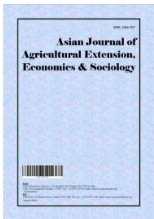

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Urbanization, Carbon Dioxide Emission, and Agricultural Productivity in Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

This study examines the effects of carbon dioxide emission and urbanisation on total agricultural production, livestock production and crop production in Nigeria. The data span from 1981 to 2014. In other to avoid endogeniety problem, the relationship among the variables was modelled using the Vector Error Correction Model (VECM). The result implies that carbon dioxide emission impacts total agricultural, total livestock and total crop production positively, but it was negative in the case of urbanization. More so, the effect of carbon dioxide emission and urbanization increase overtime.

Keywords: Carbon di-oxide; urbanization; agriculture; livestocks; vector error correction model; environmental pollution.

1. INTRODUCTION

Agriculture plays pivotal roles in economic activities across the World today. It is the main source of food supply for the sustenance of the human population. Aside from its role in poverty alleviation, it serves as an important source of sustainable employment for a larger percentage

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of the population, especially in developing countries. In Africa, for instance, over 70 percent of the population depends on agriculture for livelihood. Despite this enormous importance of the agricultural sector in Africa, the sector is constantly being hit by daunting challenges which have led to declining production, poor farming population, and increased food and nutrition insecurity for many years.

Given the growing population of the world today, it is evident that a well-developed agricultural system is needed to ensure food security and sustenance of the present generation. As reported by Irz and Roe [1], increasing agricultural productivity, through technological advancement, leads to a reduction in food prices and subsequently an increase in households' real income. The implication of this is that households will have more to spend on food and still have the capability to save, thereby improving their livelihood and standard of living,

Also, the projected rise in food needs to feed the World by 2050 is a waking call for agricultural transformation with emphasis on increased and sustainable agricultural productivity. According to Alexandratos [2], World cereal consumption is projected to rise from 2407 metric tonnes in 2015 to 3012 metric tonnes for 2050. Thus, raising productivity in agriculture to meet the projected increase in demand has become an important question confronting policymakers. This is because of the daunting challenges, such as environmental pollution, urbanization, etc faced by agriculture in the 21st century, which has manifested in low productivities and increasing food prices, leading to an increasing number of hungry and malnourished people.

For ages, humans have been preoccupied with efforts to make life better for themselves. These efforts have resulted in various activities such as building and construction, mining, deforestation, etc which have adverse effects on land and the environment. With the increasing world population, cities are also expanding to accommodate human existence as a result of urbanization. The World urban population has been rising since the '90s. In 1970, the population increased from 750,903,000 in 1950 to 1,354,215,000. In the space of 30 years, the population doubled and stood at 2,868,308,000 in 2000, and 20 years after, it has increased further as it stood at 4 378 994 thousand. By 2050, it is expected to stand at 6,679,756,000 [3].

Expansion in urban centres is associated with a change in the magnitude of land use. More importantly, expansion in cities come with an increase in energy use, resulting in carbon dioxide emission. As the urban population increases, infrastructure facilities available become over-utilized [4]. There is a rise in the number of vehicle usages, a rise in quantum of cooking fuel usages, and this may dirty fuels, especially in developing countries, etc. The resultant effect is a rise in carbon dioxide emission.

Urbanization and carbon dioxide emission have attendant effects on various sectors of the economy, especially the agricultural sector. Urbanization could affect agricultural productivity in different ways. Expansion in urban population reduces available land for agricultural activities. Also, fertile lands that could have been used for agricultural purposes are diverted to industrial and residential uses. It may further discourage investment in agriculture due to Impermanence Syndrome [5] where farmers refuse to farm based on the assumption that their lands will eventually be taken from them for industrial purposes. Besides, it fuels migration from rural areas to urban centres, which has negative implications on the farming population. Similarly, carbon dioxide emission, which may result from urbanization also affects agricultural productivity. Although there is mixed evidence on the effect of carbon dioxide emission on agricultural productivity, carbon dioxide emission affects climate change, leading to natural disasters such as flooding, which affects agricultural productivity negatively [6].

As a result of the decline in agricultural productivity over the years, Nigeria has constantly struggled with meeting her domestic food demand. From an average of 60% in the 1960s to 20% in 1980s, the contribution of the agriculture sector to Nigerian GDP has been declining, and in 2017, it stood at 25%, on average [7].

Nigeria has about 79 million hectares of arable land, of which 32 million hectares are cultivated, and over 90% of agricultural production is rain-fed (Okolo and Obidigbo, 2015). This, however, has not translated to increased productivity in agriculture. This has brought many hardships on the populace. According to Shittu, Obayelu, and Salman (2015), domestic inflation in Nigeria is a result of high, volatile, and rising food prices in the country. They also argued that households suffer welfare losses resulting from a food price hike in the country. This has further increased the poverty level of many households.

According to Mohammed, Ibrahim, and Abubaka [8], increased food price has led to a significant increase in the proportions of households' income allocated to foodstuff in Nigeria. Okuneye [9] argued that food insecurity in Nigeria has led to increased poverty level in Nigeria. This has also increased the crime rate in the country. Oyefara [10] found out that hunger and food insecurity is responsible for the increasing female commercial sex workers in Lagos metropolis, Nigeria.

Various factors have been put forward for the declining state of the agricultural sector. Some of which include urbanization and environmental pollution, especially carbon dioxide emission [11]. Any efforts at increasing the productivity of the sector must, therefore, include those of solving the problems of urbanization and environmental pollution in the country. Although there have been several studies to examine the effects of urbanization and carbon dioxide emission on agricultural productivity, efforts to compare their effects on agriculture subsectors are rare. Hence, this study examines the effects of carbon dioxide emission and urbanisation on total agricultural productivity, livestock production and crop production in Nigeria.

1.1 Carbon Dioxide Emission

As the most prevalent Chemical compound in the atmosphere, Carbon dioxide consists of two oxygen atoms and one carbon. It is generally described by its formula, CO_2. As part of Greenhouse gasses, CO_2 is considered to be part of air pollutants [12]. However, there have been divergent views on whether CO_2 is a pollutant or not. The divergent opinions hinge on its source of generation and the inherent benefits or negative effects. While authors such as Solomon, Plattner, Knutti, and Friedlingstein, [13]; Glaeser, and Khan, [14]; Baccini, Goetz, Walker, Laporte, Sun, Sulla-Menashe, and Samanta, [15] argue that CO_2 is a pollutant, others such as Fabricant [16]; Davison, [17]; Lupo, [18] argue against such view. The focus of this study is not to support any side of the argument, but to examine its relationship with agricultural productivity.

CO_2 can have beneficial effects as well as harmful ones on agricultural productivity. Agricultural products require different amount of temperature and rainfall. An increased amount of CO_2 increases the level of atmospheric temperature. While this could increase yields of some products, the reverse could be the case for some other products, necessitating the need for irrigation [19]. Similarly, it can lead to increased stress in livestock, leading to immune system breakdown, thereby making them more vulnerable to disease [20,21]. However, as noted by Mendelsohn, and Seo [22]. Increased CO_2 emission can also have positive effects on livestock through a shift from low heat-tolerant animals to high hear-tolerant ones. These foregoing implies that the effect on livestock is not sufficiently documented in literature and needs to be investigated [23].

1.2 Trend in Urbanization across the World

As shown in Fig. 1, Europe had the highest urban population in 1950, while Asia was in the second position, and North America was in the third position. Africa had a very low urban population at 32 659 thousand. However, the rise in European population has been moderate while those of Asia and Africa experienced a spike. Between 1970 and 2020, Africa added 505,101 thousand to its urban population, Europe added 141, 668 thousand, while it was 134,179 in North America. It is also projected that Africa will have the second-highest urban population after Asia by 2050.

1.3 Proportion of Nigerian Urban Population in Africa Urban Population

Table 1 shows that the urban population in Nigeria constituted 10.8% of the total urbanization in Africa in 1950. Comparatively, this accounted for 53.8% of West African urban population and 92% of that of East Africa. Although the proportion of Nigerian urban population in Africa has continued to increase, reaching 18% in 2020, this has not been in other regions of the continent. The proportion of Nigerian urban population relative to East Africa was 92% in 1950 but by 2020, it was 80%, and it is expected to fall to 68% in 2050. This shows that the urban population in East Africa is also increasing rapidly.

The proportion of Nigerian urban population to North Africa urban population was 27% in 1950 but by 2020, it was 82%, and it is expected to fall to 124% in 2050. This shows that the urban population in North Africa is also decreasing rapidly. This is also similar to that of South Africa. However, that of West Africa has remained relatively stable over time.

1.4 Trend in Urban Population in Nigeria

Fig. 1 shows an upward trend in the movement of urban population between 1980 and 2017. Between 1980 and 1985, the rate at which urban population rose was low. However, between 1986 and 2000, there was an increase in the rate at which urban population was rising. There was a further increase rise in the rate of 2000 and 2017.

1.5 Carbon Dioxide Emission

Fig. 2 shows that the CO_2 emission in the country has continued to fluctuate over time, falling from 1980 through 2000. From 2001, it began to rise through 2004 and slightly decreased. It started rising again after 2010. Comparing the emission trend with that of urbanization, there seems to be no relationship between the two. However, when the rate of change in the trend of urbanization is considered, the period of rising emission corresponds to the period of the rise in the rate of urbanization. This shows that a rise in urban population may have time lags before it starts generating carbon dioxide emission.

1.6 Contribution of Nigerian Agriculture Sector to GDP

Fig. 3 shows a downward trend in the contribution of agriculture sector contribution to GDP from 2002 to 2017. From 37% in 2002, the contribution of agriculture sector fell to 23% in 2010. The fall continued as it stood at 21% in 2017. Comparing this with trends in urbanization, it can be concluded that as urban population increases, agriculture sector's contribution to GDP falls.

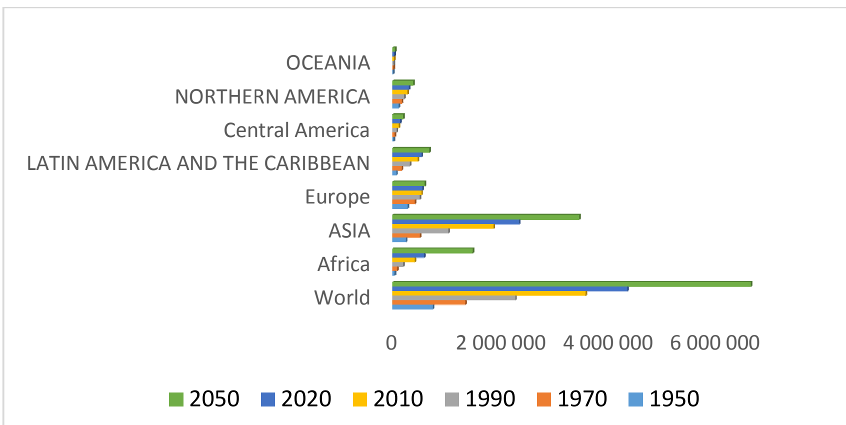

Image 1. Trend in urbanization across the world
Source: United Nations [3]

Table 1. Proportion of Nigerian urban population in Africa urban population

Year	AFR	WEST	East	Middle	North	Southern Africa
1950	10.83927	53.84314	92.26801	96.17939	27.83741	60.50875
1960	13.12195	55.79887	106.7764	121.947	34.7461	83.74618
1970	12.03124	50.21467	84.59623	110.2946	32.2898	88.14095
1980	12.54846	49.65749	75.14153	107.177	36.27003	107.0257
1990	14.1302	51.88376	78.87196	116.4837	43.78845	135.212
2000	14.90482	52.39973	77.57424	111.638	51.13834	151.398
2010	16.87519	54.45282	81.59402	116.1792	66.88997	196.8132
2020	18.22454	55.8338	80.82722	118.2006	82.98908	245.175
2030	18.96811	56.23329	77.15495	116.8793	99.01887	301.1011
2050	19.28447	55.57707	68.6559	111.6138	124.5231	433.5254

Source: United Nations [3]

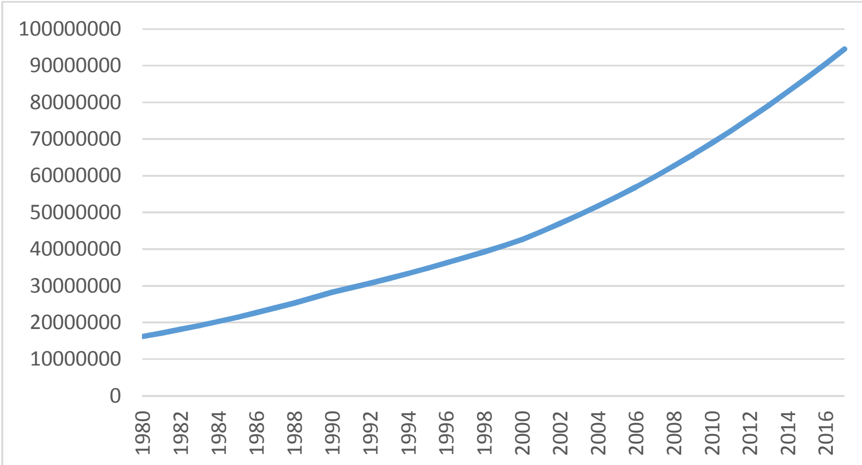

Fig. 1. Trend in urban population in Nigeria
Source: World Bank [24]

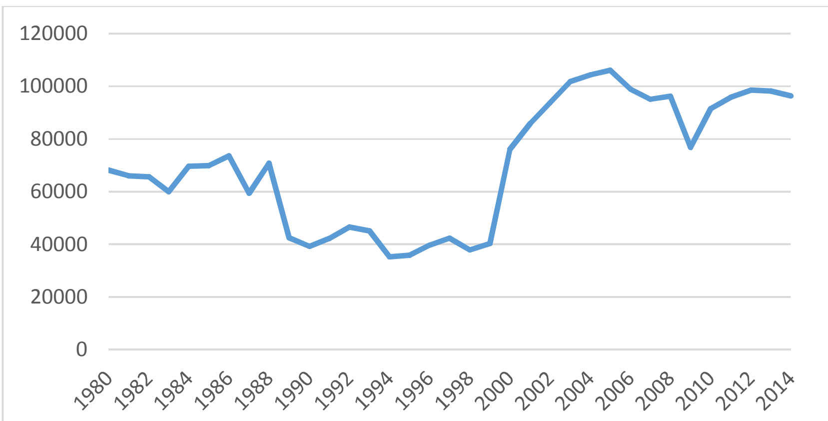

Fig. 2. Trend in Nigeria's CO_2 emission
Source: World Bank [24]

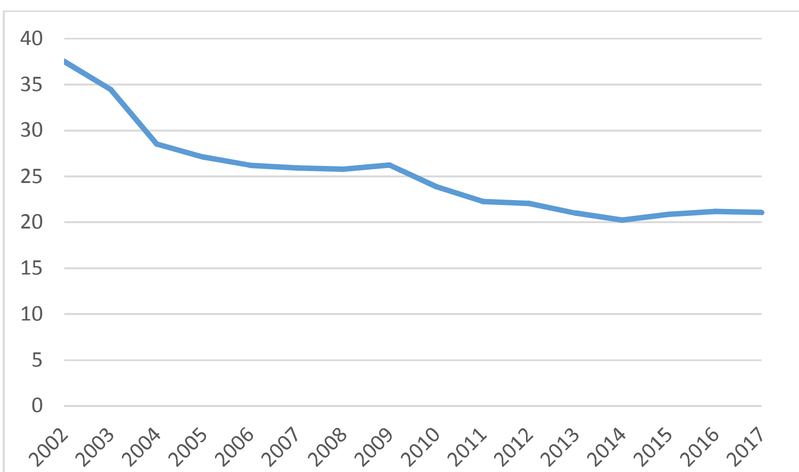

Fig. 3. Contribution of Nigerian agriculture sector to GDP
Source: World Bank [24]

1.7 A Review of Past Works

There have been several efforts in literature to examine the relationship between urbanization, carbon-dioxide emission and agricultural productivity. Iheke and Ihuoma [4] analysed the effect of urbanization on agricultural productivity in Abia State, Nigeria. The results indicate that urbanization significantly affected the respondents' agricultural productivity. Conversely, using Bayesian model averaging in Instrumental variable, Oueslati, Salanié, and Wu [25] found a positive relationship between urbanization and agricultural productivity.

Assessing the relationship between CO_2 emission and agricultural productivity in Ghana from 1961 to 2012, Asumadu-Sarkodie and Owusu [26] compared the results from VECM with that of ARDL model. Evidence found showed a causality between Co_2 emission and agriculture productivity in the two models. In a similar study and the same country, Asumadu-Sarkodie, and Owusu, [27] examined the causal relationship between CO_2 emission and the ecosystem. The results established a bi-directional causality between CO_2 and cereal production, while also establishing the sensitivity of Ghanaian agricultural ecosystem to CO_2 emission. In the same country as well, Owusu and Asumadu-Sarkodie [28] used ARDL to study data from 1960 to 2015 and found bi-directional causality between millet production and CO_2 emission, rice production and CO_2 emission, sorghum production and CO_2 emission, while a unidirectional causality was found between corn production and CO_2 emission.

According to Rehman, Ozturk, and Zhang [29] used ARDL method to establish a causal relationship between CO_2 emission and agricultural productivity in Pakistan between 1987 and 2017. The result confirmed the existence of causality between the two variables.

According to Leitão [30] incorporated energy consumption into a model to establish the relationship between emissions of CO_2 and agricultural productivity in Portugal between 1960 and 2015. Using VECM, the result indicated a causality from agricultural productivity to CO_2 emission.

Other studies including Mohiuddin, Asumadu-Sarkodie, and Obaidullah [31] found bidirectional causality between agriculture productivity and CO_2 emissions in Tunisia. Similarly, Sarkodie and Owusu [32] found bidirectional causality in the case of crop production and emissions of CO_2 and a unidirectional causality in the case of livestock production and emissions of CO_2 in Ghana. These findings corroborate that of Oyinbo, Adegboye, and Sulaiman, [33] which reported a bidirectional causality between CO_2 emissions and crop production in Nigeria.

2. MATERIALS AND METHODS

In other to estimate the relationship between urbanization, CO_2 emission, and agricultural productivity, this study hypothesized a positive relationship between economic growth and urbanization, which in turn leads to increased use of energy. An increase in energy use leads to more carbon dioxide emission, and this invariable affects agricultural productivity. This postulate indicates a possible problem of endogeneity which may question the validity of the results. To avoid this problem, a Vector Error Correction Model (VECM) was specified. Given the objectives of the study which is to examine the relationship between urbanization, carbon dioxide emission, and total agricultural production, total livestock production, and total crop production, three different models were specified.

2.1 Model One: Urbanization, Carbon Dioxide Emission, and Total Agricultural Production

$$\Delta TOGRC_t = c_1 + \sum_{i=1}^{p} \pi_{11}^{i}\, \Delta TOGRC_{t-i} + \sum_{k=1}^{p} \pi_{12}^{k}\, \Delta URBANOP_{t-k} + \sum_{m=1}^{p} \pi_{13}^{m}\, \Delta ENERUS_{t-m} + \sum_{n=1}^{p} \pi_{14}^{n}\, \Delta POLTON_{t-n} + \sum_{w=1}^{p} \pi_{15}^{w}\, \Delta GROSDP_{t-w} + +\emptyset_1 ECM_{1t-1} + \varepsilon_{1t} \quad (1)$$

$$\Delta URBANOP_t = c_2 + \sum_{i=1}^{p} \pi_{21}^{i}\, \Delta URBANOP_{t-i} + \sum_{k=1}^{p} \pi_{22}^{k}\, \Delta TOGRC_{t-k} + \sum_{m=1}^{p} \pi_{23}^{m}\, \Delta ENERUS_{t-m} + \sum_{n=1}^{p} \pi_{24}^{n}\, \Delta POLTON_{t-n} + \sum_{w=1}^{p} \pi_{25}^{w}\, \Delta GROSDP_{t-w} + +\emptyset_2 ECM_{2t-1} + \varepsilon_{2t} \quad (2)$$

$$\Delta ENERUS_t = c_3 + \sum_{i=1}^{p} \pi_{31}^{i}\, \Delta ENERUS_{t-i} + \sum_{k=1}^{p} \pi_{32}^{k}\, \Delta TOGRC_{t-k} + \sum_{m=1}^{p} \pi_{33}^{m}\, \Delta URBANOP_{t-m} + \sum_{n=1}^{p} \pi_{34}^{n}\, \Delta POLTON_{t-n} + \sum_{w=1}^{p} \pi_{35}^{w}\, \Delta GROSDP_{t-w} + +\emptyset_3 ECM_{3t-1} + \varepsilon_{3t} \quad (3)$$

$$\Delta POLTON_t = c_4 + \sum_{i=1}^{p} \pi_{41}^{i}\, \Delta POLTON_{t-i} + \sum_{k=1}^{p} \pi_{42}^{k}\, \Delta TOGRC_{t-k} + \sum_{m=1}^{p} \pi_{43}^{m}\, \Delta URBANOP_{t-m} + \sum_{n=1}^{p} \pi_{44}^{n}\, \Delta ENERUS_{t-n} + \sum_{w=1}^{p} \pi_{45}^{w}\, \Delta GROSDP_{t-w} + +\emptyset_4 ECM_{4t-1} + \varepsilon_{4t} \quad (4)$$

$$\Delta GROSDP_t = c_5 + \sum_{i=1}^{p} \pi_{51}^{i}\, \Delta GROSDP_{t-i} + \sum_{k=1}^{p} \pi_{52}^{k}\, \Delta TOGRC_{t-k} + \sum_{m=1}^{p} \pi_{53}^{m}\, \Delta URBANOP_{t-m} + \sum_{n=1}^{p} \pi_{54}^{n}\, \Delta ENERUS_{t-n} + \sum_{w=1}^{p} \pi_{55}^{w}\, \Delta POLTON_{t-w} + +\emptyset_5 ECM_{5t-1} + \varepsilon_{5t} \quad (5)$$

2.2 Model Two: Urbanization, Carbon Dioxide Emission, and Crop Production

$$\Delta TOCROP_t = a_1 + \sum_{i=1}^{q} v_{11}^{i}\, \Delta TOCROP_{t-i} + \sum_{k=1}^{q} v_{12}^{k}\, \Delta URBANOP_{t-k} + \sum_{m=1}^{q} v_{13}^{m}\, \Delta ENERUS_{t-m} + \sum_{n=1}^{q} v_{14}^{n}\, \Delta POLTON_{t-n} + \sum_{w=1}^{q} v_{15}^{w}\, \Delta GROSDP_{t-w} + +\ni_1\, ECT_{1t-1} + e_{1t} \quad (6)$$

$$\Delta URBANOP_t = a_2 + \sum_{i=1}^{q} v_{21}^{i}\, \Delta URBANOP_{t-i} + \sum_{k=1}^{q} v_{22}^{k}\, \Delta TOCROP_{t-k} + \sum_{m=1}^{q} v_{23}^{m}\, \Delta ENERUS_{t-m} + \sum_{n=1}^{q} v_{24}^{n}\, \Delta POLTON_{t-n} + \sum_{w=1}^{q} v_{25}^{w}\, \Delta GROSDP_{t-w} + +\ni_2\, ECT_{2t-1} + e_{2t} \quad (7)$$

$$\Delta ENERUS_t = a_3 + \sum_{i=1}^{q} v_{31}^{i}\, \Delta ENERUS_{t-i} + \sum_{k=1}^{q} v_{32}^{k}\, \Delta TOCROP_{t-k} + \sum_{m=1}^{q} v_{33}^{m}\, \Delta URBANOP_{t-m} + \sum_{n=1}^{q} v_{34}^{n}\, \Delta POLTON_{t-n} + \sum_{w=1}^{q} v_{35}^{w}\, \Delta GROSDP_{t-w} + +\ni_3\, ECT_{3t-1} + e_{3t} \quad (8)$$

$$\Delta POLTON_t = a_4 + \sum_{i=1}^{q} v_{41}^{i}\, \Delta POLTON_{t-i} + \sum_{k=1}^{q} v_{42}^{k}\, \Delta TOCROP_{t-k} + \sum_{m=1}^{q} v_{43}^{m}\, \Delta URBANOP_{t-m} + \sum_{n=1}^{q} v_{44}^{n}\, \Delta ENERUS_{t-n} + \sum_{w=1}^{q} v_{45}^{w}\, \Delta GROSDP_{t-w} + +\ni_4\, ECT_{4t-1} + e_{4t} \quad (9)$$

$$\Delta GROSDP_t = a_5 + \sum_{i=1}^{q} v_{51}^{i}\, \Delta GROSDP_{t-i} + \sum_{k=1}^{q} v_{52}^{k}\, \Delta TOCROP_{t-k} + \sum_{m=1}^{q} v_{53}^{m}\, \Delta URBANOP_{t-m} + \sum_{n=1}^{q} v_{54}^{n}\, \Delta ENERUS_{t-n} + \sum_{w=1}^{q} v_{55}^{w}\, \Delta POLTON_{t-w} + +\ni_5\, ECT_{5t-1} + e_{5t} \quad (10)$$

2.3 Model Three: Urbanization, Carbon Dioxide Emission, and Total Livestock Production

$$\Delta TOLIVE_t = b_1 + \sum_{i=1}^{u} f_{11}^{i}\, \Delta TOLIVE_{t-i} + \sum_{k=1}^{u} f_{12}^{k}\, \Delta URBANOP_{t-k} + \sum_{m=1}^{u} f_{13}^{m}\, \Delta ENERUS_{t-m} + \sum_{n=1}^{u} f_{14}^{n}\, \Delta POLTON_{t-n} + \sum_{w=1}^{u} f_{15}^{w}\, \Delta GROSDP_{t-w} + +\exists_1 ECO_{1t-1} + \tau_{1t} \quad (11)$$

$$\Delta URBANOP_t = b_2 + \sum_{i=1}^{u} f_{21}^{i}\, \Delta URBANOP_{t-i} + \sum_{k=1}^{u} f_{22}^{k}\, \Delta TOLIVE_{t-k} + \sum_{m=1}^{u} f_{23}^{m}\, \Delta ENERUS_{t-m} + \sum_{n=1}^{u} f_{24}^{n}\, \Delta POLTON_{t-n} + \sum_{w=1}^{u} f_{25}^{w}\, \Delta GROSDP_{t-w} + +\exists_2 ECO_{2t-1} + \tau_{2t} \quad (12)$$

$$\Delta ENERUS_t = b_3 + \sum_{i=1}^{u} f_{31}^{i}\, \Delta ENERUS_{t-i} + \sum_{k=1}^{u} f_{32}^{k}\, \Delta TOLIVE_{t-k} + \sum_{m=1}^{u} f_{33}^{m}\, \Delta URBANOP_{t-m} + \sum_{n=1}^{u} v_{34}^{n}\, \Delta POLTON_{t-n} + \sum_{w=1}^{u} v_{35}^{w}\, \Delta GROSDP_{t-w} + +\exists_3 ECO_{3t-1} + \tau_{3t} \quad (13)$$

$$\Delta POLTON_t = b_4 + \sum_{i=1}^{u} f_{41}^{i}\, \Delta POLTON_{t-i} + \sum_{k=1}^{u} f_{42}^{k}\, \Delta TOLIVE_{t-k} + \sum_{m=1}^{u} f_{43}^{m}\, \Delta URBANOP_{t-m} + \sum_{n=1}^{u} f_{44}^{n}\, \Delta ENERUS_{t-n} + \sum_{w=1}^{u} f_{45}^{w}\, \Delta GROSDP_{t-w} + +\exists_4 ECO_{4t-1} + \tau_{4t} \quad (14)$$

$$\Delta GROSDP_t = b_5 + \sum_{i=1}^{u} f_{51}^{i}\, \Delta GROSDP_{t-i} + \sum_{k=1}^{u} f_{52}^{k}\, \Delta TOLIVE_{t-k} + \sum_{m=1}^{u} f_{53}^{m}\, \Delta URBANOP_{t-m} + \sum_{n=1}^{u} f_{54}^{n}\, \Delta ENERUS_{t-n} + \sum_{w=1}^{u} f_{55}^{w}\, \Delta POLTON_{t-w} + +\exists_5 ECO_{5t-1} + \tau_{5t} \quad (15)$$

Where TOGRC is Total Agricultural Output which includes outputs of crop production subsector, livestock subsector, forestry subsector, and fishery subsector, TOCCROP is the output of crop production subsector, TOLIVE is the output of livestock subsector, URBANOP is urbanization, which was proxied by total urban population, POLTON is carbon dioxide emission, ENERUS is energy use, while GROSDP is Gross Domestic Product. All the variables were logged.

2.4 Data Type and Data Sources

The data on total agricultural output, total crop production, total livestock production, and gross domestic products were sourced from Central Bank Statistical Bulleting [7], while data on urbanization, carbon dioxide emission, energy use were sourced from World Bank [24]. The data span from 1981 to 2014.

2.5 Method of Analysis

The analysis started with ascertaining the presence of unit root in the variables. Testing for unit root is the norm in any time-series analysis to avoid running a spurious regression. The test is also important as it is indicative of the procedure for the analysis to follow. This was done using Augmented Dickey Fuller. Having established that the variables were I(1), it was tested for co-integration to ascertain the possibility of combining the variables in the long run. This was done using the Johansen Co-integrating procedure. The order of lag to be included was first determined using Schwartz Criterion. The presence of co-integration necessitated the use of VECM. The response of the Total Agricultural Output, total crop production, total livestock production to shock from urbanization, carbon dioxide emission, energy use and GDP were analysed using the Impulse Response Function, while Variance Decomposition was used to decompose the relative strength of the other variables in the model on each endogenous variable.

3. RESULTS

3.1 Testing for the Unit Root

The ADF test was carried out based on the assumption that the series contain unit root. To refute the null hypothesis depends on the significance of the p-value of the ADF statistics. If the ADF is significant as judged by the probability values, the null hypothesis is refuted, but it is upheld if it is otherwise. Table 2 shows that the p-value for the ADF when the test was conducted without differencing the exceeded 5% for each variable, indicating insignificance. Upon differencing them, the p-value was less than 5% for each variable. This, therefore, implies that the null hypothesis cannot be refuted before differencing the variables, but it is refuted after the differencing. This, therefore, led to the conclusion that the variables are I(1).

3.2 Selecting Appropriate Lag for the Models

The result of the previous section indicates that all the variables are I(1), necessitating the need to test for the relationship between the variables in each model in the long run. Doing this requires selecting an appropriate lag number to be included in the analysis. Based on Schwarz criterion, Table 3 shows that the appropriate lag for the first and second models is 1 and 2 for the third model.

3.3 Testing for Co-integration

Table 4 ascertains that relationship exists between the variables, GDP, energy use, carbon dioxide emission, urban population, used as urbanization, and total agricultural productivities, total crop production, and total livestock production in long run in the three models respectively. In the first one, both Trace and Eigen tests indicate the same number of co-integrating equations, the same number of co-integrating equations is found in the second model, while the third model indicates divergent number of equations. This, therefore, informed the estimation of VECM.

3.4 Results of the Short Run Causality

Table 5 shows that the causality between urban population and total agricultural productivity is in one direction from urban population to agriculture productivity, implying that urbanization causes

Table 2. Testing for the unit root

Variables	Variables before differencing		Variables after differencing	
	T-Statistics	Probability	T-Statistics	Probability
GROSDP	-0.079521	0.9437	-3.195238**	0.0296
POLTON	-1.135316	0.6898	-5.556751***	0.0001
URBANOP	-0.117820	0.9390	-6.847940***	0.0000
TOGR*C*	-1.472778	0.5346	-3.750789***	0.0079
TOCROP	-1.443479	0.5491	-3.988256***	0.0043
TOLIVE	-0.663363	0.8420	-3.350612**	0.0216
ENERUS	-1.148757	0.6843	-5.221778***	0.0002

**** indicates significance at 1%, ** indicates significance at 5%*

Table 3. Appropriate lag for the models using schwarz criterion

Lag	Model 1	Model 2	Model 3
0	-3.915746	-3.494993	-5.016818
1	-16.93351*	-16.66062*	-18.15682
2	-16.43818	-16.14990	-18.32928*

** indicates significance at 10%*

Table 4. Result of co-integrated relationship

Model 1		Model 2		Model 3	
Trace statistic	Max-Eigen statistic	Trace statistic	Max-Eigen statistic	Trace statistic	Max-Eigen statistic
79.30879***	44.47435***	81.07321***	44.92674***	123.4466***	47.56039***
34.83445	15.69432	36.14647	15.67329	75.88622***	26.98705
19.14013	11.96853	20.47318	12.73607	48.89917***	25.02117
7.171594	6.297700	7.737105	6.228785	23.87800**	18.52158
0.873894	0.873894	1.508320	1.508320	5.356419	5.356419

**** indicates significance at 1%, ** indicates significance at 5%*

Table 5. Causality test result

Direction of causality	Model 1	Model 2	Model 2
URBANOP → TOGR*C*	6.131968(0.0133)		
URBANOP → TOLIVE			15.56043(0.0004)
URBANOP → TOCROP		5.556039(0.0184)	
POLTON → TOGR*C*	4.003928(0.0454)		
POLTON → TOLIVE			10.58182(0.0050)
POLTON → TOCROP		3.757761(0.0526)	
ENERUS → TOGR*C*	1.543239(0.2141)		
ENERUS → TOLIVE			15.89186(0.0004)
ENERUS → TOCROP		1.388357(0.2387)	
GROSDP → TOGR*C*	0.372074(0.5419)		
GROSDP → TOLIVE			7.718903(0.0211)
GROSDP → TOCROP		0.402900(0.5256)	
TOGR*C*→ URBANOP	0.007196(0.9324)		
TOGR*C*→ POLTON	0.242015(0.6228)		
TOCROP→ URBANOP		0.001244(0.9719)	
TO*CROP*→ POLTON		0.189336(0.6635	
TOLIVE→ URBANOP			0.975003(0.6142)
TOLIVE→ POLTON			0.974645(0.6143)
URBANOP →POLTON	0.470705(0.4927)	0.694272(0.4047)	0.029717(0.9853)
URBANOP → GROSDP	1.203539(0.2726)	1.010324(0.3148)	2.123054(0.3459)
URBANOP → ENERUS	0.191533(0.6616)	0.143953(0.7044)	3.953393(0.1385)
POLTON → URBANOP	10.82569(0.0010)	11.12146(0.0009)	34.85971(0.0000)
POLTON → GROSDP	1.181425(0.2771)	0.997578(0.3179)	2.403453(0.3007)
POLTON → ENERUS	0.197391(0.6568)	0.166246(0.6835)	1.525720(0.4663)
ENERUS→POLTON	0.588916(0.4428)	0.752934(0.3855)	2.332033(0.3116)
ENERUS→ URBANOP	7.104989(0.0077)	7.654813(0.0057)	7.698481(0.0213)
ENERUS→ GROSDP	0.001603(0.9681)	0.004518(0.9464)	5.073460(0.0791)
GROSDP →POLTON	0.068758(0.7932)	0.0539359(0.8164)	1.049360(0.5917)
GROSDP → URBANOP	0.013542(0.9074)	0.085753(0.7696)	1.621494(0.4445)
GROSDP → ENERUS	0.489517(0.4841)	0.341674(0.5589)	2.213975(0.3306)

P-Values in ()

total agricultural productivity, and not the other way round. Similarly, carbon-dioxide emission had one-directional causality to total agricultural productivity. Similarly, urban population was found to cause total crop production, implying that urbanization causes total crop production.

This was not the case in case of carbon-dioxide emission.

Urban population was also found to cause total livestock production, implying that urbanization causes total livestock production. Similarly, carbon-dioxide emission causes total livestock production. This implies that agriculture production or its subsector does not cause carbon dioxide emission. Other variables such as GDP and energy use also granger causes total livestock production while energy use and carbon-dioxide emission were also found to granger cause total agricultural productivity. Carbon-dioxide emission and energy use were found to granger-cause urbanization in the three models.

3.5 Impulse Response

The responses of total agriculture production, total livestock production, and total crop production to shock in urban population carbon-dioxide emission, GDP, and energy use for a period of ten years were analysed in this section.

3.5.1 Impulse response of total agricultural product

Fig. 4 shows that total agricultural product responded positively to its own shock throughout the ten years. However, the response of total agricultural product to shock in urban population was negative, showing that as urban population grows, total agricultural product decreases. The response of total agricultural product to shock in carbon dioxide (POLTON) was positive for the ten years. This shows carbon dioxide emission does exert a negative effect on total agricultural product. This can be explained by the low level of pollution in the carbon dioxide emission in the country. Total agricultural production responded negatively to shock in energy use but, responded positively to that of GDP.

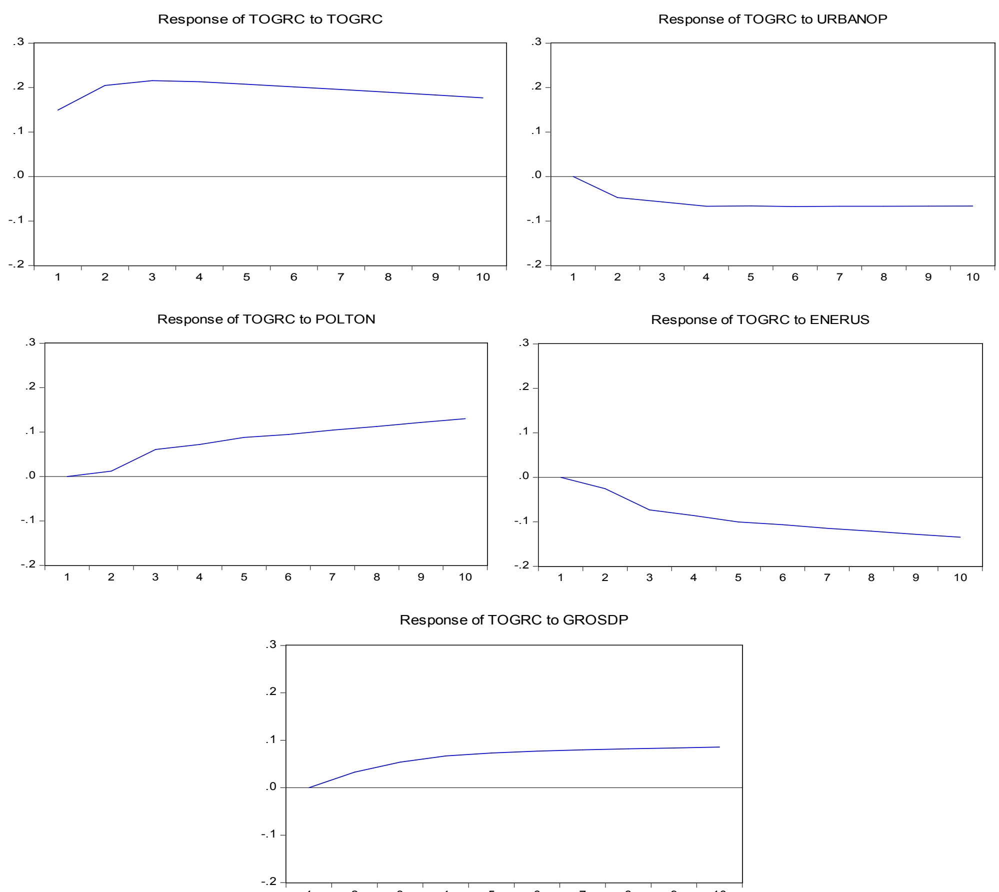

Fig. 4. Impulse response of total agricultural product

3.5.2 Impulse response of total crop production

Fig. 5 shows that total crop production responded positively to its own shock throughout the ten years. However, its response to shock in urban population was negative, showing that as urban population grows, total crop production decreases. The response of total crop production to carbon dioxide shock (POLTON) was positive for the ten years. It responded negatively to shock in energy use and positively to that of GDP.

3.5.3 Impulse response of total livestock production

Fig. 6 shows that total livestock production responded positively to its own shock throughout the ten years. Its response to shock in urban population was negative. It initially responded positively to carbon dioxide shock (POLTON) until the fifth year and became negative until the ninth year. Total livestock production responded negatively to shock in energy use, while it is positive for that of GDP.

3.6 Decomposing the Effects of Urban Population CARBON-Dioxide Emission, GDP, and Energy Use on Total Agricultural Production, Total Crop Production, and Total Livestock Production

The relative effects of urban population, carbon-dioxide emission, GDP, and energy use to understand their relative strength on the behaviour of Total Agricultural Production, Total Crop Production, and Total Livestock Production was analysed over a ten year period.

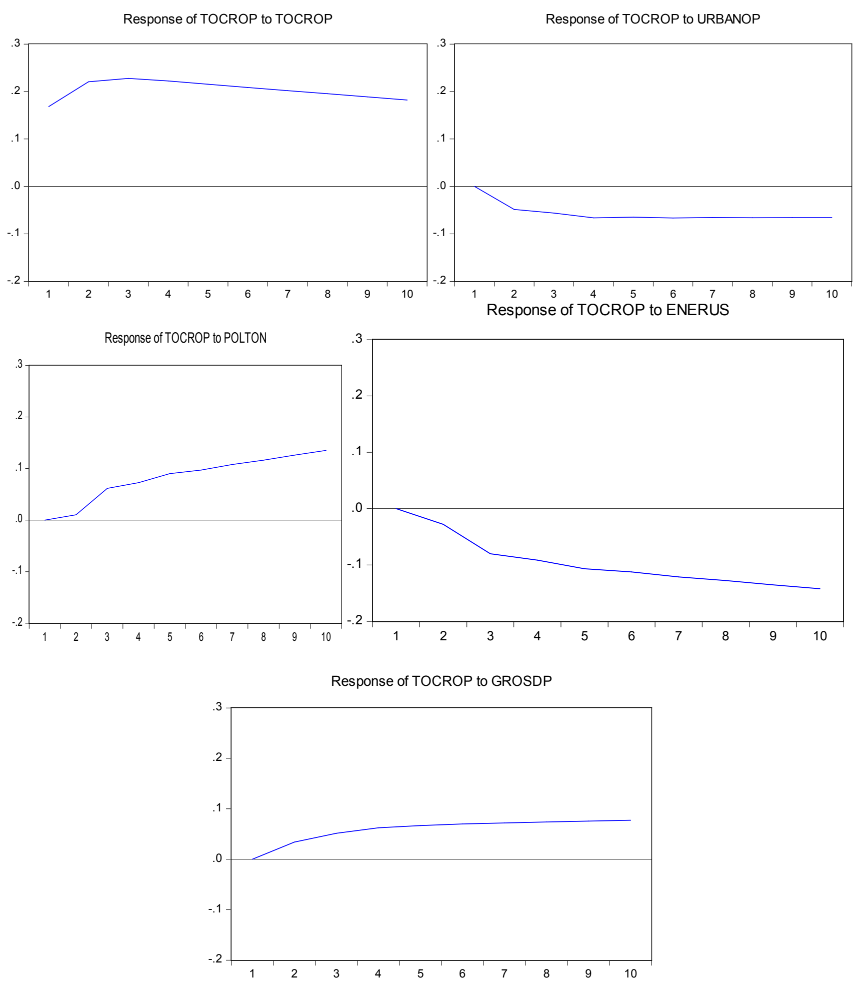

Fig. 5. Impulse response of total crop production

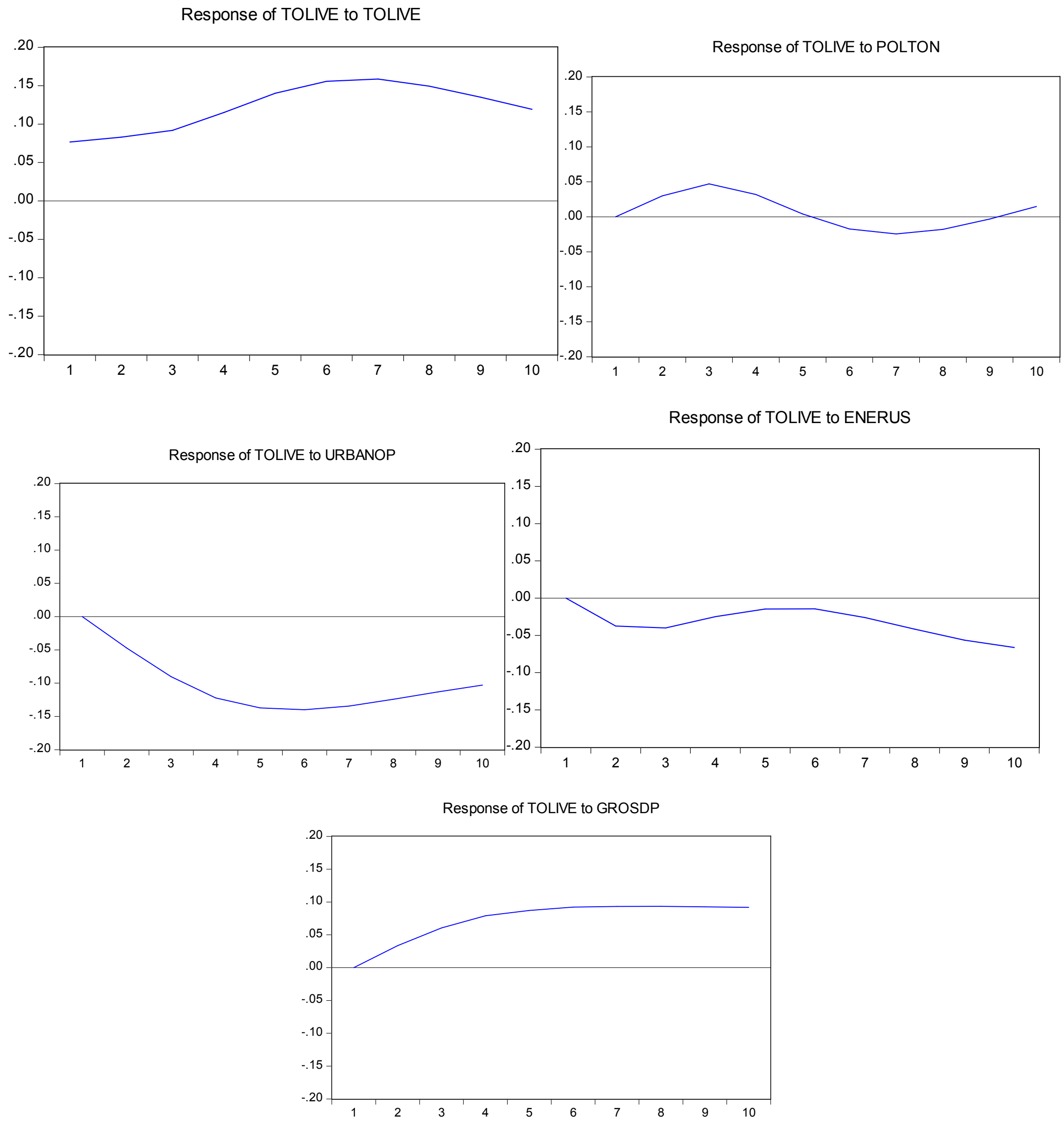

Fig. 6. Impulse response of total livestock production

3.6.1 Decomposing the effects of urban population carbon-dioxide emission, GDP, and energy use on total agricultural production

Table 6 shows that the largest effects on total agricultural production came from its own effect throughout the ten years. This effect, however, decreased with time showing that diminishing return sets in with time. This is followed by effects coming from energy use, carbon-dioxide emission, GDP, and urban population respectively. This implies that carbon-dioxide had a higher effect on total agricultural production than urban population. In the second period, carbon-dioxide emission had 0.21% influence on total agricultural production, while urban population had 3.2%. By the fifth year, carbon-dioxide emission had 6.2% influence on total agricultural production while urban population had 5.3%. By the tenth year, the influence of carbon dioxide emission had increased to 12%, while that of urbanization was still at 5.7%. This implies that both effects coming from carbon emission and urbanization increased over time but the rate of increase in carbon dioxide was higher than that of urbanization.

Table 6. Decomposition of total agricultural production

Period	S.E.	TOGRC	POLTON	URBANOP	ENERUS	GROSDP
1	0.149330	100.0000	0.000000	0.000000	0.000000	0.000000
2	0.261413	93.99578	0.212124	3.274978	0.950461	1.566656
3	0.360600	85.16501	2.953235	4.206208	4.618440	3.057112
4	0.443885	79.26693	4.593751	5.035242	6.809354	4.294720
5	0.517307	74.45542	6.265057	5.341279	8.774628	5.163615
6	0.582286	70.75433	7.587658	5.557635	10.26787	5.832510
7	0.642004	67.48348	8.892711	5.652328	11.63093	6.340546
8	0.697538	64.54251	10.13873	5.707080	12.86027	6.751404
9	0.750184	61.76623	11.39611	5.718928	14.03261	7.086123
10	0.800553	59.12361	12.65153	5.707358	15.15039	7.367120

3.6.2 Decomposing the effects of urban population carbon-dioxide emission, gdp, and energy use on total livestock production

Table 7 shows that the largest effects on total livestock production came from its own effect throughout the ten years. This is followed by effects coming from urban population, GDP, in first and second positions, while the effect of carbon-dioxide is insignificant. This implies that urban population had a higher effect on total livestock production than carbon-dioxide.

In the second period, carbon-dioxide emission had 4.8% influence on total livestock production, while urban population had 12%. By the fifth year, the effect coming from carbon-dioxide emission decreased to 3.3%, while urban population increased to 35%. The effect coming from carbon dioxide emission continued to decrease, reaching 1.5% by the tenth year. There was a marginal decrease also in that of urbanization but the rate was lower than that of carbon dioxide emission.

3.6.3 Decomposing the effects of urban population carbon-dioxide emission, gdp, and energy use on total crop production

Table 8 shows that the largest effects on total crop production came from its own effect throughout the ten years. This was followed by effects coming from energy use. The effect from urban population was higher than that of carbon-dioxide until the fifth year. After the fifth period, the effect coming from carbon-dioxide emission was higher than that of urban population. Both effects from urban population and carbon dioxide emissions increased over time.

In the second period, carbon-dioxide emission had 0.12% influence on total agricultural production, while urban population had 2.9%. By the fifth year, carbon-dioxide emission had 5.8% influence on total agricultural production, while urban population had 4.7%. By the tenth year, the influence of carbon dioxide emission increased to 12.5%, while that of urbanization was still at 5.2%. This implies that both effects coming from carbon emission and urbanization increased over time but the rate of increase in carbon dioxide was higher than that of urbanization.

4. DISCUSSION OF RESULTS

Findings from this study show that both carbon dioxide emission and urbanization cause total agricultural productivity, total crop production, and total livestock. Similarly, it was discovered that total agricultural productivity responded positively to carbon dioxide emission, and negatively to urbanization, total crop production responded positively to carbon dioxide emission, and negatively to urbanization, while total livestock responded negatively to carbon dioxide emission in the short run but became positive overtime, and the response was negative to urbanization. This shows that while urbanisation affects agriculture negatively, irrespective of the subsector concerned, carbon dioxide emission has a different effect on agriculture depending on the subsector involved.

Similarly, the relative strength of urbanization and carbon dioxide emission influence on agricultural subsectors differ from each other. In the case of livestock, urbanization has a greater effect than carbon dioxide emission. This shows that as urban population increases, cities expand, livestock farmers such as cattle rearers become discouraged because their lands are used for residential or industrial purposes. This, therefore, confirms the existence of Impermanence Syndrome. However, in the case

Table 7. Decomposition of total livestock production

Period	S.E.	TOLIVE	POLTON	URBANOP	ENERUS	GROSDP
1	0.076741	100.0000	0.000000	0.000000	0.000000	0.000000
2	0.135689	69.34046	4.898422	12.08311	7.586799	6.091211
3	0.206192	49.88888	7.334532	24.42758	7.069575	11.27943
4	0.280351	43.85361	5.261673	32.23108	4.610351	14.04328
5	0.353445	43.33000	3.324368	35.36258	3.072495	14.91055
6	0.421621	44.09644	2.505318	35.86093	2.276698	15.26061
7	0.480613	44.84083	2.188667	35.42176	2.043438	15.50531
8	0.528730	45.04446	1.922834	34.78174	2.309515	15.94144
9	0.567741	44.71859	1.670932	34.13259	2.987970	16.48991
10	0.600192	43.96577	1.555462	33.48268	3.894796	17.10129

Table 8. Decomposition of total crop production

Period	S.E.	TOCROP	POLTON	URBANOP	ENERUS	GROSDP
1	0.168344	100.0000	0.000000	0.000000	0.000000	0.000000
2	0.285304	94.59356	0.128658	2.911293	0.953970	1.412520
3	0.386342	86.32927	2.619064	3.701440	4.809728	2.540497
4	0.469653	80.81293	4.163103	4.495058	7.045889	3.483024
5	0.543218	76.11108	5.866051	4.785435	9.128475	4.108961
6	0.608187	72.46416	7.227993	5.014422	10.69266	4.600762
7	0.668195	69.16179	8.601326	5.120703	12.14538	4.970805
8	0.724107	66.17025	9.908513	5.194661	13.45057	5.276010
9	0.777351	63.31356	11.23356	5.224871	14.70286	5.525147
10	0.828445	60.58145	12.55313	5.233870	15.89491	5.736646

of crop production, it was carbon dioxide emission that had a higher effect compared to urbanization. On overall agricultural productivity, carbon dioxide emission has higher effects than urbanization urbanization does.

Similarly, the effects of carbon dioxide emission on total production and total crop production increased over time, while it decreased in the case of total livestock. In the case of urbanization, the effect increased over time in the case of total production and total crop production and livestock, but it increased at a higher rate in the case of livestock production than in the case of total production and total crop production.

5. SUMMARY AND CONCLUSION

This study was conducted to examine the relationship between carbon dioxide emission, urbanization, total agricultural productivity, total livestock production, and total crop production in Nigeria. The result confirms the existence of causal relation running from carbon dioxide emission and urbanization to total agricultural production and from carbon dioxide emission and urbanization to total livestock production, as well as from carbon dioxide emission and urbanization to crop production in the country. It also shows that urbanization has a negative effect on total agricultural production, livestock production, and crop production while the effects of carbon dioxide emission on total agricultural production and crop production were found to be positive but it was negative in the short run and positive in the long run in case of livestock production. It is therefore recommended that efforts should be made to reduce rural-urban migration by providing essential amenities in rural areas.

Also, regulations can be put in place to ensure that urban development does not erode available lands for agriculture purposes. Similarly, carbon dioxide emission has been reducing overtime in the country. With the positive effect of carbon emission on agricutuural production, it shows the low level of carbomn emission has been of grate benefit to the country. Hence, further efforts to reduce carbon emission will be of great benefits to the country.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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