

Measures for achieving sustainable environment to mitigate climate change in Africa

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Abstract

Purpose – This study examines the appropriate measures that need to be intensified among African countries to achieve sustainable environment to mitigate climate change.

Design/methodology/approach – The study employs panel data covering the period 2000 to 2020 among 54 African countries and Cox proportional hazard model for the analysis.

Findings – Estimates indicate that the practice of carbon farming, the development of rooftop gardens, renewable energy production and consumption contribute positively toward achieving sustainable environment, while governance adversely affects this objective of achieving sustainable environment.

Practical implications – The study recommends that governments should enforce the constant practice of carbon farming among these countries through passing laws to enforce its application among farmers and allocate 2% of ministry of agriculture's budget toward financing carbon farming for poor farmers.

Originality/value – Empirical studies have been carried out exploring measures to deal with climate change. Nonetheless, the appropriate measures of achieving sustainable environment to mitigate climate change have less been explored in literature on Africa. Hence, this study fills the gap in existing empirical studies.

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Keywords Sustainable environment, Climate change, Carbon farming, Rooftop gardens, Renewable energy production

Paper type Research paper

1. Introduction

Globally, one of the biggest threats to the growth of economies is the issue of climate change. Increase of heat-warming gases in the earth's atmosphere leads to health-related problems and frequent flooding, bushfires and drought in both developed and developing countries (Addae and Oppelt, 2019; Blekking *et al.*, 2022; Funke *et al.*, 2018). African countries are

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Open data statement: In the interest of transparency, data sharing and reproducibility, the author(s) of this article have made the data underlying their research openly available. It can be accessed by following the link here: [10.6084/m9.figshare.23660625].



constantly experiencing the devastating effect of flooding especially in Madagascar, Mozambique, Ghana, Malawi and others (Addae and Oppelt, 2019).

Dozens of people have been killed due to the unpleasant effect of climate change, with millions of dollars of properties destroyed (Cletus *et al.*, 2021; Henderson *et al.*, 2017). Millions of people in Africa especially in the urban areas are facing increased water stress due to excessive rising levels of carbon dioxide emission (IPCC, 2017).

Numerous measures have been implemented toward dealing with the adverse effect of climate change. In developed countries, sustainable environmental measures such as intensifying carbon farming, development of rooftop garden, development of sponge cities, production of electric cars, renewable energy production and others are being operationalized to mitigate climate change (Ferreira *et al.*, 2020; Obringer and Nateghi, 2021; Abubakar and Dano, 2020; Raimundo, 2021). For instance, with respect to carbon farming according to European Union (EU), for the past 8 years, the practice of carbon farming has been intensified between 50.6% and 54.2% on average among European countries (EU, 2019). In countries like Germany, this practice has increased by 48.4% over the period, while in Netherlands, it has increased by 32.6% (EU, 2019).

Among countries in Africa, governments and other stakeholders have implemented environmental measures toward achieving Paris climate change target of 1.5 °C. Environmental measures such as afforestation, renewable energy production, increasing waste management companies and others have been implemented toward dealing the issue of climate change in the continent (Arroyo and Miguel, 2020; Addae and Oppelt, 2019; Funke *et al.*, 2018). With respect to renewable energy consumption among African countries, statistics from World Economic Forum indicated that in 2020, renewable energy consumption accounted for 9% of total energy consumption (WEF, 2020). Statistics further indicates that North African countries are leading in terms of renewable energy consumption, while Southern African countries are lagging behind with just over 4,000 MW capacity (WEF, 2020). In addition, with respect to afforestation, these countries have worked toward increasing afforestation by 38% on average (AfDB, 2020). In countries like Cape Verde, this has increased by 67%, while in Botswana, this has increased by 48.9% (AfDB, 2020).

Despite these environmental measures operationalized among African countries, yet still Africa accounts for more than 1 billion metric tons of carbon dioxide emission annually (IPCC, 2020). Hence, the question still remains to what extent should governments and other stakeholders continue to implement measures such as carbon farming, development of rooftop garden, enhancing environmental institutions' operations, robust population control measures, production and usage of renewable energy and afforestation in order to achieve sustainable environment to mitigate climate change in Africa. This study contributes to existing empirical studies by highlighting the need to intensify sustainable environmental measures toward mitigating climate change.

2. Literature review

This section focuses on reviewing relevant theory on climate change. Moreover, it also reviews empirical studies that focus on sustainable environmental measures.

2.1 Theoretical review

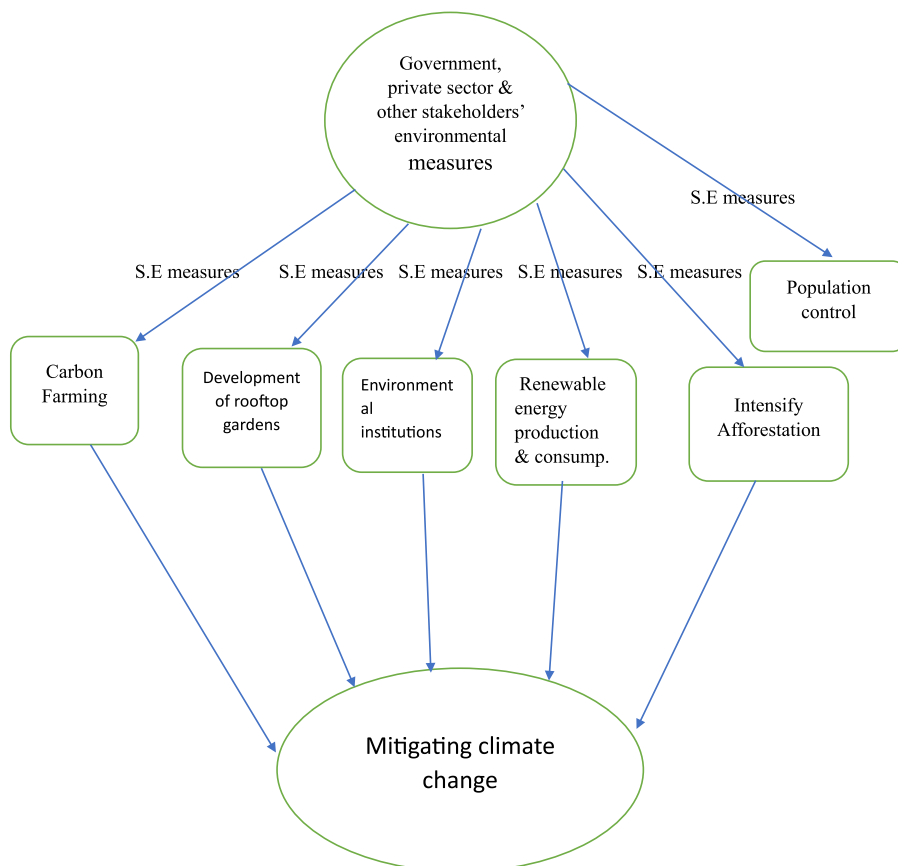
The theory of prospect which focuses on mitigation and adaptation of climate change was developed by Daniel Osberghaus (2017). The theory reiterated that indeed one of the current challenges confronting the world is the issue of climate change, which requires relevant theories and environmental policies to deal with the situation. According to the theory, governments and international bodies' ability to work toward sustainable environmental

measures should take advantage of well-researched alternative behavioral and institutional reforms to achieve this objective. This theory provides more climate change-relevant insights into robust sustainable environmental measures and expected environmental outcomes for global economies, when measures are properly implemented. The theory also postulated that there is also the need to critically examine the vulnerability, discounting, social and economic costs of these sustainable environmental measures.

The theory is relevant for the study because it provides relevant insights for governments and other stakeholders of environmental protection to critically assess the relevant sustainable environmental measures needed to be intensified among African countries to mitigate climate change. Their quest to implement relevant sustainable environmental measures should consider vulnerability, discounting, social and economic costs of these sustainable environment measures.

2.2 Conceptual framework

The conceptual framework as depicted in Figure 1 indicates how government and other stakeholders in environmental protection implement sustainable environmental measures.



Note(s): S.E measures means Sustainable Environmental Measures
Source(s): Authors own creation

Figure 1.
 Conceptual framework

Some of these measures include carbon farming, development of rooftop gardens, intensify renewable energy production and consumption, afforestation, operations of environmental institutions and population control measures toward mitigating climate change.

2.3 Empirical review

Numerous studies have been carried out examining the need to implement sustainable environmental measures to mitigate climate change, and this section reviews these empirical studies.

[Andrić et al. \(2019\)](#) examined sustainable measures implemented in developed and developing countries toward mitigating climate change. With global warming-driven changes in the ecosystems in both developed and developing countries, there is the need to investigate sustainable development strategies need to deal with the situation. Results of the study indicated that building renovations has potential role to play toward mitigating urban-related carbon dioxide emissions. These developed and developing countries should work toward adopting this measure under different climatic conditions.

[Rubeis et al. \(2020\)](#) examined establishing energy self-sufficient buildings in climate zone. The study employed EnergyPlus model, global climate models (GCMs) and multiparametric analysis for examining the subject matter. The results of the study indicated that the installation of heated ventilated air condition (HVAC) systems in buildings with condensing gas boiler should be intensified. This is because it will help toward enhancing heat energy absorption in building. The study concluded by recommending that, governments of both developed and developing countries should enforce the usage of HVAC systems in modern buildings.

[Abubakar and Dano \(2020\)](#) investigated sustainable planning strategies that will help toward tackling the issue of climate change in Saudi Arabia. In terms of global carbon dioxide emissions, Saudi Arabia is ranked seventh in the world ([Abubakar and Dano, 2020](#)). With its sensitive ecosystems, limited freshwater resources and coastal developments makes the country highly vulnerable to climate change.

Hence, assessing sustainable planning strategies needed for mitigating climate change in Saudi Arabia is relevant. Secondary data were sourced from relevant institutions for the analysis. The result of the study indicated that the implementation of urban greening, public transportation and green building projects will help toward achieving this.

[Ferreira et al. \(2020\)](#) investigated climate change mitigation measures such as technology transfers and environmental patent needed toward achieving sustainable environment and economic growth among European countries. With the use of secondary data, the result indicates that these countries' ability to effectively implement environmental patents consistently will influence innovation and entrepreneurship. This will have a pass-through effect on economic growth. Moreover, technology–organization–environment (TOE) measures and sustainability perspectives should be properly considered.

[Arroyo and Miguel \(2020\)](#) assessed the importance of renewable energies for sustainable energy governance and environmental policies to help deal with the issue of climate change in Ecuador. Ecuador's energy consumption is predominately based on fossil fuels, while renewable energy constitutes only 7.8% of its total energy consumption ([Arroyo and Miguel, 2020](#)). Hence, the study examined the role that massive usage of renewable energy in Ecuador can play toward mitigating climate change. The result of the study indicated that if Ecuador intensifies the energy consumption of solar, biomass and wind energy, it will help to reduce carbon dioxide emission by 60,233.70 kilotons by 2030. Hence, the country should work toward implementing long-term energy planning measures to achieve this.

[Tauseef Hassan et al. \(2021\)](#) assessed the relevant sustainable strategies that can help toward mitigating climate change and also achieving sustainable development in Pakistan.

Time-series models such as vector error correction model (VECM) and autoregressive distributive lag (ARDL) were employed for the analysis. The study's outcome indicates that the excessive exploring of natural resources increases carbon dioxide emission in Pakistan, and this adversely affects the quality of the environment. Result of the study indicated that the growth of urbanization helps to mitigate carbon dioxide emission thereby improving environmental quality.

Abbass *et al.* (2022) examined the adaptation and sustainable mitigation measures needed to impact on global climate change. The study employed secondary data, which covers sustainability issues with respect to environmental, social and economic viability outcomes with climate change mitigation and adaptation approaches for the analysis. The result of the study indicated that achieving effective climate change policies requires intensive involvement of government with long-term development strategies.

These empirical studies and others (Yigitcanlar *et al.*, 2015; Huovila *et al.*, 2019; Weisenfeld and Hauerwaas, 2018; Rubeis *et al.*, 2020; Gercek and Arsan, 2019; Lim and Taeihagh, 2018; MacDonald *et al.*, 2020) have highlighted the need to constantly implement sustainable environmental measures toward mitigating climate change. This study, which focuses on Africa, contributes to existing empirical studies by emphasizing the need for governments and other stakeholders in Africa to intensify the implementation of sustainable environmental measures toward mitigating climate change in Africa. Even though governments and other stakeholders have introduced measures, yet still more needs to be done as Africa still accounts for more than 1 billion metric tons of carbon dioxide emission annually (IPCC, 2020). In order to achieve Paris climate change target of 1.5 °C, these measures need to be intensified. Hence, this study is relevant for governments and other stakeholders to appreciate the need to constantly implement sustainable environmental measures to mitigate climate change.

3. Methodology

This section focuses on model specification, variables measurement, proxies used and scope of study.

3.1 Variables measurement, proxies and expected results

This section presents the variables used for the study, their proxies, definitions and the expected results. It covers the dependent variable, independent variables and control variables.

3.2 Dependent variable

In survival analysis, the dependent variable is the hazard rate, and it represents the probability of sustaining a variable (e.g. industrialization policies). The estimation technique measures hazard rate using the combination of time and event. The time represents how long to sustain the variable (e.g. industrialization policy).

Event according to the estimation technique is binary that is 1 if sustainable and 0 otherwise. For the purposes of this study, the dependent variable that represents hazard rate indicates the probability of sustaining environmental measures to help deal with climate change. Time represents how long these environmental measures are expected to be sustainable. For this study, the time period is between 10 years and 20 years. This time period is chosen based on the economic growth of these countries, which is 1.1% on average annually among these countries (AfDB, 2020). The event is 1 if environmental measures are sustainable, 0 if not sustainable.

3.3 Independent variables

Carbon farming means applying biochar to soil meant for farming. Hence, in the analysis, carbon farming is represented by the interaction between soil for farming and biochar. Soil for farming is proxied by agricultural land available for farming, and it is measured in square kilometers. Biochar is proxied by agricultural nitrous oxide. Both data are sourced from World Development Indicators (WDI) database. Biochar is made up of chemical composition, the largest among these is carbon but data on carbon are not available. Hence, the use of agricultural nitrous oxide (which is also one of the chemical compositions of biochar, with the data available) is used as a proxy for the variable. The variable is measured in metric tons. Intensifying the practice of carbon farming will contribute toward achieving carbon sequestration (i.e. absorbing carbon dioxide emissions from the atmosphere). Hence, the ability of these countries to sustain this measure will contribute toward achieving Paris Climate Change targets of 1.5°C. The data on this variable are measured in percentage.

Rooftop garden is proxied by permanent cropland. This variable refers to proportion of land which has been assigned permanently for the planting of crops, flowers or other ornamental plants. The data are sourced from WDI database. Practicing rooftop garden will help toward absorbing carbon dioxide from the atmosphere, thereby contributing toward achieving carbon sequestration. The ability of these countries to sustain and intensify this environmental practice will contribute toward mitigating climate change. The variable is measured in percentage.

Population control is proxied by the usage of condoms among males. The variable measures the percentage of males in a country that use condoms during sexual intercourse. The data are sourced from WDI database.

The ability of governments and other stakeholders in Africa to implement effective measures toward controlling the population will reduce excessive depletion of the forest toward construction purposes and control all forms of pollution and others. Governments' ability to sustain population control measures will contribute toward mitigating climate change. The variable is measured in percentage.

Environmental institution is proxied by rating on policies formulated by environmental institutions geared toward achieving environmental sustainability. The variable measures performance of countries with respect to their policies implemented by their environmental institutions toward mitigating climate change. The data are sourced from WDI database. The variable is measured on a scale from 1 to 6. A higher score represents better performance of the country. The ability of these governments to sustain the operations of these environmental institutions will contribute toward mitigating climate change through their activities like environmental campaign awareness programs and others.

Renewable energy production is proxied by electricity production from renewable source, which includes geothermal, solar, tides, wind, biomass and biofuels, as a percentage of total energy production. The data are sourced from WDI database. The country's ability to increase their renewable energy production and its consumption will contribute toward reducing carbon dioxide emission. The ability of these countries to sustain and intensify this measure will contribute toward mitigating climate change. The variable is measured in percentage.

Afforestation is proxied by percentage of land area covered by forest. This variable examines the proportion of the land area which is covered with intense planting of trees. The data are sourced from WDI database. Sustaining and intensifying afforestation will help toward absorbing carbon dioxide from the atmosphere, and this will contribute significantly toward achieving sustainable environment. The variable is measured in percentage.

3.4 Control variables

GDP growth the variable is used for the analysis. This measures the expansion in the production of goods and services in a country in a particular year. The data are sourced from WDI database.

As the economy expands, it provides governments the needed resources toward sustaining and intensifying appropriate environmental measures to mitigate climate change. The variable is measured in percentage.

Governance is proxied by six variables as postulated in the study of [Kaufmann *et al.* \(2003\)](#). These six variables are political stability, regulatory quality, control of corruption, government effectiveness, rule of law, voice and accountability. Principal component analysis (PCA) is constructed as an index to represent governance. Their values range from -2.5 to 2.5. The variable is sourced from World Governance Indicators (WGI). Good governance will ensure that effective management is appointed to manage these measures effectively for proper usage of allocated resources to achieve sustainable environment. Hence, it is expected that good governance will help toward sustaining and intensifying these environmental measures.

With respect to the usage of managed sanitation services, the variable is used for the analysis. The variable measures the percentage of the population that uses safely managed sanitation services. The data are sourced from WDI database. Consistent usage of managed sanitation services will contribute toward protecting the environment from any improper disposal of waste. This is a key toward mitigating climate change among these countries. The variable is measured in percentage.

3.5 Scope of the study

The study employs panel data covering the period 2000–2020 for the analysis. This time period is chosen because during these periods, governments and other stakeholders in environmental protection have introduced measures to protect the environment. Hence, the study is interested in finding out how these measures can be sustainable for a long period of time toward mitigating climate change.

3.6 Model specification

The study employs the Cox proportional hazard model developed by [Cox \(1972\)](#) for the analysis. This estimation technique is widely used for survival analysis where the researcher is interested in finding out how policies, approaches or relevant measures can be sustainable for long period of time toward achieving long-term objectives.

The estimation technique is deemed necessary for the study because the study is interested in finding out how environmental measures introduced by African governments and other stakeholders can be sustainable to mitigate climate change. These environmental measures include carbon farming, development of rooftop garden, operations of environmental institutions, population controls, renewable energy production and afforestation.

This estimation technique produces four results: exponential, Weibull, Gompertz and Cox regression results. The estimates from the exponential, Weibull and Gompertz represent parametric estimates, while that of Cox regression represents semiparametric result. These four regression estimates are expected to be similar when large observations minimum of 5,000 is used for the estimation. In the mid of small observations, regression estimates from Weibull and Gompertz tend to be similar; hence, the interpretation is based on these two estimates.

The Cox proportional hazard model is generally specified as

$$\lambda(t, X_j) = \lambda_0(t) \exp [X_j \beta] \tag{1}$$

where $\lambda(t, X_j)$ gives the hazard rate for the entity j , X_j is the set of p covariates for the entity j , β is the constant coefficient vector and $\lambda_0(t)$ is the baseline hazard. The use of Cox proportional hazard model is advantageous because it allows the β coefficients to be estimated even when the baseline hazard is not known. Baseline hazard measures how the risk of an event changes over time at a given baseline levels of covariates and parameters, while the hazard rate represents the probability of an event happening. For the purposes of this study, the hazard rate represents the probability of sustaining environmental measures among these countries over the period 10–20 years.

The general likelihood or probability function for the model is specified as

$$L(\beta) = \prod_{j=i}^r \frac{\exp (X_j \beta)}{\sum_{i \in R_j} \exp (X_j \beta)} \tag{2}$$

where r is the number of time periods, X_j the vector of covariates associated with the entity experiencing the event at time $i, i = 1, 2, \dots, r$ and R_j is the risk set at time i . That is the risk that will be accrued to the entity if it fails to achieve the needed mandate. The equation measures the probability of achieving the needed objective. For the purposes of this study, the x_i represents environmental measures that need to be sustainable.

Here, r represents the number of years this objective will be achieved, and R_j is the risk the continent will face if this objective is not achieved. Event in the analysis represents: 1 sustainable environmental measures and 0 otherwise, while time/spell represents how long these environmental measures need to be sustainable. With respect to this analysis, the equation presented above represents probability of sustaining these environmental measures.

For the purposes of this study, equation (1) is rewritten as

$$\lambda(t, X_{it}) = \lambda_0(t) \exp [X_{it} \beta_i] + \mu \tag{3}$$

where X_i are the covariates (measures) needed to help achieve this objective. β_i are the regression coefficients, $\lambda_0(t)$ is the baseline hazard, $\lambda(t, X_{it})$ gives the hazard rate and μ is error term.

Based on [equation \(3\)](#), the model for the study is specified as

$$\begin{aligned} SUS = \lambda_0(t) \exp [\beta_0 + \beta_1 CARFARM_{it} + \beta_2 ROOF_{it} + \beta_3 POP_{it} + \beta_4 ENVINS_{it} + \beta_5 REN_{it} \\ + \beta_6 AFFOR_{it} + \beta_7 GDP_{it} + \beta_8 GOV_{it} + \beta_9 SaniServ_{it} + \mu] \end{aligned} \tag{4}$$

where SUS = sustainability of environmental measures.

CARFARM = Carbon Farming ROOF = Rooftop Garden

POP = Population Controls ENVINS = Environmental Institutions

REN = Renewable Energy Production F TA = Afforestation

GDP = GDP growth GOV = Governance

SaniServ = Access to sanitation services

In [equation \(4\)](#), GDP growth, governance and access to sanitation services are the control variables.

4. Results and discussion

This section analyzes the estimates from descriptive statistics, correlation test and parametric estimates from the Cox proportional hazard model.

4.1 Estimates from descriptive statistics

Estimates from the summary statistics have been presented in [Table 1](#). Afforestation indicates a mean value of 28.92, minimum value of 0.045 and maximum value of 93.25. This indicates a wide difference in afforestation among these countries.

Renewable energy production estimates indicate a mean value of 3.57, minimum value of 0.48 and maximum value of 4.93, and this indicates no wide difference among these countries. The rooftop garden estimates indicate a mean value of 3.86, minimum value of 0.0018 and maximum value of 46.88. This indicates a wide difference among these countries.

Environmental institutions indicate a mean value of 3.06, minimum value of 2.89 and maximum value of 3.27, and this does not indicate any wide difference in the performance of environmental institutions among these countries. Carbon farming (the value was logged to simplify the analysis) indicates a mean value of 5.49, minimum value of 0.76 and maximum value of 21.08. This indicates a wide difference in the practice of carbon farming among these countries. Population control indicates a mean value of 50.52, minimum value of 30.77 and maximum value of 97.3. This indicates a wide difference in the practice of population control measures among these countries.

4.2 Correlation test

Correlation test is carried out for the independent variables to check for multicollinearity using the variance inflator factor (VIF). The result is shown in [Table A1](#) in the Appendix, and the highest VIF is 4.08 for environmental institution. The rule of thumb states that for a variable to cause multicollinearity, it should have a VIF greater than 5. Since none of these variables has a VIF higher than 5, there is no existence of multicollinearity among the independent variables.

4.3 Results for parametric coefficients and hazard ratios

The results for Weibull and Gompertz models' coefficients and hazard ratios have been presented in [Table 2](#). With Cox proportional hazard model estimation, the model coefficients are interpreted in terms of their signs but not the magnitude of the coefficients. In this

Variables	Observation	Mean	Standard deviation	Coefficient variation	Minimum	Maximum
Afforestation	1,121	28.92	25.02	0.87	0.045	93.25
GDP growth	1,079	3.94	6.51	1.65	-1.25	6.48
Governance	1,119	4.45	1.04	2.25	-2.86	2.98
Renewable energy	1,134	3.57	1.063	0.29	0.48	4.93
Rooftop garden	1,100	3.86	7.49	1.94	0.0018	46.88
Environmental institution	1,134	3.06	0.11	0.036	2.89	3.27
Population control	1,134	50.52	19.42	0.38	30.77	97.3
Sanitation services	546	21.93	15.42	0.70	2.12	80.76
Carbon farming	1,068	5.49	6.13	1.98	0.76	21.08

Source(s): Authors own creation

Table 1.
Descriptive statistics

Sustainable Environment	Weibull regression coefficients	Gompertz regression coefficients	Weibull hazard Ratios	Gompertz hazard ratios
Carbon farming	2.32** (1.18)	2.33** (1.18)	1.77 *** (5.80)	1.76*** (5.79)
Rooftop garden	0.0064*** (0.008)	0.0065*** (0.008)	1.09*** (0.0079)	1.08*** (0.0078)
Environmental institutions	-0.28 (1.07)	-0.28 (1.07)	0.75 (0.81)	0.75 (0.81)
Renewable energy	0.18*** (0.098)	0.19 *** (0.098)	1.81*** (0.082)	1.81*** (0.082)
Population control	-0.011 (0.0081)	-0.011 (0.0081)	0.99 (0.0079)	0.99 (0.008)
Afforestation	0.011*** (0.0032)	0.011*** (0.0032)	1.31*** (0.0033)	1.31*** (0.0033)
Governance	-0.12*** (0.082)	-0.12*** (0.082)	0.42*** (0.093)	0.42*** (0.093)
GDP growth	0.020*** (0.0077)	0.021*** (0.0077)	1.12*** (0.0078)	1.13*** (0.0079)
Sanitation services	0.0078 (0.0042)	0.0079 (0.0042)	1.40 (0.0041)	1.39 (0.0040)
Constant	-17.47*** (2.89)	-5.88*** (2.83)	2.59e-08*** (7.50e-08)	0.0028*** (0.0079)
N	483	483	483	483

Note(s): Standard errors in parentheses
 * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
Source(s): Authors own creation

Table 2.
Results from
parametric coefficients
and model hazard
ratios

analysis, positive coefficient indicates that environment measure well operationalized will help toward sustaining the environment to mitigate climate change, while negative coefficient means that the measure will adversely affect the objective of achieving sustaining environment.

Model hazard ratio is interpreted in terms of the magnitude of the value, and all the values are positive. For example, if the value is less than 1 (example 0.77), this value is subtracted from 1, which gives 0.23, this is interpreted as 23% reduction in hazard ratio. This implies that there is 23% less likely that the objective of sustaining the environment will be achieved.

Put differently, the result means that the probability of achieving this objective is very low. The reverse is the interpretation, when the value of hazard ratio is greater than one.

Regarding the estimates for carbon farming indicate positive coefficient of 2.32 and hazard ratio of 1.77 when you control for governance, GDP growth and sanitation services. The positive coefficient result implies that continuous practice of carbon farming among these countries will contribute toward achieving sustainable environment to mitigate climate change. The estimate from the hazard ratio indicates that there is 77% probability that this objective will be achieved if governments and other stakeholders intensify this practice. This result is consistent with our expectation and empirical studies carried out by [Stocchero et al. \(2017\)](#) and [Yigitcanlar et al. \(2015\)](#). In most developed countries, the practice of applying biochar to farm soil for production (which constitutes one aspect of carbon farming) is growing rapidly with the emergence of carbon credit deemed as relevant toward achieving carbon sequestration. This is not highly practiced in Africa when compared with developed countries. Governments should intensify this practice in Africa by passing laws to enforce its application, using national services personnel to educate farmers in remote areas on this practice and allocating 2% of the ministry of agriculture's budget toward financing carbon farming especially among poor farmers.

Estimate for governance indicates negative coefficient value of -0.12 and hazard ratio of 0.42. This implies that the prevailing level of governance among these African countries adversely affects the objective of achieving sustainable environment to mitigate climate change. The estimate from the hazard ratio indicates that if governance among these

countries is not strengthened, there is 58% probability that it will adversely affect this objective. This result is not consistent with our expectation and empirical study carried out by [Arroyo and Miguel \(2020\)](#). Research conducted by Transparency International (TI) in 2016 rated the effectiveness of governance among the 54 African countries as very low when compared with European countries and United States US ([Transparency International, 2016](#)). Hence, governments among these countries should work toward strengthening its effectiveness through the introduction of performance contracts, licensing and other robust frameworks to enhance its effectiveness to contribute toward achieving this objective.

With respect to the estimates for rooftop garden, model coefficient result indicates a positive value of 0.064 and hazard ratio of 1.09 when you control for governance, GDP growth and sanitation services. This means that development of rooftop garden will contribute positively toward achieving sustainable environment to mitigate climate change.

However, the result of the hazard ratio indicates that even though it will contribute toward achieving this objective, its probability contribution is 8–9%, which is low. That is, it contributes less toward achieving this objective, and this is because it can be practiced only in residential houses (this forms a small proportion of houses built in Africa). This positive contribution result is consistent with our expectation and results of these empirical studies ([Gercek and Arsan, 2019](#); [Adriane et al., 2020](#); [Biswas et al., 2022](#)). Governments and other stakeholders should work toward intensifying this practice in Africa in order to increase its probability contribution toward achieving sustainable environment. Governments should enforce this practice among new residential buildings, real estate buildings, buildings for business activities and affordable housing units to achieve this objective.

Afforestation estimate indicates positive coefficient value of 0.011 and hazard ratio of 1.31, when you control for governance, GDP growth and sanitation services. This result implies that these countries' ability to intensify afforestation exercise will contribute toward achieving this objective. Even though, it will contribute toward achieving this objective. Its hazard ratio (1.31) estimate indicates that its probability contribution is very low, which is 31%. Hence, governments and other stakeholders should work toward intensifying this practice through the planting of over 200 million trees yearly in Africa and ensure that real estate and mining companies adhere strictly to the reforestation lay-down rules and regulations.

Renewable energy production estimates indicate a positive coefficient of 0.18 and hazard ratio of 1.81, when you control for governance, GDP growth and sanitation services. Intuitively, the result means that production and usage of renewable energy will help toward achieving sustainable environment to deal with climate change. The hazard ratio estimate indicates that there is 81% probability that this objective will be achieved when renewable energy production and consumption is intensified. This result is consistent with expectation and empirical studies results of [Arroyo and Miguel \(2020\)](#), [Rubeis et al. \(2020\)](#) and [Abubakar and Dano \(2020\)](#).

Hence, more efforts should be geared toward sustaining and intensifying renewable energy production and consumption through the provision of subsidies by governments for its production and consumption. In addition, governments should impose marginal taxes on telecommunication, manufacturing, mining, oil and banking companies to mobilize revenue for investment in renewable energy.

Estimate for GDP growth indicates positive coefficient value of 0.020 with hazard ratio of 1.12. The result indicates that the expansion in economic activities among these countries will contribute toward achieving sustainable environment to mitigate climate change. This is because the expansion in economic activities will give these governments more revenue to intensify the implementation of these measures and introduction of more robust measures to achieve this objective. This outcome is consistent with expectation and empirical studies results of [Ferreira et al. \(2020\)](#) and [Jaramillo et al. \(2013\)](#). However, the estimate from the hazard ratio indicates that its probability contribution is very low with a value of 12%. Hence, governments should enhance GDP growth among these countries through ensuring public

sector efficiency, boosting domestic production and consumption, rationalization of expenditures into productive ventures and others. These will help toward raising enough revenue for governments to consistently sustain these policies.

5. Conclusion

The devastating effect of climate change has urged global governments, international bodies and other stakeholders in environment protection to work toward sustainable environmental measures to mitigate climate change. Governments among African countries are no exception; hence, the study contributes to existing empirical studies by examining how these measures (the practice of carbon farming, development of rooftop garden, population control, renewable energy production, operations of environmental institutions and afforestation) when sustained and intensified can contribute toward achieving sustainable environment. The objective of the study was achieved with the use of panel data from the period 2000 to 2020 and Cox proportional hazard model estimation technique for survival analysis.

Result of the study indicates that intensifying the practice of carbon farming among these countries will contribute positively toward achieving sustainable environment to mitigate climate change. The hazard ratio result indicates that, the probability of achieving this is 77%. The result with respect to the development of rooftop garden indicates that the ability of governments to intensify this practice especially in modern residential houses, real estate houses, buildings for companies and affordable housing units will contribute toward achieving sustainable environment.

With respect to renewable energy production, the result indicates that intensifying this practice has a probability value of 81% toward contributing positively to achieve the objective of sustainable environment to mitigate climate change. Result for governance indicates that prevailing level of governance among these countries adversely affects the objective of achieving sustainable environment. The following policy recommendations have been prescribed for governments and other stakeholders to achieve this objective:

- (1) The practice of carbon farming should be intensified among African countries by governments passing laws to enforce this practice especially among rural farmers. In addition, governments should use national services personnel toward educating farmers in remote areas about the practice and allocating 2% of ministry of agriculture's budget toward financing carbon farming among poor farmers.
- (2) The development of rooftop garden can be intensified when governments enforce that new residential buildings, real estate developers, buildings for business activities and affordable housing units should adopt this practice toward achieving sustainable environment.
- (3) Renewable energy production and consumption should be intensified among these countries by subsidizing the production and consumption of renewable energy and imposing marginal taxes on telecommunication, mining, oil, manufacturing and banking companies to help mobilize money to invest in renewable energy.
- (4) Governance among these countries should be made efficient by giving public administrators performance contracts and licensing government workers to enhance the effectiveness of their operations in order for them to contribute toward achieving sustainable environment to mitigate climate change.

The study wanted to include innovative environmental polices like development of sponge cities and implementation of green architecture with the use of HVAC systems in buildings.

The study could not do that because of unavailability of data, future studies that can get comprehensive data should include them in their analysis.

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(The Appendix follows overleaf)

Variables	VIF	1/VIF
Renewable energy	2.13	0.47
Rooftop garden	1.05	0.95
GDP growth	1.03	0.97
Population control	3.04	0.16
Carbon farming	1.09	0.92
Governance	1.11	0.90
Afforestation	1.14	0.88
Environmental institution	4.08	0.25
Sanitation services	1.15	0.87
Mean VIF	2.21	

Table A1.

Multicollinearity test

Source(s): Authors own creation**Corresponding author**Bismark Osei can be contacted at: bismarkosei84@yahoo.com

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