ASYMMETRIC IMPACT OF ENVIRONMENTAL QUALITY, CLIMATE CHANGE AND ECONOMIC GROWTH ON FOOD SECURITY IN GHANA: A NONLINEAR ARDL APPROACH

BY

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ABSTRACT

The originality of this dissertation is that it contributes to knowledge by filling up the gap identified in the existing studies on the impact of environmental quality, climate change and economic growth on food security. Specifically, this study offers nonlinear assessments of the influence of environmental quality, climate change and business cycles on food security in Ghana. The study investigates the nonlinear short- and long-run correlation between food security, environmental quality, climate change and economic growth in Ghana. The study uses the Nonlinear Autoregressive Distributed Lag Model (NARDL) to evaluate annual data spanning 1965 to 2016. The findings suggest that relying on the outcomes based on symmetric models and ignoring the potential nonlinearities may be misleading. The results reveal the presence of both short-and long-run nonlinear relationships between food security, environmental quality, climate change and economic growth. In particular, the findings suggest that the response of food security to the positive and negative changes in environmental quality (CO2 emissions), climate change (RAIN) and economic growth (GDP per capita) is statistically significant in both short- and long-term periods. There exists an inverse link between environmental quality, economic growth and food security in the long-run. Food security response to adverse effects of both CO2 emissions and GDP per capita is more robust and faster than the response of food security to the positive shocks of both variables in Ghana. Nevertheless, the response of food security to the adverse shocks of CO2 emissions is somewhat infinitesimal. Moreover, food security response to rainfall precipitation during the wet season in Ghana is more significant and faster than food security response to rainfall precipitation during the dry season. Therefore, in contrast, the relationship between food security and climate change is found to be direct in the long-run. The study reckons that a more extensive influence emanates from the positive shocks of rainfall precipitation. The findings in the short-run are mixed and ambiguous. However, the estimates reveal a nonlinear relationship between food security and the explanatory variables. Notably, in the short-run, the positive impact of an increase in CO2 emissions is more influential on food security than the negative impact, while there exists an inverse link between both rainfall precipitation and economic growth and food security in Ghana. The nonlinearity in environmental quality, climate change and economic growth revealed in this dissertation could be of important guideline for the robust evaluation and policymaking on how to mitigate the growing number of food-insecure Ghanaians. The study also reckons that stakeholders in the agricultural sector should harness the potential natural resources in the country and propagate environmentally friendly policies and practices that will help reduce the influx of greenhouse gasses and promote domestic production and food security in Ghana.

خلاصة البحث

تكمن أصالة هذه الرسالة في أنها تساهم في المعرفة من خلال سد الفجوة المحددة في الدراسات الحالية حول تأثير الجودة البيئية وتغير المناخ والنمو الاقتصادي على الأمن الغذائي. على وجه التحديد، تقدم هذه الدراسة تقييمات غير خطية لتأثير الجودة البيئية وتغير المناخ ودورات الأعمال على الأمن الغذائي في غانا. وتبحث الدراسة في العلاقة غير الخطية قصيرة وطويلة المدى بين الأمن الغذائي وجودة البيئة وتغير المناخ والنمو الاقتصادي في غانا. كما تستخدم الدراسة نموذج الانحدار الذاتي الموزع غير الخطي (NARDL) لتقييم البيانات السنوية الممتدة من عام 1965 إلى عام 2016. وتشير النتائج إلى أن الاعتماد على النتائج بناءً على النماذج المتماثلة وتجاهل العناصر اللاخطية المحتملة قد يكون مضللاً. وتكشف النتائج عن وجود علاقات غير خطية قصيرة وطويلة المدى بين الأمن الغذائي وجودة البيئة وتغير المناخ والنمو الاقتصادي. على وجه الخصوص، تشير النتائج إلى أن استجابة الأمن الغذائي للتغيرات الإيجابية والسلبية في جودة البيئة (انبعاثات ثاني أكسيد الكربون)، وتغير المناخ (RAIN) والنمو الاقتصادي (الناتج المحلي الإجمالي للفرد) ذات دلالة إحصائية على المدى القصير والطويل. كما توجد علاقة عكسية بين جودة البيئة والنمو الاقتصادي والأمن الغذائي على المدى الطويل. كانت استجابة الأمن الغذائي للآثار السلبية لكل من انبعاثات ثاني أكسيد الكربون ونصيب الفرد من الناتج المحلي الإجمالي أكثر قوة وأسرع من استجابة الأمن الغذائي للصدمات الإيجابية لكلا المتغيرين في غانا. ومع ذلك، فإن استجابة الأمن الغذائي للصدمات المعاكسة لانبعاثات ثاني أكسيد الكربون متناهية الصغر إلى حد ما. علاوة على ذلك، تعد استجابة الأمن الغذائي لهطول الأمطار خلال موسم الأمطار في غانا أكثر أهمية وأسرع من استجابة الأمن الغذائي لهطول الأمطار خلال موسم الجفاف. لذلك، على النقيض من ذلك، تبين أن العلاقة بين الأمن الغذائي وتغير المناخ علاقة مباشرة على المدى الطويل. تعتقد الدراسة أن تأثيرًا أكثر شمولاً ينبع من الصدمات الإيجابية لهطول الأمطار. النتائج على المدى القصير مختلطة وغامضة. ومع ذلك، فإن التقديرات تكشف عن علاقة غير خطية بين الأمن الغذائي والمتغيرات التفسيرية. والجدير بالذكر، على المدى القصير، أن التأثير الإيجابي لزيادة انبعاثات ثاني أكسيد الكربون يكون أكثر تأثيرًا على الأمن الغذائي من التأثير السلبي، بينما توجد صلة عكسية بين كل من هطول الأمطار والنمو الاقتصادي والأمن الغذائي في غانا. يمكن أن يكون عدم الخطية في جودة البيئة وتغير المناخ والنمو الاقتصادي الذي تم الكشف عنه في هذه الرسالة بمثابة دليل مهم للتقييم القوي وصنع السياسات حول كيفية التخفيف من العدد المتزايد من الغانيين الذين يعانون من انعدام الأمن الغذائي. وتعتقد الدراسة أيضًا أنه يجب على أصحاب المصلحة في القطاع الزراعي تسخير الموارد الطبيعية المحتملة في البلاد ونشر سياسات وممارسات صديقة للبيئة من شأنها أن تساعد في الحد من تدفق غازات الدفيئة وتعزيز الإنتاج المحلي والأمن الغذائي في غانا.

APPROVAL PAGE

I certify that I have supervised and read this study and that in my opinion, it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Master of Economics.

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DECLARATION

I hereby declare that this dissertation is the result of my own investigations, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at IIUM or other institutions.

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LIST OF ABBREVIATION

AEM	Agronomic-Economic Models
AEPA	America Environmental Protection Agency
AEZM	Agro-Ecological Zone Models
AFOLU	Agriculture, Forest and Other Land Use
AGW	Anthropogenic Global Warming
BDS	Brock, Dechert and Scheinkman Test.
DOLS	Dynamic Ordinary Least Squares.
ECOWAS	Economic Community of West African States
EFTA	European Free Trade Association
EPA	Environmental Protection Agency of Ghana.
EU	European Union
FAO	Food and Agricultural Organization
FMOLS	Fully Modified Ordinary Least Squares
GFDRR	Global Facility for Disaster reduction and Recovery.
GIPC	Ghana Investment Promotion Center
GOG	Government of Ghana
GSS	Ghana Statistical Service.
IPCC	Intergovernmental Panel on Climate Change.
IPPU	Industrial Processes and Product Use
MEP	Ministry of Environmental Protection
MESTI	Ministry of Environmental, Science, Technology and Innovation
MoFAN	Ministry of Foreign Affairs Netherlands
MoFA	Ministry of Food and Agriculture of Ghana.
MtCO2e	Million tonnes of carbon dioxide equivalent.
NDPC	National Development Planning Commission
OLS	Ordinary Least Squares
UN	United Nations
UNFCC	United Nations Framework on Climate Change
USAID	United States Agency for International Development

USDA	United States Department of Agriculture
WHO	World Health Organization

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Environmental quality and climate variability have been a great concern to climate and environmental scientists due to their threat to global sustainable development in recent years. The primary source of these environmental issues results from the emissions of greenhouse gasses (GHGs) (i.e., carbon dioxide (CO2) and many more), which are primarily due to natural and anthropogenic activities (Gershon & Mbajekwe, 2020; Yadav et al., 2019). Globally, human-induced carbon dioxide (CO2) emissions contribute about 75 percent to greenhouse gasses. Therefore, it is an important determinant in measuring the quality of a country's environment (Abbasi & Riaz, 2016; Ejemeyovwi et al., 2018; Muhammad et al., 2021). It is worth noting that agricultural activities such as crop production, livestock rearing and other land use contributed about 10.4 billion tonnes of CO2 emissions in 2017 (FAO, 2020). Additionally, in the late 19th century, the surface average temperature had risen to 1.62 Fahrenheit (0^{o}C). Before the end of the century, the average temperature is projected to increase by 3^{o}C and 6^{o}C without an adequate mitigating policy for CO2 emissions. Consequently, the temperature rise may alter the global rainfall pattern, rise in sea level, changes in the farming season, biophysical and biodiversity changes, thereby intensifying extreme atmospheric changes which trigger variations in the climate (Gershon and Mbajekwe, 2020; Rashid et al., 2020).

The world average rainfall precipitation is about 1000 millimetres (39.37 inches), which tends to increase by 2.54 millimetres (0.10 inches) every ten years since the year 1901 (Pielke et al., 2021; AEPA, 2021). Nonetheless, the distribution based on geographical and spatial characteristics is disproportionately different. Specifically, the equatorial and the monsoon of Southern Asia has the highest rainfall, while the latitude regions receive modest rainfall and finally, the desert areas of the tropicals and around the poles experience the lowest precipitation of rainfall. However, global yearly rainfall precipitation is estimated to experience a downward trend by 9 to 27 percent by the year 2100 (Minia, 2004; Yaro & Hesselberg, 2016; Saito et al., 2018).

Internationally, climate adjustment is likely to alter rainfall patterns, causing acute water shortage in the soil in semi-arid and arid developing countries, especially the tropical regions in Africa. These countries are susceptible to extreme climate events such as floods and drought (IPCC, 2014; Yaro and Hesselberg, 2016; Saito et al., 2018). These events are becoming more severe and may increase by 20 percent in West African countries over the next twenty years due to the rise in economic activities (Yaro & Hesselberg, 2016). Therefore, tropical countries with rainfed agriculture as the primary source of livelihood are more vulnerable because of the spillover effects of these climate adjustments (Gershon & Mbajekwe, 2020; Rashid et al., 2020).

The agricultural sector is one of the primary sectors in the economy that is very exposed to the negativities of climate change, though other sectors may also be affected by the frequent variations of the climate (Rashid et al., 2020). Agriculture is a significant contributor and at the same time, vulnerable to the impacts of climate change. This is because most farmers in the agricultural sector adopt modern energy-consumption agro-equipment and waste generating activities at the production stage. The prime contamination from such activities is an anthropogenic pollutant emitted into the environment from GHGs (Ngarava et al., 2019). Climate adjustment directly affects human food and health through the adverse effects imparted on agricultural food production, posing a great danger to global food security. Changes in the climate has reduced global crop production and fish stock by 21 percent in comparatively warm areas like Africa in the last six decades (Rashid et al., 2020). Specifically, crop yields decline by 33 percent and fish stock by 7.7 percent, making the agricultural sector a great contributor to food security in Africa. In the year 2019, about 690 million world population were undernourished[1]. In particular, more than 3 million people globally could not afford the cheapest balanced diet, especially in Africa, primarily because the average cost of a balanced diet surpasses the average food expenditures and the international poverty line. Intuitively, on average, a less privileged African below the poverty line cannot access adequate healthy food due to the intensifying impact climate change exerts on agricultural production and food security in general (Welsh, 2021). Furtthermore, Africa is projected to be the continent with the highest prevalence of

[1] Undernourishment is described as a state in which a person's regular food intake is insufficient to deliver the amount of dietary energy needed to live a normal, active and healthy life.

undernourished populace juxtapose to the rest of the world[2], primarily because undernourished people in Africa are estimated to rise from 19.1 percent to 26 percent by the year 2030 (FAO et al[3]., 2020).

1.1.1 Berief History of Food Security

The global food crises in the mid-1970s resulted in the erratic rise in grain food prices and attracted the international community's concerns on the frequency and magnitude of famine in both developing and developed countries, giving birth to the term food security (Shaw, 2007). A condition in which the global population is privileged to have physical and socioeconomic access to enough, safe and healthy food that meets the necessary dietary and food preference for an active and malnutrition-free lifestyle at all times is term food security (FAO et al., 2015). Rationally, when citizens of a nation can afford and have enough food supply and a healthy balanced diet, it is considered a food-secure nation. Conversely, a country where the population cannot have physical, social and economic access to a safe and sufficient healthy diet or cover all their food demand is considered a food-insecure. According to FAO (2020), conditions for food insecurity are divided into two types; namely moderate and severe food insecurity. Moderate food insecurity examines a situation in which people have to skip, forgo and reduce the quality and quantity of food consumed due to insufficient purchasing power, thereby compromising consumption consistency, to change eating patterns and declining dietary quality, which inherently caused malnutrition. In contrast, severe food insecurity is when a person experiences extreme famine and hunger and goes for days without eating due to shortage of food availability, tend to inflict adverse influence on the health and welfare of the person, which impedes sustainable livelihood of the country (FAO, 2020). However, beyond the food availability, which covers indicators such as the food production index, the crop yield index, livestock owner index and many more, food security also consists of the potential accessibility[4] components

[2] The number of undernourished population in Asia is predicted to increase by 8.3 percent while Latin America as well as Caribbeans combined will rise by almost 7.4 percent in the year 2030 (FAO et al ., 2020).

[3] Food and Agricultural Organization (FAO), International Fund for Agricultural Developmen (IFAD), United Nations Children's Fund (UNICEF), World Food Programme (WFP) and World Health Organization (WHO).

[4] Accessibility of food of encompasses indicators like food prices, income levels and assets of consumers. This is a situation in which a person have enough resouces to obtain a healthy diet.

of food, the utilization[5] components of the available food produced and food stability[6]. Impliedly, food is available for the consumption of citizenry with enough nutrition value and is domestically produced, albeit in the various agricultural sectors (Ericksen et al., 2011).

In the 2020 Global Food Security Index ranking, Ghana is ranked 82nd globally and 4th in Africa, with an aggregate percentage score of 52. In terms of the components of food security, Ghana is ranked 84th in food availability, 74th in food accessibility, 76th in utilization and 110th in natural resources and resilience out of 113 nations worldwide in terms of food security (The Economist, 2021). Despite the upsurge in food crop production, about 5 percent representing 1.2 million Ghanaians, were food insecure in 2015 (NDPC & GSS, 2018). Another report further shows a rise in the number of food-insecure people as the population grows. The findings reported in 2020 that the food-insecure population grew up to 12 percent representing 3.6 million Ghanaians, of which 22 percent (0.8 million) are urban residents and 78 percent (2.8 million) are rural dwellers, which means any unanticipated natural or human-induced shock will largely influence the level of their food security in the country (Peprah, 2020). He further reveals that there is limited information on countrywide data and analysis on food security. In particular, there is an information gap in determining the prevalence of food-insecure people in the country. This leads to inadequate and unstable evidence in formulating the specific food security mitigating policies and programs in Ghana. A robust analysis is needed to enhance policymaking and strategic development planning by government and private sector stakeholders. The five most food-insecure regions include Upper East (48.7 percent), North East (33.0 percent), Northern (30.7 percent), Upper West (22.8 percent) and Savannah 22.6 percent, which are all from the northern zone of Ghana, where agriculture is predominantly rainfed. The northern region remains the poorest due to the severe impact of climate change on rainfed agricultural production (Peprah, 2020).

Given that environmental and climate distractions are already hampering agricultural production and food security in West Africa, where Ghana is located, Ghana is naturally prone to the adverse effects of these global issues (Ray et al., 2019).

[5] Utilization of food entails consumption rate, nutritional level and how the available food are factored into the consumers livelihood.

[6] Food stability measures a situatuation in which there is frequent supply of food quantities at all times (IPCC, 2014).

In simple terms, climate disruptions are already manifesting in Ghana, thereby affecting prominent sectors such as the agricultural, water, energy used and the ecosystem at large (World Bank, 2011). For instance, since the 1990s, there has been a substantial rise in CO2 and GHGs emissions in Ghana. Specifically, CO2 emissions have increased by 24 megatons, which may cause a rise in atmospheric temperature, alter the climate and subsequently change the rainfall patterns (MESTI, 2013). Ghana's rainfall precipitation is predicted to decline by 4 percent by the year 2040. These changes in rainfall tend to be a threat to agricultural food production primarily because only 2 percent of the country's irrigation potentials are utilized (USAID, 2017). Particularly, climate and environmental distractions directly affect traditional agricultural crop productions, enhancing the spread of crop diseases and drastically affecting soil quality and causing soil infertility in the country (Kyei-Mensah, 2017). The changes are estimated to exert a decline in GDP and household consumption by 1.9 percent to 7.2 percent and 5 percent to 10 percent by the year 2050, respectively, in Ghana. These will indirectly impede the nutrition, health, food security and sustainable living standard of communities in Ghana (Kyei-Mensah et al., 2019). For example, in the year 2020, most food-insecure Ghanaians were from the deprived communities in the country. That is about 78 percent representing 2.8 million inhabitants, while the remaining 22 percent (0.8 million) Ghanaians are urban residents. Overall, the number of food-insecure people grew by 7 percent over five years (i.e., from 5 percent in 2015 to 12 percent in 2020). On aggregate, the 12 percent rise represents almost 3.6 million Ghanaians (Peprah, 2020).

The facts mentioned above indicate that food security, environmental and climate issues have become a concern for the Ghanaian stakeholders and international agencies. For instance, incorporating food security and mitigation of climate change in the UN's Sustainable Development Goals (SDGs) 2[7] and

[7] SDG 2 (End famine, food insecurity, malnutrition and sustain agricultural production): By ending hunger or famine, the United Nations aims to make available and ensure the access to enough food all year round to less privilege and marginalized groups in deprived communities worldwide. They also seek to end all types of malnutrition and to achieve minimized stunting and wasting in children under 5 years, girls of adolescent age, old persons and many more. Finally, the UN seeks to increasing agricultural production and per-capita income of small-holder or peasant farmers by securing equal access to land and other productive resources and inputs including non-farming employment and ensuring sustainable food production by adapting to practices which are resilient and adaptive to threats of climate change and environmentally friendly.

13[8], respectively shows how critical the two issues have become today. Thus, understanding the impact of environmental quality and climate change on food security has gradually become relevant. A significant number of academics and nonacademics have examined the relationship between environmental quality, climate change and food security since the middle of the previous century.

1.1.2 Environmental Quality, Climate Change and Economic Growth Trends in Ghana.

Ghana is a sovereign country located in the Western part of Africa. It is a diverse nation of private and public corporations. The service sector is the primary contributor to the country's GDP, followed by the industrial sector as the second contributor and lastly, the agricultural sector. In particular, the overall contributions for all the sectors in the year 2020 are 43 percent, 35 percent and 18 percent, respectively. Over the last five years, the country's aggregate economic growth rose by 5.2 percent, with a GDP per capita of about US$ 5,637 and about 6.1 percent growth in the year 2019. The current population of the country is about 30.4 million, while the current GDP per capita stands at US$ 2, 556.51 a substantial increase from the decline in 2020 (US$ 2,225.51) (O'Neil, 2021).

The Republic of Ghana covers a land area of approximately 238,500 km^2. To the East, Ghana shares borders with Togo, Burkina Faso to the north, to the west is the Ivory Coast and the Gulf of Guinea to the south. Ghana is one of the tropical climate countries in the world, with the West African Monsoon winds playing a significant role in the climate variations of the country. Ghana is blessed with extensive water resources such as the Lake of Volta and Bosomtwi, covering almost 3,275 km^2. Moreover, seasonal and perennial rivers cover about 23,350 km^2. The overall climate of the country is warm with varying temperature. Ghana is noted to have two rainy seasons in most parts of the country, excluding the northern part, which experiences only one rainy

[8] SDG 13 (Take pragmatic actions to fight climate varations and its implications): Countries should reinforce climate resilience capacity to all forms of hazards and disasters, incorporate global targets into national and countywide policies, increase climate sensitization and education and finally, support and promote mechanisms to enhance and build capacities of least developed economies and small island emerging nations on how to effectively and efficiently plan and manage climate associated risk and dangers.

season from May to September. The corresponding dates for the two rainy seasons are from April to July and from September to November (GFDRR, 2011).

Ghana is divided into three climatic basin systems with six agro-ecological[9] areas: the Volta basin system, the Southwestern basin system and the Coastal basin system. The southwestern zone is the most humid area in the country, with average yearly rainfall between 1500 mm and 2000 mm, while the coastal zone experiences the lowest of rainfall (900 mm), thereby making it the driest zone in the country. The volta climate zone has an average annual rainfall of about 1000 mm in the savanna zone and 1500 mm to 2000 mm in the forest regions (MoFAN, 2018). The MoFAN (2018) reports that the lowest average temperature of about 22^{o}C to 25^{o}C occurs in the south, while the highest mean temperature of about 27^{o}C to 30^{o}C occurs in the north. Figure 1 below shows the pictorial illustration of the ecological areas and neighbouring countries of Ghana.

[9] These include Sudan Savannah, Guinea Savannah, Forest-Savannah Transition, Semi-Deciduous Forest, Rain Forest and Coastal Savannah (Owusu-Ansah & Smardon, 2015).

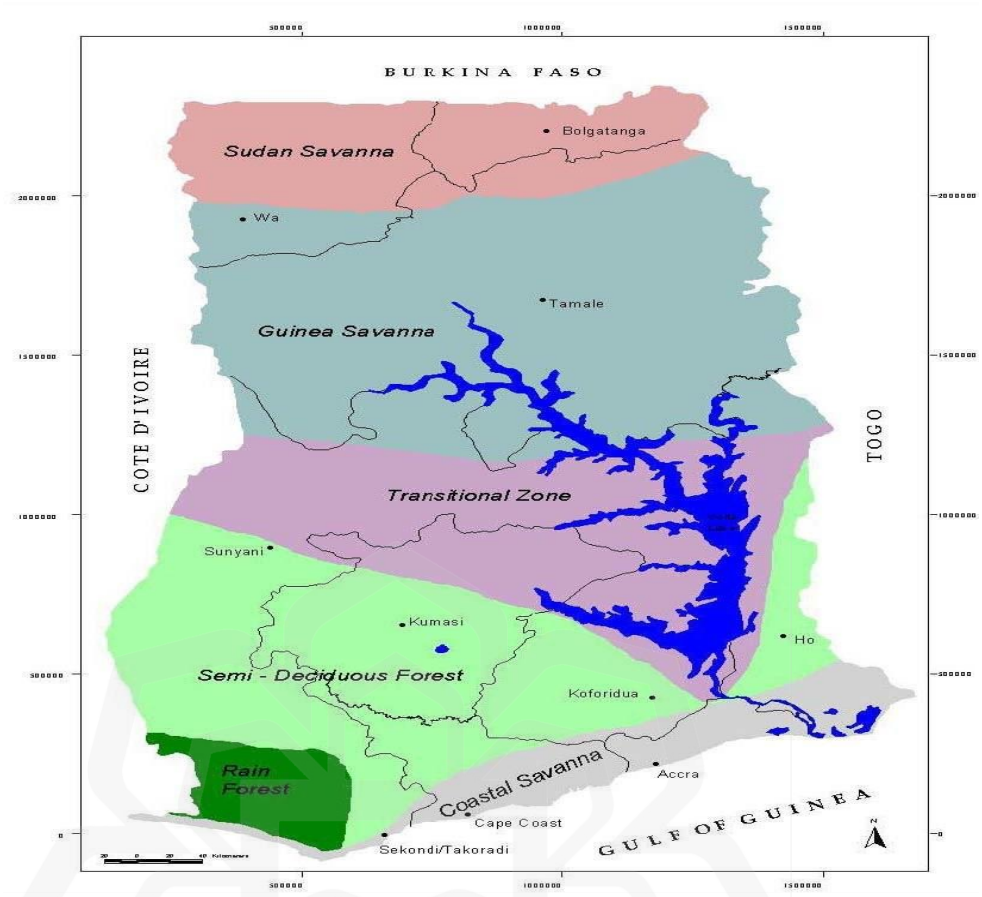

Figure 1: Ecological Areas and Neighbouring Countries of Ghana**.**

Source: Owusu-Ansah & Smardon (2015).

Overall, Ghana experiences its highest temperature in March and the lowest in August. GFDRR (2011) claims that the average annual national temperature will increase by 1ºC to 3ºC by the year 2060 and 1.5ºC to 5.2°C by the year 2090 due to the rise in atmospheric warming and greenhouse effects (GFDRR, 2011). The trend in greenhouse gases in Ghana has increased since the 1990s. In the year 2016, greenhouse gas emissions in Ghana increased to 42.2 Mt CO2e[10], which is a rise of about 66.4 percent (25.34 MtCO2e), 53 percent (27.26 MtCO2e) and 7.1 percent (39.35 MtCO2e) over the years 1990, 2000 and 2012, respectively. The annual aggregate increase in greenhouse gas emissions spanning from 1990 to 2016 (i.e., 26 years) is 2.1 percent. In nominal terms, the yearly rise in greenhouse gases is estimated to be 158.6 percent representing 17.9 Mt CO2e in the year 1990, 101.5 percent (14.7 MtCO2e) in the year

[10] Million tonnes of carbon dioxide equivalent.

2000 and 2.1 percent representing (0.6 MtCO2e) for the year 2012. The AFOLU sector[11] is the major emitter and contributor to Ghana's greenhouse gas emissions, which correspond to about 54.4 percent (22.9 MtCO2e) of the total emissions in the country, followed by the energy sector[12] waste sector[13] and IPPU[14] (EPA, 2019). The EPA (2019) further reveals that carbon dioxide (CO2) emissions are the most emitted greenhouse gas in Ghana; this massive increase in CO2 emissions is due to the immense and rise in activities of the industrial sector, transport and land use, with an average increase of 6.1 percent per year from 2012 to 2016.

According to WHO & UNFCCC (2015) report, higher events of CO2 emissions will induce an estimated increase in yearly average temperature by 4.8^{o}C from the year 1990 to the year 2100 and increase the number of warm spells days from 10 days to 280 days over the same period. The upsurge may alter the number of extreme rainfalls of 20 mm and above by an average of 4 days from the year 1990 to 2100. The total amount of yearly rainfall precipitation in Ghana is around 2000 mm in the southwestern part and the less amount of 1100 mm and 750 mm are witnessed in the north and south-eastern coastal regions, respectively. Rainfall precipitation in the country is considerably associated with interannual changes due to El-Niño incidents causing drier phenomena than regular events (MoFAN, 2018). These induce a decline in the long periods of intense storms, thereby making Ghana susceptible to extreme climate events like heavy rainfall in the southern part and prolonged drought in the country's far north, especially at the beginning of the rainy season (Incoom et al., 2020). USAID (2017) report reveals no clear trend in the current and future rainfall pattern in Ghana, which makes predicting the intensity and extremeness ambiguous[15]. The report further asserts that future annual estimates of rainfall precipitation span from − 3 percent to +7 percent and a total yearly estimate of −15 percent to +16 percent by the year 2100. USAID (2017) again suggests that by the year 2040, the overall rainfall precipitations will have

[11] Agriculture, Forestry and Other Land Use (AFOLU) consists of emissions from livelistock, land use such as convertion of land to crop, grass and forest lands and Aggregate sources and Non-CO2 emissions sources on land.
[12] The sector entails emissions from stationary,transport mobile combustion and fugitive emissions.
[13] This sector is comprised of emisions from Solid Waste Disposal, Biological Treatment of Solid Waste, Incineration and Open Burning of Waste, Wastewater Treatment and Discharge.
[14] Industrial Processes and Product Use (IPPU) sector consists of emissions from Mineral Industry, Metal Industry and Non-Energy Products from Fuels and Solvent Use.
[15] Some studies project an increase in some regions and a decrease followed by a decrease in other reions in the country in the longrun. This is because rainfall seasons are be coming more convergent, rainfall is tipped to increase from July – December and decline from March – June, thereby delying the start date of the wet season in the most vulnerable region in the country (Northern region).

a 4.4 percent downward trend. However, the decrease is more extensive in the southern zone. The country is projected to witness more erratic and intensified rainfall in the wet season, followed by a season with prolonged dry days resulting in lower precipitation.

Based on the projections and estimations on the erratic influence, climate change and environmental degradation[16] have on the Ghanaian economy, concerns on environmental protection and conservation continue to increase. For instance, Ghana, as part of the global community, is committed to focusing on environmental issues and has ratified international conventions and treaties such as the United Nations Framework Convention on Climate Change (UNFCCC) in the year 1992, Kyoto Protocol in the year 2003, UN Convention on Biological Diversity (CBD) and is also committed to enacting the environmental rules and regulations recommended by these agencies (GOG, 2017; WHO & UNFCCC, 2015). Ghana's National Development Strategy, representing the country's long-term goals, focuses on climate change concerns under the "Economic and Social Development" framework (CPESDP). The primary components of the CPESDP are agriculture, energy, water, transport, digitization and rural development. In order to ascertain the main objective of Ghana's long-term development plan on climate change mitigation, the MEP and the MESTI in Ghana rolled out some policy documents. These include the National Climate Change Adaption Strategy and National Action Plan to Combat Drought and Desertification in the year 2012, the Ghana National Climate Change and the National Environment Policy (NEP) in the year 2013. In the year 2015, the Intended Nationally Determined Contribution and National Climate Change Master Plan (2015 to 2020) were developed. These policy documents were developed to recommend and propose strategic policies to mitigate high emissions of greenhouse gases and promote enhanced technologies to control the amount of CO2 emissions by all sectors, food security and water availability in the Ghanaian economy and a road map to achieving the UN sustainable development goals. For instance, as policy initiatives and commitment of the government of Ghana, the "One District, One Dam," "Planting and Rearing for Food and Jobs" and the "Youth in Afforestation and Agriculture" are agricultural-industrialization policies developed to promote and enhance rural development. The principal aim of these policies is to enhance an agricultural development policy that is demand-driven and targets quantity,

[16] CO2 used as envronmental quality represents both positive and negative impact on the environemt, while environmental degradation proxies only negative impact on the ecosystem.

quality and delivery period of farm produce while conserving food sufficiency in the short-run and food security in the medium and long-run (GOG, 2017; USAID, 2017).

The agricultural sector remains one of the backbones of Ghana's economy. It contributes about 18 percent to 20 percent of Ghana's Gross Domestic Product (GDP) and employs approximately 42 percent of the active labour force in the Ghanaian labour market (Essegbey & Maccarthy, 2020; World Bank, 2017). The agricultural sector is predominately conventional, small-scale and rainfed crop and livestock production. It is made up of about 80 percent agricultural production and an average farm size of 1.2 hectares. In general, about 25 percent of the farming population covers a farm size of 1.2 to 2.0 hectares, while 15 percent covers more than 2.0 hectares. Besides, the rates of poverty in these farming communities surpass the national rate, thereby making peasant farming and other small agro-businesses activities the primary source of livelihood to households in Ghana's rural areas. Agricultural farming activities in the country differ according to the climate regions. The south and middle regions cultivate major tree crops like cocoa, oil palm and other staples food crops like maize, yam, plantain, cocoyam, cassava and many more. The northern part of Ghana majors in staple food croppings like maize, millet, cowpeas, groundnuts, yam and rice as well as the livestock subsector (cattle, goats, sheep, pigs and poultry). Other subsectors of the agricultural sector include fisheries (marine, inland and aquaculture fisheries) and the forestry subsector (Essegbey & Maccarthy, 2020).

Climate variability presents a great threat to the food and livestock production system, which inherently affects food crop production and availability, thereby compromising livelihood and food security in Ghana (Adu et al., 2018). Because of the adverse impacts of climate change on agricultural production, farmers switch farming systems to mitigate climate influence and enhance agricultural production. Particularly, farmers are likely to switch from highly susceptible farming systems to farming systems that are less vulnerable to climate variability over time. The most practice farming systems include food-crop, tree-crop, livestock and the combination of either two or all three known as the “mixed farming.” The corresponding percentages of the various farming systems are 17 percent, 24 percent, 8 percent and 51 percent, respectively (Adu et al., 2018). Moreover, every agricultural product grows under unique climate conditions. A suboptimal climate condition for food crops serves as the ideal climate condition for tree crops. Thus, farmers will move from food-crop production to tree-