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Environmental degradation effect on agricultural development: an aggregate and a sectoral evidence of carbon dioxide emissions from Ghana

Paul Adjei Kwakwa
University of Energy and Natural Resources, Sunyani, Ghana
Hamdiyah Alhassan
University for Development Studies, Tamale, Ghana, and
William Adzawla
International Fertilizer Development Center, Accra, Ghana

Abstract

Purpose – Quality environment is argued to be essential for ensuring food security. The effect of environmental degradation on agriculture has thus gained the attention of researchers. However, the analyses of aggregate and sectoral effect of carbon dioxide emissions on agricultural development are limited in the literature. Consequently, this study examines the effect of aggregate and sectoral carbon emissions on Ghana's agricultural development.

Design/methodology/approach – Time-series data from 1971 to 2017 are employed for the study. Regression analysis and a variance decomposition analysis are employed in the study.

Findings – The results show that the country's agricultural development is negatively affected by aggregate carbon emission while financial development, labour and capital increases agricultural development. Further, industrial development and emissions from transport sector, industrial sector and other sectors adversely affect Ghana's agriculture development. The contribution of carbon emission together with other explanatory variables to the changes in agricultural development generally increases over the period.

Originality/value – This study analyses the aggregate and sectoral carbon dioxide emission effect on Ghana's agricultural development.

Keywords Carbon dioxide emissions, Agricultural development, Sustainable development goals, Ghana, Regression analysis

Paper type Research paper

1. Introduction

Agriculture plays a critical role in achieving the Sustainable Development Goals (SDGs). The reason is that an enhanced agricultural sector has the potential to promote food security, boost income generation and employment creation, which improves the economic growth and development (Diao *et al.*, 2007; Dorosh and Thurlow, 2018; Kogo *et al.*, 2021; Ayinde *et al.*, 2021). Agriculture employs over half of Africa's population and is the largest contributor to the total gross domestic product (GDP) (AGRA, 2018). This suggests that

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agricultural development can be a significant way out of poverty and economic development in Africa.

Over the years, several attempts have been made by governments and major developmental partners in Africa to enhance agricultural productivity. This includes the Maputo Declaration in 2003, which aims to encourage governments to contribute at least 10% of national budgetary expenditure to the agricultural sector to increase agricultural output to at least 6% and enhance food security (NEPAD, 2003). There is also the Malabo Declaration (2014) that seeks to promote accelerated agricultural growth and end hunger in Africa by 2025 (AGRA, 2018). Further, the African Development Bank (AfDB) has implemented various agricultural development programmes and projects such as the second Climate Change Action Plan of AfDB (2016–2020), the Jobs for the Youth in Africa Strategy (2016–2025) and the Strategy for Agricultural Transformation in Africa (2016–2025) (AGRA, 2018).

In Ghana, several policies and programmes have been adopted to propel agricultural development. They include the Agricultural Growth and Development Strategy, Food and Agriculture Sector Development Policy (FASDEP I and FASDEP II). In spite of these efforts and attempts, growth in agricultural productivity in Ghana remains low (Food and Agricultural Organization (FAO), 2015; Ghana Statistical Service (GSS), 2016; Abdul-Rahaman *et al.*, 2021; Sekyi *et al.*, 2021; Ali *et al.*, 2021). Among other factors, the slow growth in agricultural productivity is attributed to environmental degradation such as poor soil quality, nutrient depletion and climate change (Salvo *et al.*, 2013; Mendelsohn, 2008; Amari *et al.*, 2021; Das *et al.*, 2021). For instance, changes in climate affect crop and livestock production, hydrological balance, input supplies and other components of the agricultural system. It is also evident that climate change, mainly driven by carbon dioxide emission (Kwakwa, 2021; Kizito *et al.*, 2021), has increased pest infestation, reduced soil fertility and irrigation resources, and agricultural opportunities (Malhi *et al.*, 2021). The increasing extreme weather events like irregularities in rainfall affect food production and distribution (Salvo *et al.*, 2013).

Indeed, a sustained natural environment is critical for the economy because it provides resource inputs such as land and water for agricultural production. The environment also provides environmental goods and assimilate waste products from production and consumption and coverts them into harmless and useful by-products (Tietenberg and Lewis, 2012; Adetunji and Osarenoto, 2021). Recognising the effect of the environment on agricultural development, scholars have conducted studies to investigate the nexus between agriculture and the environment (Di Falco *et al.*, 2011; Amponsah *et al.*, 2015; Chandio *et al.*, 2020; Rehman *et al.*, 2020; Khan *et al.*, 2021). For instance, Di Falco *et al.* (2011) established a negative impact of climate change on agriculture. Employing an autoregressive distributed lag (ARDL) approach, Chandio *et al.* (2020) established that carbon emission has an adverse effect on the agricultural output in China. Rehman *et al.* (2020) also employed the ARDL bound test and revealed that carbon dioxide emission has a negative effect on maize production in Pakistan. In a related study, Khan *et al.* (2021) reported that urbanisation and increased carbon dioxide emission decrease agricultural products export in Pakistan. In Ghana, Amponsah *et al.* (2015) found higher carbon emissions reduce crop yields. Majeed and Mazhar (2019) in an empirical study of 155 countries found that carbon dioxide, nitrogen oxide, methane and total greenhouse gas emissions contribute to the global output volatility, with the volatility been more in agrarian economies. In an empirical study of 53 countries on the environmental degradation effect on food production, Ching *et al.* (2021) found that carbon emission negatively affects food production. Titilola and Jeje (2008) found that about 850,000 ha of land in Nigeria is negatively affected annually or rendered useless for agricultural purposes as a result of soil erosion and deforestation. Sundström *et al.* (2014) assessed among others the future threats of environmental degradation and climate change on food security for 2012–2050 period and found that food security is threatened by climate change and environment degradation, although with some varying degree based on climate zone, public stewardship and economic strength of countries.

The above shows that despite some studies on the relationship between environmental degradation and agricultural development, much is not known about the effect of sectoral carbon emissions on agricultural development. Clearly, a sectoral and localised analysis is important to understand the nuances and the underlying roles of carbon dioxide emissions of different economic sectors on agricultural development. To contribute to the literature, this paper (1) provides evidence of the long-run relationship between agricultural development and environmental degradation in Ghana, controlling for other variables and (2) brings insights on the effect of sectoral carbon emissions on agricultural development of Ghana.

2. Literature review

Climate change caused by the emissions of greenhouse gases, especially carbon dioxide, remains one of the greatest threats to the future of humanity and ecosystems in recent times. Data show that 2015–2020 were the six warmest years on record, with greenhouse gas concentrations reaching a new high in 2019 (WMO, 2021). Carbon emissions and concentration in the atmosphere are on the rise, and this is consequential to further ozone depletion and global warming. Despite its low contribution, Africa continues to be the most vulnerable to climate change, especially due to its high dependence on rain-fed agriculture and the high contribution of agriculture to employment and GDP in the region (Alhassan *et al.*, 2019). In 2020, for instance, there was an extensive flooding that has affected several lives and properties in Africa (WMO, 2021). Agriculture provides a dominant source of income to the rural households and a source of livelihood protection for the rural poor; yet, climate variability is a major source of risk to agriculture and food systems (Chandio *et al.*, 2020). Also, although the effects of climate change are multi-sectoral, the agricultural sector is often the most vulnerable to climate change (Kogo *et al.*, 2021; Zagaria *et al.*, 2021; Bessah *et al.*, 2021; Arora, 2019; Salvo *et al.*, 2013; Mendelsohn, 2008). Environmental degradation has, therefore, been a major threat to agricultural development, especially in developing countries whose capability to respond effectively is low (Khan *et al.*, 2021).

Climate change affects crop and livestock production, hydrological balance, input supplies and other components of the agricultural system. Pest infestation, soil fertility, irrigation resources and opportunities, plant physiology and metabolic activities are negatively affected by climate change (Malhi *et al.*, 2021). There is an associated increase in land degradation due to climate change that enhances desertification and results in nutrient deficient soils (Arora, 2019). Biophysical factors such as nutrient cycle, water cycle and biodiversity, and how these are managed under agricultural and land use activities are affected by climate change (Toor *et al.*, 2020). The increasing extreme weather events such as irregularities in rainfall are threats to food production and distribution. Various land areas have become unsuitable for agricultural activities due to the deterioration of the environment. Generally, the effect of climate change on agriculture is through increase in temperature, weather variability, evapotranspiration and uncertainty of precipitation (Pant, 2009). Because of the relevance of agriculture in the economic system of developing countries, disruption in the agriculture sector retards total economic progress and household's livelihoods (Ren *et al.*, 2016).

Often, a degraded environment tends to be irreversible, thereby leading to human death, loss of output and productivity (Aboagye *et al.*, 2020). This is at variance with environmental sustainability that requires a balance, resilience and interconnectedness to enable human society meet their present needs without exceeding the capacity of its supporting ecosystems to regenerate these services in the future (Morelli, 2011). Evidence on the relationship between climate change and agriculture generally shows a negative relationship. Therefore, environmental restoration is important to avert the challenges posed by a degraded environment and to improve biodiversity conservation, empower local people, improve human livelihood and the productivity of ecosystem. This entails among other things the restoration of fragmental agricultural landscape, which requires biological and cultural processes, including the perception of people on their environment (Robertson *et al.*, 2000). It also calls for the need to reduce the rate of carbon dioxide emission so as to meet the below 2 °C temperature by 2050. To attain this, researchers have been concerned with identifying the economic and non-economic forces behind carbon dioxide emission (Aboagye *et al.*, 2020; Gyamfi *et al.*, 2021; Kwakwa, 2021; Adom *et al.*, 2018).

Mitigation and adaptation strategies are essential for minimising the negative impacts of climate change on agriculture (Bozoglu *et al.*, 2019). Mainstreaming climate services is an unfailing option towards a resilient agricultural sector (Naab *et al.*, 2020), and an improved agriculture is key to achieving SDGs. Rural people, whose primary occupation is agriculture, constitute the largest proportion of the poor in developing economies. The goal for decent work and economic growth requires that agriculture is made to meet the needs of the vast majority of people in the sector and to maximise the role of the sector as an engine of growth and a pro-poor economic growth strategy. Achieving gender equality requires that the productivity difference between men and women in agriculture is reduced. Most directly, providing food for the increasing global population means that agriculture must be made more effective to meet the rising food demands. Overall, farm development and growth, particularly for the smallholder farmers who accounts for 90% of global farms, is central to achieving nine SDGs related to zero hunger, ending poverty, gender discrimination, inequality and environmental degradation, tackling climate change and promoting and ensuring healthy lives (Abraham and Pingali, 2020). These suggest the ultimate need to ensure a robust and efficient agricultural sector. Research and development in the area of environmental degradation, especially carbon dioxide emission and agriculture, are therefore a necessary requirement to providing relevant policy options towards agriculture development. It is for this reason that although researchers (Di Falco *et al.*, 2011; Amponsah *et al.*, 2015; Chandio *et al.*, 2020; Rehman *et al.*, 2020; Khan *et al.*, 2021; Ching *et al.*, 2021; Titilola and Jeje, 2008) have examined the effect of various environmental degradation on agricultural output, the little focus on the effect of sectoral carbon emissions on agricultural development makes it crucial for further studies. It is this gap that the current study seeks to bridge.

3. Methods

3.1 Theoretical and empirical model

The endogenous growth theory (Mankiw *et al.*, 1992) posits that aggregate production (Y) is a function of real capital stock (KAP), physical labour (LAB) and technological progress (A). Thus:

$$Y = (A, KAP, LAB) \tag{1}$$

Assuming a Cobb–Douglas production function, equation (1) can be rewritten as:

$$Y_t = A\,KAP_t^{\beta} LAB_t^{\alpha} \tag{2}$$

where, t represents time, β and α are the elasticities of capital and labour, respectively. Since this study aims at examining the drivers of agricultural development, the variable aggregate production is measured by agricultural development (AD). Basically, both labour (LAB) and capital (KAP) are considered as critical inputs for boosting agricultural production. Investment in human capital, through education and health, increases productivity and efficiency of workers, which boosts agricultural production. Similarly, investment in productive capital promotes agricultural development. Technological progress measured by total factor productivity of output is determined endogenously by production factors such as financial development (FD), industrialisation (IND) and urbanisation (UB). Financial development promotes agricultural development since well-functioning financial intermediaries are efficient in channelling credit from savers to borrowers (i.e. farmers). As established by Alhassan *et al.* (2020), access to credit by farmers boost their liquidity status, which promotes investment in farm enterprises via adoption of improved technology, which in turn, propels agricultural development. The effect of industrialisation on agricultural development is mixed. Industrialisation of the economy may enhance agricultural production if industries source their raw materials locally from farmers. This enhances the farmers' income, boosts their liquidity status and propels investment in farm enterprises, which promote agricultural development. Further, adoption of eco-friendly technology by agro-processing industries has the potential to boost agricultural production through the reduction in carbon emission. By contrast, non-green industries reduce agricultural development via higher carbon emission (Wagan *et al.*, 2018). Rapid urbanisation associated with excessive clearing of vegetation for infrastructure development, and adoption of inefficient consumer durables may have adverse effects on agricultural development via the emission of carbon dioxide (Malik and Ali, 2015).

To have a comprehensive outlook on how carbon dioxide emission influences agricultural production, apart from using the aggregated carbon dioxide emission (CO_2), carbon dioxide emission was also disaggregated into four sub-sectors: residential sector ($RESCO_2$), industrial ($INDCO_2$), transportation ($TRACO_2$) and other ($OTHCO_2$) sectors. Carbon dioxide emission may be a major threat to agricultural development, as it has been identified as one of the main forces behind climate change and global warming (Salvo *et al.*, 2013; Mendelsohn, 2008). Changes in climate adversely affect crop and livestock production, hydrological balance, input supplies and other components of the agricultural system (Malhi *et al.*, 2021) through erratic rainfalls and rising temperatures.

Adding the control variables expected to influence agricultural development via technological change and log linearising equation (2) gives equation (3):

$$\mathrm{LAD}_t = \rho + \beta \ln\mathrm{KAP}_t + \alpha \ln\mathrm{LAB}_t + \Omega \ln\mathrm{FD}_t + \eta \ln\mathrm{IND}_t + \lambda \ln\mathrm{UB}_t + \delta_i \ln\mathrm{CO}_{2t} + \mathrm{e} \quad (3)$$

Empirically, five models were estimated. One model for aggregate carbon dioxide emissions and estimations for carbon dioxide emissions from each of the four disaggregated sub-sectors: residential sector, industrial sector, transportation sector and other sectors. The empirical models for the five estimations are expressed as equations (4a), (4b), (4c), (4d) and (4e) as follows:

$$\mathrm{LAD}_t = \rho + \beta \ln\mathrm{KAP}_t + \alpha \ln\mathrm{LAB}_t + \Omega \ln\mathrm{FD}_t + \eta \ln\mathrm{IND}_t + \lambda \ln\mathrm{UB}_t + \delta_1 \ln\mathrm{CO}_{2t} + \mathrm{e}_1 \quad (4a)$$

$$\mathrm{LAD}_t = \rho + \beta \ln\mathrm{KAP}_t + \alpha \ln\mathrm{LAB}_t + \Omega \ln\mathrm{FD}_t + \eta \ln\mathrm{IND}_t + \lambda \ln\mathrm{UB}_t + \delta_2 \ln\mathrm{RESCO}_{2t} + \mathrm{e}_2 \quad (4b)$$

$$\mathrm{LAD}_t = \rho + \beta \ln\mathrm{KAP}_t + \alpha \ln\mathrm{LAB}_t + \Omega \ln\mathrm{FD}_t + \eta \ln\mathrm{IND}_t + \lambda \ln\mathrm{UB}_t + \delta_3 \ln\mathrm{INDCO}_{2t} + \mathrm{e}_3 \quad (4c)$$

$$\mathrm{LAD}_t = \rho + \beta \ln\mathrm{KAP}_t + \alpha \ln\mathrm{LAB}_t + \Omega \ln\mathrm{FD}_t + \eta \ln\mathrm{IND}_t + \lambda \ln\mathrm{UB}_t + \delta_4 \ln\mathrm{TRACO}_{2t} + \mathrm{e}_4 \quad (4d)$$

$$\mathrm{LAD}_t = \rho + \beta \ln\mathrm{KAP}_t + \alpha \ln\mathrm{LAB}_t + \Omega \ln\mathrm{FD}_t + \eta \ln\mathrm{IND}_t + \lambda \ln\mathrm{UB}_t + \delta_5 \ln\mathrm{OTHCO}_{2t} + \mathrm{e}_5 \quad (4e)$$

where δ_1, δ_2, δ_3, δ_4 and δ_5 are the elasticities for aggregate carbon dioxide emission, carbon dioxide emission from residential, industrial, transportation and other sectors, respectively.

3.2 Data and estimation technique

Generally, time-series data are non-stationary at level, and this may produce spurious regression when the ordinary least squares (OLS) estimation technique is employed. To avoid this problem, the stationarity properties of the selected variables were tested using the Zivot and Andrews unit root test (Zivot and Andrews, 1992). Unlike the Dickey and Fuller (ADF) test (Dickey and Fuller, 1979), which produces wrong inferences in the presence of structural breaks, the Zivot and Andrews unit root test accommodates structural break present in the level time-series data. To test for cointegration, the bound testing approach proposed by Pesaran *et al.* (2001) within the ARDL framework was used. Then, the ARDL approach (Pesaran *et al.*, 2001) was employed to evaluate the long-run linear relationship between the variables. This model was adopted because it produces robust results and account for series with different order of integration I(0), I(1) or I(0)/I(1). Further, it corrects for issues of autocorrelation and overcomes the potential problem of endogeneity among the selected variables (Odhiambo, 2011). The linear estimation method is employed for this study since our initial graphical analysis of the dependent and independent variables gives a linear trend.

After the estimation of the long-run relationship among the variables, diagnostic tests were conducted to establish the goodness of fit of the model using the Jarque–Bera, Ramsey RESET, ARCH and Breusch–Godfrey tests to examine the presence of normality, stability, heteroscedasticity and autocorrelation in the models, respectively. Finally, variance decomposition analysis was employed to assess the proportion of variation of agricultural development explained by each independent variables over time (Vuolteenaho, 2002).

The data used in this study are annual data covering the period from 1971 to 2017. The data were obtained from the World Bank (2021). Agricultural development was measured by agriculture, forestry and fishing; value-added and industrialisation were captured as industrial and construction value added. This follows Aboagye *et al.* (2020). As used by Kwakwa *et al.* (2021), capital was measured by gross capital formation, and labour was measured by total population. Following Adom *et al.* (2018), urbanisation was measured by total urban population, and financial development was measured as domestic credit to private sector (%GDP). Like Maji *et al.* (2017), aggregate carbon dioxide emission (kt) and the sectoral carbon emissions: residential, industrial, transportation and other sectors were all measured as carbon dioxide emissions.

4. Empirical results and discussion

In this section, the results from the data analysis are presented and discussed.

4.1 Summary statistics

Table 1 provides a descriptive statistic of the variables considered in this study. The average absolute contribution of agriculture to Ghana's GDP is US$4.1bn, with a maximum of US$12.8bn over the 47 years. This represents the total value additions from the agriculture, forestry and fisheries sub-sectors. The average carbon emission within the 47 years period is about 6,123 kt with, a maximum of over 16,000. The average population of the country for the considered time period is over 17 million. Although the population is only about 16.5 million in 1971, this increased to over 29 million by 2017. The average urban population for the 47 years is about 7.5 million, although this is as high as 16.1 million in 2017. Also, the gross capital formation within the period averaged about US$3m.

4.2 Unit root and cointegration results

The results for the Zivot Andrew unit root tests with structural breaks at levels and first difference are presented in Table 2. This confirmed that at levels, none of the variables is at stationary. This led us to test for stationarity at the first difference for these nonstationary time-series variables, and the results show that at first difference, the variables are stationary at the 1% level of significance. Once stationarity of the variables has been established, the cointegration test was conducted to ascertain the existence of long-run relationship among the variables. It is also realised from Table 2 that the null hypothesis is rejected, meaning that labour, capital, financial development, industrialisation and carbon emissions are the long-run drivers of agricultural development in Ghana.

Table 1.
Descriptive statistics of variables

	AD	CO_2	LAB	UB	FD	IND	KAP
Mean	4.11E+09	6123.3	17,345,665	7,492,600	8.440772	3.64E+09	2.98E+09
Median	2.57E+09	4422.4	16,561,674	6,523,643	6.005079	1.34E+09	1.21E+09
Maximum	1.28E+10	16670.2	29,121,471	16,135,333	15.82746	2.18E+10	1.65E+10
Minimum	9.85E+08	2295.5	8,973,244	2,617,854	1.542268	2.52E+08	1.50E+08

Table 2.
Zivot and Andrews unit root and ARDL cointegration test results

	Unit root test			
Series	Levels	Break year	At first difference	Break year
$lnAD$	−3.6654	2006	−7.7497***	2002
$lnCO_2$	−4.8438	1985	−7.2594***	1999
$lnRESCO_2$	−4.9203	1998	−9.3044***	2003
$lnINDCO_2$	−4.4962	1982	−9.6640**	1988
$lnTRACO_2$	−4.2358	1998	−7.9447***	1994
$lnOTHCO_2$	−5.4820**	2002		
lnLAB	−2.3879	2011	−4.6788**	2008
lnUB	−4.3225	2011	−7.3261***	1986
lnFD	−3.8777	1996	−7.6151***	1984
lnIND	−4.8695	1991	−5.7387***	1983
lnKAP	−3.1859	2011	−7.8523***	1984

	Cointegration test			
Model	*F*-stat	Significance	I(0) bound	I(1) bound
Aggregate CO_2	4.836***	10%	2.12	3.23
		5%	2.45	3.61
		1%	3.15	4.43
Residential CO_2	4.9136***	10%	2.12	3.23
		5%	2.45	3.61
		1%	3.15	4.43
Industrial CO_2	3.0843**	10%	2.12	3.23
		5%	2.45	3.61
		1%	3.15	4.43
Transport CO_2	10.3312***	10%	2.12	3.23
		5%	2.45	3.61
		1%	3.15	4.43
Other sectors CO_2	9.4398***	10%	2.12	3.23
		5%	2.45	3.61
		1%	3.15	4.43

Note(s): Null hypothesis is that there is no cointegration among the variables; *** denotes 1% level of significance

4.3 Results of effects of aggregate carbon emissions on agricultural development

The results in Table 3 (Model 1) show that in the long-run capital, labour and financial development positively affect agricultural development, while industrialisation urbanisation and aggregate carbon dioxide emission have negative effects. The fact that capital has a positive effect on agricultural development is in line with the economic theory. Thus, as more capital is pushed into the agricultural sector, it increases investment activities and hence an expansion of the sector (Huang and Ma, 2010). The importance of labour in the growth process in an economy cannot be over-emphasised. It features strongly in the traditional economic growth model. The significant effect of labour on agricultural development of Ghana suggests that engaging more human hands in the sector will promote the development of the agricultural sector of the country. This is welcoming since youths are gradually moving into agricultural-related activities in the country.

The significant negative coefficient of aggregate carbon dioxide in Table 3 suggests that carbon dioxide emission poses a threat to Ghana's agricultural sector in the long run. That is, an increase in carbon dioxide emissions in Ghana leads to a reduction in the long-term development of the country's agricultural sector. Over the years, Ghana's agricultural sector has relied on nature for rains especially. However, the increasing global warming and climate change impacts have led to unreliable rainfall patterns, extremely high temperature and flooding in many parts of the country, which negatively affects farming activities. Since one of the main forces behind climate change and global warming menace is carbon dioxide emission, it is obvious that the local carbon emission also retards the development of the country's agricultural sector. In their analysis, Edoja *et al.* (2016) found a negative effect of carbon dioxide emissions on the agricultural productivity in Nigeria. Chandio *et al.* (2020) and Khan *et al.* (2021) have also empirically established that carbon emission has an adverse effect on agricultural output in China and Pakistan, respectively. Ching *et al.* (2021) found that carbon emission negatively affects food production of 53 countries. Farmers in some previous micro studies in Ghana expressed that the climate has changed over the past 40 years, resulting in delays in rainfall, early rains, sudden stop of rains and too much sunshine among others (Arku, 2013). This has affected farmers' productivity negatively, resulting in poor crop production, increased pest and disease and poor livestock production (Alhassan *et al.*, 2019). The empirical evidence at the macro level as revealed in this study gives credence to the findings at the micro level.

The effect of industrialisation on Ghana's agricultural development is negative in the long run. This may not be good news, especially when industrialisation has been aggressively pursued by authorities since independence. This result provides an information to suggest that the development of industrial sector in the country has not taken the agricultural sector into consideration, hence the negative relationship between the two. Moreover, urbanisation reduces agricultural development in Ghana which is in line with Malik and Ali (2015) while as argued by Alhassan *et al.* (2020), financial development is found to increase Ghana's agricultural development.

4.4 Results of sectoral carbon emission effect on agricultural development

The results of the effect of sectoral carbon emissions on agricultural development are shown in Table 3 (Models 2–5). It reveals that in the long run, with the exception of residential sector emission, which does not have significant effect on agricultural development, carbon dioxide emission from the remaining sectors significantly reduces agriculture development. The outcome suggests that carbon emissions from the residential sector seems not to be harmful to the agriculture sector of the country. Carbon dioxide emission from the industrial sector reduces agricultural development. A 1% increase in the emission rate from the sector dampens agricultural development by 0.35%. A 1% increase in the carbon emission from the

Table 3. Long-run effects of aggregate and sectoral carbon emission on agriculture

Variable	Model 1	Model 2	Model 3	Model 4	Model 5
lnLAB	86.861*** (19.021)	19.279 (15.025)	28.810*** (5.851)	44.907*** (8.969)	38.252*** (8.476)
lnKAP	0.543*** (0.145)	0.804*** (0.111)	0.695*** (0.076)	0.650*** (0.099)	0.784*** (0.108)
lnFD	0.870** (0.277)	1.057* (0.589)	0.581*** (0.111)	1.423** (0.459)	0.915** (0.364)
lnUB	−53.192*** (11.470)	−12.777 (9.780)	−18.372*** (3.692)	−28.949*** (5.957)	−25.153*** (5.565)
lnIND	−6.763*** (1.506)	−5.810*** (1.250)	−3.880*** (0.678)	−4.181*** (0.885)	−2.094*** (0.677)
lnCO_2	−2.008* (0.947)				
lnCO_2 from the residential sector		0.231 (0.133)			
lnCO_2 from the industrial sector			−0.355* (0.176)		
lnCO_2 from the transportation sector				−0.652* (0.319)	
lnCO_2 from other sectors					−0.528*** (0.179)
Constant	−561.606*** (124.424)	−110.588 (99.409)	−178.937*** (39.300)	−279.737** (58.104)	−234.418*** (55.453)

Note(s): ***, **, * denote 1, 5 and 10% level of significance, respectively; standard errors in parenthesis transport sector is associated with a 0.65% reduction in the agricultural output. Agricultural development is reduced by 0.52% following a 1% increase in carbon emission from other sectors. When compared, the emission from transport sector seems to have the greatest effect followed by emission from “other: sector, and finally, the industrial sector. This is an indication that paying attention to the sectoral emission is crucial in the fight against carbon emission as well as the mitigating practices to avert the effect of environmental damage due to carbon emission on agricultural development.

Similar to the results reported in Model 1, labour is found to positively affect agricultural development in the country. Also, capital and financial development exert positive effects on Ghana’s agricultural sector, while growth in urbanisation and industrialisation reduces agricultural development, and this is consistent with the results in Model 1.

4.5 Diagnostic tests for regression results

The diagnostic test results to ascertain the adequacy of the regression results for the models are reported in Table 4. The regression results for the agricultural development model do not suffer from the problems of non-normality, non-stability, heteroscedasticity and autocorrelation. The basis is that the null hypotheses of the presence of non-normality, non-stability, heteroscedasticity and autocorrelation in the models are rejected by the Jarque–Bera, Ramsey RESET, ARCH and Breusch–Godfrey tests, respectively. The implication is that the estimated results for the models are robust and are reliable to guide policy making.

4.6 Variance decomposition analysis

Table 5 shows the results of variance decomposition analysis that ascertained the contributions of the drivers to agricultural development over ten periods. Labour had the

Diagnostic test	Model 1	Model 2	Model 3	Model 4	Model 5
Serial correlation, Breusch–Godfrey (*F*-stat)	1.9480 (0.1930)	3.6193 (0.0836)	2.9727 (0.1126)	1.9709 (0.1939)	2.9784 (0.1614)
Normality, Jarque–Bera (prob.)	0.1078 (0.9475)	1.0020 (0.6059)	0.4316 (0.8058)	1.0555 (0.5899)	1.4314 (0.4888)
Heteroscedasticity, ARCH (*F*-stat)	2.6672 (0.1129)	0.8658 (0.6195)	1.0891 (0.4402)	1.6521 (0.1890)	0.2289 (0.9972)
Stability, Ramsey RESET (*F*-stat)	2.2287 (0.1636)	0.9281 (0.3732)	1.3634 (0.2000)	1.6756 (0.2467)	1.8271 (0.1272)

Table 4. Diagnostic test for ARDL results

Period	S.E.	lnAD	lnLAB	lnKAP	$lnCO_2$	lnIND	lnUB	lnFD
1	0.170041	100.0000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2	0.224056	91.47090	0.447744	0.380769	0.713113	0.694575	5.566352	0.726548
3	0.262697	77.29058	4.170594	1.899462	0.600926	1.091936	12.08724	2.859261
4	0.297397	65.89011	9.262314	4.347357	1.022509	1.256603	13.79691	4.424196
5	0.325081	58.96523	13.23989	6.516565	1.615525	1.104642	13.32723	5.230919
6	0.350304	53.35443	17.31070	8.117783	1.611164	1.274608	12.28759	6.043720
7	0.378008	47.63239	21.99738	9.030183	1.517033	2.372652	10.76576	6.684601
8	0.404312	42.80674	26.45621	9.404075	1.637279	3.457067	9.410817	6.827813
9	0.426092	39.03635	30.14619	9.432693	1.835773	4.275122	8.588765	6.685106
10	0.445628	35.77942	33.34242	9.220046	1.890461	5.197917	8.085947	6.483790

Table 5. Variance decomposition analysis for agricultural development

greatest effect on agricultural development than the other factors. The effect increases from 2% in Period 2 to 18% in Period 10. The share of industrialisation also increases from 2% in the second period to 17.5% in the tenth period. Although the shares of capital and aggregate carbon dioxide emission are almost same, the latter increases from 0.6% in Period 2 to 4.07% in Period 10, while that of former fluctuates between 3 and 6% in Periods 2 and 4, and falls to 4.2% in the tenth period. Thus, the contribution of carbon emission together with the other explanatory variables to the changes in the agricultural development generally increases over the period.

5. Conclusions and recommendations

Agricultural development is an essential condition for the economic development of a developing country like Ghana. Unfortunately, this is affected by the changing climate. This study analysed the effect of aggregate and sectoral carbon dioxide emissions on agricultural development of Ghana. The results lead to the conclusion that an aggregated carbon emission leads to a significant decrease in the agricultural development in the long run. Generally, there are differences in the impacts based on the sectorial carbon emission. The greatest impact of carbon emission on agricultural development is from the transportation sector, followed by emissions from other sectors and the industrial sector.

Ghana has undergone a sectoral change from agricultural- to service-led economy. It is expected that this transformation would lead to efficiency in the agricultural sector. The introduction of agro-processing industries and linking farmers to the market by connecting road networks means that more carbon dioxide would be emitted by the industrial and transportation sectors in the long run. This ultimately explains the decline in agricultural development due to higher carbon emissions from these sectors. To avert these long-run impacts, more efficient technologies that would generate less carbon emissions amidst increased agro-processing and industrialisation of the economy must be pursued. Similarly, efficient transportation methods must be used in the country to ensure that less carbon is emitted from the transportation sector. While obsolete cars must be taken off the streets of the country, the road networks in the country must also be improved to ensure that less time is spent on the roads by the cars. Also, industries must be sited based on the availability of raw material to avoid excessive transportation of raw materials to such industries. This can be a strategy to lower the rate of urbanisation of the major cities and its associated negative effects on agricultural development. Energy-efficient means of production in the various sectors must be pursued. These are necessary to ensure that Ghana becomes a low-carbon emitting economy to ensure sustainable development of the country.

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Corresponding author
Paul Adjei Kwakwa can be contacted at: Pauladkwa@yahoo.com