Website: www.chem-tox-ecotox.org/Scientific Reviews.....November 2019

SCIENTIFIC REVIEWS

"Blue Planet"is Expected to Experience Severe Water Shortages?

How climate change and rising temperatures are threatening the global water cycle on Earth

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Abstract

Planet Earth in the solar system is called the "Blue planet" because of the vast oceans that cover 2/3 of the surface. Water and the atmospheric envelope surrounding the Earth are the most important factors supporting biological life. The surface of the Earth is covered by 71% with water, but, only 3% of this water on the Earth's surface is freshwater and less than 0.5% of the fresh water is accessible for consumption as drinking water. The Hydrologic Water Cycle on Earth influences the intensity of climate variability and climate changes on Earth throughout the year and plays important part of extreme events such as cyclones, droughts and floods. The history of Earth has many examples that well established civilizations collapsed and disappeared from lack of water and especially from extensive droughts that affected agriculture and water resources. The irony is, that today more than one billion people do not have access to safe drinking water and it is estimated that by 2025, almost 20% of the global population are likely to be living in countries or regions with absolute water scarcity. Global estimates showed that 1.3 billion jobs worldwide (42% of the world's total active workforce) are heavily water-dependent, including work in agriculture, mining and industries ranging from paper to pharmaceuticals. Global water scarcity is the result of overpopulation, urbanization of more than 50% of the global population which increased consumption, intensive agriculture wasting large volumes of water, expansion of the industrial and energy sectors that need vast amounts of water are some of the causes for future water scarcity on Earth. But the most important factors are climatic change and increasing surface temperatures. This review collected some important research papers, books and reports from national and international organizations and the IPCC (Intergovernmental Panel on Climate Change) which have advanced the investigations for the scientific basis of the climate changes of the last decades and the threat of rising temperatures on Earth ecosystems, urban and coastal areas, agriculture and fresh water resources.

Introduction: Water on Earth, the most valuable natural resource

Water (H_2O) covers roughly 71% of the Earth's surface, with a volume of 1,386,000,000 cubic kilometers. The majority of Earth's water, over 96%, is saline in the oceans (with 3.5 % salt). Of the total freshwater on Earth, over 68% is locked up in ice and glaciers. Another 30% of freshwater is in the ground. Fresh surface-water sources, such as rivers, wetlands and lakes, only constitute about 93,100 cubic kilometers, which is about 1/150th of one percent of total water. Water also exists in the air as water vapour, in rivers and lakes, in icecaps and glaciers, in the ground as soil moisture and in aquifers. Rivers, lakes and artificial wells are the sources of most of the water people use globally. Water is essential to every form of life and in particular for humans. The embryo's body contains 97% water, the new-born babies' body have 80% water, and adults' body have 60-65% water.[1-3]


Figure 1. Earth is the only planet in the solar system with water and its surface is covered 71% by water (H_2O)**.** Water is also known as a "primordial soup". It is the only element on Earth capable of existing in three states of matter: solid, liquid and gas.

Water and the atmosphere surrounding the Earth are the most important factors supporting biological life. It must be stressed that less than 1% of Earth's water is freshwater that is easily accessible to us to meet our needs, and most of that water is replenished by precipitation—a vital component of the water cycle, affecting every living thing on Earth. The movement of water around Earth's surface is the **Hydrologic (water) Cycle**.

The Sun is in the centre of the solar system and despite the distance, many millions of kilometers away, provides the energy that drives the Water Cycle on Earth. Most of Earth's water is stored in the oceans where it can remain for hundreds or thousands of years.[4-6]

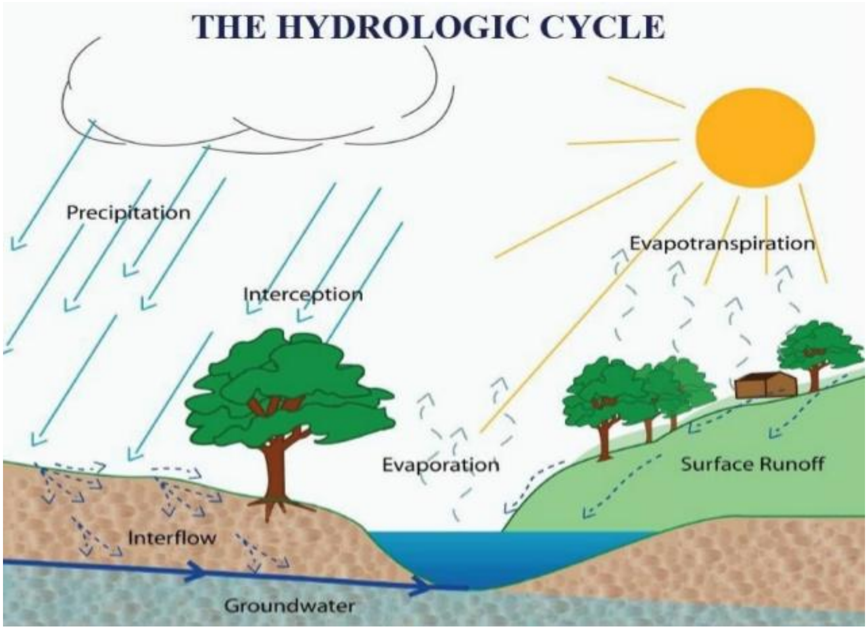

Figure 2. Hydrologic water cycle on Earth**.** The water evaporates under the influence of the Sun, rises to the atmosphere, cools and condenses into rain or snow and falls again as precipitation. Water is collected in rivers, lakes and oceans. The cycling of water and the elevation to the atmosphere is a significant aspect of the weather pattern on Earth.

The Hydrologic Water Cycle influences the intensity of climate variability and climate changes on Earth through the year. It is the key part of extreme events such as drought and floods. Its abundance and timely delivery are critical for meeting the needs of human society and ecosystems (plant, animals, forests, aquatic natural resources). Humans in every country rely on clean water supply and daily use water for drinking, industrial applications, irrigating agriculture, hydropower, waste disposal, and recreation. For centuries, humans have realized that it is important that water sources are protected from pollution, are not overused, collected and overused again.[7,8]

Water is very important both for human uses and ecosystem health. In many areas, water supplies are being depleted because of population growth, pollution, and excessive development. These stresses have been made worse by climate variations and changes that affect the hydrologic cycle. Water stress causes deterioration of fresh water resources in terms of quantity (aquifer over-exploitation, dry rivers, etc.) and quality (eutrophication, organic matter pollution, saline intrusion, etc.). Such deterioration in water sources can result in health problems to plants and animals, and in particular have a negative influence on the growth and survival of the sensitive ecosystems on Earth.[9,10]

Figure 3. Satellite image of the Sundarbans the largest delta in the world (Earth from Space. Satellite Image/BBC/DEIMOS IMAGING SLU) Mangrove area in the delta formed by the confluence of Ganges, Brahmaputra and Meghna Rivers in the Bay of Bengal. Sundarbans was victim of large-scale clearing and settlement to support one of the densest human populations in Asia, this ecoregion is under a great threat of extinction. Hundreds of years of habitation and exploitation have exacted a heavy toll on this ecoregion's habitat and biodiversity. Habitat loss in this ecoregion is so extensive, and the remaining habitat is so fragmented, that it is difficult to ascertain the composition of the original vegetation of this ecoregion.

Ancient civilizations that collapsed from lack of water and extensive droughts

The history of Earth has many examples that well established civilizations collapsed and disappeared from lack of water and especially from extensive droughts that affected agriculture.[11]

Droughts and repeated lack of fresh water for the needs of large numbers of people has been proved catastrophic in the history of the human civilization. Droughts deprive people of food (cultivated or collected from forests) and drinking water, two things necessary to sustain life. Drought causes the soil to dry up, cities lack the means to feed animals, clean spaces and provide water for many domestic activities. Lack of water forces the inevitable collapse even civilization that were very organized. People abandon lands that no longer are able to supply them with the food and fresh water. It must be emphasized that the fall of great empires or civilizations in the past is usually due to a complex set of causes, but drought has often been identified as the primary culprit or a significant contributing factor. In their specialized book Justin Sheffield and Eric Wood (Princeton University), *Drought (2011)* identified more than 10 civilizations, cultures and nations that (probably) collapsed, in part, because of drought.[12]

a. **The Akkadian Empire in Syria,** 2,334 BC – 2,193 BC**.** The civilization started in Mesopotamia 4,200 years ago, and controlled Mesopotamia, the Levant, and parts of Iran. The area was beset by a 300-year drought and literally dried up. The results of the extensive drought were swift and the consequences severe, beginning about 2,200 B.C, resulting in the final collapse of **the Akkadian civilization. .**

b. ***The Old Kingdom of ancient Egypt*****,** 4,200 years ago. The same drought severely shrank the normal floods on the Nile River in ancient Egypt. The floods of the Nile fertilized the fields and allowed the Egyptians to cultivate plants for food. The drought led to poor harvests, reduced tax income and insufficient funds to finance the pharaoh's government, hastening the collapse of Egypt's pyramid-building Old Kingdom.

c. **The Late Bronze Age civilization** in the Eastern Mediterranean. About 3,200 years ago, the Eastern Mediterranean hosted some of the world's most advanced civilizations. The Mycenaean culture was flourishing in Greece and Crete. However, around 1,200 BC, Eastern Mediterranean civilizations declined or collapsed. According to a 2013 investigation in PLOS, studying grains of fossilized pollen shows that this collapse coincided with the onset of a 300-year drought event.[13]

d. **The Maya civilization o**f 250 - 900 AD in Mexico. Severe drought killed millions of Maya people (famine and lack of water), and initiated internal collapses that destroyed their civilization at the peak of their cultural development, between 750 - 900 AD.[14]

Figure 3. The severity of drought and the demise of the Maya civilisation has been quantified, representing another piece of evidence solving the longstanding mystery. An inscription on the tomb of Ankhtifi (Ancient Egypt) during the collapse describes the pitiful state of the country when famine stalked the land: *"the whole country has become like locusts going in search of food".* The Pyramid of Khafre and the Great Sphinx of Giza.

e. **The Tang Dynasty in China**, 700 - 907 AD. China is a vast country with deserts, extensive plains and arable lands field, large rivers. China experienced through the ages many droughts. Dynastic changes in China often occurred because of popular uprisings during crop failure and famine associated with drought. The Tang dynasty began to weaken in the 8th century AD, and it fully collapsed in 907 AD. Scientific studies found sediments from Lake Huguang Maar with sudden and sustained decline in summertime monsoon rainfall. Agriculture in China depended upon the summer monsoon, which supplied plenty of water for food cultivation. A disastrous harvest precipitated by drought brought famine to China under the rule of the Tang dynasty. After nearly three centuries of rule—the dynasty fell when its emperor, Ai, was deposed, and the empire was divided (907 AD).[15]

f. **The Tiwanaku Empire of Bolivia's Lake Titicaca** region, 300 - 1000 AD. The Tiwanaku Empire was one of the most important South

American civilizations prior to the Inca Empire, dominating the region for 500 years. But the successful empire ended abruptly between 1000 - 1100 AD, following a drying of the region, as measured by ice accumulation in the Quelccaya Ice Cap, Peru. Studies of sediment cores from nearby Lake Titicaca document a 10-meter drop in lake level at this time.[16]

g. **The Ancestral Puebloan (Anasazi) culture in the Southwest U.S.** in the 11th - 12th centuries AD. Beginning in 1150 AD, North America experienced a 300-year drought called the Great Drought, which has often been cited as a primary cause of the collapse of the ancestral Puebloan (formally called Anasazi) civilization in the Southwest U.S. The Mississippian culture, a mound-building Native American civilization that flourished in what is now the Midwestern, Eastern, and Southeastern U.S., also collapsed at this time.[17,18]

h. **The Khmer Empire based in Angkor, Cambodia**, 802 - 1431 AD. The Khmer Empire ruled S. Asia for over 600 years. During this period there were a series of intense decades-long droughts interspersed with intense monsoons (14-15th centuries). These vents in combination with other factors, contributed to the empire's demise. The is climatic evidence from tropical southern Vietnamese tree rings presented in a 2010 study by Buckley *et al.*, "Climate as a contributing factor in the demise of Angkor, Cambodia".*"….The Angkor droughts were of a duration and severity that would have impacted the sprawling city's water supply and agricultural productivity, while high-magnitude monsoon years damaged its water control infrastructure."* [19]

i. **The Ming Dynasty in China**, 1368-1644 AD. The Ming Dynasty in China was one of the greatest eras of orderly government and social stability in human history--collapsed at a time when the most severe drought in the region in over 4000 years was occurring, according to sediments from Lake Huguang Maar analyzed in a 2007 article in *Nature* by Yancheva *et al.* Drought experts Justin Sheffield and Eric Wood of Princeton, in their 2011 book, *Drought,* speculated that a weakened summer monsoon driven by warm El Niño conditions in the Eastern Pacific was responsible for the intense drought, which led to widespread famine.[20]

j. **Modern Syria. Syria's devastating civil war** that began in March 2011 has killed over 300,000 people, displaced at least 7.6 million, and created an additional 4.2 million refugees. While the causes of the war are complex, a key contributing factor was the nation's devastating drought that began in 1998. The drought brought Syria's most severe set

> of crop failures in recorded history, which forced millions of people to migrate from rural areas into cities, where conflict erupted. This drought was almost certainly Syria's worst in the past 500 years (98% chance), and likely the worst for at least the past 900 years (89% chance), according to a 2016 tree ring study by Cook *et al.*, "Spatiotemporal drought variability in the Mediterranean over the last 900 years.".[21]

The role of climate and environmental changes (such as droughts) in the success or failure of human societies and civilizations in the past is a matter of intense scientific debate. But scientists propose it would be simplistic to argue that all episodes of societal change are driven by climatic events, especially in an advanced and complex society such as dynastic China or the Mayas with their sophisticated agriculture, water irrigation and social systems. But prolonged droughts and changes in rain precipitation can influence even modern societies. Water resources impact on human health including increased risk of food and water shortages, increased risk of malnutrition and higher risk of water- and food-borne diseases. Drought even today represents a constant threat to world food security, income losses in third world countries because several sectors of trade and economy infrastructure can be affected.[22,-,24]

Water resources, lack of clean drinking water, water crisis

In the last decades scientists collected extensive data on water resources, water overuse by increasing urbanization, excessive use of water by intensive agriculture and industrial production. For many years there is a consensus that planet Earth is facing a water crisis.

The irony is that at the same time one 1.2 billion people do not have access to safe drinking water (especially in African countries), and 2 billion people have inadequate sanitation. Scientists estimate that by 2025, almost 20% of the global population are likely to be living in countries or regions with absolute water scarcity. Excessive extractions of groundwater (wells) are causing rivers to run dry and wetlands to shrink; freshwater supplies and oceans are becoming polluted. Throughout the world, political tension is rife within and between countries regarding access to precious and dwindling water supplies, tensions that hinder peace processes and threaten to erupt into armed conflict.[25,26]

Figure 4. Water shortage affects every continent and around 2.8 billion people around the world do not have clean water at least for one month out of every year. More than 1.2 billion people lack access to clean drinking water.

The irony is that at the same time one 1.2 billion people do not have access to safe drinking water (especially in African countries), and 2 billion people have inadequate sanitation. Scientists estimate that by 2025, almost 20% of the global population are likely to be living in countries or regions with absolute water scarcity. Excessive extractions of groundwater (wells) are causing rivers to run dry and wetlands to shrink; freshwater supplies and oceans are becoming polluted. Throughout the world, political tension is rife within and between countries regarding access to precious and dwindling water supplies, tensions that hinder peace processes and threaten to erupt into armed conflict.[27,28]

Access to clean water and sanitation is particularly difficult in rural areas. It is estimated by WHO that 7 out of 10 people without access to clean drinking water and to improved sanitation were rural inhabitants. Access to clean water helps to avoid tropical diseases.[29] Also, the lack of clean water in the house forces young girls to be responsible to collect water from far away, making difficult to attend school.[30,31]

An estimated 800,000 children younger than 5 years of age perish from diarrhea each year, mostly in developing countries because of polluted and infected drinking water. This amounts to 11% of the 7.6 million deaths of children under the age of five and means that about 2,200 children are dying every day as a result of diarrheal diseases. Unsafe drinking water, inadequate availability of water for hygiene, and lack of access to sanitation together contribute to about 88% of deaths from diarrheal diseases. Worldwide, millions of people are infected with neglected tropical diseases (NTDs), many of which are water and/or hygiene-related, such as Guinea Worm Disease, Buruli Ulcer, Trachoma, and Schistosomiasis. These diseases are most often found in places with unsafe drinking water, poor sanitation, and insufficient hygiene practices. [32-35]

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**** The UN 8 Millennium Development Goals.** The United Nations Millennium Development Goals are 8 goals that all 191 UN member states have agreed to try to achieve by the year 2015 (signed in September 2000) and commits world leaders to combat poverty, hunger, disease, illiteracy, environmental degradation, and discrimination against women. 1. to eradicate extreme poverty and hunger; 2. to achieve universal primary education; 3. to promote gender equality and empower women; 4. to reduce child mortality; 5. to improve maternal health; 6. to combat HIV/AIDS, malaria, and other diseases; 7. to ensure environmental sustainability; and. 8. to develop a global partnership for development.

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Growing water scarcity as a leading challenge of global developments

Water is the lifeblood of Earth's ecosystems, for agriculture and food production. But Earth's freshwater resources are dwindling at an alarming rate and a global water scarcity is now one of the leading challenges for future sustainable development. Water scarcity will become more pressing as the world's population continues to grow and other considerable developments are taking place in the last decades.

a. **Overpopulation on Earth, population growth** rate

Overpopulation is considered an explosive problem for Earth's resources and in particular fresh water. In 2019 there were 7.7 billion people living on Earth. In 2018 world's population growth rate was 1,2% and average population increase was estimated at 82 million people per year. The countries with the highest population (2019) are: China 1.4 billion, India 1.355 billion, USA 330,000,000 (million), Indonesia 270,000,000, Brazil 211,000,000, Pakistan 211,000,000, Nigeria 202,000,000. It is notable that a number of the largest economies in the world have smaller populations, particularly in Europe. The United Kingdom (UK), Germany, France, Italy and the Scandinavian countries (wealthiest countries), are all among the top ten largest economies and all have smaller populations (under 100 million), except for Japan with 127,000,000 (3rd in GDP after USA and China).[36,37]

As the global population is expected to keep growing in the coming decades, the negative impact that humans will have on Earth's finite resources, especially water, will become increasingly apparent as some areas of the world will start to experience drastic shortages of water. Countries can be classified as water scarce if there are fewer than 1,000 m^3 of renewable freshwater available per person per year, and as water stressed if there are between 1,000-1,667 m^3 available per person per year.[38-,40]

b. **Socio-economic growth and globalization**

In the last 50 years the global economic development and technological growth in most countries was very robust. Globalization benefited individual economies around the world by making markets more efficient, increasing competition, limiting military conflicts, and spreading wealth more equally. Economic growth with increased output (agriculture, industry, services, tourism) was coupled with improvement in social, educational and political welfare of people within a country and increased full and productive employment. Global estimates showed that more than 1.3 billion jobs worldwide (42% of the world's total active workforce) are heavily water-dependent, including work in agriculture, mining and industries ranging from paper to pharmaceuticals. Moreover, another 1.2 billion jobs are moderately water-dependent; though they do not use large quantities, industries such as construction, recreation and transportation do need access to water resources. In total, 78% percent of global jobs need water. Investments in safe drinking water and sanitation have been shown to foster economic growth, with high rates of return. The UN Report (2016, "*Water and Jobs*") showed that good access to drinking water and sanitation promotes an educated and healthy workforce, which constitutes an essential factor for sustained economic growth.[41]

It has been proved that lack of water is a barrier to sustainable socio-economic development of many countries. Water contributes to a wide variety of natural productive process, including directly productive activities such as food production and manufacturing operations and as an element of basic economic infrastructure. Scientists argued for example that the problem of India is not the population (due to increased urbanization and industrialization) but scarcity of water resources. In the last decades India's multidimensional water development has contributed significantly to the promotion of the country's economic growth.[42]

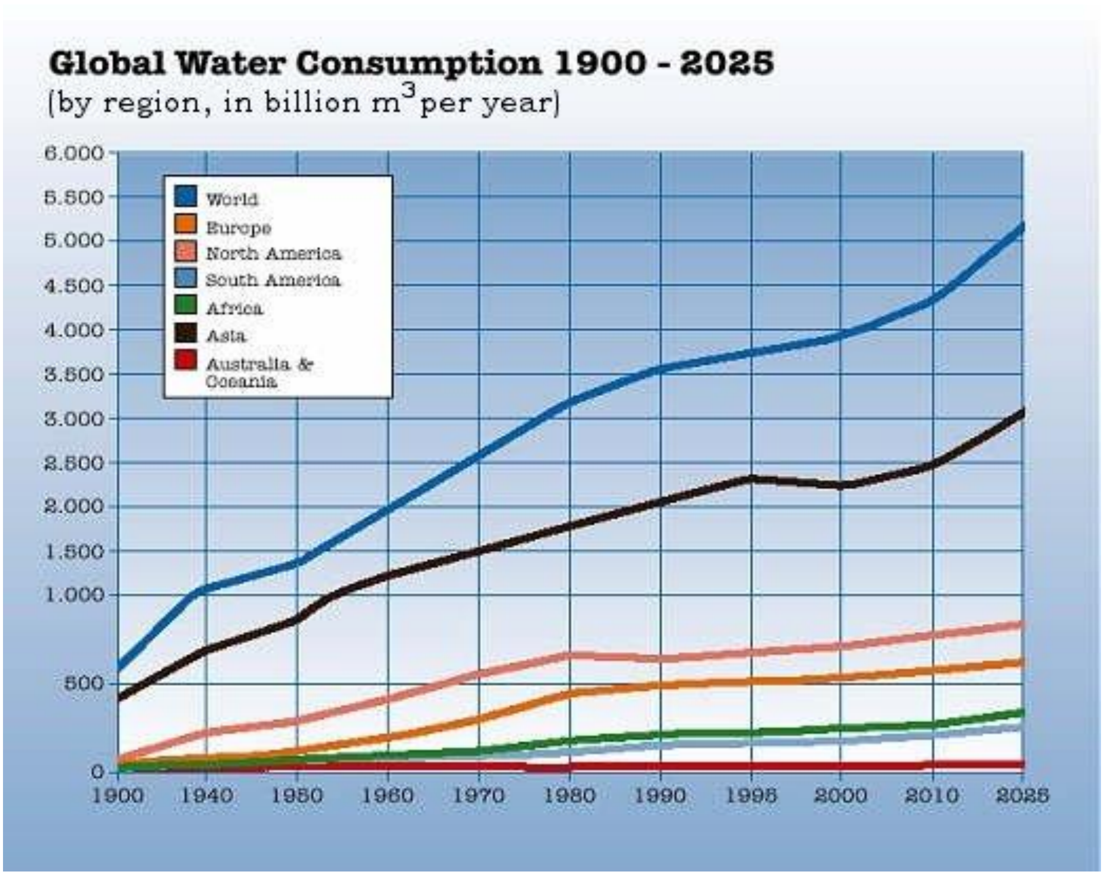

Figure 5. Global Water Consumption 1900-2025. According to UNESCO, the inhabitants of the industrialized countries consume about ten times as much water a day as the inhabitants of the emerging and developing countries. 70% of global water consumption is accounted for by agriculture.

c. **Agriculture and water scarcity**

Agriculture is both a major cause and casualty of water scarcity. Farming accounts for almost 70% of all water withdrawals, and up to 95% percent in some developing countries. Industry uses 20% of all water and domestic use the other 10%. In recent years, agricultural regions around the globe have been subject to extensive and increasing water constraints. Major droughts in Chile, the USA and in other countries have affected agricultural production while diminishing surface and groundwater reserves. Farmers in many regions of the Earth will face increasing competition from rising urban population density and water demands from the energy and industrial sectors. Scarcity of water will undermine the productivity of rain-fed and irrigated crops and livestock activities particularly in certain countries and regions. These changes could in turn further impact markets, trade, and broader food security. A very interesting assessment of future water risk have been produced by the Organization of Economic Development and Development (OECD, Paris) hotspots projects that without further action, Northeast China, Northwest India, and the Southwest United States will be among the most severely affected regions, with domestic and global repercussions.[43]

d. **Water consumption by industrial and energy sectors**

As a result of expansion of industrialization in most countries, consumption of global water by industry is expected to rise. The share of industry around the world is expected to rise 4% every year and from 21% to an estimated 38% by 2040. Power stations for electricity production are driving upwards water consumption and for this reason are increasingly being located on the coast in order to be able to use seawater. Water-dependent thermal power plants generate the majority of the world's electricity (around 80%). These plants use fuels such as coal, gas or nuclear energy to make heat, which is then converted into electrical energy. For most thermal plants, large volumes of water are a crucial part of the process, cooling high temperatures and powering turbines with steam.[44]

According to an estimate for 150 countries, electric power generation consumes more than 52 billion cubic meters (m^3) of water globally per year, for the cooling process of steam turbines to generate electricity.[45]

e. **Urbanization and water consumption**

In the last decades, the gradual shift of rural populations to urban areas has increased dramatically. In 2018, an estimated 55% (4.2 billion) of the world's population lived in urban areas and the prospects are that by 2050 to increase to 68%. Most of these increases are taking place in Asia and Africa and in countries with serious water shortages. The United Nations, Department of Economic and Social Affairs, produced a report for the 2018 revision of World Urbanization Prospects [https://www.un.org/ development/ desa/publications/2018-revision-of-world-urbanization-prospects.html]. The report indicates that India, China and Nigeria will account for 35% of the projected growth in urban population (2018-2050) and the need for more fresh water resources to feed the needs of these new urban populations. Statistical data showed that the most highly urbanized regions are in North America (82%), Latin America (81%) and Europe (74%) but Africa and Asia have one of the highest rates of urbanization growth in the last decades.

Although water and sanitation access rates are generally higher in urban areas than rural, planning and infrastructure have been unable to keep pace in many regions. Estimates showed that 700 million people living in urban areas do not have proper sanitation, contributing to poor health conditions and heavy pollution loads in wastewater, and 156 million live without improved water sources. [United Nations, Water, Water and Urbanization, https://www.unwater.org/water-facts/urbanization/, 2018].

Urbanization and increasing urban populations consume substantially higher volumes of fresh water than rural dwellers. It has been estimated that in last decades the water consumption increased at double rates than the rate of population increase, partly due to urbanization. By 2025 demand for fresh water is expected to outstrip supply by more than 50% in urban areas. It is estimated that 2 million people will face water shortages in many countries. Also, Climate change will affect negatively this crucial balance of demand and availability of fresh water. The urban dwellers suffering the most from these problems are the urban poor. They often live in slums or informal settlements following rapid urban growth, lacking many basic services such safe drinking water, adequate sanitation and durable housing. Ironically, the poor often pay far more for a litre of water than their richer neighbors, since they often lack access to the water supply system and rely on water provision from private vendors. • 62% of the sub-Saharan Africa urban population and 43% of the urban population of South-Central Asia lives in slums.[46]

f. Environmental pollution of water resources

The causes of water pollution are sewage and wastewater (harmful bacteria and toxic chemical pollutants from urban areas and industrial facilities. Many industries in developing countries do not have proper waste management systems and drain their waste in rivers, lakes canals and the sea. Mining activities produce large amounts of metal waste, sulphides, heavy metals and rocks which are polluting water sources. Accidental discharges of petroleum, oily substances and organic chemicals in the marine environment.

Figure 6. Aquatic pollution is the result of anthropogenic emissions from industrial units, power plants cooling water, sewer systems, agriculture runoffs, plastic and urban waste.

Oil spills from petroleum fields and during transportation pose a huge problem of marine pollution, marine life and oceans. The burning of fossil fuels (coal, petroleum, natural gas, biomass) produce substantial amounts of ash and toxic gases in the atmosphere and in the surface water sources. Gases like sulfur dioxide (SO_2) and nitrogen oxides (NOx) mixed with water vapour produce toxic acid rain. Chemical fertilizers and pesticide residues that are used in agriculture cause extensive pollution of water resources. Rainwater transport polluting chemicals to the sea. Leakages from landfills (places with waste and piles of garbage) occurs when it rains and pollute the surface waters as well as underground water sources. Animal waste also contributes to river and lake pollution. Plastic pollution (and subsequently the break down products, microplastics) in the aquatic environment, as well as pharmaceutical residues and cosmetics, are emerging pollutants with highly detrimental effect on water quality and sustainability of aquatic resources.[,47-51]

Climate change, global rising temperature

There are many scientific studies that support the argument "Climate change is significantly transforming the water cycle on Earth with subsequent long term implications on water scarcity and shortages in many countries".

According to an ongoing temperature analysis conducted by scientists at NASA's Goddard Institute for Space Studies (GISS), the average global temperature on Earth has increased by about 0.8° Celsius (1.4° Fahrenheit) since 1880. (NASA, National Aeronautics and Space Administration).

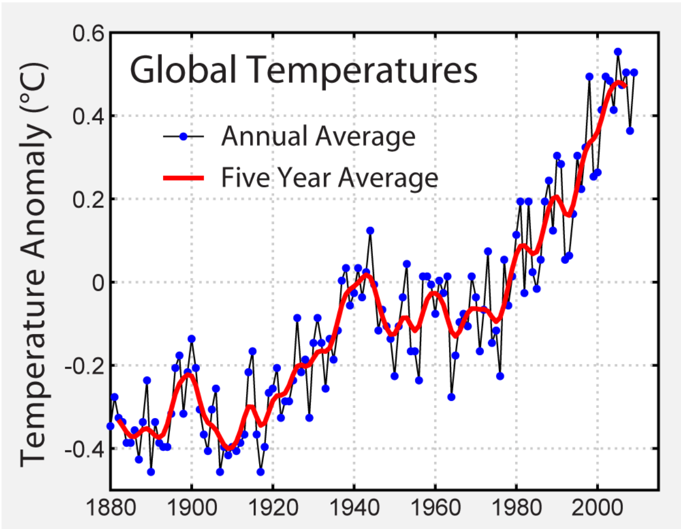

Figure 7. The diagram shows global average temperatures (NASA Goddard Institute to Space Studies, Global temperature change. *Proc Natl Acad Sci* USA 103:14288-14296, 2006.The mid-century cooling (1942-1975) has been largely due to a high concentration of sulphate aerosols in the atmosphere, emitted by industrial activities, volcanic eruptions and other pollution sources.

The year 2016 ranks as the warmest on record (Source: NASA/GISS). The collection and analysis of all these data and research is broadly consistent with similar constructions prepared by the Climatic Research Unit and the National Oceanic and Atmospheric Administration of the USA (NOAA). [https://www.climate.gov/news-features/understanding-climate/climate-change-global-temperature].

The latest data show that 2019 continues to bring record-breaking temperatures. Every month in 2019 has ranked among the four warmest for the month in question, and June was the warmest June ever recorded. It is now confirmed that July was also an exceptional month. The global average temperature for July 2019 was on a par with, and possibly marginally higher than, that of July 2016, which followed an El Niño event. This was previously the warmest July and warmest month of all on record. However, the difference between temperatures in July 2019 and July 2016 is small.[52]

Increased CO_2 concentration and temperature increase

There is an international consensus among scientists working in the international climatological community, that if human societies on Earth continue to use fossil fuel (coal, petroleum, natural gas) which increase the concentration of atmospheric carbon dioxide (CO_2), mankind will likely cause a significant average warming of the Earth's surface within the next 50 years.

The CO_2 concentration in the Earth's atmosphere is very small but its greenhouse effect very important. The Earth's atmosphere is 21% oxygen (O_2), 78% nitrogen (N_2), and 1% Argon (Ar). Less than 1% consists of trace gases, and greenhouse gases like CO_2 (0,041% of atmosphere), methane (CH_4), and nitrous oxide (N_2O). Although the concentration of CO_2 in the Earth's atmosphere is around 400 ppm (part per million), it is the most important gas for controlling Earth's surface temperature. CO_2, CH_4, and halocarbons (CFCs, organic compounds where a carbon atom is replaced with fluorine or chlorine, used as solvents, refrigerants, etc) are greenhouse gases that absorb a wide range of energy—including infrared energy (IR, heat) that is emitted upwards by the Earth's surface and then reemit it. The re-emitted energy travels out in all directions, but some returns to Earth, where it heats the surface. Without greenhouse gases, Earth would be a frozen -18 degrees Celsius (0 degrees Fahrenheit). With too many greenhouse gases, Earth would be like Venus, where the greenhouse atmosphere keeps temperatures around 400 degrees Celsius (750 Fahrenheit).[53,54]

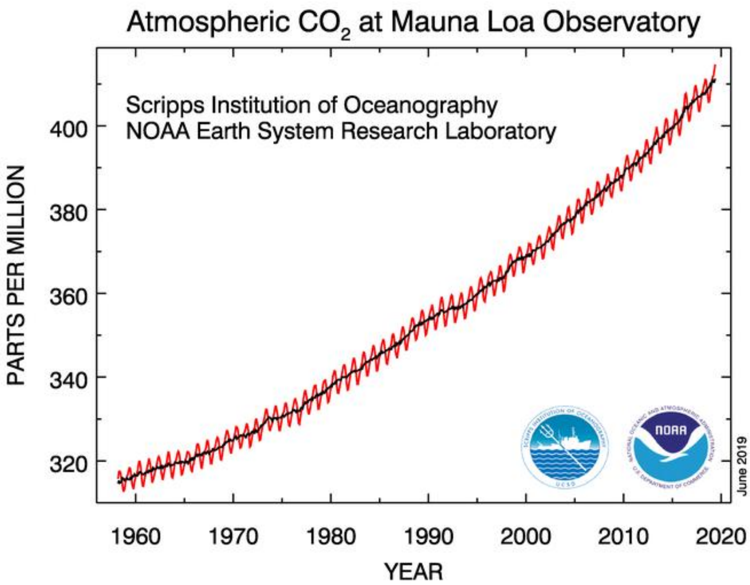

Figure 8. This chart was created using data from Mauna Loa Observatory in Hawaii, which has Earth's longest continuous record of direct measurements of atmospheric carbon dioxide (CO_2) in parts per million (ppm).

Scientific research showed that there is no correlation of CO_2 concentration and increases in surface temperature. It was postwar industrialization that caused the rapid increase of global CO_2 emissions but Earth was already in a cooling phase from 1942 to 1975. The amount of CO_2 was increasing all the time and passed a landmark 400 ppm (parts per million) concentration in 2014, up from around 280ppm before the industrial revolution. That's a 42.8% increase. Scientists attribute the growth of atmospheric CO_2 levels to a fourfold increase (x4) in emissions from human activities (mainly fossil fuel combustion for energy and transport, and cement production).The global growth rate of CO_2 has accelerated from about 0.6 ppm per year in the early 1960s to an average of 2 ppm per year during the past 10 years. Since 1990, the annual increases of CO_2 concentration have varied considerably from year to year, ranging from as little as 0.7 ppm to as much as 2.8 ppm per year. According to scientific evidence this variability in CO_2 can largely be attributed to the **El Niño–Southern Oscillation** (ENSO), an oscillating warming and cooling pattern in the central and eastern tropical Pacific Ocean that have a large impact on the natural exchange of CO_2 between land, ocean, and atmosphere.[55-57]

Also, **methane** (**CH_4**) is a greenhouse gas contributing to increasing surface temperatures but its subject is still a scientific debate. Studies have suggested that wetlands and rice cultivation in the tropics are the primary culprits for methane emissions but also oil and gas extraction plays a role. Unlike CO_2, methane has a relatively short lifetime in the atmosphere (only 9 years on average). From the wavelengths of energy each greenhouse gas absorbs, scientists can calculate how much each gas contributes to warming. CO_2 causes about 20% of Earth's greenhouse effect; water vapour accounts for about 50% and clouds account for 25%. The rest is caused by small particles (aerosols) and minor greenhouse gases like methane (CH_4).[58]

Water vapour concentrations in the air are controlled by Earth's temperature. Warmer temperatures evaporate more water from the oceans, expand air masses, and lead to higher humidity. Cooling causes water vapor to condense and fall out as rain, sleet, or snow. When carbon dioxide concentrations rise, atmospheric air temperatures go up, and more water vapour evaporates into the atmosphere—which then amplifies greenhouse heating. Although CO_2 contributes less to the greenhouse effect than water vapour, is the gas that sets the temperature.

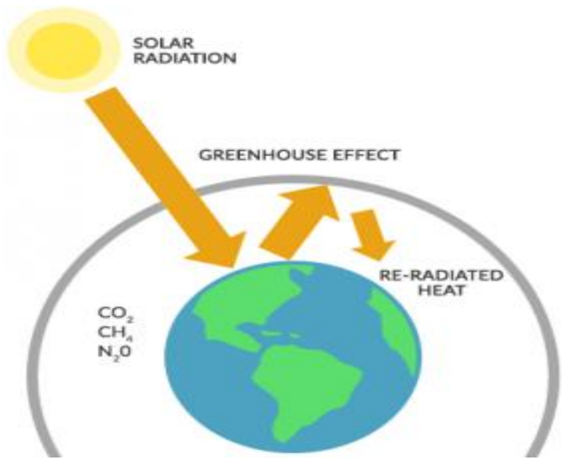

Figure 9. NASA Earth Observatory. Greenhouse effect. The CO_2, CH_4 and N_2O are the principal greenhouse gases contributing to increasing temperatures [https://earthobservatory.nasa.gov/features/CarbonCycle/page5.php].

Carbon dioxide controls the amount of water vapour in the atmosphere and as a result plays an important role in the size of the greenhouse effect. Rising CO_2 concentrations are already causing the planet to heat up because it traps re-radiated heat from the Earth. At the same time that greenhouse gases have been increasing, average global temperatures have risen 0.8 degrees Celsius (1.4 degrees Fahrenheit) since 1880.[59,60]

Global annual average temperature (as measured over both land and oceans) has increased by more than 1.5 F (0.8°C) since 1880 (through 2012). In Figure 10, red bars show temperatures above the long-term average, and blue bars indicate temperatures below the long-term average. The black line shows atmospheric carbon dioxide (CO_2) concentration in parts per million (ppm). While there is a clear long-term global warming trend, some years do not show a temperature increase relative to the previous year, and some years show greater changes than others. These year-to-year fluctuations in temperature are due to natural processes, such as the effects of El Niños, La Niñas, and volcanic eruptions.

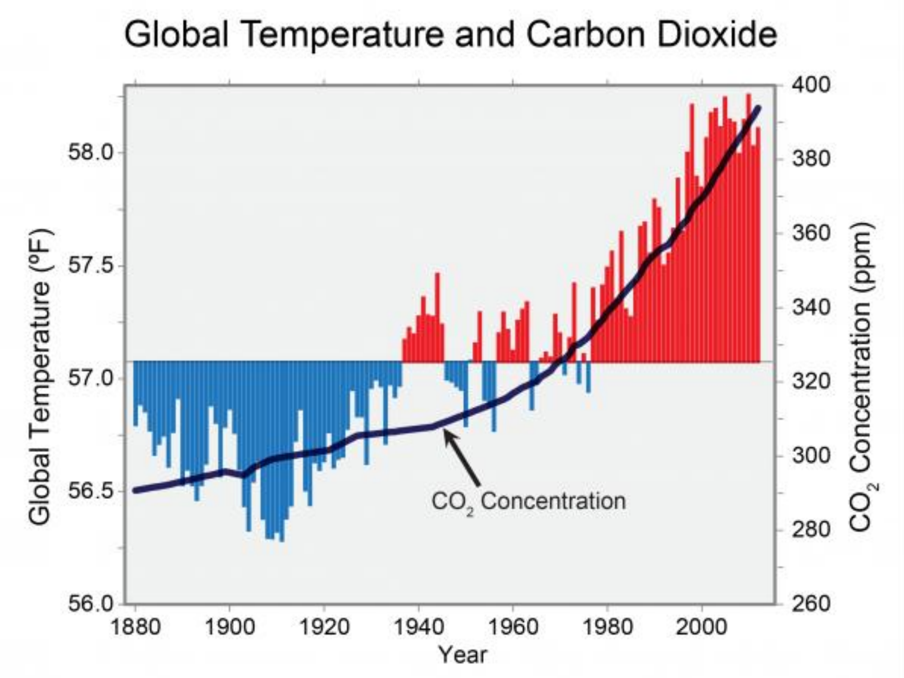

Figure 10. The diagram represent global annual average temperatures and concentrations of carbon dioxide in ppm for the period 1880-2010.
[United Sattes (US) Global Change Research Program. GlobalChange.gov [https://www.globalchange.gov/browse/multimedia/global-temperature-and-carbon-dioxide].

The Role of Earth's Oceans and atmospheric carbon dioxide

According to scientific studies about 30% of the CO_2 that human civilization have put into the Earth's atmosphere has diffused into the Earth's oceans through the direct chemical exchange. Dissolving CO_2 in the ocean creates carbonic acid (HCO_3), which increases the acidity of the water. Before the Industrial Revolution (~1750), average ocean surface pH was about 8.2 and now the average ocean pH is about 8.1 (a 30% change in acidity). In the past 200 years the oceans have absorbed approximately 50% of the CO_2 produced by fossil fuel emissions (coal, petroleum, natural gas) burning and during the global cement production. Measurements In 2017, estimated that world cement production generated around 1,5-2 Gt, billion tonnes of CO_2 [1 Gigatonne or metric gigaton (unit of mass) is equal to 1,000,000,000 metric tons]. A metric ton is exactly 1,000 kilograms (SI base unit)] - equivalent to 4-5% of the global total emissions from fossil fuels.[61]

Scientific estimates revealed that If global emissions of CO_2 from human activities continue to rise on current trends then the average pH of the oceans could fall by 0.5 units (equivalent to a three fold increase in the concentration of hydrogen ions) by the year 2100. Ocean acidification by human activities is essentially irreversible. It will take tens of thousands of years for ocean chemistry to return to a condition similar to that occurring at pre-industrial times (about 200 years ago) and it will be very difficult to reverse it by human intervention. Reducing CO_2 emissions to the atmosphere appears to be the only practical way to minimize the risk of large-scale and long-term changes to the oceans' pH and its adverse effect on marine life. The impacts of ocean acidification on marine organisms and their ecosystems are much less certain but it is likely that, because of their particular physiological attributes, some organisms will be more affected than others.[62]

A systematic review collected data from 228 studies that examined biological responses to ocean acidification. The results reveal decreased survival, calcification, growth, development and abundance in response to acidification when the broad range of marine organisms is pooled together.[63]

Also, studies have found that ocean acidification in combination with increasing surface ocean temperatures will cause detrimental effects in marine fish and other marine species.[64]

Ocean acidification is essentially irreversible for the next 100 years and more. It will take tens of thousands of years for ocean chemistry to return to a condition similar to that occurring at pre-industrial times (about 200 years ago). Our ability to reduce ocean acidification through artificial methods such as the addition of chemicals is unproven. These techniques will at best be effective only at a very local scale, and could also cause damage to the marine environment. Reducing CO_2 emissions to the atmosphere appears to be the only practical way to minimize the risk of large-scale and long-term changes to the oceans. All the evidence collected and modeled to date indicates that acidification of the oceans, and the changes in ocean chemistry are being caused by emissions of CO_2 into the atmosphere from human activities. Scientists concluded that ocean acidification and the synergistic impacts of other anthropogenic stressors (temperature, pollution) provide great potential for widespread changes to marine ecosystems.[65.]

Climatic changes on Earth because of increasing temperatures

A warming atmosphere causes more evaporation, from vegetation, land, surface water and oceans, meaning more water is available for precipitation (rain). For every one degree increase in temperature, the atmosphere can hold around 4% percent more water vapour. The result is more rain and increases the risk of flooding of rivers and streams. A warmer climate also translates to having more precipitation in the form of rain and less as snow. Snow represents natural water storage, valuable for later irrigation seasons.[66,67]

Higher temperatures cause rain seasons to become shorter**,** creating more days when irrigation is needed and therefore increasing water demands. Warmer water in streams and rivers has an impact on metabolism, life cycle, and behavior of aquatic species. These cumulative impacts on water resources make water availability harder to predict and manage. This is intensifying problems for areas that are already experiencing such impacts and extending water stress into new places that will need to learn and adapt.[68]

Scientific studies investigated the complicated relationship between water resources, energy availability, agricultural production and climate change. It has been found that climate changes related to increasing temperatures in the atmosphere has the potential to tip out the sensitive balance that has been established in the last centuries. Despite the fluctuations of climatic changes from certain periods of time in various parts of the Earth (droughts, flooding, hurricanes, storms, dry rivers, etc) the human civilization proceeded and stabilized for centuries. Even in the last centuries human societies witnessed negative developments, such as lack of clean drinking water, difficulties in adequate food production and lack of energy.[69,70]

According to the most authoritative source, the National Oceanic and Atmospheric Administration (NOAA, USA) "*Report on the State of Climate in 2018*", in the last 50 years the negative effects of global warming due to the human-generated buildup of greenhouse gases (GHGs) in the atmosphere have become more evident. Scientific measurements from various sources showed that the year 2017 was the most important in terms of concentrations of greenhouse gases, like CO_2, CH_4, and nitrous oxide (N_2O). All of them hit record levels in the atmosphere. In 2018 the CO_2 concentrations reached a global average of 405 parts per million (ppm), which was the highest ever recorded, matched only by ice core data stretching back 800,000 years. The year 2018 was also the 4th warmest year for annual global temperature since records began in the mid- to late 1800s. The four warmest years on record have all occurred since 2015 with the warmest year 2016.[71]

Also, the report (2019) of the European Environment Agency (EEA, Copenhagen) contained in the summary the following information. The average annual **CO_2** concentration level reached 403 and 405 ppm in 2016 and 2017, respectively [an increase of more than 127 ppm (+143 %), compared with pre-industrial levels in 1800]. The average annual concentration level of methane (**CH_4**) — the second most significant greenhouse gas — reached a level of 1, 842 parts per billion (ppb) in 2016, an increase of a factor of 2.4, compared with pre-industrial levels, and of about 8 ppb compared with 2015. Methane increases are partly related to biogenic sources (wetlands), rice paddies, fossil fuel and biomass burning and wildfires in forested areas of the Earth. Also, the third most important greenhouse gas nitrous oxide (**N_2O**) increased substantially. In 2016 concentration level was 329 ppb, 121 % above the pre-industrial level. Data for 2017, although not yet complete, indicate a concentration of 330 ppb. The rate of change is slightly increasing over the past 20 years from 0.6 ppb per year to 0.9 ppm per year. Other gases which contribute to the greenhouse effect are three fluorinated gases: Hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride (SF_6). Their contribution to emissions is around 2% of GHGs. These gaseous compounds contribute to the increasing atmospheric temperature. The group of HFCs is particularly broad. The concentration levels of these F-gases have increased substantially over recent decades.[72]

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** The **Kyoto (Japan) Protocol**, an international treaty which extends the 1992 United Nations Framework Convention on Climate Change (UNFCCC). The Treaty commits state parties to reduce greenhouse gas emissions based on the scientific consensus that global warming is occurring in the last decades with great consequences for Earth. The Kyoto Protocol was adopted (11 December 1997) and entered into force on 16 February 2005.

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According to the report NOOA "*State of the Climate in 2018*" report, "….the top 20 warmest years on record have come since 1995. The year 2017, was the third hottest year since the mid-1800s, and the hottest year ever without El Niño warming the world's waters. As the earth's average temperature continues to rise, scientists expect a significant impact on water resources…."

The NOAA report has special sections on global climate changes in year 2018 compared to previous years, by a careful collection of statistical evidence**.** Tropical cyclones were well above average overall in 2018. There were 95 named tropical cyclones across all ocean basins in 2018, well above the 1981–2010 average of 82. Eleven tropical cyclones reached the Saffir–Simpson scale Category 5 intensity level. This was only one less than the record of 12 Category 5 tropical cyclones in 1997.

Glaciers melted around the world. Preliminary data indicate that the world's most closely tracked glaciers lost mass for the 30th consecutive year. Since 1980, the cumulative loss is the equivalent of slicing 79 feet (24 meters) off the top of the average glacier.

The *State of the Climate in 2018* is the 29th edition in a peer-reviewed series published annually as a special supplement to the **Bulletin of the American Meteorological Society**. An international, peer-reviewed publication released each summer, the *State of the Climate* is the authoritative annual summary of the global climate published as a supplement to the *Bulletin of the American Meteorological Society*. The report, compiled by NOAA's National Centers for Environmental Information, is based on contributions from scientists from around the world. The full report is in digital form. **https://www.ametsoc.net/sotc2018/Socin2018_lowres.pdf** [https://www.ametsoc.org/index.cfm/ams/publications/bulletin-of-the-american-meteorological-society-bams/state-of-the-climate/].

Figure 11. The report, compiled by NOAA's National Centers for Environmental Information, is based on contributions from scientists from around the world. It provides a detailed update on global climate indicators, notable weather events, and other data collected by environmental monitoring stations and instruments located on land, water, ice, and in space.

The NOAA's **National Centers for Environmental Information (NCEI,** called the Nation's Scorekeeperon on climate) collected data on disasters due to severe climatic changes and the cost in dollars. NCEI with their more recent report addressed severe weather and climate events in their historical perspective. They monitored and assessed costly extreme climatic disasters in the U.S. and globally that have great economic and societal impacts from 1980 to 2019. The U.S.A. has sustained 254 weather and climate disasters since 1980 where overall damages/costs reached or exceeded $1 billion. The total cost of these 254 events exceeds $1.7 trillion. In 2019 (including October 8, 2019), there have been 10 weather and climate disaster events with losses exceeding $1 billion each across the United States. These events included 3 flooding events, 5 severe storm events, and 2 tropical cyclone events. 2019 is the fifth consecutive year (2015-2019) in which 10 or more billion-dollar weather and climate disaster events have impacted the United States. Over the last 40 years (1980-2019), the years with 10 or more separate billion-dollar disaster events include 1998, 2008, 2011-2012, and 2015-2019. [NOAA, 2019, Billion-dollar weather and climate disasters; Overview, ncdc:noaa.gov/billions/].

These excessive climatic events and their association with increasing temperatures is a subject of scientific debate. Many scientists have argued with statistical data that **extreme hurricanes** (also known as typhoons and cyclones, gigantic storms that affect the tropical areas of the world) are a natural part of Earth's climate system. But recent research suggested that there has been an increase in intense hurricane activity in the North Atlantic since the 1970s. In the future, there may not necessarily be more hurricanes, but there will likely be more intense hurricanes that carry higher wind speeds and more precipitation as a result of global warming. The worst hurricane of all time was Hurricane Katrina (29 August, 2005), which claimed the lives of 1,836 people and caused damages close to 200 billion dollars around New Orleans and the Gulf Coast of the United States. Insurance companies have paid $41.1 billion on 1.7 million different claims for damage to vehicles, houses, businesses, boats, etc.

Figure 12. The Hurricane Katrina (2005) the most destructive and costly natural disaster in U.S.A history, came ashore near the border between Mississippi and Louisiana. The city of New Orleans received severe damages, Katrina caused severe destruction along the Gulf Coast, from Florida to Texas. Brinkley, Douglas. *The Great Deluge: Hurricane Katrina, New Orleans and the Mississippi Gulf Coast*. New York: Morrow/HarperCollins, 2006. Dyson, Michael Eric. *Come Hell or High Water: Hurricane Katrina and the Color of Disaster*. New York: Basic Civitas, 2007.

Climate change, rising temperatures and agriculture

Assessment studies on the effects of climate change and crop yields have produced some interesting results. Agriculture and fisheries are highly dependent on the climate. Increases in temperature and CO_2 can increase some crop yields in some places. But food production is dependent on nutrient levels, soil moisture, water availability, and other conditions which differ around the globe. Changes in the frequency and severity of droughts and floods could pose challenges for farmers and threaten food safety. Meanwhile, warmer water temperatures are likely to cause the habitat ranges of many fish and shellfish species to shift, which could disrupt marine ecosystems. Overall, climate change could make it more difficult to grow crops, raise animals, and catch fish in the same ways and same places as farmers all over the world. In the last decades farming practices and technological applications have change agricultural production and practices. Climate change and rising temperatures are going to bring many new conditions which may have negative outcomes.[73]

Wheat, rice, maize, and soybean provide 2/3 of global human caloric intake. Assessing the impact of global temperature increase on production of these crops is therefore critical to maintaining global food supply, but different studies (4 different methods) have yielded different results. In 2017 a group of researchers compiled extensive published results from four analytical methods which consistently showed negative temperature impacts on crop yield at the global scale. The results of their analysis showed that, without CO_2 fertilization, effective adaptation, and genetic improvement, each degree-Celsius (^{0}C) increase in global mean temperature would, on average, reduce global yields of wheat by 6.0%, rice by 3.2%, maize by 7.4%, and soybean by 3.1%. Results are highly heterogeneous across crops and geographical areas, with some positive impact estimates.[74]

Researchers investigated 30 different wheat crop models of the Agricultural Model Intercomparison and Improvement Project against field experiments in which growing season mean temperatures ranged from 15°C to 32°C, including experiments with artificial heating. Many models simulated yields well, but were less accurate at higher temperatures. Extrapolating the model ensemble temperature response indicates that warming is already slowing yield gains at a majority of wheat-growing locations. Global wheat production is estimated to fall by 6% for each °C of further temperature increase and become more variable over space and time.[75]

Climate change, rising temperatures and threats to the global water cycle

With climate change and rising average global temperature, the water cycle supporting the Earth's ecosystems, is expected to go through significant and turbulent changes. For example, a warmer climate causes more water to evaporate from both land and oceans and in turn, a warmer atmosphere can hold more water – roughly 4% more water for every 0,5 ^{0}C (or 1^0 F) rise in temperature. These types of change are expected to lead to negative, consequences. In some parts of the globe can expect increased precipitation (rain) and draining away (runoff) of water from the surface of an area of land), especially in winter and spring, leading to increased flooding. Other areas of the Earth with warmer climate can expect less precipitation, especially in the warm months, and longer, more severe droughts leaving arid areas increasingly dry.[76-78]

Figure 13. Excessive flooding and droughts can affect many areas of the Earth as a result of climate change and rising temperatures.

Global warming and river flooding in a global scale has been investigated. A group of scientists from Japan simulated daily discharge derived from a relatively high-resolution (approximately 1.1-degree) general circulation model that was used to investigate future projections of extremes in river discharge under global warming. The frequency of floods was projected to increase over many regions, except those including North America and central to western Eurasia. The drought frequency was projected to increase globally. Changes in flood and drought are not explained simply by changes in annual precipitation, heavy precipitation, or differences between precipitation and evapotranspiration. Several regions were projected to have increases in both flood frequency and drought frequency.[79]

Many scientific investigations were contacted for the association of warmer weather and climate extremes in the USA in recent decades. Statistical evidence showed that the USA witnessed in the last decade more frequent heat waves, while cold waves have been decreasing. While this is in keeping with expectations in a warming climate, it turns out that decadal variations (every 10 years) in the number of U.S. heat and cold waves do not correlate well with the observed U.S. warming during the last century. Also, river flooding trends on the century scale do not show uniform changes across the country. While flood magnitudes in the Southwest have been decreasing, flood magnitudes in the Northeast and north-central United States have been increasing. Droughts also have long-term trends as well as multiyear and decadal variability. Instrumental data indicate that the Dust Bowl of the 1930s (*during the 1930s, the USA experienced one of the most devastating droughts which affected almost 2/3 of the country and was infamous for the numerous dust storms that occurred in the southern Great Plains) and the drought in the 1950s were the most significant 20th century droughts in the USA. A study with models indicated that the drought was caused by anomalous tropical sea surface temperatures during that decade.[80,81]

A recent study (2016) used climate model simulations and hydrological models in order to assess the impacts of a **+2°C global warming** on extreme floods and hydrological droughts (1 in 10 and 1 in 100 year events) in Europe. Researchers used eleven bias-corrected climate model simulations from CORDEX Europe and three hydrological models.

(****The World Climate Research Programme** established in 2009 the Task Force for Regional Climate Downscaling, which created the CORDEX initiative to generate regional climate change projections for all terrestrial regions of the globe. EURO-CORDEX is the European branch of the CORDEX initiative, to produce ensemble climate simulations based on multiple dynamical and empirical-statistical downscaling models forced by multiple global climate models, https://www.hzg.de/ms/euro-cordex/060374/index.php.en).

The results from the climate model simulations show quite contrasted results between northern and southern Europe. Flood magnitudes are expected to increase significantly south of 60°N, except for some regions (Bulgaria, Poland, south of Spain) where the results are not significant. The sign of these changes are particularly robust in large parts of Romania, Ukraine, Germany, France and North of Spain. North of this line, floods are projected to decrease in most of Finland, NW Russia and North of Sweden, with the exception of southern Sweden and some coastal areas in Norway where floods may increase. The results concerning extreme droughts are less robust, especially for drought duration where the spread of the results among the members is quite high in some areas. Drought magnitude and duration may increase in Spain, France, Italy, Greece, the Balkans, south of the UK and Ireland. Despite some remarkable differences among the hydrological models' structure and calibration, the results are quite similar from one hydrological model to another. Finally, an analysis of floods and droughts together shows that the impact of a +2°C global warming will be most extreme for France, Spain, Portugal, Ireland, Greece and Albania.[82]

Another study (2018) simulated the assessment for future changes in flood, heat-waves, and drought impacts for 571 European cities. Researchers used climate models from the Coupled Model Inter-comparison Project Phase 5 (CMIP5) for the RCP8.5 emissions scenario. The results of the models showed that heat-wave days increase across all cities, but especially in southern Europe, whilst the greatest heat-wave temperature increases are expected in central European cities. Drought conditions intensify (low impact) in southern European cities while river flooding worsens in northern European cities. Over 100 European cities are particularly vulnerable to two or more climate impacts.[83]

Report on the State of the Climate in 2018 by U.N.

[Accelerating Climate Change Impacts. United Nations. Climate Change. 27.3.2019. External Press release [https://unfccc.int/news/state-of-the-climate-in-2018-shows-accelerating-climate-change-impacts].

World Meteorological Organization (WMO), Geneva, 28 March 2019 – **"……**The physical signs and socio-economic impacts of climate change are accelerating as record greenhouse gas concentrations drive global temperatures towards increasingly dangerous levels, according to a new report from the World Meteorological Organization. The WMO Statement on the State of the Global Climate in 2018 highlights record sea level rise, as well as exceptionally high land and ocean temperatures over the past four years. This warming trend has lasted since the start of this century and is expected to continue. Since the Statement was first published, climate science has achieved an unprecedented degree of robustness, providing authoritative evidence of global temperature increase and associated features such as accelerating sea level rise, shrinking sea ice, glacier retreat and extreme events such as heat waves. These key climate change indicators are becoming more pronounced. Levels of CO_2, which were at 357.0 parts per million when the statement was first published in 1994, keep rising – to 405.5 parts per million (ppm) in 2017. For 2018 and 2019, greenhouse gas concentrations are expected to increase further…".

"……The WMO climate statement includes input from national meteorological and hydrological services, an extensive community of scientific experts, and UN agencies. It details climate related risks and impacts on human health and welfare, migration and displacement, food security, the environment and ocean and land-based ecosystems. It also catalogues extreme weather around the world. Most recently (2019) **Tropical Cyclone Idai,** caused devastating floods and tragic loss of life in Mozambique, Zimbabwe and Malawi. It was the deadliest weather-related disasters to hit the southern hemisphere…'

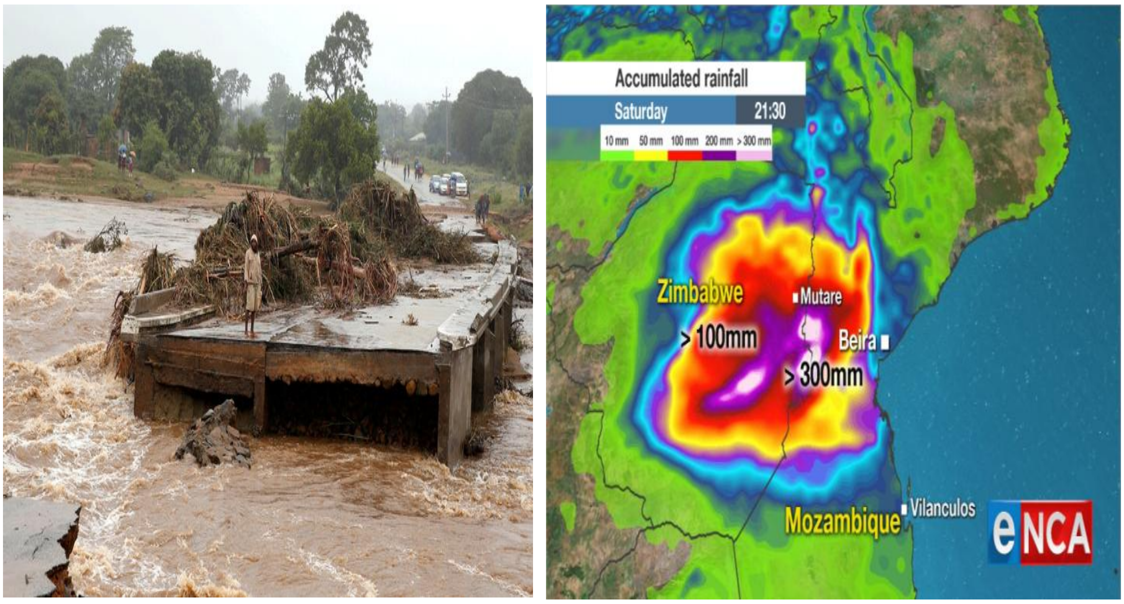

Figure 14. Tropical cyclone Idai (4-21 March 2019) made landfall over the city of Beira. The long-lived storm caused catastrophic damage in Mozambique, Zimbabwe, and Malawi, leaving more than 1,300 people dead and many more people missing, presumably drowned.

The start of 2019 has also seen warm record daily winter temperatures in Europe, unusual cold in North America and searing heatwaves in Australia. Arctic and Antarctic ice extent is yet again well below average. According to WMO's latest Global Seasonal Climate Update (March to May), above average sea surface temperatures – partly because of a weak strength El Niño in the Pacific – is expected to lead to above-normal land temperature, particularly in tropical latitudes. The data released in this report give cause for great concern. The past four years were the warmest on record, with the global average surface temperature in 2018 approximately 1°C above the pre-industrial baseline…'

Figure 15. The **Special Report on Global Warming of 1.5 C** was published by the Intergovernmental Panel on Climate Change (IPCC) on 8 October 2018. The report, approved in Incheon, South Korea, includes over 6,000 scientific references, and was prepared by 91 authors from 40 countries.

"These data confirm the urgency of climate action. This was also emphasized by the recent **Intergovernmental Panel on Climate Change** (IPCC) special report on the impacts of global warming of 1.5°C. The IPCC found that limiting global warming to 1.5°C will require rapid and far reaching transitions in land, energy, industry, buildings, transport and cities and that global net human-caused emissions of carbon dioxide need to fall by about 45% from 2010 levels by 2030, reaching net zero around 2050. There is no longer any time for delay," said Secretary-General of the United Nations Mr Antonio Guterres, who will convene a Climate Action Summit at Heads of State level on 23rd September 2019. The State of the Climate report will be one of WMO's contributions to the September 2019 Summit.

Conclusions

Climate changes and increasing temperatures in the last decades are scientific facts with authoritative evidence. Scientists use climate models indicating that Earth is likely to see in the future larger and warmer storms, resulting in increased rainfall, and extensive flooding. Also, the heavy storms, as extreme events in many countries, may not bring more water overall, leading to more frequent or severe and prolonged droughts. Changes in precipitation, reduced snowpack, and more frequent droughts are likely to increase the demand on groundwater sources, ground subsidence, and decreased water quality. These changes will brink severe problems on water sources and scarcity of drinking water in many parts of the Earth.

Increasing temperatures will cause sea level rise in many low lying areas, not only threatening coastal communities, but also their health and water supply system. Sea level rise in the future will lead to flooding of low lying areas, loss of coastal wetlands, saltwater contamination of drinking water sources, and adverse impacts on roads, bridges and other infrastructure facilities.

Climate change is expected to impact Earth's supply and demand for water in critical and non-complimentary ways. This trend can be spread in many countries reducing water available for agriculture, the environment, and a growing population. Decreased snowpack because of rising temperatures is a critical concern for many areas. The loss of snowpack means less water available during the hot summer months and growing seasons. Hydroelectric operations may become less reliable, while higher temperatures increase the demand for electricity for air conditioning. Increasing temperatures will affect agricultural crops. Finally, climate change and rising temperatures will affect ecosystem functioning. Forests face risks from increased pests, disease, changes in species composition, and fire.

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