**CHAPTER ONE**

**INTRODUCTION**

Global warming is the long-term rise in the average temperature of the Earth's climate system. It is a major aspect of climate change and has been demonstrated by direct temperature measurements and by measurements of various effects of the warming.Global warming and climate changeare often used interchangeably.But, more, accurately, global warming is the mainly the human-caused increase in global surface temperatures and its projected continuation, while climate change includes both global warming and its effects, such as changes in precipitation. While there have been prehistoric periods of global warming, many observed changes since the mid-20th century have been unprecedented over decades to centuries. Climate proxy records show that natural variations offset the early effects of the Industrial Revolution, so there was little net warming between the 18th century and the mid-19th century, when thermometer records began to provide global coverage. The IPCC has adopted the baseline reference period 1850–1900 as an approximation of pre-industrial global mean surface temperature.

Multiple independently produced instrumental datasets confirm that the 2009–2018 decade was 0.93 ± 0.07 °C warmer than the pre-industrial baseline (1850–1900). Currently, surface temperatures are rising by about 0.2 °C per decade since 1950, the number of cold days and nights has decreased, and the number of warm days and night has increased. Historical patterns of warming and cooling, like the Medieval Climate Anomaly and the Little Ice Age, were not as synchronous as current warming, but may have reached temperatures as high as those of the late-20th century in a limited set of regions. Past examples of climate change provide insight into modern climate change.

Although the most common measure of global warming is the increase in the near-surface atmospheric temperature, over 90% of the additional energy stored in the climate system over the last 50 years has warmed ocean water. The remainder of the additional energy has melted ice and warmed the continents and the atmosphere.

The warming evident in the instrumental temperature record is consistent with a wide range of observations, documented by many independent scientific groups;for example, in most continental regions the frequency and intensity of heavy precipitation has increased. Further examples include sea level rise, widespread melting of snow and land ice, increased heat content of the oceans, increased humidity, and the earlier timing of spring events, such as the flowering of plants.

Today’s global warming is an unprecedented type of climate change, and it is driving a cascade of side effects in our climate system. It’s these side effects, such as changes in sea level along heavily populated coastlines and the worldwide retreat of mountain glaciers that millions of people depend on for drinking water and agriculture, that are likely to have a much greater impact on society than temperature change alone.

**CHAPTER TWO**

**2.0 HISTORY OF GLOBAL WARMING AND CLIMATE CHANGE**

Climate change is the long-term alteration in Earth’s climate and weather patterns. It took nearly a century of research and data to convince the vast majority of the scientific community that human activity could alter the climate of our entire planet. In the 1800s, experiments suggesting that human-produced carbon dioxide and other gases could collect in the atmosphere and insulate Earth were met with more curiosity than concern. By the late 1950s, CO2 readings would offer some of the first data to corroborate the global warming theory. Eventually an abundance of data, along with climate modelling would show not only that global warming was real, but that it also presented a host of dire consequences. Dating back to the ancient Greeks, many people had proposed that humans could change temperatures and influence rainfall by chopping down trees, plowing fields or irrigating a desert.

One theory of climate effects, widely believed until the Dust Bowl of the 1930s, held that “rain follows the plow,” the now-discredited idea that tilling soil and other agricultural practices would result in increased rainfall. Accurate or not, those perceived climate effects were merely local. The idea that humans could somehow alter climate on a global scale would seem far-fetched for centuries.

In the 1820s, French mathematician and physicist Joseph Fourier proposed that energy reaching the planet as sunlight must be balanced by energy returning to space since heated surfaces emit radiation. But some of that energy, he reasoned, must be held within the atmosphere and not return to space, keeping Earth warm. He proposed that Earth’s thin covering of air—its atmosphere—acts the way a glass greenhouse would. Energy enters through the glass walls, but is then trapped inside, much like a warm greenhouse.

Experts have since pointed out that the greenhouse analogy was an oversimplification, since outgoing infrared radiation isn’t exactly trapped by Earth’s atmosphere, but absorbed. The more greenhouse gases there are, the more energy is kept within Earth’s atmosphere. But the so-called greenhouse effect analogy stuck and some 40 years later, Irish scientist John Tyndall would start to explore exactly what kinds of gases were most likely to play a role in absorbing sunlight.Tyndall’s laboratory tests in the 1860s showed that coal gas (containing CO2, methane and volatile hydrocarbons) was especially effective at absorbing energy. He eventually demonstrated that CO2 alone acted like sponge in the way it could absorb multiple wavelengths of sunlight. By 1895, Swedish chemist Svante Arrhenius became curious about how decreasing levels of CO2 in the atmosphere might cool Earth. In order to explain past ice ages, he wondered if a decrease in volcanic activity might lower global CO2 levels. His calculations showed that if CO2 levels were halved, global temperatures could decrease by about 5 degrees Celsius (9 degrees Fahrenheit).

Next, Arrhenius wondered if the reverse were true. Arrhenius returned to his calculations, this time investigating what would happen if CO2 levels were doubled. The possibility seemed remote at the time, but his results suggested that global temperatures would increase by the same amount—5 degrees C or 9 degrees F.Decades later, modern climate modelling have confirmed that Arrhenius’ numbers weren’t far off the mark.

Back in the 1890s, however, the concept of warming the planet was remote and even welcomed. As Arrehenius wrote, “By the influence of the increasing percentage of carbonic acid [CO2] in the atmosphere, we may hope to enjoy ages with more equable and better climates, especially as regards the colder regions of the earth.”By the 1930s, at least one scientist would start to claim that carbon emissions might already be having a warming effect. British engineer Guy Stewart Calendar noted that the United States and North Atlantic region had warmed significantly on the heels of the Industrial Revolution.

Callendar’s calculations suggested that a doubling of CO2 in Earth’s atmosphere could warm Earth by 2 degrees C (3.6 degrees F). He would continue to argue into the 1960s that a greenhouse-effect warming of the planet was underway. While Callendar’s claims were largely met with skepticism, he managed to draw attention to the possibility of global warming. That attention played a part in garnering some of the first government-funded projects to more closely monitor climate and CO2 levels.

Most famous among those research projects was a monitoring station established in 1958 by the Scripps Institution of Oceanography on top of Hawaii’s Mauna Loa Observatory.

Scripps geochemist Charles Keeling was instrumental in outlining a way to record CO2 levels and in securing funding for the observatory, which was positioned in the center of the Pacific Ocean.

Data from the observatory revealed what would become known as the “Keeling Curve.” The upward, saw tooth-shaped curve showed a steady rise in CO2 levels, along with short, jagged up-and-down levels of the gas produced by repeated wintering and greening of the Northern Hemisphere. The dawn of advanced computer modelling in the 1960s began to predict possible outcomes of the rise in CO2 levels made evident by the Keeling Curve. Computer models consistently showed that a doubling of CO2 could produce a warming of 2 degrees C or 3.6 degrees F within the next century. Still, the models were preliminary and a century seemed a very long time away.

In the early 1970s, a different kind of climate worry took hold: global cooling. As more people became concerned about pollutants people were emitting into the atmosphere, some scientists theorized the pollution could block sunlight and cool Earth.

In fact, Earth did cool somewhat between 1940-1970 due to a postwar boom in aerosol pollutants which reflected sunlight away from the planet. The idea that sunlight-blocking pollutants could chill Earth caught on in the media, as in a 1974 Time magazine article titled “Another Ice Age?”But as the brief cooling period ended and temperatures resumed their upward climb, warnings by a minority of scientists that Earth was cooling were dropped. Part of the reasoning was that while smog could remain suspended in the air for weeks, CO2 could persist in the atmosphere for centuries.

The early 1980s would mark a sharp increase in global temperatures. Many experts point to 1988 as a critical turning point when watershed events placed global warming in the spotlight. The summer of 1988 was the hottest on record (although many since then have been hotter). 1988 also saw widespread drought and wildfires within the United States. Scientists sounding the alarm about climate change began to see media and the public paying closer attention. NASA scientist James Hansen delivered testimony and presented models to congress in June of 1988, saying he was “99 percent sure” that global warming was upon us.

One year later, in 1989, the Intergovernmental Panel on Climate Change (IPCC) was established under the United Nations to provide a scientific view of climate change and its political and economic impacts. As global warming gained currency as a real phenomenon, researchers dug into possible ramifications of a warming climate. Among the predictions were warnings of severe heat waves, droughts and more powerful hurricanes fuelled by rising sea surface temperatures. Other studies predicted that as massive glaciers at the poles melt, sea levels could rise between 11 and 38 inches (28 to 98 centimetres) by 2100, enough to swamp many of the cities along the east coast of the United States.

Government leaders began discussions to try and stem the outflow of greenhouse gas emissions to prevent the most dire predicted outcomes. The first global agreement to reduce greenhouse gases, the Kyoto Protocol, was adopted in 1997.The protocol, which was signed by President [Bill Clinton](http://history.com/topics/us-presidents/bill-clinton), called for reducing the emission of six greenhouse gases in 41 countries plus the European Union to 5.2 percent below 1990 levels during the target period of 2008 to 2012.

In March 2001, shortly after taking office, President [George W. Bush](http://history.com/topics/us-presidents/george-w-bush) announced the United States would not implement the Kyoto Protocol, saying the protocol was “fatally flawed in fundamental ways” and citing concerns that the deal would hurt the U.S. economy. That same year, the IPCC issued its third report on climate change, saying that global warming, unprecedented since the end of the last ice age, is “very likely,” with highly damaging future impacts. Five years later, in 2006, former Vice President and presidential candidate [Al Gore](http://www.history.com/topics/al-gore) weighed in on the dangers of global warming with the debut of his film An Inconvenient Truth.

Politicization over climate change, however, would continue, with some skeptics arguing that predictions presented by the IPCC and publicized in media like Gore’s film were overblown. Among those expressing skepticism over global warming was future U.S. president [Donald Trump](http://history.com/topics/us-presidents/donald-trump). On November 6, 2012, Trump tweeted “The concept of global warming was created by and for the Chinese in order to make U.S. manufacturing non-competitive.”

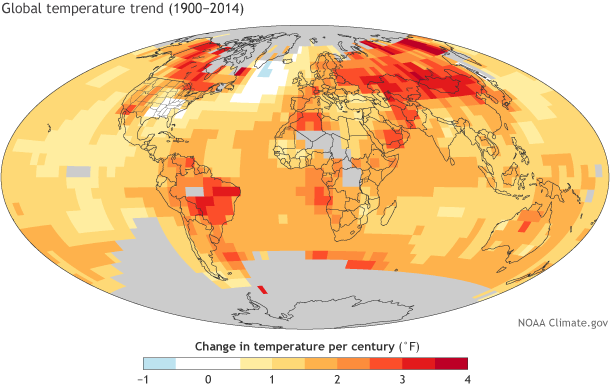


Figure 1: Global temperature trend( 1900-2014)

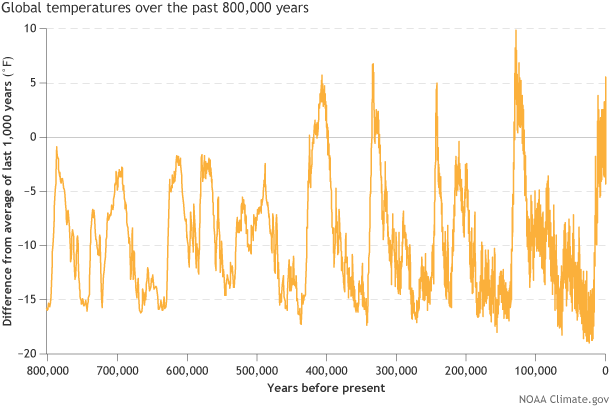


Figure 2: Global temperature over 800,000 years

**2.1 HISTORICAL IMPACT OF GLOBAL WARMING AND CLIMATE CHANGE**

Approximately one millennium after the 7 Ka (32nd Century BCE) slowing of sea-level rise, many coastal urban centres rose to prominence around the world. It has been hypothesized that this is correlated with the development of stable coastal environments and ecosystems and an increase in marine productivity (also related to an increase in temperatures), which would provide a food source for hierarchical urban societies.

The last written records of the Norse Greenlanders are from a 1408 marriage in the church of Hvalsey, today the best-preserved of the Norse ruins. Climate change has been associated with the historical collapse of civilizations, cities and dynasties.

There are two proposed methods of Classic Maya collapse: environmental and non-environmental. The environmental approach uses paleoclimatic evidence to show that movements in the intertropical convergence zone likely caused severe, extended droughts during a few time periods at the end of the archaeological record for the classic Maya. The non-environmental approach suggests that the collapse could be due to increasing class tensions associated with the building of monumental architecture and the corresponding decline of agriculture increased disease and increased internal warfare. The Harappa and Indus civilizations were affected by drought 4,500–3,500 years ago. A decline in rainfall in the Middle East and Northern India 3,800–2,500 is likely to have affected the Hittites and Ancient Egypt.

Notable periods of climate change in recorded history include the medieval warm period and the little ice age. In the case of the Norse, the medieval warm period was associated with the Norse age of exploration and arctic colonization, and the later colder periods led to the decline of those colonies. Climate change in the recent past may be detected by corresponding changes in settlement and agricultural patterns. Archaeological evidence, oral history and historical documents can offer insights into past changes in the climate. Climate change effects have been linked to the collapse of various civilizations.

**2.2 DIFFERENCES BETWEEN GLOBAL WARMING AND CLIMATE CHANGE**

**The phrase global warming is used by scientists to mean a long-term increase in [Earth](https://www.britannica.com/place/Earth)’s average air temperature. It can refer specifically to such warming that is due to the influence of rising concentrations of [greenhouse gases](https://www.britannica.com/science/greenhouse-gas) in the [atmosphere](https://www.britannica.com/science/atmosphere).** Earth’s surface gets most of its [heat](https://www.britannica.com/science/heat) from the [energy](https://www.britannica.com/science/energy) associated with the [Sun](https://www.britannica.com/place/Sun)’s rays, which strike the planet’s surface during the day. At night most of this energy is radiated back into space. Greenhouse gases (such as carbon dioxide, methane, nitrous oxides and chlorofluorocarbons)

absorb [infrared radiation](https://www.britannica.com/science/infrared-radiation) (net heat energy) emitted from Earth’s surface and radiate it back to the surface, thus contributing to the [greenhouse effect](https://www.britannica.com/science/greenhouse-effect). Though the recent rise in greenhouse gases in the atmosphere is arguably the main factor affecting global warming, other factors are involved (such as variations in Earth’s [orbit](https://www.britannica.com/science/orbit-astronomy), the angle of the planet’s axis, and variations in the Sun’s energy output). Nevertheless, as higher concentrations of greenhouse gases allow Earth’s atmosphere to hold on to greater amounts of heat that would normally escape into space at night, Earth’s average [temperature](https://www.britannica.com/science/temperature) rises.“Global warming” refers to the long-term warming of the planet. Global temperature shows a well-documented rise since the early 20th century and most notably since the late 1970s. Worldwide, since 1880 the average surface temperature has risen about 1 °C (about 2 °F), relative to the mid-20th-century baseline (of 1951-1980). This is on top of about an additional 0.15 °C of warming from between 1750 and 1880.

Climate, on the other hand, is the average condition of the atmosphere in a given location over a long period of time, such as 30 years or more. Thus, **climate change is a longer-term change in the average condition of the atmosphere.**

Human beings most certainly contribute to climate change by adding greenhouse gases to the atmosphere, but this is only part of the equation. Earth’s climate can change over time not only because of changes in the atmosphere but also because of interactions between the atmosphere and various geologic, chemical, biological, and geographic factors. For example, regional climates (as well as Earth’s global climate) can change in response to a sustained period of heavy [volcanic activity](https://www.britannica.com/science/volcano). Much of that activity is related in turn to the movement of Earth’s [tectonic plates](https://www.britannica.com/science/plate-tectonics), which drives the [continents](https://www.britannica.com/science/continent) across the surface of the planet. Over hundreds of thousands to millions of years, the continents collide with other continents or break apart, changing the paths of [ocean currents](https://www.britannica.com/science/ocean-current) and local [winds](https://www.britannica.com/science/wind). This affects the transport of heat from the tropics to the poles. Earth’s global climate has also changed in response to drastic changes in atmospheric chemistry—notably the rise in [oxygen](https://www.britannica.com/science/oxygen) concentrations billions of years ago when [plants](https://www.britannica.com/plant/plant), [algae](https://www.britannica.com/science/algae), and other forms of [life](https://www.britannica.com/science/life) capable of [photosynthesis](https://www.britannica.com/science/photosynthesis) began to spread across the planet.

As the world continues to come to grips with how human activities influence Earth’s climate, the tangible effects of climate change that is caused by global warming—such as melting [glaciers](https://www.britannica.com/science/glacier) and ice caps, rising [sea levels](https://www.britannica.com/science/sea-level), and changes in seasonal temperature and [rainfall](https://www.britannica.com/science/rain) patterns—are becoming the focus. With such disruptions becoming more and more apparent, many scientists are discussing them increasingly in terms of real long-term climatic changes rather than simply remarking about Earth’s average temperature. Consequently, **climate change can also refer to the cause-and-effect relationship between global warming and 3X climate change. That is, it can refer to a change in the average condition of the atmosphere brought on by global warming.** “Climate change” encompasses global warming, but refers to the broader range of changes that are happening to our planet. These include rising sea levels; shrinking mountain glaciers; accelerating ice melt in Greenland, Antarctica and the Arctic; and shifts in flower/plant blooming times. These are all consequences of the warming, which is caused mainly by people burning fossil fuels and putting out heat-trapping gases into the air. The terms “global warming” and “climate change” are sometimes used interchangeably, but strictly they refer to slightly different things.

**CHAPTER THREE**

**3.0 MICROBIAL ACTIVITIES AND THEIR RELATIONSHIP TO CLIMATE CHANGE**

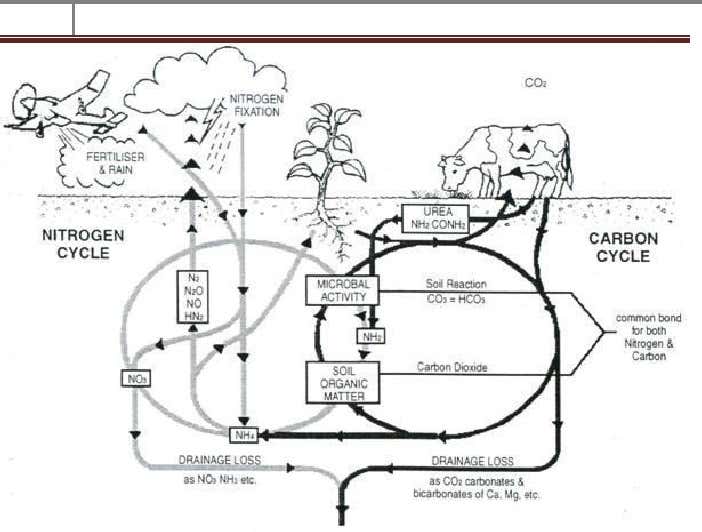
Organic matter degradation .Organic substance recycling is a complex process involving the activity of many microbial communities. Organic matter production takes place during photosynthesis, and carbon dioxide from the atmosphere is fixed and converted to carbohydrates. The process is mostly carried out by plants in the presence of sunlight. A proportion of the fixed carbon is respired by the plants themselves and transferred back to the atmosphere. Plants also release a considerable amount of organic substances through their roots and it is used as a source of nutrients by the microorganisms. During decomposition of root exudates and dead vegetable and animal biomass, a significant amount of carbon dioxide is produced and released [1]. A smaller amount of organic carbon, recalcitrant in its nature, cannot be used and remains stored in the soil. Some anthropogenic activities (eg burning fossil fuels) are significant contributors and sources of carbon dioxide.

**Methanogenesis:** If the degradation of the organic substance takes place under anaerobic conditions, the final product is methane. Methanogenesis occurs mainly in aquatic environment, rumen of herbivorous animals or intestinal niche of some insects (e.g., termites). Methane production is carried out by an anaerobic archaea group responsible for the emission of 250 million tonnes/year. A number of human activities, such as rice cultivation or livestock farming, releases more methane to the atmosphere than natural sources, the amount is estimated to about 320 million tonnes/year, most of which have a microbial origin. Methane can be oxidized under the action of methanotrophs, a bacterial group responsible for the consumption of a significant amount in some natural environments.

**Denitrification:** The highest amount of N2O is produced during the microbial nitrification and denitrification, recent studies providing direct and strong evidence between bacterial communities and nitrous oxide production in soils. Industrialization, burning of fossil fuels, and intensive agriculture were anthropogenic activities with the greatest contribution (three to five-fold increases in concentration) to the emission of N2O in the atmosphere over the last century. Microbially mediated nitrogen transformation are processes carried out by very diverse bacterial populations, existing in a variety of natural niches. Most of N2O production is typically the result of incomplete denitrification, this activity being distributed among very diverse phylogenetic bacterial populations.

**3.1 BIOGEOCHEMICAL CYCLE AND MICROBIAL END PRODUCT**

Micro-organisms play a central role in nutrient cycling in the environment. In soil systems they mediate decay of plant matter, consumption and production of trace gases, transformation of metals and plant growth (Panikov, 1999). Through these roles microorganisms have the potential to impact climate; and due to their vast numbers and widespread distribution they have immense effect at a global scale. Soil micro-organisms contribute significantly to the production and consumption of greenhouse gases, including carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), and nitric oxide (NO), and human activities such as waste disposal and agriculture have stimulated the production of greenhouse gases by microbes (fig.3). As concentrations of these gases continue to rise, soil microbes may have various feedback responses that accelerate or slow down global warming, but the extent of these effects are unknown.

FIG 3: inter-relationship between the two major biogeochemical cycles, i.e., Carbon and Nitrogen cycles occurring simultaneously on the Earth (Lester, 2018).

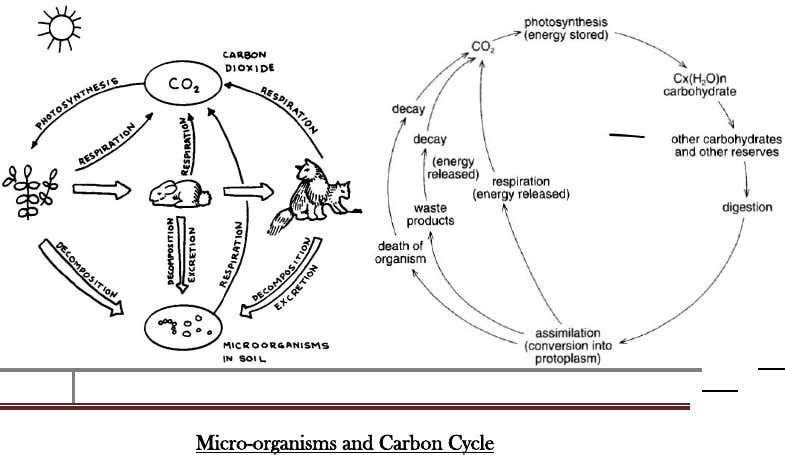
Microbial ecology and metabolic diversity go hand in hand. By understanding the role of soil microbes which have both contributors to and reactive components of climate change can help us determine whether they can be used to curb emissions or if they will push us even faster towards climatic disaster.

This essay is concerned with the role of microorganisms in climate change with particular reference to their carbon and nitrogen cycling activities. We will see how micro-organisms and their metabolic reactions play key roles in maintaining the web of life on Earth and are of crucial importance for supporting different aspects of climatic conditions and their variable changes.

**CARBON CYCLE**

The carbon cycle describes the fluxes of carbon among various reservoirs in the Earth system. Carbon (C) is the fourth most abundant element in the universe after the Hydrogen (H), Helium (He) and Oxygen (O). It is the building block of all life-on Earth, and plays crucial roles in the climate system, climate change and energy resources on which humanity is most dependent.

When organisms die they decompose or rot. This is largely brought about through the actions of bacteria and fungi. These and other so-called decomposers feed on dead organisms using some of the carbon in the dead tissues for growth, with the remaining carbon in the dead organism returned back to the atmosphere as the carbon dioxide which is a by-product of the decomposers' own respiration. Green plants of all kinds can then use these newly freed carbon atoms during photosynthesis.

FIG 4: Left – Interaction between autotrophs and heterotrophs in any carbon cycle (Tsaile, 2019). Right – The CO2 incorporates into carbohydrate by fluxes (Copyrights 2019 © Biocyclopedia.com).

Living organisms are connected between ecosystems in many ways. A prominent example will be the exchange of carbon between autotrophs and heterotrophs within and between various ecosystems by way of atmospheric carbon dioxide (fig.4, left). It is the CO2 which is considered as the building block that autotrophs use to build multi-carbon, high-energy compounds, such as glucose.

Among various autotrophs, like the plants, photosynthetic bacteria, algae, lithotrophs, and some methanogens, uses CO2 as the sole source of carbon for growth. This reduces the molecule to organic cell material (CH2O). Even heterotrophs require organic carbon for growth and ultimately convert it back to CO2 (fig.4, right). Thus, a relationship is established between autotrophs and heterotrophs wherein autotrophs fix carbon needed by heterotrophs and heterotrophs produce CO2 used by the autotrophs.

CO2 + H2O CH2O (organic material) autotrophy

CH2O + O2 CO2 + H2O heterotrophy

Since CO2 is the most prevalent greenhouse gas in the atmosphere, it would not be good if the two equations get out of balance (i.e. heterotrophy predominating over autotrophy, e.g. rain forests are destroyed and replaced with cattle).

**Key groups of organisms:-**

* Carbon dioxide fixation
* Fermentation and anaerobic respiration.
* Methanogenesis and methanogenic archaea.
* Methane oxidation and methylotrophic bacteria.

Carbon cycles are floating around in the form of reservoirs, pools, storage sites, sinks and sources. There are certain series of fluxes which may be utilized as transfer or processes. These carbon sources and fluxes are dependent on each other and plays significant role to the various carbon cycles occurring on the earth. Mainly three key fluxes are part important.

**Photosynthesis** is the basic chemical process in plants, algae, and phytoplankton. In this chemically simplest form, it looks like this:

Energy (sunlight) + 6CO2 + 6H2O C6H12O6 + 6O2 (C6H12O6 is a generic carbohydrate)

Plants use solar radiation, carbon dioxide (CO2) from the atmosphere, and water (H2O), and they produce carbohydrates and release oxygen into the atmosphere. Animals then eat those carbohydrates and breathe that oxygen.

**Respiration** is the process in which animals acquire oxygen from the atmosphere, and release carbon dioxide into the atmosphere.

**Combustion** is the burning of organic matter in the presence of oxygen. Oxygen-free conditions prevent combustion. In its chemically simplest form, combustion looks like this:

CH4 + O2 CO2 + H2O + energy (heat)

In a slightly more complex, but still simple form:

C6H12O6 + 6O2 6CO2 + 6H2O + energy (heat)

The organic molecules in these equations (CH4 and C6H12O6) could be wood, paper, plastic, cloth or any fossil fuel (coal, oil, natural gas). It could also be food for an animal, which is known as metabolism instead of combustion. Whatever the fuel, it is burned along with oxygen to produce energy and water, and to release carbon dioxide to the atmosphere.

Autotrophs, being the primary producers, are always at the bottom of the food chain. They are responsible for converting CO2 to a form required by the heterotrophs. Among prokaryotes, the cyanobacteria, the lithotrophs and the methanogens are the formidable biomass of autotrophs that account for a corresponding amount of CO2 fixation in the global carbon cycle.

The lithotrophic bacteria and archaea oxidizes reduced nitrogen (N) and Sulphur (S) compounds. All these autotrophs play important roles in the natural cycles of N and S. These organisms are prevalent in sulphur-rich environments like, hot springs, marine sediments, thermal vents, endosymbionts, etc. This may indicate an unfavourable role to these prokaryotes as primary producers of organic carbon on earth.

The methanogens significantly play a dual role in the carbon cycle. The archaea are inhabitants for all these anaerobic environments where CO2 and H2 occur naturally. They use these CO2 in their metabolism in two different ways. During autotrophic growth, around 5% of CO2 taken up is reduced to cell material and the remaining 95% is reduced to CH4 gas during a unique process of generating cellular energy. Thus, the CH4 which accumulates in the rocks as fossil fuels (natural gas), in the rumen of cows and guts of termites, swamps, sediments, landfills and sewage digesters.

CO2 + H2 CH2O (cell material) + CH4 methanogenesis

CH4 is the second most prevalent of the greenhouse gases. It is best to discourage the processes that lead to its accumulation in the atmosphere. In aerobic conditions, the CH4 and its derivatives (methanol, formaldehyde, etc.) can be oxidized as energy sources by bacteria called methylotrophs. This is a metabolic version of decomposition or biodegradation during the carbon cycle.

In the carbon cycle, the microbes are responsible for the process of Biodegradation. It is the decomposition of organic material (CH2O) back to carbon dioxide (CO2), water (H2O) and hydrogen (H2).

For soil habitats, the fungi play a significant role in biodegradation, but the prokaryotes are equally important.

**NITROGEN CYCLE**

Nitrogen is one of the primary nutrients critical for the survival of all living organisms (Bernhard, 2018). Although it is abundant in the atmosphere, it is highly inaccessible to most organisms in this form. It is one of the major components for many biomolecules, including amino acids, proteins and nucleic acids, DNA and chlorophyll. It is a crucial plant nutrient. Although nitrogen is abundant in the atmosphere in the form of dinitrogen gas (N2), but it is highly inaccessible in this form to most organisms (Bernhard, 2018). This makes nitrogen a very scarce resource and often limiting primary productivity in many ecosystems. It becomes available to primary producers (such as plants), only when this gas is converted from dinitrogen gas into ammonia.

Nitrogen exists in many different forms, including both inorganic (e.g., ammonia, nitrate) and organic (e.g., amino and nucleic acids) forms. Thus, nitrogen undergoes into different transformations in the ecosystem. This change is from one form to another as organisms use it for growth as well as for energy. Nitrogen when applied to soil undergoes transformation processes before becoming available for plants. The major transformations of nitrogen are involved through nitrogen fixation, nitrification, denitrification, anammox and ammonification (fig.6). The transformation of N2 into various oxidation states is the key to productivity in the biosphere. This is highly dependent on the activities of a diverse assemblage of microbes, such as bacteria, archaea and fungi.

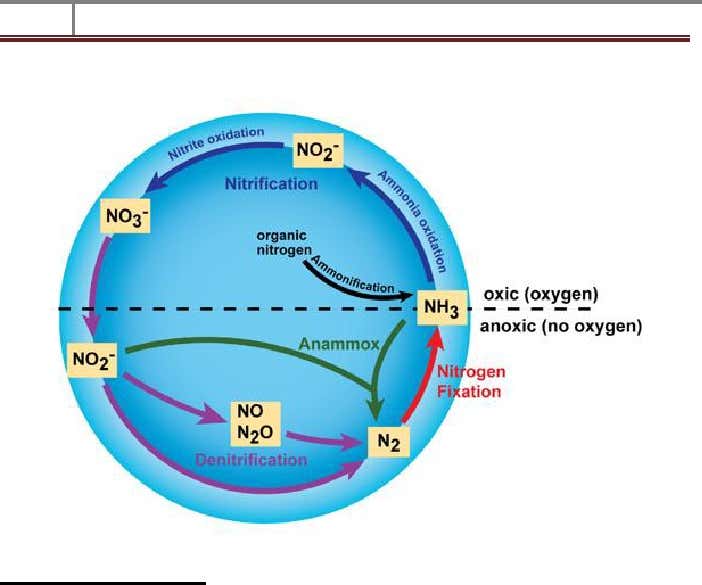


Figure5: Major transformations in the Nitrogen cycle (Copyrights 2018 © Nature Education).

**The key groups of microbes:-**

* Nitrification and Nitrosomonas, Nitrobacter, etc
* Denitrification.
* Nitrogen fixation, detection by acetylene reduction.
* Rhizobium and symbiotic associations etc - free living nitrogen fixation.

The plants absorb the nitrate ions and form vegetable proteins from them by nitrate assimilation. The plants can also use ammonium ions (NH4+). Animals excrete nitrogenous waste materials, such as urea, uric acid, ammonia. Urea and uric acid are converted into ammonium compounds and CO2 by the putrefying bacteria (Bacillus ramosus and B. vulgaris) are some fungi found in the soil and in the mud bottom of water bodies. They also decompose the nitrogenous compounds (proteins) of the dead animals and plants into NH4+ compounds.

Some NH4+ compounds, nitrites (NO2-) and nitrates (NO3-) are converted by bacteria and fungi into molecular nitrogen (N2) which escapes into atmosphere or is added to water, and is lost from the cycle. The process is called denitrification. The bacterium Pseudomonas aeruginosa reduces nitrates to molecular nitrogen. Other denitrifying bacteria are Micrococcus denitrificans and Thiobacillum denitrificans.

NO3- NO2- N2 (denitrification)

Most of the NH4+ compounds formed by the putrefying bacteria and fungi are oxidized by the nitrite bacteria (Nitrosomonas and Nitrococcus) to soluble nitrites, which are further oxidized by nitrate bacteria (Nitrobacter and Nitrocystis) and fungi to soluble nitrates. The process of nitrate formation is known as nitrification, and the bacteria responsible for it as the nitrifying bacteria. The nitrates so formed are added to the soil and water, thus completing the cycle (fig.6).

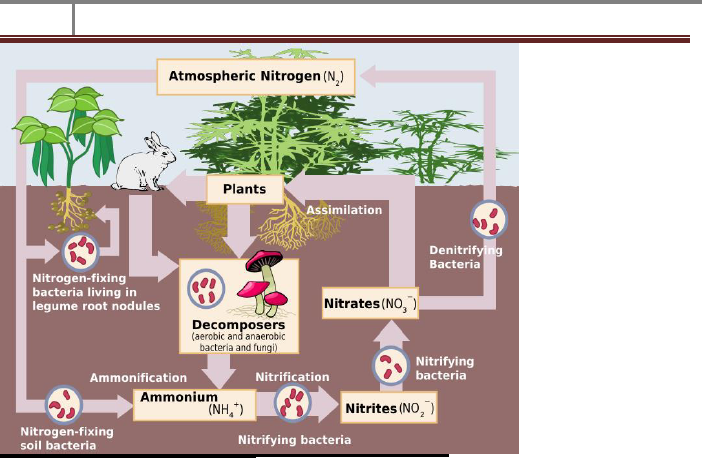


Figure 6: Schematic representation of the flow of nitrogen (Copyrights 2019 © United States Environmental Protection Agency).

**Free living Nitrogen fixing bacteria:-**

* Obligate anaerobes, e.g*. Clostridium pasteurianum*
* Facultative anaerobes, e.g., *Klebsiella spp.*, a close relative of *E. coli.*
* Photosynthetic bacteria, e.g. *Rhodobacter spp.*
* Many cyanobacteria, e.g*. Nostoc spp.*
* Obligate aerobes such as Azotobacter f. Some methanogens

Since nitrogenase is inactivated by O2, the fixation of N must occur under conditions which are anaerobic at least locally. For anaerobes there is no problem. Facultative organisms such as purple photosynthetic bacteria or *Klesbsiella spp.* fix nitrogen only when anaerobic. Other organisms have protective mechanisms.

In Azotobacter, an obligate aerobe, the O2 concentration inside the cell is held down by partial uncoupling of a highly active respiratory chain. This wastes carbohydrate, but if growth is limited by absence of nitrogen compounds then this is justifiable. The cyanobacteria in O2 are actually generated by photosynthesis. Fixation of N occurs in special cells known as heterocysts which do not photosynthesize but are devoted solely to N2 fixation.

In root nodules, the O2 level is regulated by special haemoglobin – leghaemoglobin. The globin protein is encoded by plant genes but the heme cofactor is made by the symbiotic bacteria. This is produced only when the plant is infected with *Rhizobium*. The plant root cells convert sugar to organic acids which they supply to the bacteroids. In exchange, the plant receives amino-acids (rather than free NH3).

**The overall process of Nitrification**

2NH4+ + 3O2 Nitrosomonas 2NO2- + 4H+ + 2H2O

2NO2- + O2 Nitrobacter 2NO3-

2NH4+ 2O2 Nitrifiers NO3- + 2H+ + H2O

An important aspect of the nitrogen cycle that involves prokaryotes, though not exclusively, is decomposition of N-containing compounds. Mostly, the organic N (in the form of protein) yields NH3 during the process of deamination. Fungi are involved in decomposition as well. The plants, animals and protista, even prokaryotes, completes the nitrogen cycle during the uptake of the element for their own nutrition. Usually the N assimilation is usually in the form of NO3-, an amino group or NH3.

Moreover, the rate of denitrification of NO3- in soil is dependent on various factors such as the pH, temperature and H2O content in the soil. With the increased rise in soil pH, there is a high acceleration of denitrification which turns to a higher adverse when the pH level rises to 8.0 – 8.6. Similarly, denitrification increases when temperature rises from 2 degrees to 25 degrees, the optimum temperature is about 60 degrees.

The degree of water saturation of the soil has a profound influence on the rate of denitrification. No denitrification is occurs below a certain moisture level, but above this level, denitrification increases rapidly with the increase in moisture content. The critical moisture level is about 60% of the water-holding capacity of the soil. A prominent example to withstand this critical moisture level can be water-logging.

The atmospheric increase of N2O due to anthropogenic activities is a cause for concern. This greenhouse gas (N2O) has 300 times the heat absorbing capacity as CO2. Denitrifying bacteria respire using N2O as an electron acceptor yielding N2 and thereby provide sink for N2O.

**Transformations of fertilizer nitrogen in the soil**

Nitrogen when applied to soil undergoes transformation processes before becoming available for plants. The following two different sources of nitrogen explain the soil nitrogen cycle; Nitrogen transformations when applying Ammonium Nitrate

* Application of fertilizers, containing mineral nitrogen as ammonium and nitrate. Organic fertilizers contain mostly complex forms of N and NH4+.
* Uptake of nitrate is rapid due to the high particle mobility. Most plants therefore prefer nitrate over NH4+.
* Uptake of ammonium is slower than that of NO3-. NH4+ is bound to clay particles in the soil and roots have to reach it. Most of the NH4+ is therefore nitrified before it is taken-up by plants.
* Nitrification by soil bacteria converts NH4+ into NO3- in between a few days and a few weeks. N2O and NO are lost to the atmosphere during the process.
* Denitrification is favoured by lack of O2 (e.g. water logging). Soil bacteria converts NO3- and NO2- into gaseous N2O, NO and N. These are lost to the atmosphere.
* Immobilization transforms mineral N into soil organic matter. Activity of soil microbes is mainly stimulated by NH4+. Immobilized N is not immediately available for plant uptake, but needs to be mineralized first. Mineralization of soil organic matter (and manure) releases NH4+ into the soil.
* Ammonia volatilization occurs when NH2+ is converted to NH3 and lost to the atmosphere. A high soil pH level and temperature favour conversion of NH4+ to NH3. If conversion takes place at the soil surface, losses are highest.
* Leaching of NO3- occurs mainly during winter and fallow periods when percolating rainfall washes residual and mineralized NO2- below the root zone. Accurate fertilization increases N use efficiency and reduces the risk of leaching during the growth period and afterwards.

**Nitrogen transformations when applying Urea**

* Application of fertilizers, containing mineral N as urea. Organic fertilizers contain mostly complex forms of N and NH4+.
* Hydrolysis of urea by soil enzymes converts urea into ammonium and CO2 gas. Depending on temperature, hydrolysis takes a day to a week. The soil pH around the urea granules strongly increases during this process, favouring NH3 volatilization.
* Ammonia volatilization occurs when NH4+ is converted to NH3 and lost to the atmosphere. A high soil pH level and temperature favour conversion of NH4+ to NH3. If conversion takes place at the soil surface, losses are highest. These conditions are met when urea is spread and not immediately incorporated.
* Nitrification, by soil bacteria converts NH4+ into NO3- in between a few days and a few weeks. N2O and NO are lost to the atmosphere during the process.
* Uptake of nitrate is rapid due to high particle mobility. Most plants therefore prefer NO3- over NH4+.
* Uptake of ammonium is slower than that of nitrate. NH4+ is bound to clay particles in the soil and roots have to reach it. Most of the NH4+ is therefore nitrified before it is taken-up by plants.
* Denitrification is favoured by lack of oxygen (e.g. water logging). Soil bacteria convert NO3- and NO2- into gaseous NO, N2O and N. These are lost to the atmosphere.
* Immobilization transforms mineral N into soil organic matter. Activity of soil microbes is mainly stimulated by NH4+. Immobilized N is not immediately available for plant uptake, but needs to be mineralized first. Mineralization of soil organic matter releases NH4+ into soil.
* Leaching of NO3- occurs mainly during winter and fallow periods when percolating rainfall washes residual and mineralized nitrates below the root zone. Accurate fertilization increases N use efficiency and reduces the risk of leaching during the growth period and afterwards.

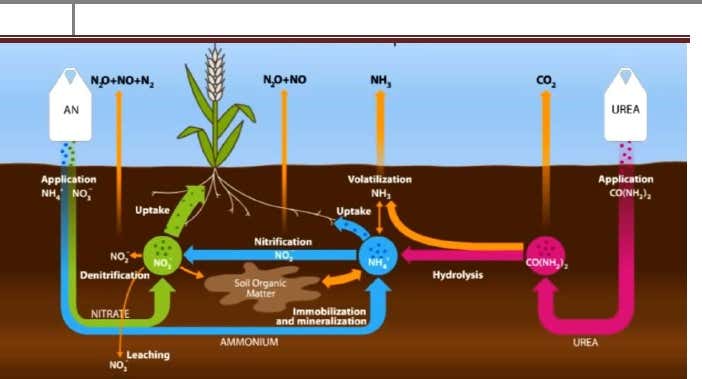


Figure 7: Nitrogen undergoes transformations in the soil depending on the chemical composition of the nitrogen applied (Copyrights 2019 © Yara International, Norway).

The major human activities that today influence the global N cycle are fossil fuel combustion, the production and use of chemical fertilizer, and the growing of N-fixing crops. These activities are reported to have doubled the magnitude of N fixation over continents. The major environmental issues associated with this enhancement are global climate change, stratospheric ozone depletion, regional smog, visibility degradation, acid rain, water-use impairment, and eutrophication.

**3.2 CLIMATE CHANGE AND MICROBIAL METABOLIC RESPONSES**

The interaction between microbial communities and climate changes can be studied by measuring the rate of transformation of compounds at different stages of biogeochemical cycles. These measurements are the basis for the development of predictive climate models. Some important potential effects that microorganisms can have on climate change are unknown or partly known due to limited knowledge of microbial diversity and physiology under natural conditions. The influence of temperature, CO2 concentration, and precipitation on microbial processes can vary. It depends on the response of microbial communities that is modulated by specific diversity. This can be illustrated by methanogenesis, a process during which component A is transformed into a component B. The process can take place at a theoretical (k) rate and can follow two pathways:

* Quantitatively by increasing the intensity of growth and respiration rate
* Qualitatively by changing the population composition.

In this case, new microbial communities exhibit a different metabolism, determined by distinct organisms. Most climate models use kinetics assuming that microbial populations might perform the function. The process rate is controlled by known environmental factors (temperature, moisture, oxygen concentration). Such models work well within known quantitative limits, but when variations are of a qualitative nature (population or physiological changes), predictions of climate models are exposed to errors. There is the theoretical possibility that the change of microbial physiology may be due to the loss of a function or gain of new one, more efficient in new conditions, change that affect the rate of biogeochemical transformations. In this case, the effects of climate change can have unexpected consequences, difficult to estimate in the long run.

**3.4** **MICROBIAL COMMUNITIES AND MITIGATION POSSIBILITIES OF GREENHOUSE GAS EMISSIONS**

Manipulating microbial processes from terrestrial and aquatic ecosystems provide a potential way to mitigate anthropogenic climate change. Most of the organic carbon is found in soils, and reducing its degradation could limit the process of producing and transferring carbon dioxide into the atmosphere. Since microorganisms are responsible for the degradation of this carbon fraction, deeper knowledge of their physiology could lead to long-term solutions in limiting the effect of climate warming. Depending on the amount of organic matter required for growth, microorganisms can be grouped into oligotrophs and copiotrophs. Unlike copiotrophs, oligotrophs require smaller amounts of nutrients for growth and for this reason they degrade slower the organic matter. During heterotrophic respiration, oligotrophs release a lower amount of carbon dioxide into the atmosphere. From this point of view, theoretical manipulation must be based on those biological activities that reduce the rate of soil respiration and favor the growth of slow carbon-degrading oligotrophic communities. Reducing the amount of carbon dioxide emitted from biological processes could be achieved in systems under the human control, such as agricultural land, in several ways:

* By using low-tillage practices;
* Stimulating activities of slow-degrading bacteria;
* Favouring conditions the growth of fungi.

Long-term carbon sequestration requires a deeper understanding of the interaction between biological processes and external environmental factors. However, tasks such as decreasing of organic matter degradation and reducing carbon dioxide emission are difficult to achieve on a global scale because of the complex mechanisms that control these processes and to our current limits of knowledge.

**Reduction of carbon dioxide emissions**

Soils harbour enormous amounts of carbon two times higher than that present in the atmosphere. As we have shown above, the use of soils can favor carbon sequestration by

manipulating the intensity of heterotrophic respiration and consumption of organic matter. In this respect, measures such as changing the arable soil in woodland, reducing the nitrogen input in agriculture systems, etc could lead to shifts of bacterial communities by promoting oligotrophic species. Agricultural systems lose large amounts of organic carbon during tillage. Therefore, low-tillage practices could favor communities of fungal communities with lower rates of organic carbon degradation than bacteria. Another useful practice is the conversion of agricultural land into permanent grassland that can retain significant amounts of organic carbon on the soil surface. Long-term carbon sequestration requires knowledge of the real potential of soils, as well as the interaction between microbial activity and external factors (temperature, moisture) that affect carbon recycling. In this respect, the manipulation of microbial processes by changing the use of soils can lead to the sequestration of an additional amount of carbon. On a global scale, however, reducing the amount of carbon dioxide emitted into the atmosphere is a difficult task to achieve due to the complexity of processes that control carbon dynamics in different ecosystems, compartments and reservoirs,

**Reduction of methane emissions**

The largest amount of methane emitted in the atmosphere is of microbial origin. Therefore, the reduction of methane emitted can be achieved by controlling methanogenesis. CH4 can be oxidized by methanotrophic bacteria and used as a source of carbon and energy. The process is responsible for consuming a considerable quantity of methane in soil while in the atmosphere it is insignificant Potential strategies for reducing CH4 emissions from terrestrial environment were imagined:

* Introduction of agricultural practices that improve the frequency and duration of flooding in rice paddies which would allow improved soil oxygenation and increased rate of biological oxidation of methane.
* Transformation of arable land and grassland into woodlands.
* Control of methane emissions from ruminants by the use of methanogenesis inhibitors (antibiotics, vaccines).
* The use of fertilizers (eg ammonium sulphate) which promotes the growth of sulphate reducers with competitive inhibitory effect on methanogens.

**Reduction of N2O emissions**

Since a major source of N2O emissions relies on the use of nitrogen fertilizers in agriculture, it is believed that improved management measures such as

* Limiting anaerobic conditions and consequently limiting denitrification in soil;
* Application of slow-release fertilizers
* Using of nitrification inhibitors could contribute to reducing global emissions of this compound into the atmosphere.

**CHAPTER FOUR**

**4.0 CAUSES OF GLOBAL WARMING AND CLIMATE CHANGE**

**Atmospheric Carbon Dioxide Carbon dioxide**

This is commonly known as the greenhouse gas. It is responsible for about half of the atmospheric heat retained by trace gases and also for 50% of the greenhouse effect. Methane (CH4) is 20-30 times more effective than CO2 in trapping heat. The potential of a greenhouse gas to cause greenhouse warming is expressed by “Global Warming Potential” (GWP). The rate and duration of the warming of the 20th century is larger than any other time during the last 1,000 years. The 1990s are likely to have been the warmest decade of the millennium in the Northern Hemisphere, and 1998 is likely to have been the warmest year. Volcanic Eruptions Mount Etna, an active but at present a relatively subdued volcano in Sicily, is a case in point. It is one of the most potent natural sources of carbondioxide. Every year it adds about 25 million tons of carbon dioxide to the atmosphere. The entire region around the volcano is, therefore, enriched in carbon dioxide.

Humans have been emitting extra greenhouse gases, which are the result of burning fossil fuels (like coal, oil and gas). In the next 100 years, CO2 produced by man will cause a lot more warming, from as low as three degrees C to as high as 8 or 10 degrees C.

• Human-caused global warming may have already doubled the chance of “killer” heat waves like the one that scorched Europe in July–August 2003. Strong evidence indicates that the summer was the hottest in Europe in at least the past 500 years (Luterbacher et al., 2004).

• The UHI (Urban Heat Island) is enhanced by human activities within the urban environment. Pollution has a warming effect on a city, in addition to the heat released by industrial processes, household heating and car use. As cities grow, the UHI effect becomes stronger, creating an artificial warming.

• CFCs (Chlorofluorocarbons) are believed to be responsible for 24% of the human contribution to greenhouse gases. They also deplete ozone in the stratosphere.

• Most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic GHG (green house gas) concentrations.

• Humanity may have only a narrow window of time left, perhaps a decade or so, to begin the long process of stabilizing greenhouse gas concentrations at a level that can avert devastating and irreversible impacts from

**Travel and Transportation**

The vast majority of vehicles on the road (and in the air and water) are powered via fossil fuels, such as gasoline. As they burn this fuel to power their engines, these vehicles release carbon and other pollutants, affecting both air and water quality.

**Industrialization**

The transition of economies from primarily farming-based to primarily industrial is likely to have been the earliest cause of the rampant global warming we see today. Research suggests global warming was kicked off partly by the Industrial Revolution in many countries, which occurred in the mid-19th century.

While these changes took place within those times, other global economies are starting to emerge today, further contributing to industrialization and related pollution.

**Deforestation**

Thisis the removal of a [forest](https://en.wikipedia.org/wiki/Forest" \o "Forest) or stand of trees from land which is then [converted](https://en.wikipedia.org/wiki/Land_conversion" \o "Land conversion) to a non-forest use. Deforestation can involve conversion of forest land to [farms](https://en.wikipedia.org/wiki/Farm" \o "Farm), [ranches](https://en.wikipedia.org/wiki/Ranch" \o "Ranch), or [urban](https://en.wikipedia.org/wiki/Urban_area" \o "Urban area) use. The most concentrated deforestation occurs in [tropical rainforests](https://en.wikipedia.org/wiki/Tropical_rainforest" \o "Tropical rainforest). About 31% of Earth's land surface is covered by forests.

The removal of trees without sufficient [reforestation](https://en.wikipedia.org/wiki/Reforestation" \o "Reforestation) has resulted in [habitat damage](https://en.wikipedia.org/wiki/Habitat_destruction" \o "Habitat destruction), [biodiversity loss](https://en.wikipedia.org/wiki/Biodiversity_loss" \o "Biodiversity loss), and [aridity](https://en.wikipedia.org/wiki/Arid" \o "Arid). Deforestation causes [extinction](https://en.wikipedia.org/wiki/Extinction" \o "Extinction), changes to climatic conditions, [desertification](https://en.wikipedia.org/wiki/Desertification" \o "Desertification), and displacement of populations, as observed by current conditions and in the past through the [fossil](https://en.wikipedia.org/wiki/Fossil" \o "Fossil) record. Deforestation also has adverse impacts on [bio sequestration](https://en.wikipedia.org/wiki/Biosequestration" \o "Biosequestration) of atmospheric [carbon dioxide](https://en.wikipedia.org/wiki/Carbon_dioxide" \o "Carbon dioxide), increasing negative feedback cycles contributing to [global warming](https://en.wikipedia.org/wiki/Global_warming" \o "Global warming). [Global warming](https://en.wikipedia.org/wiki/Global_warming" \o "Global warming) also puts increased pressure on communities who seek [food security](https://en.wikipedia.org/wiki/Food_security" \o "Food security) by clearing forests for agricultural use and reducing arable land more generally. Deforested regions typically incur significant other environmental effects such as adverse [soil erosion](https://en.wikipedia.org/wiki/Soil_erosion" \o "Soil erosion) and degradation into [wasteland](https://en.wiktionary.org/wiki/wasteland" \o "wikt:wasteland).

Deforestation is more extreme in tropical and subtropical forests in emerging economies. More than half of all plant and land animal species in the world live in [tropical forests](https://en.wikipedia.org/wiki/Tropical_forest" \o "Tropical forest). As a result of deforestation, only 6.2 million square kilometres (2.4 million square miles) remain of the original 16 million square kilometres (6 million square miles) of tropical rainforest that formerly covered the Earth. An area the size of a [football pitch](https://en.wikipedia.org/wiki/Football_pitch" \o "Football pitch) is cleared from the [Amazon rainforest](https://en.wikipedia.org/wiki/Amazon_rainforest" \o "Amazon rainforest) every minute, with 136 million acres (55 million hectares) of rainforest cleared for animal agriculture overall. More than 3.6 million hectares of virgin tropical forest was lost in 2018.

Millions of acres of forest are cleared every year, whether to harvest wood for making lumber or paper, to clear land for farming and ranching or to make way for residential land industrial areas.

Forests store enormous amounts of carbon, essentially removing it from the air and preventing it from being absorbed into the atmosphere, and this is especially true of rainforests, which are even more endangered than other areas. In addition to losing the natural air – scrubbing function of trees, deforestation decreases biodiversity, which can cause ripple effects throughout entire ecosystems, putting whole species at risk.

**Livestock Production**

Ranching contributes to climate change in a few ways. In addition to clearing trees to make room for large areas adequate for the care and feeding of animals for food, these animals create a huge amount of waste, which produces methane, a very harmful greenhouse gas. Consumption of meat and meat products is expected to continue growing, even doubling by 2050, according to one projection.

**Factory Farming**

The industrialization of agriculture takes the potential negative effects of livestock production and amplifies them. While organic farming can have a positive impact on global warming by reducing carbon through the growth of crops, large-scale, industrialized farming negates the positive impact of organic food and animal production. These large-scale animal producing farms, known as **Concentrated Animal Feeding Operations** (CAFOs) have risen sharply in recent years. CAFO production as a percentage of global production.

**Overuse of Electricity**

The gasoline your car burns was made using fossil fuels, which is how most people get their electricity as well. In most countries, electricity generation is the biggest greenhouse gas contributor, accounting for 28 percent.

**Overfishing**

Hundreds of millions of jobs around the world centre on fishing, and about 3 billion people depend on fish as their main source of protein from food. But just as with most industries, humans have created too much of a good thing, and overfishing is putting the oceans at risk.

Human population growth and resulting over fishing are depleting natural marine stocks, which impacts the health and biodiversity of the entire ocean.

**Use of Aerosols**

Though some forms of aerosols have been banned in many countries, other forms of them still are in wide use. These products are loaded with greenhouse gases, including CO2 and methane, as well as chlorofluorocarbons. Production of aerosols has actually increased throughout the world, with most aerosols being produced in Europe.

**Inability to Change**

Even if we addressed every single other issue, the impact of human-caused global warming will remain for decades, if not centuries. The magnitude of the issue is, quite simply, too difficult for many of us to comprehend. So, many of us think if we can’t truly fix this issue what’s the point of even trying? After all, it’s our very inaction that has worsened many of these issues.

**4.1 EFFECTS OF GLOBAL WARMING AND CLIMATE CHANGE**

The **effects of global warming** or **climate damage** include far-reaching and long-lasting changes to the [natural environment](https://en.wikipedia.org/wiki/Natural_environment" \o "Natural environment), to [ecosystems](https://en.wikipedia.org/wiki/Ecosystems" \o "Ecosystems) and human societies caused directly or indirectly by human emissions of [greenhouse gases](https://en.wikipedia.org/wiki/Greenhouse_gas" \o "Greenhouse gas). It also includes the economic and social changes which stem from living in a warmer world.

**4.1.1 EFFECTS ON THE ENVIRONMENT**

**Physical environment**

The environmental effects of global warming are broad and far-reaching. They include effects on the oceans, ice, and weather and may occur gradually or rapidly.

Between 1993 and 2017, the [global mean sea level rose](https://en.wikipedia.org/wiki/Sea_level_rise" \o "Sea level rise) on average by 3.1 ± 0.3 mm per year, with an acceleration detected as well over the 21st century. The rate of ice loss from glaciers and ice sheets in the Antarctic is a key area of uncertainty since this source could account for 90% of the potential sea level rise, increased ocean warmth is undermining and threatening to unplug Antarctic glacier outlets, potentially resulting in more rapid sea level rise. The [retreat of non-polar glaciers](https://en.wikipedia.org/wiki/Retreat_of_glaciers_since_1850" \o "Retreat of glaciers since 1850) also contributes to sea level rise.

Global warming has led to decades of [shrinking and thinning of the Arctic sea ice](https://en.wikipedia.org/wiki/Arctic_sea_ice_decline" \o "Arctic sea ice decline), making it vulnerable to atmospheric anomalies Projections of declines in Arctic sea ice vary. While ice-free summers are expected to be rare at 1.5 °C degrees of warming, they are set to occur once every three to ten years at a warming level of 2.0 °C increasing the [ice–albedo feedback](https://en.wikipedia.org/wiki/Ice%E2%80%93albedo_feedback" \o "Ice–albedo feedback). Higher atmospheric CO2 concentrations have led to an increase in dissolved CO2, which causes [ocean acidification](https://en.wikipedia.org/wiki/Ocean_acidification" \o "Ocean acidification). Furthermore, oxygen levels decrease because oxygen is less soluble in warmer water, an effect known as **[ocean deoxygenation](https://en.wikipedia.org/wiki/Ocean_deoxygenation" \o "Ocean deoxygenation).**

Many regions have probably already seen [increases in warm spells and heat waves](https://en.wikipedia.org/wiki/Effects_of_global_warming" \l "Extreme_weather" \o "Effects of global warming), and it is virtually certain that these changes will continue over the 21st century. Since the 1950s, [droughts](https://en.wikipedia.org/wiki/Drought" \o "Drought) and [heat waves](https://en.wikipedia.org/wiki/Heat_wave" \o "Heat wave) have appeared simultaneously with increasing frequency.Extremely wet or dry events within the [monsoon](https://en.wikipedia.org/wiki/Monsoon" \o "Monsoon) period have increased in [India](https://en.wikipedia.org/wiki/India" \o "India) and East AsiaVarious mechanisms have been identified that might explain [extreme weather](https://en.wikipedia.org/wiki/Extreme_weather" \o "Extreme weather) in mid-latitudes from the rapidly warming Arctic, such as the [jet stream](https://en.wikipedia.org/wiki/Jet_stream" \o "Jet stream) becoming more erratic. The maximum rainfall and wind speed from [hurricanes and typhoons are likely increasing](https://en.wikipedia.org/wiki/Tropical_cyclones_and_climate_change" \o "Tropical cyclones and climate change).

[Long-term effects of global warming](https://en.wikipedia.org/wiki/Long-term_effects_of_global_warming" \o "Long-term effects of global warming): On the timescale of centuries to millennia, the magnitude of global warming will be determined primarily by anthropogenic CO2 emissions. This is due to carbon dioxide's very long lifetime in the atmosphere. The emissions are estimated to have prolonged the current [interglacial](https://en.wikipedia.org/wiki/Interglacial" \o "Interglacial) period by at least 100,000 years. Because the great mass of glaciers and ice caps depressed the Earth's crust, another long-term effect of ice melt and deglaciation is the gradual rising of landmasses, a process called [post-glacial rebound](https://en.wikipedia.org/wiki/Post-glacial_rebound" \o "Post-glacial rebound). This could be facilitating seismic and volcanic activity in places like [Iceland](https://en.wikipedia.org/wiki/Iceland" \o "Iceland). [Tsunamis](https://en.wikipedia.org/wiki/Tsunami" \o "Tsunami) could be generated by submarine landslides caused by warmer ocean water thawing ocean-floor permafrost or releasing [gas hydrates](https://en.wikipedia.org/wiki/Clathrate_hydrate" \o "Clathrate hydrate). Sea level rise will continue over many centuries.

[Abrupt climate change](https://en.wikipedia.org/wiki/Abrupt_climate_change" \o "Abrupt climate change), [tipping points in the climate system](https://en.wikipedia.org/wiki/Tipping_points_in_the_climate_system" \o "Tipping points in the climate system): Climate change could result in global, large-scale changes Some large-scale changes could occur [abruptly](https://en.wikipedia.org/wiki/Abrupt_climate_change" \o "Abrupt climate change), i.e. over a short time period, and might also be [irreversible](https://en.wikipedia.org/wiki/Effects_of_global_warming" \l "Irreversibilities" \o "Effects of global warming). One potential source of abrupt climate change would be the rapid release of methane and carbon dioxide from [permafrost](https://en.wikipedia.org/wiki/Permafrost" \o "Permafrost), which would amplify global warming. Another example is the possibility for the [Atlantic Meridional Overturning Circulation](https://en.wikipedia.org/wiki/Atlantic_Meridional_Overturning_Circulation" \o "Atlantic Meridional Overturning Circulation) to slow or shut down (see also [shutdown of thermohaline circulation](https://en.wikipedia.org/wiki/Shutdown_of_thermohaline_circulation" \o "Shutdown of thermohaline circulation)). This could trigger cooling in the North [Atlantic](https://en.wikipedia.org/wiki/Atlantic" \o "Atlantic), Europe, and North America.

The main impact of global warming on the weather is an increase in extreme weather events such as heat waves, droughts, cyclones, blizzards and rainstorms. Of the 20 costliest climate and weather disasters that have occurred in the United States since 1980, eight have taken place since 2010, four of these in 2017 alone. Such events will continue to occur more often and with greater intensity.Episodes of intense precipitation contribute to flooding, soil erosion, landslides, and damage to structures and crops.

**PRECIPITATION**

Higher temperatures lead to increased evaporation and surface drying. As the air warms, its water-holding capacity also increases, particularly over the oceans. In general the air can hold about 7% more moisture for every 1°C of temperature rise. In the tropics, there's more than a 10% increase in precipitation for a 1°C increase in temperature. Changes have already been observed in the amount, intensity, frequency, and type of [precipitation](https://en.wikipedia.org/wiki/Precipitation_(meteorology)" \o "Precipitation (meteorology)). Extreme precipitation events are sometimes the result of [atmospheric rivers](https://en.wikipedia.org/wiki/Atmospheric_river" \o "Atmospheric river) - wide paths of atmospheric moisture composed of condensed water vapour. Widespread increases in heavy precipitation have occurred even in places where total rain amounts have decreased. Projections of future changes in precipitation show overall increases in the global average, but with substantial shifts in where and how precipitation falls. Projections suggest a reduction in rainfall in the [subtropics](https://en.wikipedia.org/wiki/Subtropics" \o "Subtropics), and an increase in precipitation in sub polar latitudes and some [equatorial regions](https://en.wikipedia.org/wiki/Equatorial_region" \o "Equatorial region). In other words, regions which are dry at present will in general become even drier, while regions that are currently wet will in general become even wetter. This projection does not apply to every locale, and in some cases can be modified by local conditions. Although increased rainfall will not occur everywhere, models suggest most of the world will have a 16-24% increase in heavy precipitation intensity by 2100.

**Temperatures**

Over most land areas since the 1950s, it is very likely that at all times of year both days and nights have become warmer due to human activities. There may have been changes in other climate extremes (e.g., [floods](https://en.wikipedia.org/wiki/Flood" \o "Flood), [droughts](https://en.wikipedia.org/wiki/Drought" \o "Drought) and [tropical cyclones](https://en.wikipedia.org/wiki/Tropical_cyclone" \o "Tropical cyclone)) but these changes are more difficult to identify.

Some changes (e.g. more frequent hot days) will probably be evident in the near term (2016–2035), while other near-term changes (e.g. more intense droughts and tropical cyclones) are more uncertain.

Future climate change will include more very hot days and fewer very cold days. The frequency, length and intensity of [heat waves](https://en.wikipedia.org/wiki/Heat_wave" \o "Heat wave) will very likely increase over most land areas. Higher growth in anthropogenic GHG emissions would cause more frequent and severe temperature extremes. If GHG emissions grow a lot, already dry regions may have more droughts and less [soil moisture](https://en.wikipedia.org/wiki/Soil_moisture" \o "Soil moisture). Over most of the mid-latitude land masses and wet tropical regions, extreme precipitation events will very likely become more intense and frequent.

#### Heat waves

[Global warming](https://en.wikipedia.org/wiki/Global_warming" \o "Global warming) boosts the probability of [extreme weather](https://en.wikipedia.org/wiki/Extreme_weather" \o "Extreme weather) events such as [heat waves](https://en.wikipedia.org/wiki/Heat_wave" \o "Heat wave) where the daily maximum temperature exceeds the average maximum temperature by 5°C (9 °F) for more than five consecutive days.

In the last 30–40 years, heat waves with high humidity have become more frequent and severe. Extremely hot nights have doubled in frequency. The area in which extremely hot summers are observed has increased 50-100 fold. These changes are not explained by natural variability, and are attributed by climate scientists to the influence of [anthropogenic](https://en.wiktionary.org/wiki/anthropogenic" \o "wikt:anthropogenic) climate change. Heat waves with high humidity pose a big risk to human health while heat waves with low humidity lead to dry conditions that increase [wildfires](https://en.wikipedia.org/wiki/Wildfires" \o "Wildfires). The mortality from extreme heat is larger than the mortality from hurricanes, lightning, tornadoes, floods, and earthquakes together.

#### Oxygen depletion

Warmer water cannot contain as much oxygen as cold water, so heating is expected to lead to less oxygen in the ocean. Other processes also play a role: stratification may lead to increases in respiration rates of organic matter, further decreasing oxygen content. The ocean has already lost oxygen, throughout the entire water column and [oxygen minimum zones](https://en.wikipedia.org/wiki/Oxygen_minimum_zone" \o "Oxygen minimum zone) are expanding worldwide. This has adverse consequences for ocean life.

**Biosphere**

In terrestrial [ecosystems](https://en.wikipedia.org/wiki/Ecosystem" \o "Ecosystem), the earlier timing of spring events, as well as pole ward and upward shifts in plant and animal ranges, have been linked with high confidence to recent warming. It is expected that most ecosystems will be affected by higher atmospheric CO2 levels and higher global temperatures. Global warming has contributed to the expansion of drier climatic zones, such as, probably, the [expansion of deserts](https://en.wikipedia.org/wiki/Desertification" \o "Desertification) in the [subtropics](https://en.wikipedia.org/wiki/Subtropics" \o "Subtropics). Without substantial actions to reduce the rate of global warming, land-based ecosystems risk major shifts in their composition and structure. Overall, it is expected that climate change will result in the [extinction](https://en.wikipedia.org/wiki/Extinction" \o "Extinction) of many species and reduced diversity of ecosystems. Rising temperatures push bees to their physiological limits, and could cause the extinction of bee populations.

The ocean has heated more slowly than the land, but plants and animals in the ocean have migrated towards the colder poles as fast as or faster than species on land. Just as on land, heat waves in the ocean occur more due to climate change, with harmful effects found on a wide range of organisms such as corals, [kelp](https://en.wikipedia.org/wiki/Kelp" \o "Kelp), and [seabirds](https://en.wikipedia.org/wiki/Seabirds" \o "Seabirds). Ocean acidification threatens damage to [coral reefs](https://en.wikipedia.org/wiki/Environmental_issues_with_coral_reefs" \o "Environmental issues with coral reefs), [fisheries](https://en.wikipedia.org/wiki/Fishery" \o "Fishery), [protected species](https://en.wikipedia.org/wiki/Protected_species" \o "Protected species), and other [natural resources](https://en.wikipedia.org/wiki/Natural_resource" \o "Natural resource) of value to society. Higher oceanic CO2 may affect the brain and central nervous system of certain fish species, which reduces their ability to hear, smell, and evade predators.

**4.1.2 EFFECTS ON HUMANS**

The [effects of climate change on human systems](https://en.wikipedia.org/wiki/Effects_of_climate_change_on_humans" \o "Effects of climate change on humans), mostly due to warming and shifts in [precipitation](https://en.wikipedia.org/wiki/Precipitation" \o "Precipitation), have been detected worldwide. The future social impacts of climate change will be uneven across the world. All regions are at risk of experiencing negative impacts with low-latitude, [less developed areas](https://en.wikipedia.org/wiki/Developing_countries" \o "Developing countries) facing the greatest risk. Global warming has likely already increased global economic inequality, and is projected to do so in the future.[Regional impacts of climate change](https://en.wikipedia.org/wiki/Regional_effects_of_global_warming" \o "Regional effects of global warming) are now observable on all continents and across ocean regions. The Arctic, [Africa](https://en.wikipedia.org/wiki/Africa" \o "Africa), small islands, and [Asian](https://en.wikipedia.org/wiki/Asia" \o "Asia) [megadeltas](https://en.wikipedia.org/wiki/River_delta" \o "River delta) are regions that are likely to be especially affected by future climate change. Many risks increase with higher magnitudes of global warming.

**Food and water**

[Crop production](https://en.wikipedia.org/wiki/Crop_productivity" \o "Crop productivity) will probably be negatively affected in low-latitude countries, while effects at northern latitudes may be positive or negative. Global warming of around 4°C relative to late 20th century levels could pose a large risk to global and regional food security. The impact of climate change on crop productivity for the four major crops was negative for wheat and maize, and neutral for soy and rice, in the years 1960–2013.Up to an additional 183 million people worldwide, particularly those with lower incomes, are at risk of hunger as a consequence of warming. While increased CO2 levels help crop growth at lower temperature increases, those crops do become less nutritious. Based on local and indigenous knowledge, climate change is already affecting food security in mountain regions in South America and Asia, and in various drylands, particularly in Africa. Regions dependent on glacier water, regions that are already dry, and small islands are also at increased risk of water stress due to climate change. A number of climate-related trends have been observed that affect [water resources](https://en.wikipedia.org/wiki/Water_resources" \o "Water resources). These include changes in precipitation, the cryosphere and [surface waters](https://en.wikipedia.org/wiki/Surface_water" \o "Surface water) (e.g., changes in [river flows](https://en.wikipedia.org/wiki/River_flows" \o "River flows)). Observed and projected impacts of climate change on [freshwater](https://en.wikipedia.org/wiki/Freshwater" \o "Freshwater) systems and their management are mainly due to changes in temperature, sea level and precipitation variability. Changes in temperature are correlated with variability in precipitation because the [water cycle](https://en.wikipedia.org/wiki/Water_cycle" \o "Water cycle) is reactive to temperature. Temperature increases change precipitation patterns. Excessive precipitation leads to excessive sediment deposition, nutrient pollution, and concentration of minerals in [aquifers](https://en.wikipedia.org/wiki/Aquifer" \o "Aquifer).

**Health and security**

Generally, [impacts on public health](https://en.wikipedia.org/wiki/Effects_of_global_warming_on_human_health" \o "Effects of global warming on human health) will be more negative than positive. Impacts include the direct effects of extreme weather, leading to injury and loss of life; and indirect effects, such as [under nutrition](https://en.wikipedia.org/wiki/Undernutrition" \o "Undernutrition) brought on by [crop failures](https://en.wikipedia.org/wiki/Crop_failure" \o "Crop failure). Temperature rise has been connected to increased numbers of suicides. Climate change may also lead to new human diseases. For example, while ordinary temperatures usually kill off the yeast *[Candida auris](https://en.wikipedia.org/wiki/Candida_auris" \o "Candida auris)* before it infects humans, three strains have recently appeared in widely separate regions, leading researchers to postulate that warmer temperatures are driving it to adapt to higher temperatures at which it can more readily infect humans. Climate change has been linked to an increase in violent conflict by amplifying poverty and economic shocks, which are well-documented drivers of these conflicts. Links have been made between a wide range of violent behaviour including fist fights, [violent crimes](https://en.wikipedia.org/wiki/Violent_crime" \o "Violent crime), [civil unrest](https://en.wikipedia.org/wiki/Civil_disorder" \o "Civil disorder), and [wars](https://en.wikipedia.org/wiki/War" \o "War). Humans are exposed to climate change through changing weather patterns (temperature, precipitation, sea-level rise and more frequent extreme events) and indirectly through changes in water, air and food quality and changes in ecosystems, agriculture, industry and settlements and the economy. Air pollution, wildfires, and heat waves caused by global warming have significantly affected human health, and in 2007, the World Health Organization estimated 150,000 people were being killed by climate-change-related issues every year.

A study by the [World Health Organization](https://en.wikipedia.org/wiki/World_Health_Organization" \o "World Health Organization)concluded that climate change was responsible for 3% of [diarrhoea](https://en.wikipedia.org/wiki/Diarrhoea" \o "Diarrhoea), 3% of [malaria](https://en.wikipedia.org/wiki/Malaria" \o "Malaria), and 3.8% of [dengue fever](https://en.wikipedia.org/wiki/Dengue_fever" \o "Dengue fever) deaths worldwide in 2004. Total attributable mortality was about 0.2% of deaths in 2004; of these, 85% were child deaths. The effects of more frequent and extreme storms were excluded from this study.

**Livelihoods, industry, and infrastructure**

In small islands and [mega deltas](https://en.wikipedia.org/wiki/Mega_delta" \o "Mega delta), [inundation](https://en.wikipedia.org/wiki/Inundation" \o "Inundation) from sea level rise is expected to threaten vital infrastructure and human settlements. This could lead to [homelessness](https://en.wikipedia.org/wiki/Climate_refugee" \o "Climate refugee) in countries with low-lying areas such as [Bangladesh](https://en.wikipedia.org/wiki/Bangladesh" \o "Bangladesh), as well as [statelessness](https://en.wikipedia.org/wiki/Statelessness" \o "Statelessness) for populations in island nations, such as the [Maldives](https://en.wikipedia.org/wiki/Maldives" \o "Maldives) and [Tuvalu](https://en.wikipedia.org/wiki/Tuvalu" \o "Tuvalu). Climate change can be an important driver of [migration](https://en.wikipedia.org/wiki/Environmental_migrant" \o "Environmental migrant), both within and between countries.

The majority of severe impacts of climate change are expected in [sub-Saharan Africa](https://en.wikipedia.org/wiki/Sub-Saharan_Africa" \o "Sub-Saharan Africa) and [South-East Asia](https://en.wikipedia.org/wiki/South-East_Asia" \o "South-East Asia), where existing poverty is exacerbated. Current inequalities between men and women, between rich and poor and between people of different ethnicity have been observed to worsen as a consequence of climate variability and climate change. Existing stresses include poverty, political conflicts, and [ecosystem](https://en.wikipedia.org/wiki/Ecosystem" \o "Ecosystem) degradation. Regions may even become uninhabitable, with humidity and temperatures reaching levels too high for humans to survive.

**4.1.3 REGIONAL EFFECTS**

Regional effects of global warming vary in nature. Some are the result of a generalised global change, such as rising temperature, resulting in local effects, such as melting ice. In other cases, a change may be related to a change in a particular ocean current or weather system. In such cases, the regional effect may be disproportionate and will not necessarily follow the global trend.

There are three major ways in which global warming will make changes to regional climate: melting or forming ice, changing the [hydrological cycle](https://en.wikipedia.org/wiki/Hydrological_cycle" \o "Hydrological cycle) (of [evaporation](https://en.wikipedia.org/wiki/Evaporation" \o "Evaporation) and [precipitation](https://en.wikipedia.org/wiki/Precipitation_(meteorology)" \o "Precipitation (meteorology))) and changing [currents in the oceans](https://en.wikipedia.org/wiki/Ocean_current" \o "Ocean current) and air flows in the atmosphere. The coast can also be considered a region, and will suffer severe impacts from [sea level rise](https://en.wikipedia.org/wiki/Sea_level_rise" \o "Sea level rise).

The [Arctic](https://en.wikipedia.org/wiki/Arctic" \o "Arctic), [Africa](https://en.wikipedia.org/wiki/Africa" \o "Africa), small islands and [Asian](https://en.wikipedia.org/wiki/Asia" \o "Asia) [megadeltas](https://en.wikipedia.org/wiki/River_delta" \o "River delta) are regions that are likely to be especially affected by climate change. [Low-latitude](https://en.wikipedia.org/wiki/Tropics" \o "Tropics), [less-developed](https://en.wikipedia.org/wiki/Developing_country" \o "Developing country) regions are at most risk of experiencing negative impacts due to climate change.[[121]](https://en.wikipedia.org/wiki/Effects_of_global_warming" \l "cite_note-schneider_distribution_of_impacts-121) [Developed countries](https://en.wikipedia.org/wiki/Developed_countries" \o "Developed countries) are also vulnerable to climate change.[[122]](https://en.wikipedia.org/wiki/Effects_of_global_warming" \l "cite_note-schneider_regional_vulnerabilities-122) For example, developed countries will be negatively affected by increases in the severity and frequency of some [extreme weather](https://en.wikipedia.org/wiki/Extreme_weather" \o "Extreme weather) events, such as [heat waves](https://en.wikipedia.org/wiki/Heat_wave" \o "Heat wave). Projections of future climate changes at the regional scale do not hold as high a level of scientific confidence as projections made at the global scale. It is, however, expected that future warming will follow a similar geographical pattern to that seen already, with the greatest warming over land and high northern [latitudes](https://en.wikipedia.org/wiki/Latitude" \o "Latitude), and least over the [Southern Ocean](https://en.wikipedia.org/wiki/Southern_Ocean" \o "Southern Ocean) and parts of the [North Atlantic Ocean](https://en.wikipedia.org/wiki/North_Atlantic_Ocean" \o "North Atlantic Ocean). Land areas warm faster than ocean, and this feature is even stronger for extreme temperatures.

**4.2 GLOBAL WARMING AND CLIMATE CHANGE PREVENTION**

Renewable energy sources are important because they are clean. They avoid burning polluting dirty fossil fuels. This is energy derived from natural resources which cannot be depleted over time and can be replenished within a short period. Some of the widely used renewable energy sources include solar power, wind energy, hydropower, biomass, geothermal, and waste conversion. [Different Types of Renewable Energy](https://www.trvst.world/inspiration/different-types-of-renewable-energy/) gives an in-depth explanation of how energy can be harvested from these sources.

#### ****Switching away from fossil fuels****

To reduce the progress of climate change, we should all work towards switching from non-renewable sources to renewable power sources. This is because the harmful processes and emissions that come with the former, have little to no presence with the latter.

Let’s take a look at some of the renewable sources available and their potential impact on the climate.

* **Solar energy**is derived from the sun. [Solar energy is produced using processes that require no gas emissions](https://www.trvst.world/inspiration/how-is-solar-energy-produced/). As long as the sun is burning, we can never use up its resources.
* **Wind power**is driven by the temperature of the earth’s surface. Although land space is required, there is less disruption to natural habitats from wind turbines which help balance the [advantages and disadvantages of wind energy](https://www.trvst.world/inspiration/advantages-and-disadvantages-of-wind-energy/).
* **Hydropower**relies on the water cycle and the force of flowing water for energy conversion. We’ve had a long [history with hydroelectric energy](https://www.trvst.world/inspiration/the-history-of-hydroelectric-energy/) dating from early mills grinding grain for bread. Energy companies use hydropower to generate electricity.
* **Geothermal**is generated using the heat within the earth’s crust. People use this source to heat buildings, bathwater, and to generate electricity.
* **Biomass**and [bioenergy are produced from organic plant and animal materials](https://www.trvst.world/inspiration/how-is-bio-energy-produced/). We convert biomass to liquid biofuels or biogas to use

These sources don’t have the impact that non-renewable sources have on the environment. Gas emissions are low, or non-existent in some cases. The structure of the earth does not have to be compromised through drilling or blasting. Generating energy from these [renewable energy sources](https://www.trvst.world/inspiration/different-types-of-renewable-energy/) doesn’t require a constant release of metal and toxins into our water bodies.

**Sustainable infrastructure**

In order to reduce the CO2 emissions from buildings - caused by heating, air conditioning, hot water or lighting - it is necessary both to build new low energy buildings, and to renovate the existing constructions.

**Sustainable transportation**

Promoting public transportation, carpooling, but also electric and **[hydrogen mobility](https://solarimpulse.com/hydrogen-mobility-solutions)**, can definitely help reduce CO2 emissions and thus fight global warming.

**Responsible consumption & recycling**

Adopting responsible consumption habits is crucial, be it regarding food (particularly meat), clothing, cosmetics or cleaning products. Last but not least, recycling is an absolute necessity for dealing with waste.

**Energy & water efficiency**

Producing clean energy is essential, but reducing our consumption of energy and water by using more efficient devices (e.g. LED light bulbs, innovative shower system) is less costly and equally important.

CONCLUSION

Human-induced climate change has contributed to changing patterns of extreme weather across the globe, from longer and hotter heat waves to heavier rains. From a broad perspective, all weather events are now connected to climate change. While natural variability continues to play a key role in extreme weather, climate change has shifted the odds and changed the natural limits, making certain types of extreme weather more frequent and more intense.

While our understanding of how climate change affects extreme weather is still developing, evidence suggests that extreme weather may be affected even more than anticipated. Extreme weather is on the rise, and the indications are that it will continue to increase, in both predictable and unpredictable ways.