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# CARBON FOOTPRINTS & GLOBAL CLIMATE CHANGE IN RELATIONSHIP TO PUBLIC HEALTH & LOCAL ECONOMIC EFFECTS.

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## ABSTRACT

Carbon footprints of individuals and organizations around the globe are fueling the current climate change trend leading to enormous negative effects on human health and the economy. The carbon generated by humans and their activities are heating the earth unsustainable and the evidence is well established in the literature. The impacts of human carbon footprints induced climate change on health and the economy are been published widely in the literature. This review succinctly x-rayed the impact of human carbon footprints on public health and the economy within the African context. The relationship between carbon footprint and public health was conceptualized as continuous cyclic interaction, continuously bringing woes to mankind. Carbon footprint impact on public health was presented to be in two ways – directly or indirectly. The direct impact of carbon footprints on public health was explored under five (5) thematic areas, which are: impact on extreme weather events (hurricanes, storms, and floods), impacts on temperature, impacts to air pollution, impacts to water- and foodborne diseases, and impacts to vector and rodent-borne diseases. The impact of a carbon footprint on the economy was seen as an indirect impact on humans and a huge change in human lives. It is recommended that carbon footprints should be calculated at every level individual, organization, process, product, national and continental; to drive accountability to the environment by all and for all.

**Keywords:** *Carbon footprint, Climate penalty, Climate change, Public health, Economy*

## INTRODUCTION

Carbon footprints of individuals and organizations around the globe are fueling the current climate change trend leading to human health and economic impacts. Carbon footprint is the quantity of Green House Gases (GHGs) expressed in terms of $CO_2$ and methane emitted into the atmosphere by an individual, organization, process, product, or event from within a specified boundary (Pandey and Pandey, 2011). Although industrial activities in terms of oil and gas exploration, factory production, large-scale land cultivation, and a host of others contribute majorly to carbon-containing gases greenhouse gases like carbon dioxide and methane. As a result of human activities, every individual, organization, product, or process contributes its quota of the global carbon footprint. This may range from simple breathing to heavy carbon-contributing activities like dependency on fossil fuels for cooking, transportation, and other individual product, process, or organizational needs. According to Ascui (2014), carbon footprint measurements help to bring in the concept of accountability to every individual, product, process, or organization as carbon footprint accounting can be carried out at a variety of levels (national, per person, product, and services).

Why carbon footprints should be of great concern to us as individuals, organizations, nations, or as a continent? Greenhouse gases (GHGs) are not in themselves bad, however, they occur naturally, providing vital services of trapping heat from escaping the earth to keep the atmosphere warm enough to sustain life (Kweku *et al*., 2018; Chilingar *et al*., 2009). However, the problem results when these GHGs are excessively released into the atmosphere beyond the sustainability level. The result will now be an earth's atmosphere that is warmer than the normal atmospheric temperature. The warmer temperature would translate into melting of the sea ice which would affect sea level rise thereby resulting in flooding in low land and coastal plains. Succinctly, authorities have established those human activities that produced GHGs are the major drivers of the current climate change trend by the Intergovernmental Panel on Climate Change (IPCC) (Stocker *et al*., 2013). Currently, human activities are still heavily dependent on burning fossil fuels to meet energy needs. Fossil fuel utilization and cement manufacturing alone have been estimated to have accounted for over 60% GHGs in the atmosphere (Olubusoye and Musa, 2020). Although a host of other clean energy sources have successfully been established and are in use, they are no match to fossil fuels in terms of cost and availability.

Collective carbon footprints heat the planet earth at an unsustainable rate. The IPCC's fifth assessment report warned that this current carbon trend could lead to an increase of 2.6-4.8$^0$C in the global temperature by 2100 (Scott *et al*., 2016). According to the report, there was an increase in the land surface temperature of 0.5$^0$C or more at least in the last 50 – 100 years and a corresponding global mean sea level rise by at least 19 cm between 1900 and 2010 in most African countries. Beyond sea level rise which brings in the risk of flooding, climate change largely induced by carbon footprints has brought enormous negative impacts on human health and economic activities. This review was aimed at x-raying the various ways carbon footprint-induced climate change and its effect on public health and the economy, particularly in the African context.

### Carbon Footprints and Public Health

Carbon footprints of individuals, communities, and organizations around the world have significantly influenced the current climate change trend which has in turn brought enormous impacts on public health and safety globally. This relationship can be termed a cyclic chain reaction (Figure 1) where the people affected by climate change-induced health challenges are more likely to visit health care has its significant carbon footprint (Malik *et al.*, 2018). Bi and Hansen (2018) described the relationship between carbon emissions and public health as ‘an inverse association’ due to the way flow of continuous interaction. In public health care, hospital buildings are specialized facilities that require intensive energy for purposes ranging from constant basic lighting and ventilation to the use of energy-intensive equipment and the need for the temperature to be controlled for 24 hours per day. The hospital’s high carbon footprint may also be a result of its high consumption of resources and production of large waste products. The pharmaceuticals sector of public health care is another high contributor to direct $CO_2$ emissions (Malik *et al.*, 2018). Public health care's carbon footprint contribution to climate change is well-established in several countries (Eckel man & Sherman, 2016).

Although no such national carbon footprint ($CO_2$ emissions) study on health care has been done to date in Nigeria; one can have a clue of the extent of the carbon footprint contribution of the nation’s health care system from that of other countries. United States health care in 2008 contributed 8% to that of the country’s entire carbon footprint (Chung & Meltzer, 2009), which was updated in 2016 to 10% (Eckelman & Sherman, 2016). Whereas in 2012, England reported a more modest 4% of their $CO_2$ emissions is attributed to health care ( Malik *et al*., 2018). Australia’s healthcare carbon footprint alone is 7% of the national carbon footprint (Malik *et al*., 2018). This implies that public health especially the health care component involving health facilities and pharmaceuticals is contributing enormously to the carbon footprint thereby impacting climate change which in turn affects public health.

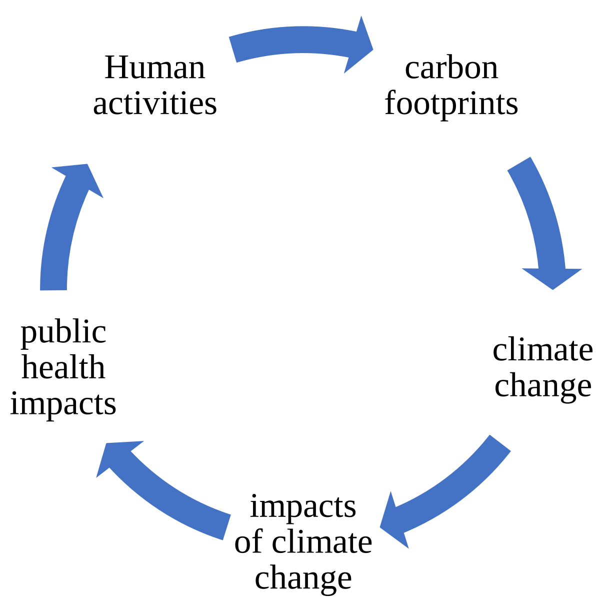


**Figure 1**: showing the cyclic continuous flow of interaction between climate change and public health

Figure 1 aptly illustrates the cyclic continuous flow of climate change and public health interactions. An Individual's or organization's contribution of $CO_2$ and other GHGs emissions to the environment is a function of the individual or organization's carbon footprint. Human activities that contribute to carbon footprint can range from as simple as breathing, and cooking to more massive industrial activities like farming, exploration of fossil fuel and other energy sources, waste disposal, industrial processing, and transportation. Collective carbon footprints of humans worldwide have been reported to be responsible for the current trend of climate change (Smith *et al*., 2014.). Climate change, in turn, has brought an untold number of changes that have made man's adaption to the planet increasingly challenging thereby leading to various disease outbreaks and other health conditions from climatic conditions and natural disasters, especially weather-related extreme events. For example, an estimated 500000 people with severe dengue require hospitalization each year, a large proportion of whom are children (Suaya *et al*., 2009). This will no doubt lead to more demand on the public health care system like the hospitals and pharmaceuticals which are well-established contributors to national and global carbon footprints, thereby leading to climate change. Healthy individuals after receiving healthcare are active contributors to the carbon footprint.

Direct (from energy used within an economic sector, e.g., on-site natural gas use) and indirect (electricity generation elsewhere, plastics and drug manufacture) emissions of carbon are two major classes of carbon footprint. Similarly, climate change's impact on public health can be direct or indirect.

**Direct Impacts of Climate Change on Public Health**

Humans depend directly on the environment for food and shelter. Climate change has led to changes in atmospheric conditions like rainfall, and temperature increase which has led to sea level rise and others which has affected human health and safety directly. The health sector component of the first U.S. National Assessment, published in 2000 (Patz *et al*., 2001), captured the direct impact of climate variability and change attributed to public health under five categories which are the impact of extreme weather events (hurricanes, storms, and floods ), impacts to temperature, impacts to air pollution, impacts to water- and foodborne diseases, and impacts to vector- and rodent-borne diseases.

**Public health effects of climate change related to extreme weather events**

Weather-related extreme events are not just increasing in frequency but also increasing in intensity thereby leading to a huge impact on public health in terms of poor health conditions and deaths. A twenty years global review of natural disasters revealed that an overwhelming majority of the disasters (90%) are caused by weather-related events like floods, storms, hurricanes, and others which claimed 606,000 lives with an additional 4.1 billion people injured, left homeless, or in need of emergency assistance (CRED and UNISDR, 2015). Captured in this data is the 2012 flooding disaster episode in Nigeria due to increased rainfall intensity causing the River Niger and River Benue to overflow leading to the loss of 363 people lives, 5,851 injured, 3,891,314 affected, and 3, 871, 53 displaced (FRN, 2012).

Carbon footprint-induced climate change has been implicated in the current occurrences of natural hazards especially weather-related extreme events like flooding, hurricane, wildfire, heat wave, and other natural disasters. The IPCC stated that a changing climate leads to changes in the frequency, intensity, spatial extent, duration, timing of extreme weather, climate events, unprecedented extreme weather, and climate events (Scott *et al*., 2016). Anderson and

Baruch (2006) posited that human activities will drive more climate change and more extreme weather events. Therefore, any hope of reducing the increase in natural hazards lies in humans putting a hurt to environmental exploitation. Raven and Wagner (2021) argued that even if all humans make the needed commitment to the international climate agreement miraculously it will take a long time before any noticeable effect on the current climate change trend and then on natural hazards occurrence.

**Public health effects of climate change related to temperature**

Global warming is real as evident in higher global average land and ocean surface temperatures, higher rates of ice melting, rising global mean sea levels, higher atmospheric concentrations of greenhouse gases, and "extremely likely" traceable to carbon footprints (IPCC, 2013). Extreme heat events like heat waves have been linked to higher mortality, especially in relationship with respiratory and cardiovascular diseases (Lin *et al*., 2009). Berko (2014) reported that from 2006 to 2010 deaths attributed to heat, cold, and other weather events in the United States revealed that heat is among the deadliest weather-related phenomena in the US, killing more Americans in a typical year than floods, lightning, and storms combined.

The 5$^{th}$ Assessment Report of IPCC (2013) established that over the past 100 years the global temperature has increased by about 1.5 $^{0}$F and it has been projected that it could rise by an additional 2 $^{0}$F by mid-century due to climate change. This present fear not just for extreme heat which has been the focus of major studies but also for moderate heat which by definition occurs more often than extreme heat. Due to the frequency of moderate heat increase across the globe, it would have been having far-reaching health impacts. An increase in moderate temperature has been attributed to the following health conditions - cardiovascular disease, respiratory disease, mental, and nervous systems disorders, diabetes, and kidney and urinary system diseases (IPCC, 2013; Basagan *et al*., 2011). Extreme heat can harm persons who are already sick from other causes. Heat may affect these frail individuals differently depending on the disease. Knowing which patients are more vulnerable could help improve the preparedness of the health system for primary and secondary prevention during heat waves.

**Public health effects of climate change related to air pollution**

Carbon footprints induced climate change is projected to have negative impacts on public health through an increase in ground-level ozone and/or particulate matter air pollution in some locations. Although some small amount of ozone does occur naturally from plants and soil as well as from the stratosphere in terms of downward migration; none of these sources contribute enough ozone to be considered a threat to the health of humans or the environment. Unlike other air pollutants, ground-level ozone is not released directly into the air. They are formed as a result of chemical interactions between sunlight and pollutants including nitrogen oxides ($NO_X$) and volatile organic compounds (VOCs). Although some other natural sources like vegetation and wildfire emissions could lead to ground-level ozone formation, the majority of the ground-level ozone comes from human sources like vehicle exhaust and emissions from factories, power plants, and refineries. Even if humans reduce their activities to reduce ground level, changes in climatic conditions which are precursors to ground-level ozone formations will continue to yield more ground-level ozone. This concept is called the 'climate penalty' (Jacob & Winner, 2009; Wu *et al*., 2008; Fu, & Tian, 2019). The major climatic precursors to the ground-level ozone level are air temperatures, humidity, cloud cover, precipitation, wind trajectories, and the amount of vertical mixing in the atmosphere. Kim *et al*. (2016) explained that higher temperatures can increase the chemical rates at which ozone is formed and increase ozone precursor emissions from anthropogenic and biogenic (vegetative) sources. And also, lower relative humidity reduces cloud cover and rainfall, promoting the formation of ozone and extending ozone lifetime in the atmosphere.

Ground-level ozone affects human health through diminished lung function, increased hospital admissions, emergency room visits for asthma, and increases in premature deaths. Ground-level ozone air pollution irritates the respiratory system thereby having a higher potential to worsen health outcomes for asthmatic patients. Populations exposed to ozone air pollution are at greater risk of dying prematurely, being admitted to the hospital for respiratory hospital admissions, being admitted to the emergency department, and suffering from aggravated asthma, among other impacts (Jerret *et al*., 2009; USEPA, 2013; Bell, 2004).

Other than ground-level ozone there are other air pollutions induced by carbon footprints. Fine particle pollution has also been linked to even greater health consequences through harmful cardiovascular and respiratory effects. A changing climate can also influence the level of aeroallergens such as pollen, which in turn adversely affect human health (Beggs 2004). Rising levels of $CO_2$ increase the severity and prevalence of allergic diseases in humans. Higher pollen concentrations and longer pollen seasons can increase allergic sensitization and asthma episodes and thereby limit productivity at work and school (D'Amato *et al*., 2020 ).

**Public health effects of climate change attributable to vector and rodent-borne diseases**

Changes in precipitation and temperature could lead to the spread, introduction, or reestablishment of waterborne illnesses and vector-borne diseases. Vector-borne diseases continue to contribute significantly to the global burden of disease and cause epidemics that disrupt health security and cause wider socioeconomic impacts around the world. All are sensitive in different ways to weather and climate conditions so the ongoing trends of increasing temperature and more variable weather threaten to undermine recent global progress against these diseases. Vector-borne diseases are among the best well-studied diseases associated with climate change, owing to their large disease burden, widespread occurrence, and high sensitivity to climatic factors. In contrast to some other climate-sensitive health risks, such as heat stress, or exposure to storms and floods, the influence of meteorological factors is less direct, and more diverse, both within and between individual diseases (Smith *et al*., 2014). According to Campbell-Lendrum *et al*. (2015), the simplest connections are through temperature, affecting the biting, survival, and reproductive rates of the vectors, and the survival and development rates of the pathogens that they carry. Precipitation also exerts a very strong influence, most obviously in the case of diseases transmitted by vectors that have aquatic developmental stages (such as mosquitoes), but also, via humidity, on diseases transmitted by vectors without such stages, such as ticks or sandflies.

Consequently, placing vector-borne diseases into perspective, the World Health Organization, WHO (2008) established that one-sixth of the illness and disabilities suffered worldwide as a result of vector-borne diseases, with more than half of the world's population currently at risk. Annually, more than one billion people are infected, and more than one million people die from vector-borne diseases, including malaria, dengue, schistosomiasis, leishmaniasis, Chagas disease, and African trypanosomiasis (WHO, 2014 ). More worrisome is the fact that previously relatively stable geographical distributions are now changing owing to human activity ranging from 'intensive farming, dams, irrigation, deforestation, population movements, rapid unplanned urbanization, and phenomenal increases in international travel and trade' (WHO, 2014).

Similarly, rodent-borne diseases are also affected by climate change in the same manner as vector-borne diseases. Clegg (2009) pointed out that climate change-induced environmental alterations have the potential to affect the three factors that make infectious diseases possible; (i) changes in abundance, virulence, or transmissibility of infectious agents, (ii) an increase in the probability of exposure of humans and (iii) an increase in the susceptibility of humans to infection and the consequences of infection. As regards the population of rodents, while drought can lead to a reduced rodents population, high precipitation, on the other hand, can increase their population thereby increasing the possible risk of interacting with humans to cause infections. For instance, concerning Lassa fever in Africa, Fichet-Calvet and Rogers (2009) reported that the 1951 to 1989 period study of the distribution of human Lassa fever outbreaks and cases revealed that areas of medium risk had an annual rainfall in the range of 1200-1500 mm, whereas rainfall in the range of 1500-3000 mm was associated with a high risk of disease. Therefore, high precipitation appears to be a major risk factor in the incidence of Lassa fever.

**Public health effects related to water and foodborne diseases**

Just like vector and rodent-borne diseases the current rate of precipitation is a key driver of water and foodborne diseases. In addition to precipitation, temperature rise could influence the replication cycles of most food- and waterborne pathogens as well as influence human adaptive behaviors that could lead to more exposure of food and water sources to contamination. Semenza *et al*. (2012) conducted about 11-year-period meta-analysis (1998-2009) on the effect of climate change on water- and foodborne diseases. Semenza *et al*. (2012) found that the risk of campylobacteriosis is associated with mean weekly temperatures, although this link is shown more strongly in the literature relating to salmonellosis. Irregular and severe rain events are associated with *Cryptosporidium* sp. outbreaks, while noncholera *Vibrio* sp. displays increased growth rates in coastal waters during hot summers. In contrast, for Norovirus and *Listeria* sp. the association with climatic variables was relatively weak but much stronger for food determinants. It can be concluded that the current climate change conditions in terms of temperature rise and high precipitations will continue to influence water and foodborne diseases if urgent measures are not taken to reduce the current trend of carbon footprints.

**Economic impact as indirect impact of a carbon footprint on humans**

Today, most global production relies heavily on energy produced from burning fossil fuels which emit carbon dioxide as a byproduct. Although over recent decades carbon-free energy sources such as wind and solar have greatly increased, there still exists an enormous challenge in decarbonizing our electricity, especially concerning the transportation and industrial sectors (Faehn *et al*., 2020). Because of the foregoing, the carbon footprint threshold of economic activity will continue to dominate our climate throughout the 21st century. The resulting carbon emissions in interaction with climatic factors will continue to warm the earth unsustainable. As pointed out earlier in this review, even if current carbon footprints reduce drastically due to a successful global shift from carbon fossil fuel to a cleaner energy source, the concept of climate penalty where the current climatic conditions would interact with the already release carbon and other environmental pollutants to produce products like ground-level ozone that would still be warming the earth. This self-sustaining system may endure for a long time before the effect of carbon footprint emissions could be seen.

There is no gainsaying that global warming influenced by carbon footprints is harming welfare and diminishing economic productivity. There are several ways in which climate change is affecting the per capita productivity which can be termed as the life wire of the economy. One way the economy is impacted negatively is through reduced per-capita productivity by the diversion of resources into adaptation measures and production and adoption of more expensive carbon-free energy technologies (Caldeira & Brown, 2019). The economic impact of such adaptation measures and the adoption of carbon-free energy technologies is especially enormous for developing countries. Although developing countries have been made to believe that the adoption of carbon-free technologies and adaptations will make them overcome their current developmental challenges and reduce their carbon emissions which are expected to overtake that of developed countries with time, this would lead to unsustainable economic loss if appropriate assistance is not given. Using India as a case study, Parikh and Krishnamurthy (2007) examined the consequences of various carbon emission mitigation measures on economic development and, in particular, the implications for the poor by empirically implementing an economy-wide model for over 35 years. The study found that carbon dioxide ($CO_2$) emission reduction imposes costs in terms of lower Gross Domestic Product (GDP) and higher poverty. The effects of environmental constraints are found to be virtually equivalent to a major oil shock, lending credence to the belief that constraining carbon emissions of developing countries without providing adequate compensation imposes large costs on these economies and denies them access to legitimate avenues of development. Another interesting finding of the study was that the effect of increased population growth rates on the carbon emission profile is found to be not as large as surmised. This implies raising a false alarm to get these developing countries to adopt carbon-free technologies and adaptation measures that will adversely affect the economy of the countries.

The Environmental Kuznets Curve hypothesis (EKC) may help to provide some insights into the relationship between economic growth and carbon emissions (Purcel, 20202). This hypothesis is of the view that economic growth and carbon footprints are an inverted-U relationship. This means that as economic growth increases, the level of carbon emissions increases but when a certain level of economic growth is reached, the level of carbon emissions will decline. Aye & Edoja (2017) explained that during the early stage of economic growth, the economy relies on poor technology that degrades the environment through carbon emissions. When the economy rises to a high-income level, it can now afford new and improved technology, most especially the ones that rely on carbon-free energy sources. Using this hypothesis would help developing countries in Africa to decide when to make the quantum leap to carbon-free energy sources or ascertain what assistance is needed to adopt carbon-free energy sources. A study (Olubusoye,2020) examined the EKC hypothesis in 43 African countries pooled into 3 income groups from 1980–2016. This result shows that carbon emissions increase as economic growth increases in 79% of the countries while economic growth will lead to lower carbon emissions in only a few countries (21%). The study concludes that an increase in economic growth will induce higher emissions in most countries in Africa.

Secondly, labour productivity reduces under high-temperature conditions (Sudarshan, 2015; Zivin & Neidell, 2014). Also, due to the loss of infrastructure associated with both mean changes, for example, the sea level rise has brought enormous flooding that has led to the loss of economic goods and infrastructures (Ranger *et al*., 2011 ). Natural hazards especially weather-related extreme events like hurricanes, heat waves, tsunamis, and others have led to enormous economic loss. Aside from the direct economic loss from natural disasters, the interruption of economic activities and funds for the rehabilitation of devasted regions place a heavy weight on any national economy. Disease outbreaks from vector and rodent bore as well as from water and foodborne diseases lead to huge economic loss.

Another area climate change affects the economy is due to decreases in agricultural yields. Studies have established that the current climate change trend is affecting agricultural yields (Lobell *et al*., 2011; Schlenker and Roberts, 2009). Agricultural activities rely directly on climatic factors – temperature, precipitation, and soil nutrients. Extreme weather-related events like floods and drought affect crop and animal production leading to economic loss.

## CONCLUSION

From the literature, it is evident that carbon footprints at all levels - individuals, products, processes, nations, and continents – are cumulatively warming the planet earth with deleterious effects on human health and the economy. The relationship between carbon footprint and public health was conceptualized as continuous cyclic interaction, continuously bringing woes to mankind. Carbon footprint impact on public health was presented to be in two ways – directly or indirectly.

The carbon footprints induced climate change has had significant impacts on the economy. This range from heat-induced low productivity, poor agricultural yields, extreme weather events, and devastation to economic loss due to carbon-free energy sources adoption or carbon reduction measures. In conclusion, carbon footprints from all spheres of human life and activities are impacting negatively public health and the economy.

## RECOMMENDATIONS

Based on the conclusion, the following are therefore recommended:

1. Carbon footprints should be calculated by independent research organizations at every level in Africa – individual, organization, sector, process, product, national, and continental to drive accountability to the environment by all and for all.
2. There are need for continued research works by the relevant continental, national and sub-national organizations to establish the impact of carbon footprints on every aspect of human health and economy.
3. Government and Civil society organizations should utilize carbon footprint estimations under their scope of coverage to demand effective carbon accountability and mitigation measures.
4. National governments in Africa should balance the economic implications of a carbon-free technology or approaches before signing into its adoption in international conventions
5. Both at the continental, national and sub-national state levels, there should be an organized interval of conventions by relevant stakeholders to ascertain the current carbon footprint level against the established bench for a sustainable environment and economic prosperity.

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