income Group Countries	Angola, Benin, Bangladesh, Bolivia, Bhutan, Côte d'Ivoire, Cameroon, Algeria, Egypt Arab Rep., Ghana, Guinea, Honduras, India, Iran, Islamic Rep., Jordan, Kenya, Kyrgyz Republic, Cambodia, Lao PDR, Lebanon, Sri Lanka, Morocco, Myanmar, Mongolia, Mauritania, Nigeria, Nicaragua, Nepal, Pakistan, Philippines, Papua New Guinea, Senegal, Eswatini, Tajikistan, Tunisia, Tanzania, Ukraine, Uzbekistan, Vietnam, Vanuatu, Samoa, Zambia, Zimbabwe.	Congo, Rep., Comoros, Cabo Verde, Djibouti, Micronesia, Fed. Sts.,Haiti, Kiribati, Lesotho, Solomon Islands, São Tomé and Príncipe, Timor-Leste, Tanzania, Uzbekistan, Vanuatu, Samoa.
Middle-High Income Group Countries	Albania, Argentina, Armenia, Azerbaijan, Bulgaria, Bosnia and Herzegovina, Belarus, Belize, Brazil, China, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, Fiji, Gabon, Georgia, Equatorial Guinea, Guatemala, Indonesia, Iraq, Jamaica, Kazakhstan, Libya, Moldova, Mexico, North Macedonia, Mauritius, Malaysia, Namibia, Peru, Paraguay, Russian Federation, El Salvador, Suriname, Thailand, Turkmenistan, Türkiye, South Africa.	Botswana, Dominica, Grenada, St. Lucia, Maldives, Marshall Islands, Montenegro, Palau, West Bank and Gaza, Serbia, Tonga, Tuvalu, St. Vincent and the Grenadines, Kosovo
High Income Group Countries	Australia, Austria, Belgium, Canada, Switzerland, Chile, Cyprus, Czechia, Germany, Denmark, Spain, Estonia, Finland, France, United Kingdom, Greece, Croatia, Hungary, Ireland, Iceland, Israel, Italy, Japan, Korea, Rep., Lithuania, Latvia, Netherlands, Norway, New Zealand, Oman, Panama, Poland, Portugal, Qatar, Romania, Saudi Arabia, Slovak Republic, Slovenia, Sweden, Taiwan, China, Uruguay, United States.	Aruba, Andorra, United Arab Emirates, American Samoa, Antigua and Barbuda, Bahrain, Bahamas, The Bermuda, Barbados, Brunei Darussalam, Channel Islands, Curaçao, Cayman Islands, Faroe Islands, Gibraltar, Greenland, Guam, Guyana, Hong Kong SAR China, Isle of Man, St. Kitts and Nevis, Kuwait, Liechtenstein, Luxembourg, Macao SAR China, St. Martin (French part), Monaco, Malta, Northern Mariana Islands, New Caledonia, Nauru, Puerto Rico, French Polynesia, Singapore, San Marino, Sint Maarten (Dutch part), Seychelles, Turks and Caicos Islands, Trinidad and Tobago, British Virgin Islands, Virgin Islands (U.S.)

Table 2. Variables, symbols and data sources used in the research.

Variables	Symbol	Unit	Data Resource
Total CO_2 emissions (per thousand ha)	$C1_{it}$	kt	World Bank
Arable land size (per thousand ha)	$C2_{it}$	Thousand ha	FAOSTAT
Pesticide use in agriculture (per thousand ha)	$C3_{it}$	ton	FAOSTAT
Animal manure use in agriculture (per thousand ha)	$C4_{it}$	kg	FAOSTAT
CO_2 released from agricultural energy (per thousand ha)	$C5_{it}$	kt	FAOSTAT
Agricultural nitrogen use (per thousand ha)	$C6_{it}$	ton	FAOSTAT

hectares. The hypothesised functional relationship for the variables related to the income groups is as follows;

$$\ln C1_{it} = f(\ln C2_{it}, \ln C3_{it}, \ln C4_{it}, \ln C5_{it}, \ln C6_{it}) \quad (1)$$

In order to determine the functional relationship in question, Panel Unit Root Test (Levin et al. 2002; Im et al. 2003), Panel Cointegration Analysis and Panel FMOLS tests were performed on the variables used in the research.

Panel unit root test

Econometrics for panel data examines both temporal and cross-sectional differences (Cameron and Trivedi 2005). Unit root tests are important in both time series and panel data analyzes. Modeling done without unit root tests can lead to biased and inconsistent results. It also makes it difficult to examine the long-term relationship. In practice, many unit root tests are used to examine the stationarity of series (Dickey and Fuller 1979; Dickey and Fuller 1981; Phillips and Perron 1988; Maddala and Wu 1999; Hadri 2000; Kao and Chiang 2000; Choi 2001; Levin et al. 2002; Im et al. 2003). These can be defined as first-generation unit root tests (Doğan 2018).

In this study, the panel unit root tests developed by Levin, Lin and Chu (LLC) (2002) and Im, Pesaran and Shin (IPS) (2003) were used. The reason for this is that these tests also take into account the inhomogeneous situation in the panel data set (Guloğlu and İspir 2009). In the theoretical framework, the notation for the unit root test can be expressed as in equation (2);

$$\Delta Y_{it} = \alpha_i Y_{it-1} + \sum_{j=1}^{p} \beta_{ij} \Delta Y_{it-j} + X_{it}\delta_i + \varepsilon_{it} \quad (2)$$

Panel Full Modified Ordinary Least Square (Panel FMOLS)

The nonparametric panel FMOLS test was proposed by Phillips and Hansen (1990) and further developed by Pedroni (2001a) for analyzes other than coefficient estimates and exogeneity. Panel FMOLS takes into account the possible correlation between the error term and the first differences of the independent variables and the constant term to eliminate corrections for serial correlation (Maeso-Fernandez et al. 2006). In panel cointegration analyses, the use of the OLS method in estimating long-run relationships has a disadvantage: if the regressors are not strictly exogenous, large parameter biases, heteroscedasticity and dispersion problems can occur. OLS estimates are not standardised, which leads to the failure of the standard test procedure (Ugrinowitsch etal. 2004). Therefore, OLS estimation cannot be used for generally valid conclusions (Kao and Chiang 2000). In contrast, FMOLS provides a consistent estimate of standard errors that can be used to make assumptions (Masih and Masih 1996). Comments on the FMOLS equation can be made using equations 3,4,5,6,7;

$$\mathrm{C1}^*_{NT} = \mathrm{N}^{-1}\sum_{i=1}^{N}\left[\sum_{t=1}^{T}(\mathrm{C2}_{it}-\overline{C2_{\iota\iota}})^2\right]^{-1}\left[\sum_{t=1}^{T}(\mathrm{C2}_{it}-\overline{\mathrm{C2}_{\iota\iota}})\mathrm{C1}^*_{it}-T\hat{\tau}_{it}\right] \quad (3)$$

$$\mathrm{C1}^*_{it} = \mathrm{N}^{-1}\sum_{i=1}^{N}\left[\sum_{t=1}^{T}(\mathrm{C3}_{it}-\overline{C3_{\iota\iota}})^2\right]^{-1}\left[\sum_{t=1}^{T}(\mathrm{C3}_{it}-\overline{\mathrm{C3}_{\iota\iota}})\mathrm{C1}^*_{it}-T\hat{\tau}_{it}\right] \quad (4)$$

$$\mathrm{C1}^*_{it} = \mathrm{N}^{-1}\sum_{i=1}^{N}\left[\sum_{t=1}^{T}(\mathrm{C4}_{it}-\overline{C4_{\iota\iota}})^2\right]^{-1}\left[\sum_{t=1}^{T}(\mathrm{C4}_{it}-\overline{\mathrm{C4}_{\iota\iota}})\mathrm{C1}^*_{it}-T\hat{\tau}_{it}\right] \quad (5)$$

$$\mathrm{C1}^*_{it} = \mathrm{N}^{-1}\sum_{i=1}^{N}\left[\sum_{t=1}^{T}(\mathrm{C5}_{it}-\overline{C5_{\iota\iota}})^2\right]^{-1}\left[\sum_{t=1}^{T}(\mathrm{C5}_{it}-\overline{\mathrm{C5}_{\iota\iota}})\mathrm{C1}^*_{it}-T\hat{\tau}_{it}\right] \quad (6)$$

$$\mathrm{C1}^*_{it} = \mathrm{N}^{-1}\sum_{i=1}^{N}\left[\sum_{t=1}^{T}(\mathrm{C6}_{it}-\overline{C6_{\iota\iota}})^2\right]^{-1}\left[\sum_{t=1}^{T}(\mathrm{C6}_{it}-\overline{\mathrm{C6}_{\iota\iota}})\mathrm{C1}^*_{it}-T\hat{\tau}_{it}\right] \quad (7)$$

Panel cointegration analysis

Cointegration analyzes are used to identify long-term relationships and non-stationary interactions (Pedroni 2001b; Westerlund 2007). The Pedroni cointegration test (Pedroni 2004), the Kao cointegration test (Kao 1999) and the Johansen-Fisher panel cointegration test are used as dependent variables. The Pedroni cointegration test, which is based on the Engle-Granger approach, was used in this study. This test provides both intra- and inter-dimensional results. It also tests panel cointegration, which allows for heterogeneous axis intercepts and trend coefficients in different cross-sections (Pedroni 2004).

Emprical results

The change in the average usage of the variables examined within the scope of the research according to the countries in the previous income group and the countries in the low income group is given in Table 3.

Table 3. Between 2000–2022 Years Percent change in the average usage of the variables examined.

% change in average usage compared to the previous income group (% of change between Low Income Countries-Low-Middle Income Countries % of change Middle Income Countries-Middle-High Income Countries % of change Middle-High Income Countries-High Income Countries	C1	C2	C3	C4	C5	C6
Low Income Countries	-	-	-	-	-	-
Low-Middle Income Countries	1299,78	88,39	373,02	251,76	1069,92	606,44
Middle-High Income Countries	77,21	26,95	326,56	74,23	165,37	73,18
High Income Countries	1695,23	-33,38	-10,02	195,46	122,55	55,30
% change in average usage by low income group	C1	C2	C3	C4	C5	C6
Low Income Countries	-	-	-	-	-	-
Low-Middle Income Countries	1299,78	88,39	373,02	251,76	1069,92	606,44
Middle-High Income Countries	2380,56	139,18	1917,77	512,89	3004,67	1123,49
High Income Countries	44431,78	59,33	1715,40	1710,87	6809,59	1800,19

Table 4. Descriptive Statistics.

			Low Income Countries			
	C1	C2	C3	C4	C5	C6
Mean	1.09	5214.84	0.36	2220.43	0.06	7.22
Median	0.49	4515.00	0.21	1986.79	0.02	2.86
Std. Dev.	2.28	4489.56	0.44	1855.25	0.11	11.15
Skewness	4.13	1.24	2.04	0.74	3.48	2.81
Kurtosis	19.77	3.76	8.00	2.60	17.41	11.88
Jarque-Bera	4889.65	93.67	581.88	32.64	3584.98	1544.84
Probability	0.00	0.00	0.00	0.00	0.00	0.00
Observations	336	336	336	336	336	336
			Low-Middle Income Countries			
Mean	15.31	9824.72	1.73	7810.66	0.66	50.99
Median	5.03	3150.00	0.69	3907.12	0.14	19.83
Std. Dev.	31.62	25447.78	2.69	10459.01	1.50	79.39
Skewness	3.78	5.08	2.88	2.61	3.69	3.04
Kurtosis	18.10	29.36	12.28	10.95	16.71	13.94
Jarque-Bera	9726.53	27222.09	4072.65	3082.29	8273.40	5348.32
Probability	0.00	0.00	0.00	0.00	0.00	0.00
Observations	819	819	819	819	819	819
			Middle-High Income Countries			
Mean	27.13	12472.65	7.36	13608.81	1.75	88.31
Median	15.91	1744.00	2.29	5324.58	0.52	54.32
Std. Dev.	39.79	27194.37	13.10	23192.45	5.82	116.19
Skewness	4.27	3.15	3.07	3.44	7.03	3.39
Kurtosis	24.42	12.46	12.47	15.55	62.63	17.71
Jarque-Bera	18612.84	4521.70	4456.28	7166.90	131358.48	9186.09
Probability	0.00	0.00	0.00	0.00	0.00	0.00
Observations	840	840	840	840	840	840
			High Income Countries			
Mean	487.08	8308.76	6.63	40209.04	3.88	137.15
Median	40.76	1446.00	3.20	17760.93	0.90	89.45
Std. Dev.	2154.75	25224.52	13.22	73661.57	12.63	150.69
Skewness	6.35	5.45	9.11	4.36	6.38	3.33
Kurtosis	45.37	33.26	113.19	24.16	45.16	14.37
Jarque-Bera	71915.51	38019.47	458417.41	19242.23	71303.41	6383.98
Probability	0.00	0.00	0.00	0.00	0.00	0.00
Observations	882	882	882	882	882	882

When examining Table 3, the most striking elements can be seen in the middle- and high-income countries. In the changes from the previous income group, the size of arable land in the high-income countries decreased by 33%, the use of pesticides decreased by 10% and the use of agricultural nitrogen increased in some cases to 55.3%. In the low- to middle-income countries, however, these increases are relatively higher than in the previous group. In comparison with the countries in the low-income group, the countries in the high-income group again show an increase of only 59% in the size of arable land. Pesticide use, animal manure use, CO_2 release from agricultural energy, total CO_2 emissions and nitrogen use in agriculture increased 18.15-fold, 18.10-fold, 69.09-fold, 445.31-fold and 19-fold respectively.

Table 4 presents descriptive statistics on the amount of arable land, the use of pesticides in agriculture, the use of animal manure in agriculture, the amount of CO_2 released by agricultural energy and the use of agricultural nitrogen, which are assumed to have an impact on the total carbon dioxide emissions of the groups of countries studied. The mean, standart deviation, kurtosis, skewness and distribution normality of the variables were tested under descriptive statistics. Accordingly, the average arable land size is 5214.84 thousand ha in low-income countries, 9824.72 thousand ha in low-middle income countries, 12472.65 thousand ha in middle-high income countries and 8308.76 thousand ha in high-income countries. In low-income countries, pesticide use in agriculture per 1000 ha is determined as 0.36 tons, animal manure use is 2220.43 kg, CO_2 level released from agricultural energy is 0.05 kt, total CO_2 emission is 1.09 kt and agricultural nitrogen use is 7.22 tons. . In low-middle income countries, pesticide use in agriculture per 1000 ha is 1.72 tons, animal manure use is 7810.65 kg, CO_2 level released from agricultural energy is 0.66 kt, total CO_2 emissions are 15.31 kt and agricultural nitrogen use is 50.99 tons. was obtained as. In middle-high income countries, pesticide use in agriculture per 1000 ha is 7.36 tons, animal manure use is 13608.80 kg, CO_2 level released from agricultural energy is 1.74 kt, total CO_2 emission is 27.13 kt and agricultural nitrogen use is 88.31 tons. was seen as. In high-income countries, pesticide use in agriculture per 1000 ha was determined as 6.63 tons, animal manure use as 40209.04 kg, CO_2 level released from agricultural energy as 3.88 kt, total CO_2 release as 487.08 kt and agricultural nitrogen use as 137.15 tons.

Unit root test results of the variables examined in the study are given in Table 5.

Levin-Lin-Chu (LLC) and Im-Peseran and Shin (IPS) tests were used in the unit root test. According to the test results, in low-income countries, animal fertilizer use is at I(0) level according to the IPS test, and the CO_2 level released from agricultural energy according to the LLC and IPS test has unit root and is stationary at I(1) level. According to the IPS test at the I(0) level in low-middle income countries, the CO_2 level released from pesticide use and agricultural energy contains unit root and is stationary at the I(1) level. According to the IPS test in middle-high income countries, animal fertilizer use contains unit root at level I(0) and is stationary at level I(1). In high-income countries, animal fertilizer use according to the IPS test at the I(0) level, and the CO_2 level released from agricultural energy according to the IPS and LLC test contains unit root and is stationary at the I(1) level. At the I(1) level, according to the LLC and IPS test, agricultural nitrogen use contains unit root and is stationary at the I(0) level. All other variables were determined to be stationary at I(0) and I(1) levels across all countries.

Cointegration analysis is performed to examine the long-term movements of variables that are stationary at the same level. While cointegration analysis gives an idea about whether the series move together or not, other analyzes are needed to determine the strength of the long-term relationship.

The panel cointegration analysis results of the variables examined on a country basis are given in Table 6.

When the panel cointegration analysis results are examined, it can be said that, according to various statistical indicators used in the cointegration analysis, the variables examined are cointegrated in the long term in all countries in terms of income group.

The results of the Panel FMOLS test, which was performed to determine the effect of the variables determined to be cointegrated in the long term after the panel cointegration analysis, on the dependent variable, are given in Table 7.

The results of the FMOLS panel test show that for a 1% increase in CO_2 release from agricultural nitrogen use, cropland size, animal manure use and agricultural energy in low-income countries, total CO_2 emissions increase by 0.057%, 0.441%, 0.753% and 0.233%, respectively. If the use of pesticides increases by 1%, total CO_2 emissions decrease by 0.085%. In low-and middle-income countries, total CO_2 increases by 0.109%, 0.656%, 1.00%, 0.262% and 0.099%, respectively, when nitrogen use in agriculture, arable land size, animal manure use, pesticide use

Table 5. Unit Root Test Results.

Variables	Unit root test method	Low Income Countries		Low-Middle Income Countries		Middle-High Income Countries		High Income Countries	
		I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
C1	Levin-Lin-Chu	-1.14	-5.95*	-3.22*	-5.00*	-6.58*	-6.96*	-1.78*	-3.65*
	Im, Peseran and Shin	-0.71	-6.92*	2.78	-8.08*	-2.55*	-9.97*	3.98	-8.96*
C2	Levin-Lin-Chu	-3.79*	-4.21*	-91.92*	1.10	-2.81*	-10.11*	-4.66*	-11.67*
	Im, Peseran and Shin	-2.63*	-6.75*	-13.88*	-7.74*	-2.71*	-10.49*	-0.79*	-11.09*
C3	Levin-Lin-Chu	-3.13*	-4.46*	-3.45*	-9.30*	-2.61*	-7.73*	-4.14*	-12.86*
	Im, Peseran and Shin	-1.27***	-8.14*	-0.31	-12.74*	-1.26***	-13.65*	-2.44*	-13.89*
C4	Levin-Lin-Chu	-2.39*	-8.83*	-5.09*	-10.14*	-3.55*	-7.65*	-3.70*	-7.87*
	Im, Peseran and Shin	-0.50	-8.30*	-3.05*	-11.89*	-0.08	-10.39*	0.48	-10.20*
C5	Levin-Lin-Chu	0.33	-4.15*	-1.51***	-8.49*	-5.32*	-13.07*	0.41	-10.92*
	Im, Peseran and Shin	0.68	-5.65*	0.83	-11.74*	-3.61*	-13.08*	1.04	-13.22*
C6	Levin-Lin-Chu	-4.45*	-9.06*	-4.74*	-15.27*	-3.45*	-11.12*	-2.28**	-10.92
	Im, Peseran and Shin	-2.69*	-11.50*	-2.48*	-17.71*	-2.35*	-17.21*	-1.31***	-13.22

*, **,*** statistically significant at the 1%, 5% and 10% levels, respectively.

Table 6. Panel Cointegration Analysis Results.

	Low Income Countries		Low-Middle Income Countries		Middle-High Income Countries		High Income Countries	
	Statistic	Weighted Statistic	Statistic	Weighted Statistic	Statistic	Weighted Statistic	Statistic	Weighted Statistic
Panel v-Statistic	-1.05	-0.75	1.03	2.00	2.04	2.30	0.13	0.30
Panel rho-Statistic	1.90	2.02	3.07	3.94	3.57	2.75	3.18	3.71
Panel PP-Statistic	-3.20*	-3.20*	0.41	0.81	4.08	5.91*	1.02	0.86
Panel ADF-Statistic	-1.99**	-2.00**	0.61	0.39	3.35	1.76	3.31*	2.78*
Group rho-Statistic	3.58		5.93		5.27		6.41	
Group PP-Statistic	-3.31*		-2.35*		9.05*		1.08	
Group ADF-Statistic	-1.68**		0.32		0.62		4.16	

*,**,*** are statistically significant at the 1%, 5% and 10% levels, respectively.

Table 7. Panel FMOLS Test (Fixed Modified OLS) Results.

	Independent Variables	Low Income Countries	Low-Middle Income Countries	Middle-High Income Countries	High Income Countries
Dependent Variable C1	C2	0.441*	0.656*	-0.958	-0.055
	C3	-0.085*	0.262*	0.117*	0.156*
	C4	0.753*	1.00*	0.084	0.426*
	C5	0.233*	0.099*	-0.006	0.247*
	C6	0.057*	0.109*	0.134*	-0.108*
	R^2	0.97	0.96	0.96	0.99

*,**,*** are statistically significant at the 1%, 5% and 10% levels, respectively.

and CO_2 released by agricultural energy increase by 1%. shows. If nitrogen use in agriculture and pesticide use increase by 1% in middle- and high-income countries, total CO_2 increases by 0.134% and 0.117% respectively. If the CO_2 content released by the use of animal manure, pesticides and agricultural energy increases by 1% in high-income countries, the total CO_2 content increases by 0.426%, 0.156% and 0.247% respectively. If the use of nitrogen in agriculture increases by 1%, the total CO_2 content decreases by 0.108%. Land use changes, disposal of animal waste, rice production, fertilisation and the use of pesticides can be mentioned as factors that cause greenhouse gas emissions in agricultural production (Şahin and Avcıoğlu 2016). It is stated that 25% of greenhouse gases in agricultural production come from animal production (FAOSTAT 2021). Of the many effective factors relating to CO_2 emissions from agricultural activities, livestock farming is the most important (Figure 1–II). The results of this study are similar for all countries. It is found that methane released from animal waste is very important for global warming (Bauer 1994). CH_4 emissions from livestock account for about 80% of total agricultural emissions and 35% of total anthropogenic CH_4 emissions. The approximate rate of methane emissions from animal manure is 7%. N_2O emissions released from livestock account for about 65% of total anthropogenic N_2O emissions and 75% to 80% of agricultural N_2O emissions (Ersoy 2017). The release of greenhouse gasses from livestock farming occurs in two ways. These are enteric fermentation and animal manure. Proteins, carbohydrates, etc. in animal manure. Methane gas is produced by the decomposition of organic compounds in an aerobic environment (Demir and Cevger 2007). Although the emissions released by enteric fermentation are the subject of various studies, animal manure management is also very effective in the process of global warming and climate change. Another factor in anthropogenic emissions is soil management. It is reported that about 10% of greenhouse gases in the atmosphere are formed by soil (Raich and Potter 1995). When the carbon in the organic structure of the soil encounters more oxygen through tillage, it turns into CO_2 and causes emissions (West and Marland 2002; De-Oliveira Silva et al. 2019). As can be seen from this, there is a linear relationship between the degree of tillage and CO_2 emissions. However, as some countries have adopted no-till production systems such as no-till in their agricultural production systems, the contribution of CO_2 emissions may be minimal, regardless of how much the amount of arable land increases. There may even be an inverse relationship between them. In an experimental study, no-till farming was found to emit less CO_2 than traditional tillage (Turgut and Koca 2019). In addition, the soil structure of arable land can also be a decisive factor for microbial activities and thus for CO_2 emissions (Rastogi et.al. 2002; Yerli et al. 2019). One of the effective factors in greenhouse gas emissions from agricultural production is the effect of fertilization (Cole et al. 1997; Yerli et al. 2019). Although the use of nitrogenous fertilizers is a necessity to meet the needs of the growing world population, it is known that low nitrogen use causes significant environmental problems. Improper use of nitrogen fertilizers leads to soil and water quality degradation, pollution of underground and surface water resources, air pollution, biodiversity decline and also increases greenhouse gas emissions (Şahin and

Onurbaş Avcıoğlu 2016). The type and nature of the fertilizer used can influence this process. For example, it has been reported that CO_2 emissions from the soil decrease by 30–40% when ammonium nitrate is applied to the soil (Sitaula et al. 1995). On the other hand, it is reported that the environmental cost is low because the use of slow-release fertilizers leads to higher use efficiency of nitrogenous fertilizers through the use of nitrification and urease inhibitors (Lal and Singh 2000; Tolay et al. 2010; Zhai et al. 2011) explained this situation with the change in soil pH, salinity and microbial activity as a result of applied fertilizer. It is possible to explain the negative impact of agricultural nitrogen use on CO_2 levels in high-income countries. On the other hand, another emission factor that is considered important is the use of pesticides in agricultural production. It has increased significantly in the last 30 years (Ayyıldız 2022). However, pesticide use varies within countries as well as from country to country in the same region (Gün and Kan 2009). Although it is stated that there is a decrease in total use in developed countries, it can be said that pesticides are used at significant levels in some countries in this group (FAOSTAT 2023). When the average usage amounts are examined on the basis of the country groups examined in this research, it can be seen that low-income countries have a minimal use of 0.36 tons per 1000 ha. Pesticides can disrupt the microbial structure of the soil due to intensive use and indirectly affect CO_2 emissions. In addition, they can mix with groundwater through leaching and then create emissions through evaporation or direct evaporation. Some studies conducted in the USA and Korea have revealed that organochlorine pesticides have higher volatility rates in hot weather (Nations and Hallberg 1992; Yeo et al. 2003). Similar studies also stated that atmospheric concentrations of some pesticides showed a statistically significant positive correlation with temperature (Holland and Sinclair 2003; Bloomfield et al. 2006; Navarro et al. 2007; Steurbaut 2009). Bossi et al. (2008) stated that re-emission may occur from the soil surface due to the effect of temperature. Furthermore, it is arguable that the soil moisture resulting from rainfall will aid in the disintegration of the pesticide, as outlined by Navarro et al. (2007). While political approaches to addressing climate change adaptation and reducing emissions differ across the globe, they share common objectives. Policies to achieve these goals can be formulated for specific sectors. Emissions and energy consumption from the agricultural sector are lower than other sectors in relation to policy measures that have been implemented (Xiong et al. 2016). This is due to the numerous emission outlets for direct greenhouse gas emissions from agricultural activities, resulting in higher greenhouse gas emissions through relationships with other sectors. However, the impact of energy usage in agriculture on the CO_2 level remains unchanged (Alexander et al. 2015; Bennetzen et al. 2016). The variation in agricultural practices and mechanization levels across different regions, as explained by Paustian et al. 1998 and Van den Berg et al. 2007, account for this phenomenon.

Recommendation and conclusion

Climate change is one of the most important issues of the third millennium. If you consider the consequences, you can talk about many social and economic problems. The process of climate change is a two-way mechanism. On the one hand, it affects all sectors and people, and on the other hand, it is influenced by all sectors and people. In fact, the intensity of the influence increases with the second aspect, the influence. This is because the process can be described as an anthropogenic process. The environmental costs of all human-induced interactions are increasing. The growing world population and the need to meet demand are changing production processes. Especially after the industrial revolution, an intensive production process began and the environmental costs caused by each unit of goods produced increased. One of the most important sectors in this production process is agriculture. The inputs used release CO_2 into the atmosphere. Many elements such as the intensive use of inputs in intensive agriculture to meet global food demand, the mobility of production factors, energy consumption in the chain of all agricultural goods and services from production to consumption, land use change and livestock management are the sources of emissions from the agricultural sector. Indeed, there are proposals in the literature to reduce the inputs used in agriculture. However, the scarce resources used in agriculture on Earth to meet the demands of a growing global population suggest that the recommendations should be rejected. It could be argued that reducing the inputs used to meet increasing food demand might hinder access to food rather than solve the issue. The level of development, educational structure, technological opportunities, and qualified input vary among countries. The inputs utilised should be ecologically sound, while fertilisers must possess a high level of efficacy through slow-release. It is imperative that soil cultivation practices are conducted in accordance with the law to reduce emissions. It is also crucial to use residue-reducing or low-volatility compounds in pesticides and plant high-genetic-resistant varieties. Moreover, the use of biological and biotechnical practices in diseases and pests must be adopted. It is suggested that countries such as Canada and Sweden have been able to reduce pesticide use by half without significant decreases in productivity and quality parameters (Pimenteletal., 2005). In contrast, attaining a global consensus on transforming energy resources and reducing the dependency on fossil fuels appears feasible. Conscious and technical production enables the efficient use of limited resources, while also benefitting the environment. Manure management is a crucial concern in animal agriculture. An investment can be made to harness methane from animal manure as an energy source. This process prevents greenhouse gas emissions from being released by storing or leaving it on the pasture, and it adds value to energy production. Similarly, the adoption of agricultural production-oriented training in every country can be seen as a way out. Within the context of achieving climate change adaptation and emission reduction goals, it is recommended that input use optimizations be legally mandated through the adoption of environmentally friendly and qualified inputs and agricultural production systems, without any decrease in output. Furthermore, the implementation of carbon taxes that consider each country's development level and respective emission potential may also be worth considering as a viable solution. Different calculations based on the ratio of inputs employed in the agricultural industry and tailored to individual enterprises can avert inadvertent and unauthorised use of inputs. These guidelines can be tailored based on factors such as countries' agricultural prospective, developmental stage, and socio-political structure, in different parts of the globe.

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