International Journal of Economics, Commerce and Management
United Kingdom ISSN 2348 0386 Vol. 11, Issue 2, Feb 2023

https://ijecm.co.uk/

ENVIRONMENTAL DEGRADATION AND HEALTH OUTCOME IN SUB-SAHARA AFRICA; DOES AGRICULTURAL PRODUCTION MATTERS?

Menang Etiene Fomonyuy
Faculty of Economics and Management Sciences, The University of Bamenda, Cameroon
fomotah@gmail.com

Vukengkeng Andrew Wujung
Higher Institute of Commerce and Management, The University of Bamenda, Cameroon

Jumbo Urie Eleazar
Faculty of Economics and Management Sciences, The University of Bamenda, Cameroon

Abstract

Environmental degradation has been a vital aspect when considering the functioning of the ecosystem and it inhabitants. The purpose of this article was to examine the effect of environmental degradation on health outcome and if agricultural production matters in Sub-Sahara Africa over the period from 1996 to 2020. To achieve this, we assumed infant mortality variable as an indicator of health outcome, greenhouse gases as an indicator for environmental degradation and agricultural value added as an indicator for agricultural production. The data for study was collected from the World Bank Development Indicators database 2020. Concerning the estimation, the Seemingly Unrelated Regression (SUR) model was used. The results indicated that, without interaction, an increase in greenhouse gases has a positive and statistically significant influence on infant mortality and with interaction, agricultural production will affect environmental degradation negatively and this will further has a positive and statistically significant influence on infant mortality in Sub-Sahara Africa. It is therefore of vital importance that, information about environmental degradation should be made known to the public through sensitisation and an interactive and participatory approach to policy making concerning environment laws and its sustainability needs to be advocated.

Keywords: Agricultural production, Environmental degradation, Health outcome, Infant Mortality rate, Sub-Sahara Africa, SUR

INTRODUCTION

Environmental degradation and health outcome are complex and challenging issues the world is facing in recent decades; they have become global issues since the 1970s when the world became more conscious of the adverse consequences of human activities on the earth (Lewis *et al.,* 1995). Over the decades, environmental degradation was seen as the problem of industrialized countries and many of the less developed countries did not take it seriously (Chioma and Felix 2017, Myint, 2002). However, the threat to humans and animals from the massive progressive and the deterioration of the biosphere has emerged as a central issue in recent decades, as they faced high risk of extinction (Gaymoard *et al.,* 2015; Badulescu *et al.*, 2019). That is why, in 1988, the intergovernmental panel on climate change (IPCC) was created by the world meteorological organisation and the United Nations environmental program to help mitigate and clearly present current scientific knowledge about climate change, its impacts and policy response, (Lorraine, 2005).

As a results of environmental degradation, several international summits have been organised such as the United Nations Conference on Environment and Development at Stockholm in 1972, The Brundland report in 1987 and the United Nations Conference on Environment and Sustainable Development in Rio de Janeiro in June 1992 with the adoption of the Rio Agenda 21 often referred to as the World's Summit. During these summits, the issue of environmental degradation and health outcome were all agreed on. Other summits such as a summit on Sustainable Development in South Africa Johannesburg, the Copenhagen summit in 2009 and the Cop21 in Paris in 2015 made climate conditions a central point of discussion. Recently, in 2016, over 200 Heads of government meeting at Cop22 in Marrakech and in 2017 at Cop23 in Bonn agreed to implement the Paris climate change agreement in December 2018 which led to the Cop24 in Poland and environmental conference in Glasgow in 2022, (Alim and Demanou, 2020)

However, the issue is the pace at which this environmental degradation is taking place. The measurement by Mouna Loa in Hawai since 1959 indicates that, there is an average of over 1.5ppm (part per million) carbon dioxide concentration that is (0.4%) in the atmosphere each year, (Lorraine, 2005). Furthermore, the activities in Sub-Sahara Africa are centered on deforestation, agriculture, burning of fossil fuels (Coal, Oil and Gas), driving of vehicles and clement production, (IPCC, 2007). These activities usually increased the amount of greenhouse gases in the atmosphere such as Carbon dioxide (CO2), methane emission (CH4) and Nitrous oxide emission (N_2O), (Wang *et al.,* 2008; Snezena *et al.,* 2020). The consequences on health in sub-Sahara Africa can better be understood by incorporating social and economic factors such as health expenditure, urbanization and the economic level of the population. Also, weak

political institutions in the region and none respect of the environmental policies are among the major challenges that have constrained on the effective sustainability of the environmental laws, (Mutizwa and Makockhankanwa, 2015).

In 2013, the World Health Organisation noted that environmental degradation is the presence of agents that have the potentials of damaging its own environment (WHO, 2013) as the health of individuals and nations around the globe are being attacked by various epidemics cause by environmental degradation such as HIV/AIDs, Malaria, Ebola, Zikar and Covid-19 viruses. However, the healthcare systems in Sub-Sahara Africa usually faces serious challenges of resource scarcity as these Sub-Sahara countries do not have enough resources to respond to all health problems cause by environmental degradation, (Molem *et al.,* 2017). United Nation Development Program (2010) reported that, about 1.75 billion people in 104 countries lived in poverty, meaning that, at least 30% of the welfare indicators in health, education and material are being deprived of especially woman and children. That is why the United International Children's Emergency Fund (2013) has stressed on the importance of child protection and participation as part of sustainable future which is already guided by ranges of international conventions like Rio Convention of Basel, the Rotterdam and Stokholm were all adopted to ensure a healthy environment and to significantly protect children from chemical exposure and waste.

However, agricultural production has remain a challenging factor in Sub-Sahara Africa, as there is an increase in population, industrialization and agricultural land among others factors that causes much environmental degradation, (Pimental and Kounang, 1998; David *et al.,* 2005). It is estimated that, about 75 billion tons of fertile soil are lost from Agricultural activities each year and much of the soil erosion occurs on natural ecosystems. (Lal and Stewart, 1990) stated that, one-third of the 50% of the earth surface used for agriculture is used for planted crops and close to 80% of the agricultural land globally suffers from moderate to severe erosion and 10% suffers from slight erosion. Thus the quantity and quality of food available in the region depends so much on climate change. Such as increasing rainfall, floods, drought and sometimes extreme hot weather conditions influence agricultural production which is the livelihood of many in the region, (Amrita *et al*., 2017). Many farms in the region are often located in marginal land where soil quality is usually poor and the topography is steep, (UN-NADAF, 1996).

Based on the above trend about environmental degradation, the objective of this paper is to examine the effect of environmental degradation on health outcome in Sub-Sahara Africa and specially, to analyse the moderating effect of agricultural production on the relationship between environmental degradation and health outcome in Sub-Sahara Africa from 1996 to 2020.

This paper is organised into 5 sections; section 1 is the introduction which is made up of background and the objective, the literature review is presented in section 2. Section 3 is the presentation of methodology used in the study. Section 4 is the presentation of the results and discussion. The conclusion and recommendation of the study are presented in section 5.

LITERATURE REVIEW

This part of the study centers on the conceptual issues and the empirical literature review. The section begins by explaining the important key concepts and the conceptual framework that is relevant to this study. The empirical literature is also reviewed and it focuses on the previous works to provide explanations on the relationship between the various variables used in the study.

Conceptual issues

Environmental degradation refers to a process by which the natural environment is compromised by reducing biological diversity and the general health of the environment. Environmental degradation can be defined as the process by which the environment gradually gets rid of its original state, (Schubert *et al.,* 1995). Many researchers often refer to environmental degradation and climate change as nontrivial and contentious, (Todorov, 1986). Environmental degradation is a serious problem the world is facing and it covers a wide variety of issues such as pollution, biodiversity loss, animal extinction, deforestation and desertification, global warming and a lot more (Tian *et al,.* 2013). The deterioration of the environment through depletion of resources can include all biotic and abiotic elements that form our surrounding: That is the air, water, soil, plants, animals and all other living and non-living element of the earth (Gascon *et al.,* 2000). With environmental degradation, more gens have been created and others declined as the environment constantly changes caused by human activities.

More than 75% of the world population depends directly on the activities from the natural resources while the remaining 25% relies on the resources directly for food, fuel, industrial output among others, (Ravens *et al.,* 1998) Most of these natural resources around the world are in serious state of extinction. The use of chemicals such as fertilizers for agricultural production is a major contributor to soil quality, soil erosion, salinity and general loss of agricultural land as well as loss of agricultural production especially the quality of the crop (Acharya *et al,.* 2020 and Rodrigues *et al,.* 2020).

In many arid and semi-arid areas, underground waters aquifers are over exploited, the water on the surface of the earth are over polluted and as a result, drinking water and water for irrigation continues getting polluted and scarce. The quantity of Fishery yield keeps on declining

and also the quality of the air is deteriorating. This increase in pollution of air, water and land poses a serious threat to human health and her longevity on the planet earth (Malik *et al.,* 2018, Yadav and Bethard, 2019). It should be noted that, good environmental management is very important for economic growth and development. Climate change and environmental degradation affects all aspects of development. So if agencies are serious about poverty reduction, they must handle considerations to climate and environmental hazards which affect their projects (Acharya *et al,.* 2020). It was estimated that, slowing population growth reduces emission of carbon dioxide by16% to 29% by 2050 so as to avoid dangerous climate change, (Neill *et al.,* 2010). They also reported that slowing this population growth could save 1.4 to 2.5 billion tons of carbon emission per year by 2050 which will certainly help in solving climatic problem.

There are basically two main causes of environmental degradation that is human and natural activities. Human activities (modern urbanisation, industrialisation, over population growth, deforestation among others) and natural activities such as floods, typhoons, droughts, rising temperatures among other factors act as a major cause to environmental degradation (Wieland *et al.,* 2020). The different human activities are the main reasons for these environmental degradation. The increased in automobiles and industries that produce poisonous gases like SO_x, NO_x, CO and smoke into the atmosphere. Unplanned urbanisation and industrialisation have caused water, air, soil and noise pollution on the earth. Industrialization, urbanization and sewage of waste from urbanisation helps to increase pollution in many sources of water (Olorode *et al.,* 2015). That notwithstanding, the smoke emitted by vehicles and industries around the world like chlorofluorocarbon, nitrogen oxide, carbon monoxides and some other dust particles pollute the air. Man has continuously played an important role in the evolution of the natural environment.

Empirical literature

So many researchers have been interested in the ecosystem and its environment especially on the effects of environmental degradation on the health outcomes of the individuals. Hence, the relationship between environmental degradation and health outcomes have been confirmed by many studies but the role played by agricultural production is still lacking in determining the strength of the relationship. Thus, the role agricultural production plays can be direct (moderating) or indirect (mediating). However, this study will concentrate more on literature that creates a direct link between environmental degradation and health outcomes. It is in this latter context that, the analysis of the moderating effect of agricultural

production on the relationship between environmental degradation and health outcome in Sub-Sahara Africa is examined.

Furthermore, the literature in this study can be divided into two groups; the first group analysis the link between environmental degradation and health outcomes as is observed in the works of (Novignon & Lawanson, 2017; Majeed *et al.,* 2020; Fourati, 2021) among others that all failed to account for the moderating role of agricultural production on the link between environmental degradation and health outcome. The second part is more on the analytical part of agricultural production on the relationship between environmental degradation and health outcomes. This is attested by the works of (Oluwantoyin *et al.,* 2018; Emma and Gardon, 2015; Mathew *et al.,* 2020 and Rakesh *et al.,* 2013).

In examining the relationship between environmental degradation and health outcomes, some works have pointed to the fact that, greenhouse gases can generate a negative effect on the health outcomes. This can better be seen in the theory of Environmental Kuznet curve model (1952). In his model, Kuznet believed that, environmental degradation tends to worsen as the economy grows until it reaches a certain level of development before it starts reducing. (Grossman and Krueger, 1995) popularized the environmental Kuznet model and came out with some main explanation that causes negative impact on health status as the global pollution level is expected to worsen over a long period but (Lieb, 2003), pointed out that, a fall in environmental degrading factors can be replaced with new technological advancement.

With this light, Speldewinde *et al.,* 2009 made studies on the nexus between environmental degradation and health outcomes in rural Western Australia and arrived at the conclusion that, there is a negative association between environmental degradation and mental health related issues. In a similar study, Zhou *et al.,* 2020 noted a similar finding to that of M Afrafat *et al.,* 2022. They all found out that, environmental degradation is negatively related to health status. It can also be argue that, the adoption of sustainable lifestyle and healthy practice of lifestyle through environmental literacy can improve on the health outcomes. Majeed *et al.,* (2020) also found a negative relationship between environmental degradation and health outcomes.

Similarly, Woodruff *et al.,* (1997) observed that, environmental degradation prevent infants from living a long life. The study revealed that, post neonatal infant mortality was high in united State due to air pollution from the emission of greenhouse gases in the atmosphere. Lu *et al.,* 2017 supported the argument that environmental degradation has a negative effect on health using the Simultaneous equation model (SEM) that is made up of three separate equations. The study argues that, environmental pollution negatively affect health and that

economics and social factors also affect health like the real GDP that has a negative significant effect on mortality rate, while education also contribute significantly in promoting health status.

Furthermore, Bogdanovica *et al.,* (2020) carried out a research on the effect of $C0_2$ concentration on children's well-being during the process of learning in Latvia. Data of the study was gotten from more than 200 thousands pupils in Latvia. The studies revealed that, the concentration of CO_2 increases temperature and humidity and causes environmental quality to be low causing fatigue and difficulties in school performance. The study recommended that, $C0_2$ concentration should be extended throughout the school year so that, classrooms in the schools should be made ventilated.

Foden *et al.,* (2009) in trying to understand the relationship between environmental factors and health asked the question "How serious is the problem of poor access to safe water and sanitary facilities"? The study on access to safe drinking water and health had been further popularized as they wish to find out whether or not, access to safe sources of water is important in improving health level of household. According to (Kremer & Holla, 2009; Clasen *et al.,* 2006), the question that most of these researchers asked was, "it is important to have access to safe water sources or to treat water at household use level? With much of the debate being that, recontamination mostly occurred during transportation and storage putting in question on the whole purpose of a safe water source. The answer is access to water source affect health outcomes.

Matthew, (2020) carried out a study on Carbon emission, agricultural output and life expectancy in West Africa from 2000 to 2018 using the two stage least Square econometrics technique. It was revealed that, an increase in carbon emission will bring about reduction in agricultural production. In line with Alissa & Ferns (2017) that carried out a study on dietary fruits and vegetables and cardiovascular disease risk, they pointed on the importance of protective nutrients on individual health in line with Smith *et al.,* 2015.

Some other studies have established a linked between health expenditure and infant mortality. Novignon & Lawanson (2017) in a panel data from 45 countries in Sub-Sahara Africa from 1995 to 2011 investigated the relationship between health expenditure and health outcomes and the study used fixed and random effects models in estimating the model. This was in line with Sanglimsuwan (2011) made an attempt to establish the link that could be existing between health and environment.

To conclude, from the literature review on the relationship between environmental degradation and health outcomes, it can be deduced that, in many of the cases, environmental degradation has a negative impact on the health status of human especially those of infants in Sub-Sahara Africa. However, the existing empirical literature has provided limited evidence on

how agricultural production affects the relationship between environmental degradation and health outcome. This study therefore used the opportunity to fill in the gap in the literature with especial attention placed on agricultural value added.

METHODOLOGY

The Data

This descriptive study uses a panel dataset of 42 countries for the period 1996 to 2020. The secondary data used in the analysis is gotten from the World Bank Development Indicator database 2020. The selection in the time period involved in this study is a trade-off between the various countries that were included in the study and also on the availability of data. This gives justification why we have only 42 countries in Sub-Sahara included in the study.

Model Specification and Estimation Techniques

The paper has as its specific objective to analysis the moderating effect of agricultural production on the relationship between environmental degradation and health outcomes. This tells us that there is a moderator between the two variables which have a direct effect. The moderator here is agricultural production which has the ability to strengthen or lessen the relationship between environmental degradation which is the independent variable and health outcomes which is the dependent variable.

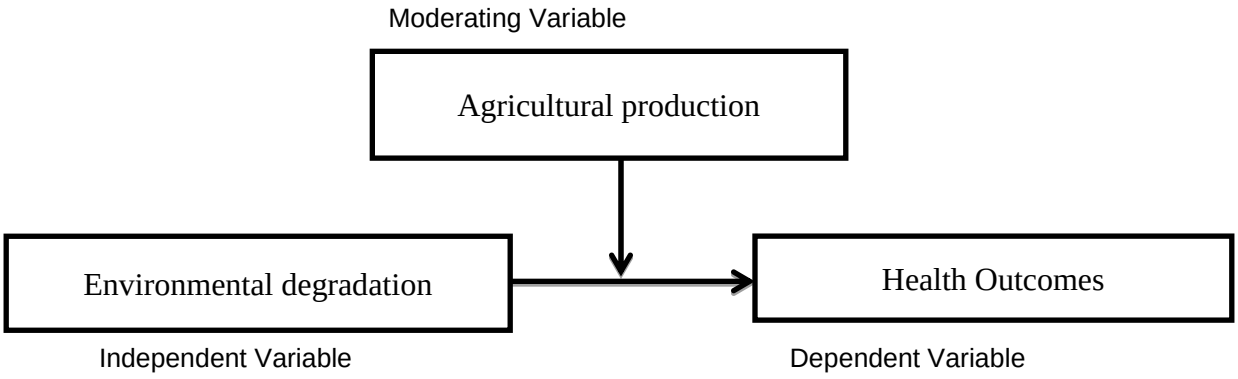

Figure 1: Moderating effect of agricultural production

Source: Adopted from Roland Helm, 2012

Therefore, to analysis the moderating effect, agricultural production (variable Z) on the relationship between an independent environmental degradation (variable X_p) and a dependent health outcome (variable Y), the predict of the two variables will be (X_P *Z). To calculate for the nonlinear interaction, the two regression are then tested first for the main effect of X_p and Z on Y

and the second on the regression to test for multiplicative terms X_p*Z. Following the work of Zellner (1962), we can formulate a general mathematical equation form to health outcomes decision model.

$Y_{it} = a + b_{1it}X_{pit} + b_2Z_{it}$……1

$Y_{it} = a + b_1X_{pit} + b_2Z_{it} + b_3 X_p*Z_{it} + U_{it}$ ……..1

Where,

Y_{it} denote infant mortality rate faced by i^{th} population in j^{th} specific country

With all these, infant mortality is seen as a function of

IMR = f(AVA, GHG. GDP, HE URB)……..3

Using the logarithmic in the specification of each equation in M, we have

$$\text{Log } (IMR)_{it} = (\beta_0 + \beta_1 \ln(AVA)_{it} + \beta_2 \ln(GHG)_{it} + \beta_3 \ln(HE)_{it} + \beta_4 \ln(GDP)_{it} + \beta_5 \ln(URB)_{it} + \beta_6 \ln(AVA * GHG)_{it} + U_{it} \ldots\ldots 4$$

Where,

i represent country and t represent time. IMR = Infant Mortality rate, AVA = Agricultural Value Added, GHG = Greenhouse Gases. HE = Health Expenditure, GDP = Gross Domestic Product, URB = Urbanisation.

This study uses the Seemingly Unrelated regression system which was proposed by Zellner. This technique of analysis comprises of several individual relationships which are often linked by the error term which are correlated. There are basically two main reasons why we adopted Seemingly Unrelated regression method in this paper; firstly, the fact that it gains efficiency in estimation by combining information from different equations and secondly due to the fact that, the test restrictions which usually involve the parameters in different equations, (Roger *et al.,* 2006). Seemingly Unrelated Regression method is known for its applicability to large classes of modeling as increasing availability of cross sectional data over several time period usually provides it as the more acceptable method. Analysis was carried out with the aid of STATA (version 14).

ANALYSIS AND DISCUSSION OF RESULTS

Descriptive Statistics

Table 1 presents the summary of the descriptive statistics of the variables of this paper between the periods 1996 to 2020. A total of 1025 observations were considered. This means that, the number of the years which a particular variable have been used (25 years) and multiple by the number of countries (41). Table 1 therefore shows the different facts about the data such as the mean, standard deviation and the minimum and maximum values.

Table 1: Summary of Descriptive Statistics

Variable		Mean	Std. Dev.	Min	Max	Observations
Lnimr	Overall	4.458512	.5942381	2.617396	5.583496	N = 1025
	Between		.5308162	2.64583	5.136509	n = 41
	Within		.2792078	3.761593	5.172421	T = 25
lnco2	Overall	7.889239	1.574077	4.382027	13.0125	N = 985
	Between		1.548523	4.973927	12.82535	n = 41
	Within		.4239125	4.925375	8.987435	T = 24.0244
Lnhe	Overall	3.931964	1.107329	1.536606	6.733736	N = 945
	Between		.9973477	2.439382	6.299056	n = 41
	Within		.5166657	1.451753	5.310138	T-bar = 23.0488
Lngdppc	Overall	7.032635	1.265252	1.190976	9.70739	N = 1025
	Between		1.262208	1.954307	9.411378	n = 41
	Within		.2122116	5.032975	8.121767	T = 25
Urb	Overall	39.35926	15.79345	7.412	90.092	N = 1025
	Between		15.44449	10.27876	83.8332	n = 41
	Within		4.060942	20.72298	51.63598	T = 25

The study reveals that, the mean value of In-infant mortality was 4.458 while the minimum value stood at 2.617396 and maximum value at 5.583496. The standard deviation of infant mortality of overall during the same period of the study was 0.59081, with over 1025 observations in 41 countries over a period of 25 years.

The statistics shows that, the average in Carbon-dioxide emission (InCO2) for the overall stood at 7.889239, with the minimum value of 4.382027 and the maximum value of 13.0125. The standard deviation is 1.574077 with the total number of observations N= 985 and in 41 (n) countries for the period of T=24.0244 years.

Furthermore, the average of health expenditure over the period of the study for the overall stood at 3.931964 while the minimum value over the same period is 1.536606 and the maximum value of 6.733736 with the standard deviation of 1.107329. The total number of observation that is being considered stands at 945 over the time lag of 23.0488 years.

For the gross domestic product per capita, the mean of the overall is 7.032635 with the minimum value of 1.190976 and the maximum value of 9.70739. The standard deviation of this variable is 1.265252 with the total number of observations at 1025.

Finally, urbanisation (Urb) has the mean of overall at 39.35926 with the minimum value of 7.412 and the maximum value of 90.092 over the period of the study. The standard deviation stood at 39.35926 with over 1025 observations over 25 years.

Correlation Analysis

To measure the degree of relationship existing among variables, the correlation analysis was performed. Table 2 provide the correlation matrix of residuals between different variables used in environmental degradation, health outcomes and agricultural production.

Table 2: Correlation Matrix of residuals

	Lnimr	Lnghg	Lnhe	Lngdppc	Urb
Lnimr	1.0000				
Lnghg	-0.1005	1.0000			
	(0.0016)				
Lnhe	-0.6496	0.2976	1.0000		
	(0.0000)	(0.0000)			
Lngdppc	-0.4581	0.2338	0.7036	1.0000	
	(0.0000)	(0.0000)	(0.0000)		
Urb	-0.3707	0.2880	0.5300	0.5946	1.0000
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	

Diagnostic Test Results

Before starting on estimating the regression and drawing the conclusions from the results obtained, some important pre and post-test were conducted on the data. The pre-test are the im-Pesaran-Shin (2003) stationary test and the post test is the Breuch-Pagan test.

Stationary Test results

To check for the stationary of the results, the paper employed Im-Pesaran-Shin unit root test. The results are presented in table A in the appendix. The results from the Im-Pesaran-Shin unit root indicate that, none of the variable was stationary at level. However, after the first difference, with the exception of urbanisation, all other variables obtained their stationarity. That is, infant mortality rate, greenhouse gases emission, health expenditure and gross domestic product per capita. It was only after the second difference that urbanisation became stationary.

Breusch-Pagan Test Results

The Breusch-Pagan test was carried out to test for the presence of heteroskedasticity. The Breusch-pagan test has a null hypothesis H_0: homoscedasticity. Table A2 in the appendix reveals that, there is the presence of heterokedasticity as the p-value = 0.0000<0.01. Thus, we can therefore reject the null hypothesis of homoscedasticity and accept the alternative of

heterokedasticity. We will use Seeming Unrelated regression to correct the problem of heterokedasticity.

Regression Results

Table 3 presents the results of Seeming Unrelated Regression estimation without interactions and Seemingly Unrelated Regression with interactions.

Table 3: Seemingly Unrelated regression results (SUR)

	(SUR model without interaction)			(SUR model with interaction)		
Variables	Ava	Lnimr	Lnghg	Ava	Lnimr	Lnghg
Ava		0.00499***	0.0385***		0.0983***	0.0379***
		(0.00148)	(0.00499)		(0.00592)	(0.00499)
Lnghg	2.190***	0.120***		2.110***	0.339***	
	(0.266)	(0.00986)		(0.265)	(0.0162)	
Lnhe	`	-0.270***			-0.262***	
		(0.0195)			(0.0169)	
Lngdppc		0.0450***	-0.241***		0.0642***	-0.240***
		(0.0166)	(0.0489)		(0.0145)	(0.0489)
Urb		0.000479	-0.00931**		-0.00238**	-0.00925**
		(0.00115)	(0.00395)		(0.00101)	(0.00395)
Fdi	0.206***		-0.0193**	0.210***		-0.0172**
	(0.0642)		(0.00804)	(0.0632)		(0.00805)
Ind	-0.571***		0.0558***	-0.567***		0.0549***
	(0.0301)		(0.00445)	(0.0299)		(0.00445)
Top	-0.106***			-0.115***		
	(0.0130)			(0.0129)		
Aprod*envdeg					-0.00996***	
					(0.000610)	
Constant	21.95***	3.925***	9.550***	23.24***	1.840***	9.566***
	(2.848)	(0.173)	(0.418)	(2.841)	(0.201)	(0.418)
Observations	849	849	849	849	849	849
R-squared	0.454	0.487	0.099	0.455	0.595	0.102

Note: ***1% ** 5% * 10% Level of significance

The coefficients in table 3 revealed that, greenhouse gases emission in seemingly unrelated regression model without interactions is positive while the results in the model with interaction is also positive meaning that, an increase in greenhouse gases emission will lead to an increase in infant mortality rate. These results are statistically significant at 1% level of significant and in line with the a priori expectations. This result is in confirmative with the findings of Snezana *et al.,* (2020) but in contrast to Mutizwa and Makochekanwa, (2015). This positive effect of greenhouse gases emission on infant mortality rate in SSA can partly be explained by the fact that, almost all countries in Sub-Sahara Africa are basically involved in primary and secondary activities to raise their incomes. These activities usually create a lot of greenhouse gases but unfortunately, almost all countries in SSA do not have environmental laws put in place and even where there exist, the implementation of these laws are very weak across SSA as various agent degrade the environment without any punishment or fine, thus infant whose body system is weak are easily affected.

Similarly the results revealed that the coefficient of log of health expenditure for the both models shows that, the model without interaction and the model with interaction, the relationship existing between health expenditure and infant mortality are negative. This means that, in the both models, when health expenditure increases, infant mortality rate will reduce. However, the degree to which these two coefficients in the two model decreases is not the same. The result explains that, a 1% increase in health expenditure will cause infant mortality rate in the model without interaction to decrease by 0.27% while the same 1% increase in health expenditure will cause infant mortality rate in the model with interaction to fall by 0.26%. This is in line with the findings of Kiross *et al.,* (2020) and Novignon & Lawanson, (2017). This fall in infant mortality rate as a result of increase in health expenditure could be explained by the fact that, when resources are provided and allocated for health services such as the provision of health facilities, drugs, physicians among others, infants are easily taken care of and this usually lead to a fall in their mortality rate.

Furthermore, the finding also showed the relation between log of gross domestic product per capita and infant mortality rate in model without interaction and model with interaction. In the both models, it revealed that, gross domestic product per capita has a positive effect on infant mortality rate in contrast to Fayissa and Gutema, (2005) but in line with the work of Josephine *et al.,* (2016). Meaning that, an increase in gross domestic product per capita will lead to an increase in infant mortality rate. Although both models results have positive link, the magnitude between the coefficients are not the same but they are all significant at 1% level. This positive relation existing between gross domestic product and infant mortality rate in Sub-Sahara Africa can be explained by the fact that, SSA countries mostly generate their income through primary

and secondary activities. These activities usually cause a lot of environmental degradation. Thus, income will rise as a result of exploitation of the resources but the environment will be spoiling as a result of the various methods used to exploit the environment causing many infant to die as is the case in Niger delta in Nigeria.

The findings further revealed the coefficient of urbanisation for both models. It showed that in the model result without interaction, urbanisation has a positive relation with infant mortality rate. That is an increase in urbanisation will lead to an increase in infant mortality rate. This result is not statistically significant and in line with Cleopatra and Tolulope, (2020). This can be explained by the facts that, urbanisation in SSA in most cases do not consider the development of health facilities to match up with the urbanisation. Fewer resources are allocated for the development of health infrastructure and even the small resources meant for the development of health facilities are mismanaged, thus leading to increasing infant mortality rate.

However, with the interactions, the model results revealed that, there is a negative relation between urbanisation and infant mortality rate. This means that, an increase in urbanisation will lead to a fall in infant mortality. This result is statically significant at 5% level in confirmative with the works of Davenport, R. J. (2020) and Kelly *et al.,* (2014) that supported the fact that, urbanisation will reduce infant mortality. This negative relation can be explained by the fact that, urbanisation usually brings a lot of environmental awareness among citizens such as good sanitation, good drinking water, waste management among others things. The advancement of these environmental conditions because of urbanisation helps to protect infants who are more susceptible to sickness and the rate at which they die falls.

Finally moderating agricultural production on environment degradation revealed that, the interaction of these two variables has a negative impact to infant mortality. This means that, an increase in these interactive variables will lead to a fall in infant mortality. This result is statistically significant at 1%. The explanation to this negative effect can be explained from the sfact that, SSA population mostly depends on agriculture for their livelihood. The use of chemicals usually boss-up agricultural production, thus mothers have food feeding varieties such help to reduce mortality rate in infants in the region.

CONCLUSION AND POLICY IMPLICATIONS

This paper was out to analysis the moderating effect of agricultural production on the relationship between environmental degradation and health outcome in Sub-Sahara Africa. Using a mixed research design as it uses both descriptive and evaluative research design and the Seemingly Unrelated regression (SUR) estimation technique to analyse the dataset for SSA.

The finding revealed that, environmental degradation has a positive effect on infant mortality in Sub-Sahara Africa. The results also revealed that, agricultural production strongly cause environmental degradation to affect health outcome negatively in Sub-Sahara Africa. This paper concludes by recommending that, information about environmental degradation should be made known to the public and also that policies and laws governing environmental sustainability should be promoted. Also, various agents should make sensitisation about the various environmental laws and the punishment that follows for degrading the environment. Finally, an interactive and participatory approach to policy making concerning environmental laws and its sustainability needs to be advocated. Concerning scope for further studies, this article recommends that, the aspect of poverty and cultural practices be incorporated when examining the effect of environmental degradation on health outcomes in Sub-Sahara Africa.

REFERENCES

Acharya, S., Chouhan, S. S., & Delsing, J. (2020, June). An Additive Production approach for Microvias and Multilayered polymer substrate patterning of 2.5 µm feature sizes. In 2020 IEEE 70th Electronic Components and Technology Conference (ECTC) (pp. 1304-1308). IEEE.

Alim and Demanou (2020). Climate change, agricultural production and Food security in Sahelian Zone: Journal of Economics and Management Sciences. Vol.2, N^0 1, 2020.

Alissa, E. M., & Ferns, G. A. (2017). Dietary fruits and vegetables and cardiovascular diseases risk. *Critical reviews in food science and nutrition*, *57*(9), 1950-1962.

Amrita Sujlana, M. Parampreet Pannu and B, japneet (2017). Double mesiosens: a rewiew and report of 2 cases Gen Dent.

Bogdanovica, S., Zemitis, J., & Bogdanovics, R. (2020). The effect of CO2 concentration on children's well-being during the process of learning. *Energies*, *13*(22), 6099.

Chioma,O N.P and Felix (2017). Evaluation of the contemporary issues in data Mining and data Warehousing. Evaluation, 31.

Clasen, C., Plog, J. P., Kulicke, W. M., Owens, M., Macosko, C., Scriven, L. E., ... & McKinley, G. H. (2006). How dilute are dilute solutions in extensional flows?. *Journal of Rheology*, *50*(6), 849-881.

Cleopatra and Tolulope (2020). Environmental Quality, Economic Growth, and Health Expenditure: Empirical Evidence from a Panel of African Countries. Research gate.

David,D, Gene, S and Andy (2005). Boron fertilization of rice with soil and foliar applications. Crop management, 4(1), 1-7

Davenport, R. J. (2020). Urbanization and mortality in Britain, c. 1800–50. *The Economic History Review*, *73*(2), 455-485.

Emma and Gordan (2015). Dietary Fruits and Vegetables and Cardiovascular Diseases Risk. Sussex Research online

Fayissa*, B., & Gutema, P. (2005). Estimating a health production function for Sub-Saharan Africa (SSA). *Applied economics*, *37*(2), 155-164.

Fourati, M., Najeh, B., & Idriss, A. (2021). Blockchain towards secure uav-based systems. In *Enabling Blockchain Technology for Secure Networking and Communications* (pp. 149-174). IGI Global.

Foden, W., Mace, G. M., Vié, J. C., Angulo, A., Butchart, S. H., DeVantier, L., ... & Turak, E. (2009). Species susceptibility to climate change impacts. *Wildlife in a changing world–an analysis of the 2008 IUCN Red List of threatened species*, *77*.

Gascon, C., Malcolm, J. R., Patton, J. L., da Silva, M. N., Bogart, J. P., Lougheed, S. C., ... & Boag, P. T. (2000). Riverine barriers and the geographic distribution of Amazonian species. *Proceedings of the National Academy of Sciences*, *97*(25), 13672-13677.

Grossman, G. M., & Krueger, A. B. (1995). Economic growth and the environment. *The quarterly journal of economics*, *110*(2), 353-377.

Josephine et al; (2016). Health risks from environmental degradation in the Niger Delta, Nigeria. Environment and Planning C: Government and Policy 0(0) 1–21.

Kelly, M., Mokyr, J., & Gráda, C. Ó. (2014). Precocious Albion: a new interpretation of the British industrial revolution. *Annu. Rev. Econ.*, *6*(1), 363-389.

Kiross, G,T., Chojenta, C., Barker, D.,&Loxton, D.(2020).The effects of health expenditure on infant mortality in Sub-Sahara Africa: evidence from panel data anaylsis, Health Economics review, 10. 1-9

Kremer, M., & Holla, A. (2009). Improving education in the developing world: what have we learned from randomized evaluations?. *Annual review of economics*, *1*, 513.

Lal, R and Steward,B, A (1990). Soil degradation: A global threat. Advances in soil

Lieb, C. M. (2003). *The environmental Kuznets curve: a survey of the empirical evidence and of possible causes* (No. 391). Discussion paper series.

Lorraine (2005). A Study of Public Understanding of and Response to Climate Change in the South of England. University of Bath.

Lewis, B,J. Ande,B. Morel, B. Dehaudt, P,Maro, D. Purdy, P, L and Lorenz, R,A (1995). Modelling the release behavior of cesium during several fuel degradation. Journal of nuclear materials,227 (1-2), 83-109

Lu, L., Guo, X., & Zhao, J. (2017). A unified nonlocal strain gradient model for nanobeams and the importance of higher order terms. *International Journal of Engineering Science*, *119*, 265-277.

M. Arafat, W. M. G., Haq, I. U., Mehmed, B., Abbas, A., Gamage, S. K. N., & Gasimli, O. (2022). The Causal Nexus among Energy Consumption, Environmental Degradation, Financial Development and Health Outcome: Empirical Study for Pakistan. *Energies*, *15*(5), 1859.

Majeed, M. T., & Ozturk, I. (2020). Environmental degradation and population health outcomes: a global panel data analysis. *Environmental Science and Pollution Research*, *27*(13), 15901-15911.

Malik, A. A., Williams, C. A., Weston, K. L., & Barker, A. R. (2018). Perceptual and prefrontal cortex haemodynamic responses to high-intensity interval exercise with decreasing and increasing work-intensity in adolescents. *International Journal of Psychophysiology*, *133*, 140-148

Matthew, O. A. (2020). Carbon emissions, agricultural output and life expectancy in West Africa. *670216917*.

Matthew, O., Osabohien, R., Fasina, F., & Fasina, A. (2018). Greenhouse gas emissions and health outcomes in Nigeria: Empirical insight from ARDL technique. *International Journal of Energy Economics and Policy*, *8*(3), 43-50.

Molem, Beri and Ntangsi (2017). Determinants of the inefficiency of public health Hospitals in Cameroon. available at http:www.death reference.com. Governing Health System in Africa.

Mutizwa, A., and Makochekanwa, A. (2015). Impact of environmental quality on health status: a study of 12 southern African development community (SADC) countries between 2000 and 2008. Botswana Journal of Economics, 13(1), 87-111.

Myint,T.(2002). Managing complexities in global environmental governance: Issues-interests-actors network model for the transnational environmental governance in the Mekong River Commission and the international Commission for the protection of the Rhine. PIk report, 106

Neill, D. R., Wong, S. H., Bellosi, A., Flynn, R. J., Daly, M., Langford, T. K., ... & McKenzie, A. N. (2010). Nuocytes represent a new innate effector leukocyte that mediates type-2 immunity. *Nature*, *464*(7293), 1367-1370

Novignon, J., & Lawanson, A. O. (2017). Health expenditure and child health outcomes in Sub-Saharan Africa. *African Review of Economics and Finance*, *9*(1), 96-121.

Olorode, O. A., Bamigbola, E. A., & Ogba, O. M. (2015). Comparative studies of some river waters in port Harcourt based on their physico-chemical and microbiological analysis, Niger Delta Region of Nigeria. *International Journal of Basic and Applied Science*, *3*(3), 29-37.

Oluwatoyin A. M, Oluwarotimi A. Owolabi1, Romanus O, Ese U, Toun O, Tomike I. Olawande, Oluwatosin D. Edafe, Praise J and Daramola (2018). Carbon Emissions, Agricultural Output and Life Expectancy in West Africa. International Journal of Energy Economics and Policy, 2020, 10(3), 489-496.

Pimental, D and Kounang, N (1998). Ecology of soil erosion in ecosystems. Ecosystems, 1(5), 416-426

Rakesh, S., Anil, D., Juttu, R., Jogula, K., Reddy, S. B., Raju, B., ... & Kumar, R.(2013). Technology and Policy Options: Opportunities for Smallholder Farmers to Achieve Sustainable Agriculture. In *Innovation in Small-Farm Agriculture* (pp. 65-73). CRC Press.

Ravens-Sieberer, U., & Bullinger, M. (1998). Assessing health-related quality of life in chronically ill children with the German KINDL: first psychometric and content analytical results. *Quality of life research*, *7*(5), 399-407.

Rodrigues, L. A., OLIVEIRA, I. C. D., Nogueira, G. A., SILVA, T. R. B. D., CANDIDO, A. C. D. S., & Alves, C. Z. (2020). Coating seeds with silicon enhances the corn yield of the second crop. *Revista Caatinga*, *32*, 897-903.

Roger, J. C., Mallet, M., Dubuisson, P., Cachier, H., Vermote, E., Dubovik, O., & Despiau, S. (2006). A synergetic approach for estimating the local direct aerosol forcing: Application to an urban zone during the Expérience sur Site pour Contraindre les Modèles de Pollution et de Transport d'Emission (ESCOMPTE) experiment. *Journal of Geophysical Research: Atmospheres*, *111*(D13).

Sanglimsuwan, A., Seeponkai, N., & Wootthikanokkhan, J. (2011). Effects of concentration of organically modified nanoclay on properties of sulfonated poly (vinyl alcohol) nanocomposite membranes. *International Journal of Electrochemistry*, *2011*.

Schubert, U., Hüsing, N., & Lorenz, A. (1995). Hybrid inorganic-organic materials by sol-gel processing of organofunctional metal alkoxides. *Chemistry of materials*, *7*(11), 2010-2027.

Smith, M. R., Singh, G. M., Mozaffarian, D., & Myers, S. S. (2015). Effects of decreases of animal pollinators on human nutrition and global health: a modelling analysis. *The Lancet*, *386*(10007), 1964-1972.

Snezana B, Jurgis Z and Raimonds B (2020). The Effect of CO2 Concentration on Children's Well-Being during the Process of Learning. Energies 2020, 13, 6099

Speldewinde, P. C., Cook, A., Davies, P., & Weinstein, P. (2009). A relationship between environmental degradation and mental health in rural Western Australia. *Health & place*, *15*(3), 880-887.

Tian, S., Qin, G., & Li, B. (2013). Reactive oxygen species involved in regulating fruit senescence and fungal pathogenicity. *Plant molecular biology*, *82*(6), 593-602.

Todorov, P. G. (1986). The radii of convexity of order alpha of certain Schwarz analytic functions. *Complex Variables and Elliptic Equations*, *6*(2-4), 159-170.

UN-NADAF (2006). Un-NADAF mid-term Review Focus on key sectors. Environment. Africa Recovery 10(2); pp 23

Wang, L., Dankert, H., Perona, P and Anderson, D.J (2008). A common genetic target for environmental and heritable influnces on aggressive in Drosophila. Proceedings of the National Academy of sciences, 105(15), 5657-5663.

World Health Organization (2013). Global tuberculosis report 2013. World Health Organization.

Wieland, M., Lynch, R., & Nydam, D. (2020). Effect of manual forestripping on teat tissue condition and milking performance in Holstein dairy cows milked three times daily

Woodruff, T. J., Grillo, J., & Schoendorf, K. C. (1997). The relationship between selected causes of postneonatal infant mortality and particulate air pollution in the United States. *Environmental health perspectives*, *105*(6), 608-612.

Yadav, V., & Bethard, S. (2019). A survey on recent advances in named entity recognition from deep learning models. *arXiv preprint arXiv:1910.11470*.

Zellner, A. (1962). An efficient method of estimating seemingly unrelated regressions and tests for aggregation bias. *Journal of the American statistical Association*, *57*(298), 348-368.

Zhou, J., Liu, L., Xue, P., Yang, X., & Tang, X. (2020). Mental health response to the COVID-19 outbreak in China. *American Journal of Psychiatry*, *177*(7), 574-57

APPENDICES

Table A: Summary of Im-Pesaran-Shin Unit-Root Test of Stationarity

Variables	Test statistics at levels	Critical values at 5%	Test statistics after first difference	Critical value at 5%	Test statistics after second difference	Critical value at 5%	Decision
lnIMR	18.6984	-1.730	-3.1413	-1.730	-	-	I(1)
lnghg	2.9108	-1,730	-14.4412	-1.730	-	-	I(1)
lnhe	1.2527	Not available	-11.9916	Not available	-	-	I(1)
lngdppc	1.8885	-1.730	-10.4330	-1.730	-	-	I(1)
Urb	25.1014	-1.730	9.0889	-1.730	-9.8470	-1.730	I(2)

Table B: Breusch-Pagan test results for heteroskedaticity

Chi^2 (3)	**73.776)**
	Prob>chi^2 = 0.0000