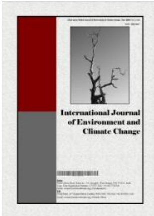

International Journal of Environment and Climate Change

10(2): 70-80, 2020; Article no.IJECC.54534
ISSN: 2581-8627
(Past name: British Journal of Environment & Climate Change, Past ISSN: 2231–4784)

Climate Change: Global Indicators, Socio-economic Implications and Mitigation

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Authors' contributions

This work was carried out in collaboration among all authors. Authors DEA and GUC designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author MUI managed the analyses of the study. Authors DEA and FCA managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJECC/2020/v10i230182
Editor(s):
(1) Dr. Arjun B. Chhetri, Dalhousie University, Canada.
Reviewers:
(1) Agu Eensaar, Tallinn University of Applied Sciences, Estonia.
(2) Aloysius Ezeabasili, Nigeria.
(3) Fotios Chatzitheodoridis, University of Western Macedonia, Greece.
Complete Peer review History: http://www.sdiarticle4.com/review-history/54534

Review Article

Received 10 December 2019
Accepted 16 February 2020
Published 05 March 2020

ABSTRACT

Climate change which is the variation in the climate condition over comparable periods has some indicators like surface temperature, atmospheric carbon and greenhouse gases (GHGs) and ozone layer area. This paper seeks to examine the state of the climate change indicators, their effects and how climate change can be mitigated. A review of data sources and literature reveal that global average temperature has increased more than 0.8ºC above the pre-industrial baseline over the past 100 years with 2016 and 2017 being the warmest years. Fossil carbon emissions also reached up to 41.5 billion tons in 2018. The extent of depletion of the ozone reduced to an area of 24.8×10^6 km^2 in 2018 as against its value of 28.2×10^6 km^2 and 29.6×10^6 km^2 in 2015 and 2006 respectively. The effects of climate change on the socio-economic development were identified to include; natural disasters, food insecurity, diseases, human mobility and population displacement. To mitigate the adverse effects of climate change, minimizing our dependence on petroleum and fossil fuels by using cleaner and renewable energy sources, carbon capture and sequestration, proper management of land, forest and the entire ecosystem was highlighted. If these options are explored, climate change will drastically reduce while fostering global economic, environmental and social well-being.

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Keywords: Climate change; indicators; emission; ozone; carbon.

1. INTRODUCTION

Climate is the average state of the atmosphere for a given time scale and a geographical region [1]. This implies that for the state of the climate to be ascertained in a particular geographical region, the average state statistics for a given time scale including all deviations from the mean are obtained from the ensemble of conditions recorded for many occurrences for the specified period. This time scale, however, ranges from hours to millennia [2].

The climate of the atmosphere is jointly determined by the five components in the geophysical system namely; the atmosphere, ocean, land surface, ice and snow surfaces and the biosphere (both terrestrial and marine). Nonetheless, there are other factors which are also variable that determine the nature of climate. They are referred to as external forcing factors and they include the sun, earth orbital parameters, land-ocean distribution, earth topography and the basic composition of the atmosphere and ocean. Climate change is therefore defined as the variation of the climatic condition which is attributed directly or indirectly to human activity which in addition to natural climate variability is observed over comparable periods [1].

Scientists actively work to understand past and future climate by using observations and theoretical models. A climate record-extending deep into the Earth's past — has been assembled, and continues to be built up, based on geological evidence from borehole temperature profiles, cores removed from deep accumulations of ice, floral and faunal records, glacial and periglacial processes, stable-isotope and other analyses of sediment layers, and records of past sea levels [3]. Majority of these climate scientists agree that human activities, especially the burning of fossil fuels (coal, oil, and gas), are responsible for most of the climate change currently being observed [4].

Global warming which is defined as the gradual increase in the average temperature of earth's atmosphere and oceans is closely associated with climate change especially as a co-traveller in the interplay of the equilibrium between the natural and man-made components of the Green House Gases (GHGs). The emission of GHGs is due to the burning of fossil fuels (oils, natural gas, coal), burning of wood, wood products and solid wastes, raising of livestock, decomposition of organic wastes in solid wastes landfills; combustion of solid wastes and fossil fuels in industrial and agricultural activities; bush burning; and deforestation [5].

The greenhouse gases are both natural and artificial. The natural ones are water vapour, carbon (iv) oxide, methane and nitrous oxide while the artificial GHGs include; the chlorofluorocarbons (CFCs), sulfur hexane fluoride-(SF6), hydro-fluorocarbons-(HFCs) and perfluorocarbons (PFCs). The mam-made GHGs outweighs the natural GHGs which causes an imbalance between the natural and artificial GHGs leading to the warming of both the atmosphere and the oceans [3].

2. CLIMATE CHANGE INDICATORS

Climate change indicators are useful for various specific, technical and scientific purposes. Identifying a subset of the key indicators that capture the components of the climate system and their essential changing behaviour comprehensively helps us to understand easily the changes in the parameter of the climate system. The world meteorological Organization (WMO) has drawn from the fifty-five global climate observing systems (GCOS), seven states of the climate indicators which include; surface temperature, ocean heat, atmospheric carbon(iv)oxide (CO_2), ocean acidification, sea level, glaciers, arctic and Antarctic sea-ice extent [6].

However, additional indicators are usually addressed to allow a more detailed picture in the respective domain. They include (but not limited to) precipitation, greenhouse gases (GHGs) other than CO_2, snow cover, ice sheet, extreme events and climate impacts [7]. This paper examines the global state of some of the indicators; surface temperature, greenhouse gas emission and ozone depletion.

2.1 Surface Temperature

Global temperature is usually considered concerning a baseline. The difference in temperature from the average of the baseline is termed an anomaly and is used in making inference(s) on the state of the climate. Temperature anomalies are representative of much wider areas though actual temperatures can vary greatly over short distances. Averaged over a month, coherent areas of above-or-below-average temperature anomalies can extend to thousands of kilometres [6].

The baseline for considering temperature anomalies in this study is the pre-industrial period (1850-1900) as adopted by the Intergovernmental Panel on Climate Change (IPCC) report which is also in tandem to the Paris agreement which limits global warming to 1.5ºC or 2ºC above pre-industrial conditions [8-9].

Data sets from temperature measurements made at weather stations over land and by ships and buoys on the oceans combined with statistical methods were used ascertain the global temperature anomalies as reported by the World Meteorological Organization. The global surface air temperature anomaly is as shown in Fig. 1. Fig. 2 shows the global mean temperature anomalies in 2018 concerning the pre-industrial baseline for five different data sets called HadCrut, NOAA global Temp, GISTEMP, ERA-Interim and JRA-55. These data sets were respectively obtained from; the UK meteorological office Hardley Centre and Climatic Research Unit at the University of East Anglia [10], National Oceanic and Atmospheric Administration (NOAA), National Aeronautics and Space Administration Goddard Institute for Space Studies (NASAGIS), European Centre for Medium-Range weather forecasts (ECMWF) and Japan Meteorological Agency (JMA).

From the IPCC report on the global warming of 1.5ºC, the average global temperature for the periods; 2006-2015, 2009-2018, 2014-2018 were 0.86ºC, 0.93±0.07ºC and 1.04±0.09ºC respectively above the pre-industrial baseline [6]. This implies that the earth’s average temperature has increased more than 0.8ºC over the past 100 years with much of the increase taking place in the last 35 years. This temperature increase is significant when considered as a permanent increase averaged across the entire planet [4]. From the foregoing, 2015-2018 were the four warmest years in the global temperature record, 2016 and 2017 being the warmest.

From Fig. 2, annul average temperature exceeded 2ºC over the arctic just as areas extending across Europe, parts of North Africa, the Middle East and Southern Asia, South-Western United States, Eastern parts of Australia were exceptionally warm. Conversely, some parts of North America and Greenland, Central Asia, Western parts of North Africa, Parts of East Africa, Coastal Areas of Western Australia were cooler than average.

2.2 Green House Gases (GHGs) and Ozone

Greenhouse gases are good absorbers of heat radiation coming from the earth surface and act as a blanket over the earth's atmosphere thereby keeping it warmer than it will be [5]. Some GHGs occur naturally in the earth's atmosphere. For instance, CO_2 is produced and consumed in many natural processes that are part of the carbon cycle [4].

However, human activities like burning of fossil fuels, deforestation and industrialization release additional CO_2 to the atmosphere much more rapidly than the natural carbon cycle [11,12]. Methane and Nitrous oxide has also increased due to human activities. Certain industrial chemicals like the chlorofluorocarbons (CFCs) act as potent greenhouse gases and they are long-lived in the atmosphere [6]. GHGs concentration has increased in the atmosphere and they are the drivers to climate change. Fig. 3 (a,b) shows the GHG concentration over the years.

In 2017, the globally averaged molar fractions of CO_2, CH_4 and NO_2 are 405.5±0.1 part per million (ppm), 1859±2 parts per billion (ppb), 329.9±0.1 ppb respectively. These values also constitute 146%, 257% and 120% respectively of pre-industrial levels with CO_2 emission growing at the rate of 1.5% per year from 2008- 2017 [13].

The global carbon budget quantifies; the input of CO_2 to the atmosphere by emissions from human activities, the growth rate of atmospheric CO_2 concentration and the resulting changes in the storage of carbon in the land and ocean reservoirs in response to increasing atmospheric CO_2 levels, climate change and variability and other anthropogenic and natural changes [11, 14]. Fossil CO_2 emissions have grown continuously for the past two centuries and emissions to date continued to grow at 1.6% and 2.0% in 2017 and 2018 respectively with an average emission of 41.5±3.0 billion tons in 2018. On the other hand, land use and land cover emissions were on the average 2.0±2.6 billion tonnes per year over the past decade [13]. Fig. 4 shows the surface average atmospheric CO_2 concentration.

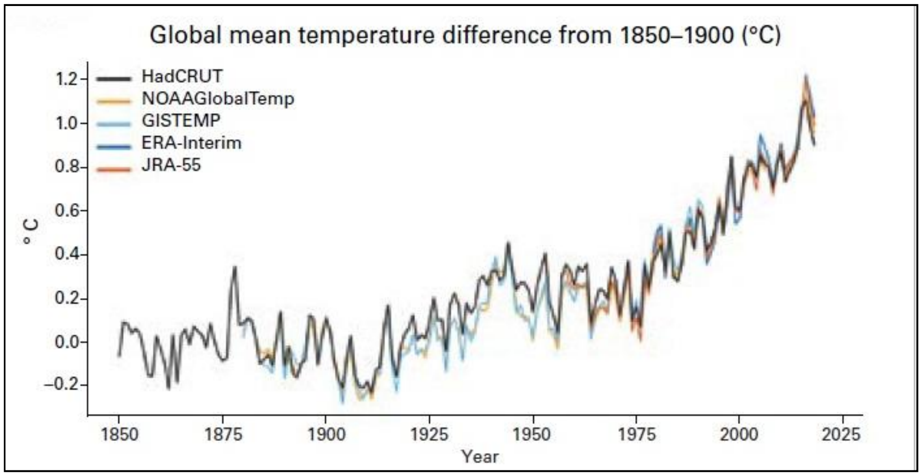

Fig. 1. Global mean temperature anomalies concerning the 1850–1900 baseline for the five global temperature datasets [6]

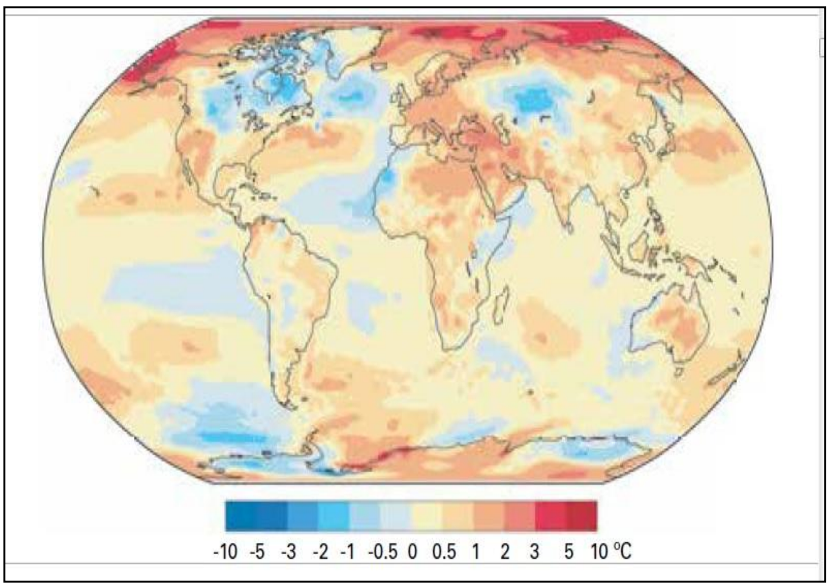

Fig. 2. Surface-air temperature anomaly for 2018 concerning the 1981–2010 average [6]

Halons and CFCs present in the atmosphere destroy the ozone at certain altitudes in Antarctica. The ozone hole size varies as the years go by and is to a large extent governed by meteorological conditions [15]. Fig. 5 shows the size of the ozone hole from 1979 to 2018 based on data from NASA's ozone monitoring instruments and total ozone mapping spectrometer.

In 2008, ozone depletion started relatively in the early months and remained above the long term average until about mid-November. Consequently, the ozone hole area reached its maximum for 2018 in September with an area of $24.8x10^6$ km^2 [6].

Nevertheless, depletion of the ozone decreased in 2018 when compared to the maximum area of the ozone at 28.2 $x10^6$ km^2 and 29.6 $x10^6$ km^2 in 2015 and 2006 respectively [6]. This decline is due to the Montreal Protocol which phased out the production of numerous substances that are responsible for ozone depletion [6,16]. As a consequence of this development, climate projections indicate that the ozone layer will return to 1980 levels between 2050 and 2070 [17].

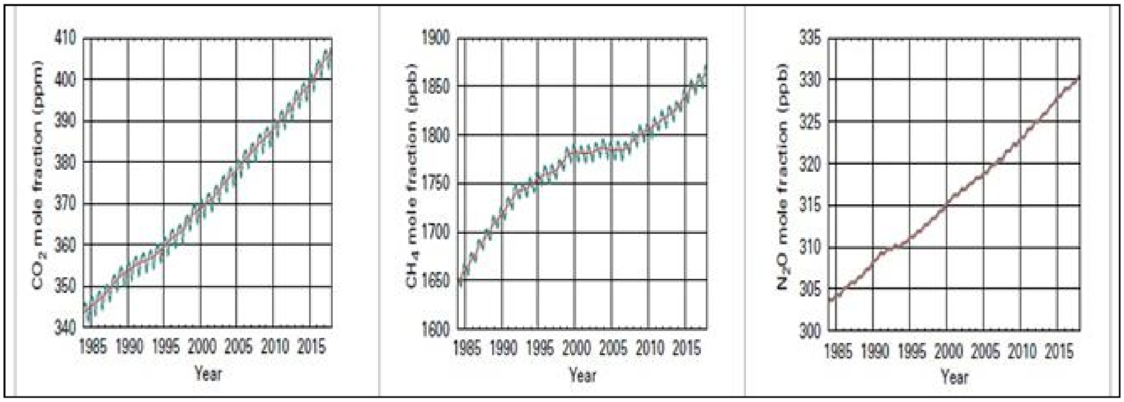

Fig. 3(a). Globally averaged mole fraction (a measure of concentration) of GHGs from 1984 to 2017. The red line is the monthly mean mole fraction with the seasonal variations removed; the blue dots and line show the monthly averages [6]

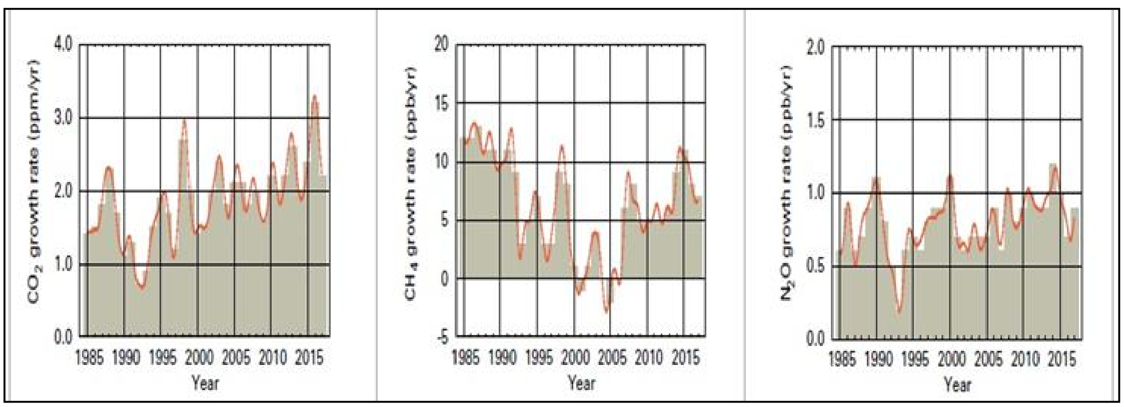

Fig. 3(b). Growth rates representing increases in successive annual means of mole fractions for GHGs [6]

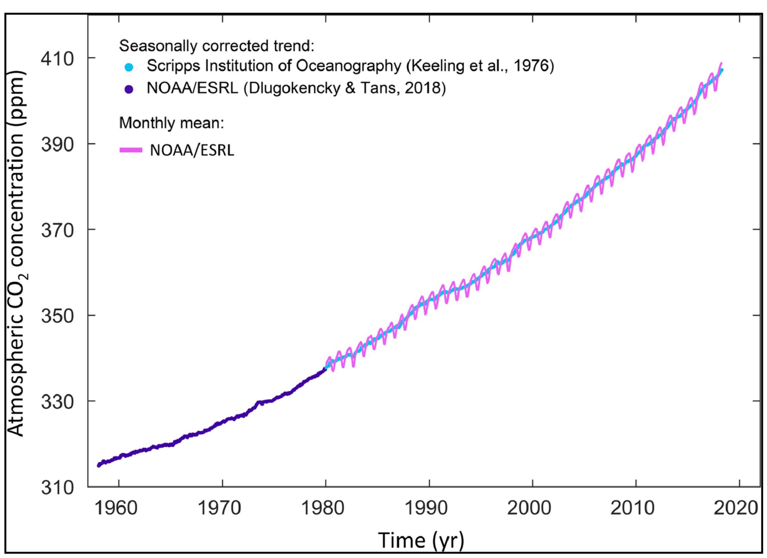

Fig. 4. Surface average atmospheric CO_2 concentration [13]

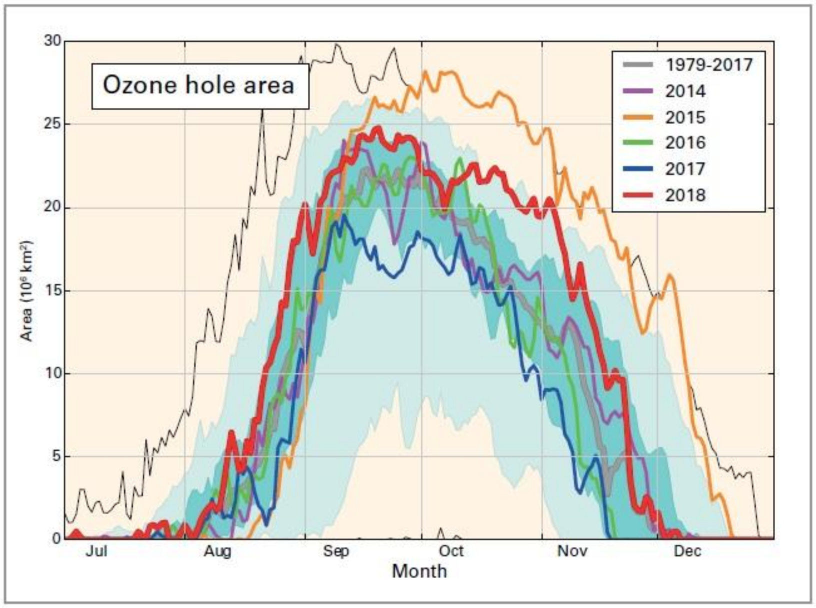

Fig. 5. Area of the ozone from 1979 - 2018 [6]

3. SOCIO-ECONOMIC IMPLICATIONS OF CLIMATE CHANGE

The change in the climatic conditions of a particular area affects its socio-economic development. Some of the risks in the perennial climatic variations include; natural disasters, food insecurity, population displacement, human mobility and diseases.

Natural Disasters and Human Mobility: Natural disasters such as flooding, hurricane and heatwaves can be attributed to climate change [18]. In 2018 according to an analysis of 281 events recorded by the Centre for Research on the Epidemiology of Disasters (CRED), weather and climate events accounted for most of the nearly 62 million people affected by natural hazards [19]. CRED also has it that over 9 million people were affected by drought worldwide.

Furthermore, drought, floods and storms (including hurricanes and cyclones) due to adverse climatic conditions constituted the greatest number of disaster-induced displacement in 2018 [6]. In Nigeria, floods resulted in 0.18% losses of farmlands, livestock and population displacement in 2012 while 32,000 farmers have affected annually [5]. These displaced persons are faced with food, shelter and security challenges which also affect the economy due to its accompanying loss of infrastructure, properties as well as lives.

Food Insecurity: Since agricultural activities are largely dependent on the climatic condition of an area, climate variability and extremes can contribute to hunger and food insecurity [20]. Food and Agricultural Organisation (FAO) has shown a continuing rise in world hunger. The number of undernourished people increased to 821 million in 2017 due to severe drought associated with the strong El Nino of 2015 and several localized extreme weather and climate events [21]. This hunger will be worse in countries and regions with agricultural systems that are highly sensitive to precipitation and temperature variability.

In Africa, about 59 million people were affected by acute hunger and malnutrition in 2017 [22]. Agricultural practices like dryland farming, pastoral rangeland systems which support 70 – 80% of the rural population are most vulnerable to climate variability [6].

Globally, in 2017, there are about 590 million undernourished persons in countries with high exposures to climate extremes and 210 million undernourished persons in countries with low exposure to climate extremes as shown in Fig. 6 [6]. However, crop yield and productivity vary from region to region depending on certain factors as irrigation options, agricultural infrastructure and adaptations in farming practices.

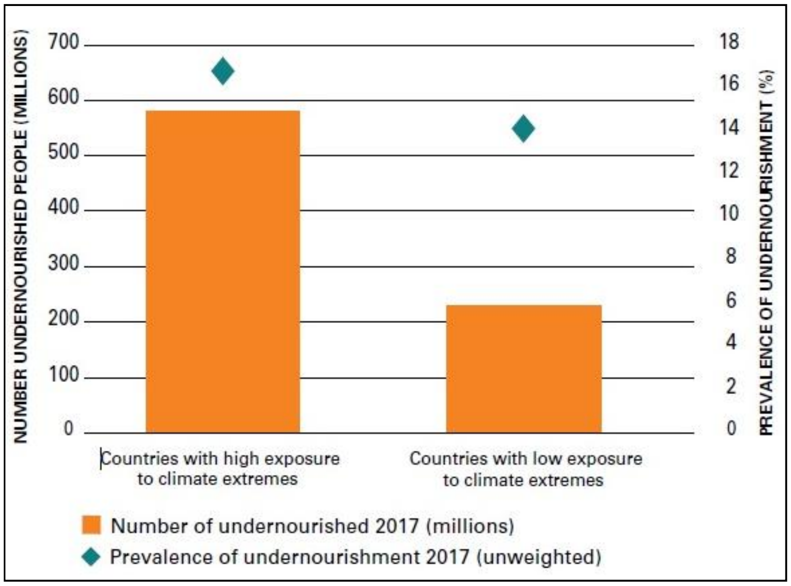

Fig. 6. Number of undernourished people in 2017 [6]

Environmental and Health Impacts: Some of the environmental impacts of climate change include; desertification, reduced level of oxygen in the oceans, sea-level rise, land degradation, forest fires, coastal erosion, and salination of freshwater peatlands [1]. Desert areas lack moisture and it impedes the growth of plants. Desertification due to human activities like over-cultivation, overstocking, fuel and wood collection and urbanization is occurring at 17% of the total earth land surface [1]. This, therefore, causes economically productive land to become less productive.

The climate change temperature increase increases the stress on plants which accentuates desertification processes especially in arid regions of the world.

Inland salinization can also occur due to salt accumulation related to erosion, seepage and wind deposition [1]. The temperature increase in the ocean leads to change in sea level due to thermal expansion and ice melting which are of comparable importance. The global sea level has risen in the last 100 years between 8 to 31 cm with the overall global mean value estimated to be between 10 and 25 cm as shown in Fig. 7 [23].

However, the sea level is expected to rise between 20 and 100 cm by the year 2100 (Fig. 8) [24]. This is about five times its level in the past 100 years and as such, it will have impacts in coastal zones and small islands. There'll be more coastal erosions, flooding and saltwater intrusion and these will have a rippling effect on; human settlements, agriculture, freshwater quality, fisheries and human health [1].

Climate change can lead to serious health issues due to direct and indirect causes. Some of the climate-related diseases include; cardiovascular disease, diabetes, psychological distress, asthma and an increase in the risk of accidents and infectious diseases majorly due to heat stress where high outdoor and indoor temperatures have an impact on mortality [25]. Exposure to thermal extremes especially heat waves, the concentration of toxic and carcinogenic air pollutants are also direct causes of climate-related ailments.

Between 2000 and 2016, the number of people exposed to heatwaves was estimated to have increased by around 125 million (Fig. 9), as the average length of individual heatwaves was 0.37 days longer, compared to the period between 1986 and 2008. In 2015 alone, a record of 175 million people was exposed to 627 heat waves. Each event at the local level translates to significant and varied impacts [26].

The indirect health effects result chiefly from disturbances of the ecological system like changes in food production and the range of diseases transmitted by organisms in air or water. Some of the health risks associated with these ecological changes include;

malnourishment, stunted growth of children, vector-borne diseases, asthma and allergic disorders, infectious diseases and psychological disorders [24].

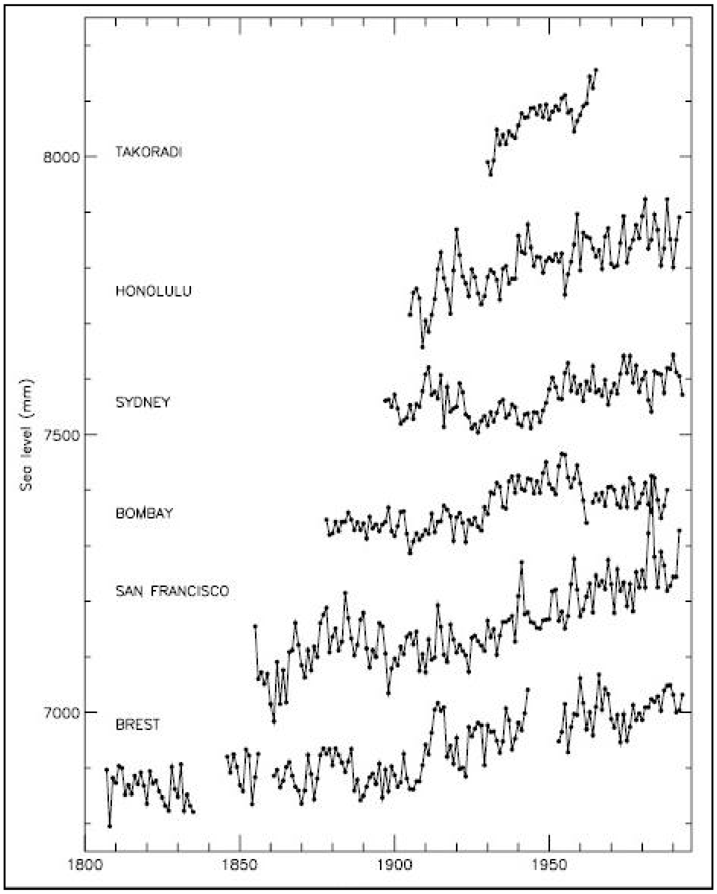

Fig. 7. Six long sea-level records from major world regions: Takoradi (Africa), Honolulu (Pacific), Sydney (Australia), Bombay (Asia), San Francisco (North America) and Brest (Europe). The observed trends (in mm/yr) for each record over the 20th century are, respectively, 3.1, 1.5, 0.8, 0.9, 2.0 and 1.3. [23]

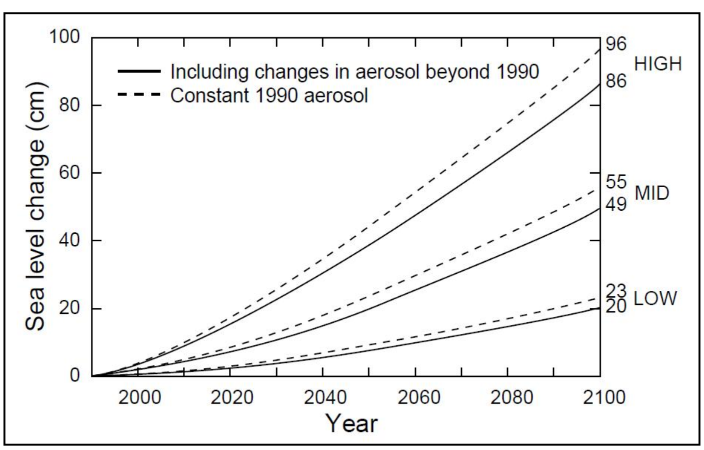

Fig. 8. Sealevel rise from 1990 to 2100 for high, medium and low ice-melt parameter specifications [24]

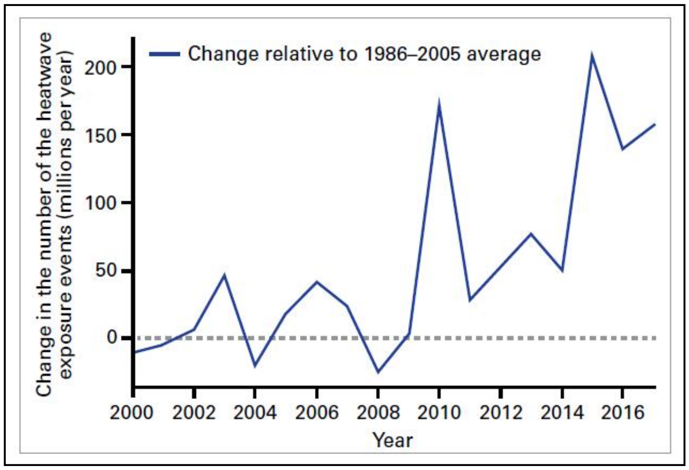

Fig. 9. The change in the number of people exposed to heatwaves from 2000 to 2017 relative to the 1986–2005 average [26]

4. MITIGATION OF CLIMATE CHANGE

To mitigate the impacts of climate change, every sector of the society and our relationship with the natural environment must experience certain changes. Our path of development should be inclusive and sustainable where people and nature will thrive. According to IPCC [8], there is an overarching need for us to transform into a net-zero emission globally by 2050. This, however, can occur if anthropogenic CO_2 emissions are balanced by anthropogenic removals.

Therefore, the key to mitigating climate change is to reduce how much carbon compounds that are emitted and are accumulated in the atmosphere. This can be achieved by; reducing the underlying demand for goods and services that require energy sources from carbon and fossil fuels i.e curtailing the sprawling development patterns that further our dependence on petroleum.

Furthermore, efficient energy sources and appliances should be used. For instance, we can switch from coal and oil to natural gas, expand the use of renewable energy sources like solar, wind, geothermal and hydroelectric power as well as a nuclear power. The emitted carbon can also be captured and sequestered directly from the atmospheres through proper soil and forest management [4].

Nonetheless, the competing demand on land for human settlement, infrastructural development, food, livestock feed, fibre, bioenergy and other ecosystem services should be checked with sustainable policies. Approaches such as conservation agriculture, irrigation, landscape restoration and afforestation should be encouraged [27].

Since water availability is under pressure due to climate change in many regions, water will need to be balanced sustainably for all ecosystems. Oceans and coastal ecosystems will need to be made more resilient by improving coastal defences and sustainable management of the ocean ecosystem. The transport system will need to be de-carbonized by shifting to electric vehicles as well as developing alternatives to fossil fuels for long-distance transport, aviation and shipping.

These mitigation options if well explored will not only limit the risks and damages associated with climate change, it will result in manifold economic, social and environmental benefits. According to Partnership [27], bold action on climate action can yield a direct economic gain of USD 26 trillion by 2030 and generate over 65 million new jobs while preventing 700,000 premature deaths due to air pollution globally.

5. CONCLUSION

Climate change has posed a serious challenge to experts across the globe. Concerted efforts by scientists, policymakers and all stakeholders should be made to increase the awareness of its perennial impacts to the socio-economic well being of the society. Furthermore, cleaner energy sources should be encouraged and harnessed to reduce the high rate of emission of carbon and other GHGs in the atmosphere. Informed decisions should be made by policymakers, individuals, government and non-governmental organizations of global repute to mitigating the impacts of climate change while meeting the sustainable development goals.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
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