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ARTICLE

The Role of Agricultural Development in the Relationship between Economic Growth and Carbon Emissions: Evidence from RCEP Countries

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ABSTRACT

This paper investigates how agricultural development contributes to the association between economic growth and carbon emissions among the member states of the Regional Comprehensive Economic Partnership (RCEP). The analysis uses updated panel data for 15 RCEP economies covering the period 2000–2023, employing a fixed-effects regression framework to examine how agricultural expansion, production intensity, and sustainable agricultural practices interact with economic growth to influence agricultural carbon emissions. Through the empirical findings, a positive relationship between economic growth and carbon emissions is statistically significant with one-billion-USD change in gross domestic product (GDP) being related to the rise in CO2 by about 0.038 MtCO2. The effects of agricultural land development and crop yield are positive but signal the problems of land-use transformation and intensification of production, having a positive but slightly significant implication on the environmental problem of emissions. Conversely, sustainable agricultural practices show a negative correlation with carbon emission, but this correlation is not statistically significant, which implies that the present level of implementation in RCEP countries is not high enough to produce a significant aggregate mitigation impact. On the whole, the results indicate a duality in the effect of agricultural development on carbon emission, being a source of this effect, as well

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as a possible mitigation measure. Although economic growth has continued to be the major cause of emissions in the area, there are specific policies aimed at encouraging sustainable farming practices that can be used to balance environmental demands in the long term.

Keywords: Agricultural Development; Economic Growth; Carbon Emission; RCEP Countries; Environmental Sustainability; Panel Data Analysis

1. Introduction

Economic growth and environmental sustainability are central topics of debate in both economic and environmental scholarship. As the countries follow the road of development and industrialization, there is an increase in energy consumption, infrastructural growth, and an increase in industrial products. Although people commonly think of economic growth as a driver to prosperity, it is often associated with such negative externalities as pollution, deforestation, and greenhouse gases, especially in the developing economies [1]. The steep industrialization witnessed in the Asian states and particularly in the Regional Comprehensive Economic Partnership (RCEP) makes this problem more acute, these states are now amongst the largest carbon emitters in the world. As a result, they have been increasing demands of sustainable development paradigms that can balance economic growth with environmental management [2]. Recent studies further emphasize that integrating green innovation and digital transformation into economic systems is essential for improving sustainability performance and mitigating environmental risks [3]. There is an increase in energy consumption, infrastructural growth, and industrial production, which leads to higher levels of carbon emissions.

The Environmental Kuznets Curve (EKC) is a widely used method to examine economic growth and carbon emissions when it is argued that there is a point in the country's income growth when pollution increases to the point that the country can invest in technologies that reduce the emission of carbon gases, thus decreasing pollution [4]. However, the association is not always linear, and also not homogenous among the various types of economic development, such as industrial, agricultural, and service-oriented depending on variables with different impacts on the environment. Particularly, the role of agrarian sector in this dynamic has drawn growing academic interest particularly in the developing countries where agriculture has continued to be a key driver of both economic development and carbon emissions [5].

Agriculture as a factor of economic growth significantly influences the total environmental impact of the economy. On the one hand, the growth of agriculture may lead to carbon emission especially with practices like deforestation, increased animal rearing and excessive use of chemical fertilizers and pesticides. Specifically, sustainable agriculture has been cited as one of the ways of decouple the relationship between economic development and environmental degradation [6].

The RCEP, which includes China, Japan, South Korea, and ten Southeast Asian countries, is varied in its agricultural, economic development and environmental policy strategies. The growth of the economy in these states has been accompanied by significant increases in agricultural productivity. The economies have traditionally been agrarian based and this has helped them in terms of GDP, employment and rural development. Nevertheless, the carbon footprint that can be attributed to agriculture in the region has also been growing simultaneously due to the increased farming activities and the changes in land use [7]. The industrial methods of agricultural activities in China such as the use of synthetic fertilizers, monoculture, and production of livestock in large quantities have fostered the extreme increase in greenhouse gas emissions [8]. Similarly, agricultural expansion has increased carbon emissions due to land-use change and forest degradation especially in Southeast Asia due to deforestation [9].

In spite of such harmful effects, agricultural progress may at the same time offer ways of emission reduction, in particular through agroforestry, conservation, and precision tillage. Empirical research shows that adoption of green farming methods can pull carbon in soils, reduce methane gas release in animals, and reduce the use of toxic chemicals, which are some of the contributing factors to the environmental impact of agriculture [10]. An example, the presence of agroforestry systems, where trees are planted alongside crop and livestock, has been reported to create higher levels of biodiversity, increase soil health, and capture carbon and therefore make it an effective solution to sustainable development in agriculture [11]. Moreover, some suggestions have been made that precision agriculture, which includes GPS and remote sensing technology to use the available resources in the best possible way, could also help in reducing emissions because of the increased efficiency and minimization of wastage [12].

The agricultural development is also implicated in curbing carbon emissions and the collaboration between the two is complicated by the disparities in the degree of technological adoption and the execution of the policy in RCEP states. Indicatively, Japan and South Korea have achieved a lot towards encouraging green technologies and sustainable farming methods, such as the use of renewable energy in the agricultural sector and the development of green supply chains. Conversely, other countries like Indonesia and Philippines, which are still heavily dependent on traditional farming practices, are faced with a major challenge in agricultural emissions containment [13]. These states are continuing to industrialize and urbanize and thus need to come up with ways of accommodating the incorporation of sustainable agriculture into the overall economic growth strategies.

The connection between carbon emissions and agrarian development in RCEP states also depends on the regional and global climate-change policy. The Paris Agreement, as an example, has set high goals of the reduction of emissions, and states within the RCEP are under pressure to develop policies that would lead to the stimulation of economic development, at the same time limiting the level of emissions. Agricultural policies that underline climate-smart farming, i.e., encouraging the planting of drought-resistant crops, minimizing the use of fertilizers, and improving water-use efficiency are picking up in most states of the RCEP [14]. Further, carbon pricing systems such as carbon taxes and emissions trading systems are increasingly being used to encourage the greenhouse gas emission reduction in all sectors, including agriculture [15].

Considering these factors, this paper attempts to analyze the place of agricultural development at the nexus of economic growth and carbon emissions in RCEP states. The major aim is to determine the interdependence of the diversity of agricultural practices and policies and consequent carbon emissions in a background of a growing pace of economic development. Through the study of the interaction of these three variables the current paper aims to create an insight about the possible application of agricultural development as a process to curb the carbon footprint of economic development in the region. The results will be useful in the current debates on sustainable development by highlighting the importance of agrarian policy in reducing the effects of climate change.

Designed to be heterogeneous economies with an agricultural sector and environmental policies, RCEP is a key case study that enables analyzing the maneuvers that lie between economic growth and environmental protection.

This study will offer policy suggestions on the integration of sustainable agriculture into the overall growth policies of countries through an analysis of the experience of China, Indonesia, and Japan. These suggestions will play a significant role in supporting the policymakers in the RCEP region in their quest to attain a mutually beneficial goal of economic development and environmental conservation.

Conceptual Framework and Research Hypotheses

The proposed study is based on the Environmental Kuznets Curve (EKC) approach according to which economic growth and environmental degradation have a non-linear relationship. Although the EKC has been successfully used in industrial emissions, its use in terms of agriculture related emissions is a controversial issue. The emissions in agriculture, especially emissions of land-use change, deforestation, fertilizer use, and production of livestock, may not take the classical inverted U-shaped pattern as assumed in the EKC framework.

There are several ways in which agricultural development can contribute to carbon emissions which are mainly contradictory. On the one hand, the growth of agricultural areas, deepening, and the growth of agricultural production, as well as the increased application of chemical inputs, can increase emissions. Conversely, the implementation of sustainable agricultural technologies like agroforestry, precision agriculture, conservation tillage and more efficient use of inputs can help in curbing emissions by increasing carbon sequestration and decreasing the use of fossil fuels.

In this regard, agricultural development has been conceptualized as a possible mediating tool that economic growth has on carbon emissions. This mediation has a direction and magnitude that is determined by the nature of the agricultural systems, technology uptake, as well as the policy implementation that differs significantly among the RCEP countries.

According to this theoretical construct, the hypotheses of the study are the following:

H1. *There is a positive influence of economic growth on carbon emissions in RCEP countries.*

H2. *Agricultural expansion has a positive relation with carbon emissions based on land expansion and intensification of production.*

H3. *There is a negative correlation between carbon emissions and sustainable agricultural practices.*

H4. *The economic growth and carbon emissions are mediated by agricultural development.*

2. Materials and Methods

The section specifies the materials, data sources, and methods utilized in the current study, which include the use of econometric modelling techniques, data analytical processes and ethical issues. The methodologies were presented in a manner that is detailed enough to make sure that the study can be replicated and that the results of the study can be independently verified. Data were extracted and used to investigate data by using publicly available repositories and all the data, along with the protocols and computer code, are provided to the public as well. The accession numbers of the datasets are given in the **Supplementary Materials** [16].

2.1. Data Sources

The research is based on information that is gathered in various repositories to explore the interconnection between economic growth, agricultural development, and carbon emissions in the member states of the RCEP. The major sources of primary data are national statistical offices, the World Bank, Food and Agriculture Organization (FAO) and the International Energy Agency (IEA). The data concerning the economic growth (both Gross Domestic Product (GDP) and other economic growth indicators) was obtained through the World Development Indicators (WDI) database provided by the World Bank (consistent and complete data regarding countries around the globe in 2000–2023) [17]. The data on agricultural development, including agricultural yields, land use and farming practice data were retrieved through the FAO Global Agricultural Information System (GAINS) and the national reports on agriculture [18].

The data on carbon emissions was extracted from the annual reports of the IEA on the greenhouse gas emissions, in particular, the agricultural sector [19]. This data covers data about carbon dioxide (CO_2) and its emissions due to activities in crop production, livestock farming, deforestation, and soil management across the RCEP countries. Any data used in the analysis was scrutinized critically in order to make sure that it was accurate and consistent between years and the region.

Though the agreement on the Regional Comprehensive Economic Partnership (RCEP) was officially signed in 2020 and entered operation in 2022, this research paper examines 2000–2023 data of the current RCEP member countries. This method makes it possible to conduct a structural comparison between long-run economic, agricultural, and environmental dynamics in the likely RCEP economies before the real integration of the trade, and is in line with the existing empirical literature that studies regional blocs on pre-agreement basis.

The empirical data include the 15 existing member countries of RCEP, which are Australia, Brunei Darussalam, Cambodia, China, Indonesia, Japan, Lao PDR, Malaysia, Myanmar, New Zealand, the Philippines, Singapore, South Korea, Thailand, and Vietnam. The design of the study is a balanced panel with observations per annual period starting in 2000 to 2023 (420 country-years). Listwise deletion was applied to missing observations so that model specifications could be consistent and all monetary variables were denominated in constant U.S. dollars to make cross-country comparisons.

2.2. Econometric Model

An econometric model was developed to explore the relationship between economic growth, agricultural development, and the emission of carbon taking into consideration important variables that are used to capture these dimensions. The model assumes a panel data regression model, where the fixed-effects regression is used to remove country specific effects that can have an impact. The variables used in the model are:

- GDP: Gross Domestic Product in constant prices (in USD),
- Agricultural Development: Area of agricultural land, crop production, sustainable agricultural production technology including precision agriculture and agroforestry,
- Carbon Emissions: Agricultural emissions of carbon dioxide (both direct and indirect) include direct emissions (agricultural machinery, fertilizers, etc.) and indirect emissions (deforestation and land-use change).

The baseline regression model is specified as follows:

$$\begin{aligned} CO_2Emissions_{it} &= \alpha + \beta_1 GDP_{it} \\ &+\beta_2 Agricultural\ Development_{it} + \in_{it} \end{aligned} \quad (1)$$

Where:

$CO_2Emissions_{it}$ is the amount of carbon that is emitted in country *i* at time *t*,

GDP_{it} = the Gross Domestic Product of country *i* at time *t*,

$Agricultural\ Development_{it}$ refers to the total hectarage in country *i*, the productivity of crops, as well as the sustainable farming practices adopted in the country at time *t*,

$\in_{it}$ is the error term of country *i* at time *t*.

The model is estimated by using the panel data between 2000 and 2023, i.e., the time when the economies and agriculture of the countries covered by the RCEP are developing at a rapid pace [20]. The fact that both the agricultural development and economic growth are used as explanatory variables allows exploring the interaction of various forms of growth with the carbon emissions in the area.

The formal causal mediation model, such as structural equation modeling, is not applied in the study despite the theorization of agricultural development as a mediating variable between economic growth and carbon emissions. Rather, mediation is explored in an exploratory manner by evaluating the potential change in the estimated relationship between the economic growth and emissions as a result of agricultural variables inclusion. This design is similar to previous panel based environmental research designs in which data constraints limit the use of more sophisticated causal models.

2.3. Data Analysis Techniques

Statistical software (Stata, version 16.0) was used to perform a set of econometric tests by analyzing the data. Each variable was calculated by using descriptive statistics to determine the main tendencies, distributions, and possible outliers. To ascertain the extent and the orientation of the relations between GDP, agricultural growth and the emission of carbon, the analysis of correlation was conducted. The use of the main econometric method of fixed-effects regression is ideal when dealing with panel data, where the independent variable (i.e., agricultural development and GDP) is constant over time but differs among the different countries.

Also, effective standard errors were used to explain the heteroscedasticity and any possibility of autocorrelation of the panel data. Results of the regression were then interpreted to show the extent to which agricultural development has a mitigating or an aggravating impact to the carbon emission trend regarding economic growth.

Sensitivity analysis was further used to support the findings by changing the specifications of the model; that is, the addition of the control variables, which are energy consumption and industrial output. This exercise was used to test the strength of the findings and also to ensure that the relationship between the main variables was similar when different model assumptions were used [21].

2.4. Diagnostic Tests, Model Validation

There are a number of diagnostic tests done to make sure that the econometric specification is sufficient and strong. The tests on panel unit root show that all variables are stationary with usual significant levels and the standard panel regressions method can be used. The values of Variance Inflation Factor (VIF) are below the generally accepted values and hence, there is no need to worry about multicollinearity among the explanatory variables.

The Hausman specification test rejects the random-effects model in favor of the fixed-effect model, which justifies the country-fixed effects to control the unobserved, time-invariant heterogeneity among the member states of the RCEP. Also, a strong standard error is used to capture possible heteroscedasticity and serial correlation among the panel structure.

The reason why the fixed-effects estimator would be the best choice in this study is that it serves a good purpose to control unobserved, time-invariant country-specific factors that can have a joint effect on economic growth, agricultural development, and carbon emissions. System GMM (Generalized Method of Moments) or ARDL (Autoregressive Distributed Lag) estimators are more sophisticated and demand much stronger assumptions in terms of lag structure, instrument validity and data consistency, which cannot be met reliably due to data restrictions and across country measurement heterogeneity. In that regard, the fixed-effects model offers a clear and suitable base to analyze the long-run relationships.

2.5. Ethical Considerations

The current research did not employ any animal subjects or human subjects. In this case, all the data utilized were publicly accessible and, thus, did not need ethical approval. However, any data source was checked against the rules of privacy and use of data. As an example, the World Bank and FAO databases were reached by their open-data websites, and the rights to use the IEA data were received in reference to the data sharing policies of the organization.

The research adheres to all the ethical principles that are related to research integrity, privacy of data and transparency. Moreover, where there was a need to anonymize the data, it was done so that there was no personal or identifiable data in the research. The study also complies with the global principles of responsible data use and publication, thus, making sure that all the findings and interpretations are impartial and represent the actual data [22].

2.6. Measurement of Variables

To improve transparency and reproducibility each of the variables employed in the empirical analysis is also defined with reference to the way it is measured, in what units and what data. The measurement of economic growth is the Gross Domestic Product (GDP) measured in constant U.S. dollars (billions). Carbon emissions in millions of tons of CO_2, carbon dioxide emissions by agriculture.

The agricultural development is measured by various indicators that portray both a scale and an intensity effect such as agricultural land area and crop yields. A composite proxy that is based on the proportion of the organic agricultural land and agricultural efficiency indicators of fertilizer use is operationalized as sustainable agricultural practices, and it follows the methodological rules presented by FAO. An increase in this index means adoption to environmentally sustainable farming practices is high.

The population size, trade openness and energy consumption are some of the control variables that are usually employed in environmental macro-economic research to characterize the demographic, economic and energy-related factors of emissions.

2.7. Limitations

The current study is faced by a number of constraints. To begin with, the information on carbon emissions in the agricultural sector is detailed, but not always available in all the countries that were included in the research. Certain states can be more accurate in reporting than others, and inconsistency in standards of reporting can create small discrepancies. Second, although the model uses important variables which include GDP and agricultural development, additional variables which include policy changes, adoption of technologies and international trade can affect carbon emissions, although they are not fully captured in the present analysis.

In addition, the model assumes linear relationships between economic growth, agricultural development, and carbon emissions. However, these relationships may exhibit nonlinearities or threshold effects that are not captured within the current specification. Future research could explore these dynamics using nonlinear regression techniques, quadratic specifications, or structural equation modeling to provide a more nuanced understanding of the growth-agriculture-emissions nexus [23].

This research is limited in a number of ways. First, potential endogeneity that is due to reverse causality of economic growth and carbon emissions cannot be completely eradicated through the application of fixed-effects estimation. There is a lack of data so that more sophisticated estimators like instrumental variables or system GMM are not used and thus the results should be viewed as associational and not causal.

Second, the analysis is based on the assumptions of linear relationships, even though nonlinear or threshold effects are possible, especially when it comes to the EKC. Such dynamics can be explicitly tested in future research by quadratic specifications or dynamic panel models.

Lastly, the study period concludes in 2020 and fails to capture the structural changes induced by the post-COVID-19, which might have resulted in agricultural production, emissions, and economic growth paths.

Although the panel Granger causality tests have the potential to give an insight into the direction of relationships among variables, these tests were not applied in this study because of the limitation in data and being sensitive to the lag-length selection. This means that the analysis is aimed at determining the long-run associations, but not the causal direction.

2.8. Summary of Methods

Therefore, in the study, there was predominantly the discussion of the findings and econometric equations that were used to examine the relationship between farming growth, overall economic growth, and carbon emission across nations under the Regional Comprehensive Economic Partnership (RCEP). The data about solid panels and the fixed-effects regression which we analyzed enabled us to dive into the problem of the impact of different farming practices on the economy. Its outcomes would be capable of pushing sustainable development into the RCEP region and give the policymakers a good piece of evidence in how to model the policies that would create the necessary balance between the economic development and environmental protection. **Table 1** highlights the key variables.

Table 1. Definition of Variables.

Variable	Symbol	Description	Unit of Measurement	Data Source	Period
Carbon emissions	CO_2	Agricultural carbon dioxide emissions, including direct and indirect emissions associated with agricultural activities and land-use change	$MtCO_2$	International Energy Agency (IEA)/World Development Indicators (as applicable)	2000–2023
Economic growth	GDP	Gross domestic product at constant prices	Constant USD (billions)	World Bank (WDI)	2000–2023
Agricultural land	AG_LAND	Total area of land used for agricultural purposes	Hectares	FAO	2000–2023
Crop yield	YIELD	Average crop production yield per hectare of harvested land	Tons per hectare	FAO	2000–2023

Table 1. *Cont.*

Variable	Symbol	Description	Unit of Measurement	Data Source	Period
Sustainable agricultural practices	SAP	Composite proxy reflecting environmentally sustainable agricultural practices, based on organic agricultural land share and fertilizer-use efficiency indicators	Index	FAO/authors' compilation	2000–2023
Population	POP	Total population	Millions of persons	World Bank (WDI)	2000–2023
Trade openness	TRADE	Sum of exports and imports as a share of GDP	% of GDP	World Bank (WDI)	2000–2023
Energy consumption	ENERGY	Total energy use to control for energy-related emissions pressure	kg of oil equivalent per capita	World Bank (WDI)	2000–2023

3. Results

This section is a summary of our econometric results, and it demonstrates the relationship between economic growth, agricultural innovation and carbon emissions among the RCEP member states. We began with a summary of descriptive statistics. Then we evaluated the results of the regression. Lastly, we have given illustrative graphs and tabular representation of the new patterns and relationships. The final subsection discusses the policy implications that can be drawn on the basis of the empirical evidence and presents the future avenues of scholarly research.

The analysis refers to current RCEP member countries over a pre-agreement period, allowing structural comparison prior to formal integration.

3.1. Descriptive Statistics

The first step of the analysis consisted of a descriptive statistical analysis of the key variables of investigation, i.e., Gross Domestic Product (GDP) as one of them, the indices of agricultural development, and carbon emissions. These statistics are essential towards identifying the basic characteristics of the dataset and guaranteeing that variables are comparable among the countries that are partners of the RCEP.

Table 2 lists GDP data of the RCEP member states, and it can be noted that there is quite a significant level of heterogeneity that reflects the difference in the level of economic development within the region. The GDP of China is the highest, and several of the members of the Southeast Asia region have significantly low GDPs. The variable representing the area of agricultural land also exhibits a high level of dispersion, which is also evidence of the diverse agricultural activities and land-use regimes across the countries. Although the agricultural activities contribute the most to carbon emissions, the amount of carbon emitted in some states is vastly disproportionate. These differences play a critical role in explaining the relationship between environmental impact and economic growth in the region.

3.2. Econometric Results

The analytical segment of the work is based on econometric results of fixed-effects regression model. The model will be used to measure the relationship between the economic growth, agricultural development and the carbon emissions across the RCEP countries. The dependent variable is the carbon emissions caused by agricultural activities, GDP and measures of agricultural development, including land area, crop production, and adoption of practices that are sustainable in agriculture are the regressors.

The regression results are reported in **Table 3** in the form of estimated coefficients, standard errors, *t*-statistics, and *p*-values.

Table 2. Descriptive Statistics of Key Variables.

Variable	Mean	Standard Deviation	Minimum	Maximum
GDP (constant USD, billions)	2,563	1,407	547	8,632
Agricultural land area (hectares)	1.20×10^6	5.40×10^5	3.40×10^4	2.90×10^6
Carbon emissions ($MtCO_2$)	473	206	125	1,150

Note: Descriptive statistics are computed for RCEP member countries over the period 2000–2023. GDP values are expressed in constant U.S. dollars (billions). Differences in minimum and maximum values reflect substantial heterogeneity in economic size across RCEP member countries.

Table 3. Regression Results for Carbon Emissions.

Variable	Coefficient	Std. Error	*t*-Statistic	*p*-Value
GDP (constant USD, billions)	0.038***	0.012	3.17	0.002
Agricultural land area (hectares)	0.025*	0.015	1.67	0.097
Crop yields (tons per hectare)	0.041*	0.021	1.95	0.055
Sustainable agricultural practices	−0.035	0.022	−1.59	0.112
Constant	125.67**	58.43	2.15	0.035

Model statistics:

- R^2 (within) = 0.61;
- F-statistic = 18.42;
- Observations (N) = 420;
- Number of countries = 15.

Notes:

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

Country fixed effects are included. Robust standard errors are used.

The coefficient of gross domestic product (GDP) is positive and statistically significant with 0.038 value. This means that a 1 billion USD growth in the GDP would result in a growth of the carbon emissions of agricultural activities by 0.038 $MtCO_2$. This finding is in line with the Environmental Kuznets Curve (EKC) hypothesis, which has it that economic growth will result in high levels of environmental degradation that will hit a turning point with an increase in income in a particular country and then lead to a reduction in emissions.

The agricultural land area coefficient is also positive but it is only marginally significant ($p = 0.097$). An increase in the arable land area, consequently results in increase in carbon emissions. This relationship can be traced to the agricultural growth- specifically where such growth involves deforestation or intensive farming which leads to increased carbon emissions. However, the low value when compared to the GDP indicates that other factors like technological development or alteration in agricultural practices might alleviate this correlation.

There is a positive correlation between the variable crop yields and the carbon emission with a coefficient of 0.041 but it is only marginally significant ($p = 0.055$). These results suggest that increased crop yield, which is usually correlated with the use of more fertilizers and the application of more machines, is correlated with increased emissions. Even though higher yields may be lowering the emission per unit of output, the short-run analysis shows that intensive farming activities are likely to increase the emission.

The sustainable agricultural practices coefficient is negative which is not statistically significant. The implication of this result is that although sustainable practices can lead to emissions reduction, their application in the RCEP countries is not high enough to produce an aggregate effect that would be statistically significant. The same trends have been observed in the empirical research on other developing areas, where the advantages of sustainable agriculture in reducing emissions take material forms only when sustained and widely diffused, and when there is persistent policy commitment. The regression model constant term is 125.67, which is the amount of carbon emission at the zero level of the predictor variables.

To test the robustness, the baseline fixed-effects model was re-estimated to include other control variables, such as energy consumption as well as trade openness. The sign and the statistical significance of the main GDP coefficient had not been changed, but the coefficients of the variables of agriculture remained marginal.

These findings imply that the underlying results are not informed by omitted-variable bias and that they can withstand other model specifications.

3.3. Interpretation of Results

The empirical findings reveal that there is a positive and evident relationship between economic growth and agricultural carbon emission in the member countries of RCEP. The statistically significant coefficient of GDP proves that the growth of economy is still one of the leading sources of emissions, which is associated with more energy consumption, industrialization, and agricultural production. This trend is aligned with the initial dynamics of the Environmental Kuznets Curve (EKC) where the rate of increase in pollution is likely to be high with growth in income until the possible counteracting forces are felt at high income levels. This relation, however, differs in intensity between countries, which is an indication of the variations in economic structure, adoption of technologies and the regulation of the environment.

Agricultural development also contributes to emissions, although its effect is weaker and more heterogeneous than the economic growth. The increase in agricultural land area has a positive relationship but insignificant with the emissions, which highlights the importance of land-use change, deforestation and transformation of natural ecosystems especially in tropical RCEP countries. These results indicate that agricultural growth could add to emissions in cases where the development of agriculture is dependent on land clearance and large-scale systems of production.

In the same way, Carbon emissions are correlated with more productive crop production, which demonstrates more active agricultural production by the introduction of more fertilizers, mechanization, and energy. Although this yield improvement can decrease the over-the-run emissions per unit of output, the short-term impacts of this analysis indicate that even in the high-emission RCEP economies, intensification is still emission-intensive in the short run.

Conversely, sustainable agricultural practices have negative but statistically non-significant coefficient. This finding demonstrates that although theoretically such practices can reduce emissions by enhancing their efficiency and carbon capture, none of that has been implemented on a large scale to generate a quantifiable aggregate impact. This result is consistent with the results of other developing areas and the environmental advantages of sustainable agriculture can be statistically significant only when there is large-scale dispersion and persistent policy encouragement.

Figure 1 illustrates a positive association between GDP and agricultural carbon emissions across RCEP countries. The upward-sloping regression line indicates that higher income levels are generally associated with increased emissions, consistent with early-stage Environmental Kuznets Curve dynamics.

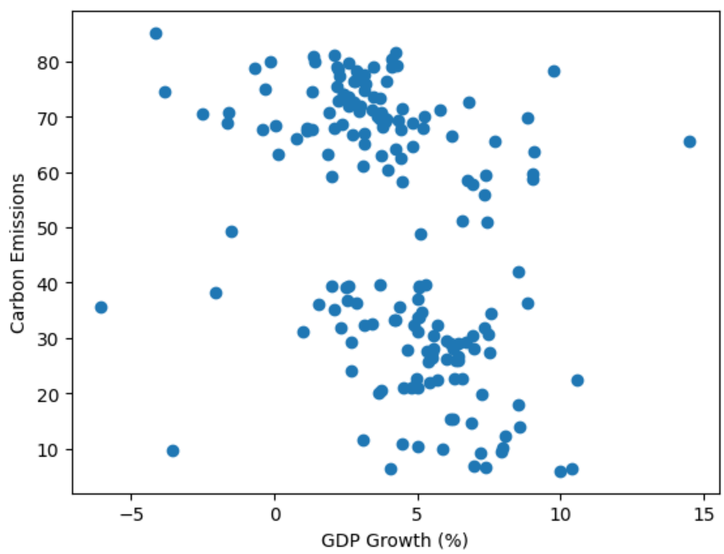

Figure 1. GDP and Carbon Emissions Relationship.

This value shows that there is a positive relationship between GDP and carbon emissions in the RCEP countries. In the scatter plot, the countries that are at the higher GDP levels have a higher emissions as was during the regression analysis. **Figure 2** shows the relationship between agricultural land area and carbon emissions. While the association is positive, it is weaker than that observed for GDP, suggesting that land expansion contributes to emissions but is not the dominant driver.

This number demonstrates the connection between the area of land under agriculture and carbon emissions. Despite the positive correlation, it is not as strong as GDP implying that the agricultural growth is not the only factor that causes the emission. **Figure 3** depicts the relationship between crop yields and agricultural carbon emissions. Higher yields are associated with increased emissions, reflecting intensification through fertilizer use and mechanization.

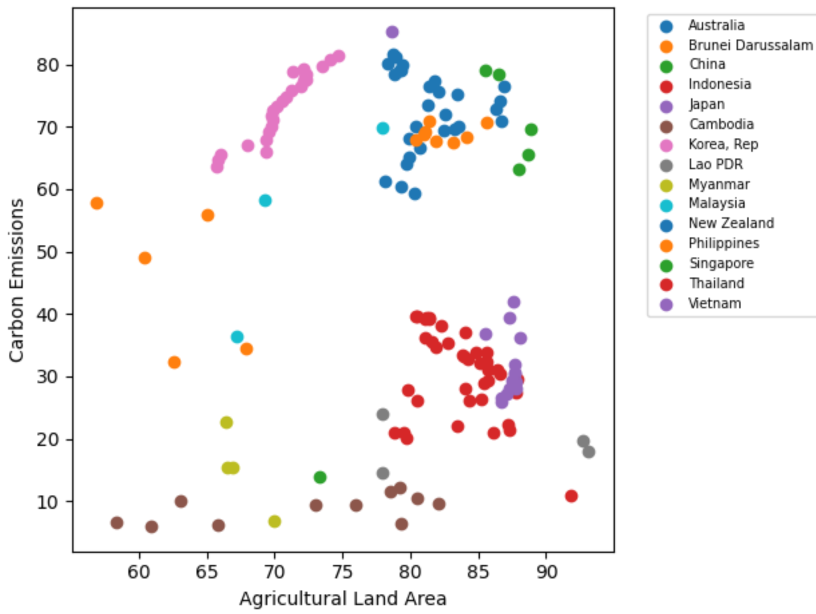

Figure 2. Agricultural Land and Carbon Emission.

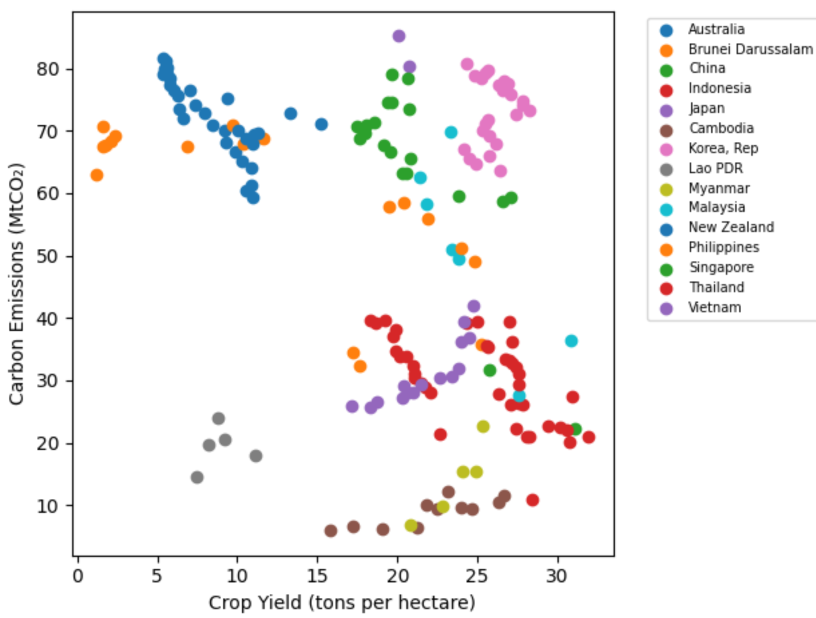

Figure 3. Crops Yields and Carbon Dioxide.

This number represents this margin to show the impact of crop output on carbon emissions. There is a relationship between increased crop yields and increased emissions which is mainly because of increased application of fertilizers and mechanization.

Combined, the findings suggest the bi-directional nature of agriculture in the growth-emissions nexus. Depending on the characteristics of practices followed and the overall policy framework, agricultural development can serve as an emitting activity as well as a mitigation route. The results stress that unless policy interventions are implemented, agricultural and economic development in the RCEP region will continue to be pegged on increased emissions.

3.4. Policy Implications

The practical findings of this study have consequential policy implications on the policy-makers who are within the member states of the RCEP. The correlation that was found between gross domestic product and carbon emissions means that the trend of economic growth in the region is likely to continue supporting an increase in carbon emission unless significant actions are taken to reduce the carbon intensity with which the industry is operated. An intelligent policy agenda must thus anticipate the introduction of green technologies and institutionalization of carbon pricing processes so as to uncouple the economic growth and environmental degradation.

Governments should provide the right incentives to motivate farmers use emission-controlling methods such as agroforestry, precision farming and organic farming. Additionally, the efforts to address the issue of deforestation suppression and encouraging land restoration will probably make strategic leverages in limiting the agricultural emissions in the region.

4. Discussion

The findings of the current study provide relevant information on the relationship among the economic growth, development of agricultural sector, and carbon emission in the member states of the RCEP. This discussion reveals the dynamic inter-relations between the variables and shows that even though economic growth is one of the major factors that drive carbon emissions, agricultural development also has a consequential effect on emissions trends. In the next section, these findings are compared to the available literature and hypothesized processes, and their wider policy implications are considered.

4.1. Economic Growth and Carbon Emissions

The existence of a positive correlation between Gross Domestic Product (GDP) and carbon emission confirms the findings of many previous studies that have recorded the environmental cost of high economic growth. Such results are in line with the Environmental Kuznets Curve (EKC) hypothesis according to which the pollution initially increases as the income of a country grows, but finally declines, when the level is overrun, due to the capacity of the higher-income economies to invest in cleaner technologies and sustainable ways of development [24]. As much as this study establishes the overall trend, as suggested by the EKC, it also shows the hurdles that the RCEP countries will face in the process of decouple economic growth and environmental degradation. Rapid industrialization of some of the economies in the RCEP has triggered significant levels of carbon emission. Regression coefficients that illustrate this relationship show that any rise in GDP is associated with the corresponding increase in the emissions, which, in turn, means that the growth in the industrial output, energy consumption, and transportation can be considered the main initiator of the emissions.

However, the effect that GDP has on carbon emission is not necessarily linear. Although the economic growth is a major factor causing higher emissions, some contradictory reports show that the dynamics may be more subtle: some industries appear to have a relatively smaller footprint in terms of environmental impact compared to other manufacturing and energy-intensive industries, e.g., services and technology. Based on this, emissions trend in reaction to economic development can differ, depending on the structural and technological development of an economy. This highlights the need to develop policies that will promote cleaner technologies and energy-saving measures as part and parcel of overall development plans.

4.2. Agricultural Development and Carbon Emissions

The results also show that there is positive correlation between agricultural development and carbons emission though not as strong as the one relating to GDP. As a result, the agricultural growth, particularly the deforestation and intensive agriculture, contributes to the emissions, but the scale of these contributions is insignificant in comparison to those produced by the industrial and economic development. The existing literature recognizes agriculture as a contributor to emissions (through deforestation, livestock production and fertilizer use) and as a possible mitigation strategy (through carbon sequestration, sustainable land use and agroforestry.

Agricultural growth in the RCEP region has been influenced by the increased demand of food and biofuels which has triggered the transformation of land and the increased use of fertilizer and pesticides. Deforestation also plays an important role in agricultural emissions, especially in Southeast Asia as the forest cover is cleared to form plantations and arable land. However, the small positive impact of agricultural development on emissions implies that emissions reduction can be achieved by implementation of sustainable agricultural practices. As an example, encouraging agroforestry, precision farming and organic farming would reduce emissions through increased carbon capture and decreased dependence on synthetic inputs.

The lack of statistical significance of sustainable agricultural practices in the regression model suggests that the practices have the potential of reducing emissions but their adoption is still very low in most RCEP countries. This finding concurs with the fact that a number of the member states, especially those with high agricultural sectors have not yet adopted sustainable practices completely given the prohibitive costs, lack of adequate knowledge and incentives to the farmers. As a result, intense policy action is in control such as subsidies and technical support is highly required to propagate the spread of sustainable agricultural practices.

4.3. Policy Implications

The results of the current research drive the urgency of having RCEP economies implement policies that would generate economic growth and an environmentally sustainable society at the same time. The positive correlation between the GDP and the emissions can be taken to demonstrate the importance of incorporating the environmental concerns into the economic policy making, particularly in the rapidly expanding industrial sectors. Use of green technologies, i.e., renewable energy, energy efficient production, and clean transportation is essential in the decoupling of economic growth and environmental degradation.

In the agricultural sector, the information indicates that agricultural development can be viewed not only as the source of emissions but also as a means of combating climate change. Sustainability, such as agroforestry, precision farming, and conservation tillage, are policies that can be used to decrease emissions without adversely affecting productivity. In addition, agricultural emissions can be significantly reduced through land-use policies that will prevent deforestation and promote reforestation.

The governments in the RCEP area also have to offer monetary rewards to farmers when they embrace low-carbon technologies. This may take the form of subsidies on renewable energy instalment in farms, tax cuts on sustainable farming methods and the research on more efficient farming methods. Also, carbon pricing schemes, including carbon taxes or emissions trading programs, would bring financial incentives to reduce emissions in all the industries, including the agricultural sector.

4.4. Future Research Directions

Despite the fact that this study provides useful results regarding the correlation between economic growth, agricultural development, and carbon emissions, there are a few directions that should be studied. Further studies may look into the non-linearity of the growth-emissions nexus, and acknowledge that the EKC perhaps is not consistent across the RCEP economies. The fact that some countries can attain high levels of economic growth but without similar levels of emission growth is possible especially when countries also invest in clean technologies as well as embracing power saving measures.

Further studies are needed to determine regional differences between the effects of agricultural development on emissions. Such comparison of the effectiveness of particular agricultural practices as organic farming, agroforestry, conventional industrial agriculture deserves a closer study in order to determine their comparative efficiency in mitigation of emissions. Moreover, it requires long-term research to assess the long-term effects of agricultural sustainability on emissions because some agricultural methods like agroforestry can take decades before they can have any significant impacts.

5. Conclusions

In general, the results suggest strong empirical data of long-term relationships between economic growth, agricultural development, and carbon emissions in the countries that are members of RCEP. Although economic growth is the main cause of the emissions, agricultural development presents a two-sided nature where on one side, it causes emissions through growth and intensification and, on the other side, there is a potential to mitigate the problems through sustained practices. Based on recognized data and methodological constraints, the findings can be perceived as interrelated and not causal. However, the research provides valuable policy-related findings and background of the future research that uses dynamic and disaggregated analytical models. These findings are consistent with recent evidence suggesting that integrating sustainable agricultural practices into broader economic development strategies is essential for achieving long-term emissions reduction in developing and emerging economies [24]. These findings further indicate that emission mitigation in the agricultural sector can be achieved without compromising food security, provided that productivity enhancing and climate smart farming practices are scaled up through targeted policy support [25].

Supplementary Materials

The supporting information can be downloaded athttps://journals.nasspublishing.com/files/RWAE-3054-Supplementary-Materials.xlsx.

Author Contributions

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Conflicts of Interest

The authors declare no conflict of interest.

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