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TEACHER'S GUIDEBOOK

Learn about climate change

The CCEDU project

The CC-EDU Simplify climate change education for better communication in elementary and lower secondary school with project number 2019-1-FR01-KA201-063200, is a 24-month long strategic partnership composed by

- Sustainable Development Management Institute, France
- Associazione progetto MARCONI, Italy
- Center for Educational and Cultural Development "RACIO", North Macedonia
- Sehit Mehmet Lutfi Gulsen Anadolu from Konya Turkey
- SMART IDEA Slovenia
- Fondatsia Evropeiski center za inovatsii, obrazovanie, nauka i kultura, Bulgaria

As a whole, the wide experience gathered for the CC-ED project will offer complementary skills and competencies, necessary for offering tools and resources for helping EU teachers develop a wide set of skills, encompassing communication skills, competence in climate change, and related science and social topics, necessary to nurture EU students and help them face future challenges.

The products prepared with the contribution of the consortium,

Main editor Valeria ELIA

All materials are available for free download and use via the project's website.

https://ccedu.erasmus-projects.eu/

The final version, released in January, 2021.

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About the CCEDU resources

The purpose of the CC-EDU project is to equip students (such as the next generations) in having a holistic perspective over climate change and learn about collective responsibility toward environmental protection and prevention of further damaging situations. The aim of the project is to prepare teachers to deal with the complexity of the topic, making it factual and with a view on local, regional, and international situations, using different approaches.

Climate change should occupy a major node in school education. Given the actual situation, it is important that schools tie climate change education to their communities, teaching their students both civic engagement and providing important examples of how solutions are being developed to global issues in real-time.

CCEDU support tools

CCEDU teachers' GUIDEBOOK

This guidebook will help the teachers understand and get to discuss climate change with the students. The guidebook will offer reading materials to help teachers to deal with some of the many challenging questions: How should such a complex topic be approached in schools? How much should be explained, based on the age of the students? How can teachers create hope instead of anxiety? On one hand, teachers have to be sensitive and prepared to deliver the contents, on the other, students have to be aware and develop skills to contribute to solving the situation.

CCEDU CLIMATE CHANGE manual

The CCEDU offers 12 topics concerning climate change. They are introduced in a short summary that is visible to all users on the website, and in a more wider and accurate way for registered users.

TOOLBOX

Inventory of skills that teachers need to develop in order to be able to simplify the interdisciplinary and cross-curricular approach to the complex topic, and some techniques that can be used to present the topics to the children.

CLASS ACTIVITIES

Inventory of short and ready-to-use lessons or exercises, to be used independently or together with a subject in the curriculum, to make it easier for teachers to associate them to what they usually do in class. For example, a music class can provide an opportunity to review environmental songs or a cycling trip combined with learning about the environmental impacts of transportation. In mother tongue and literature classes, students can read and write stories about the environment and launch citizen initiatives as an interdisciplinary learning project with visual arts.

INFOGRAPHICS

Prepared to introduce climate change-related topics to the class. They are meant for direct use with the children. They are a visual presentation of complicated topics, teachers can use to offer climate change-related information in a nice and simple way. A teacher should read the full scientific background and then use this easy-to-understand representation of the same information to introduce the topic to the class, before a class activity.

The aim of the tools and materials offered are for teachers to

- Increase their ability to talk about complex topics and simplify them, while remaining faithful to the science
- Understand the complexity of climate change and being able to view it from different angles and perspective
- Learn how to connect climate change issues with other subjects taught in class
- Increase skills and abilities needed to engage students to have them focus on these important topics
- Understand the “big picture” and ability for a holistic approach to issues related to climate change and their connection and impact on our everyday life
- Learn about new teaching methods for updating their skills for the benefit of their students, present and future

Climate change and nature

AIR POLLUTION AND CLIMATE CHANGE

Image by Foto-Rabe from Pixabay

Air pollution and climate change are closely related. Many air pollutants contribute to climate change by affecting the amount of incoming sunlight that is reflected or absorbed by the atmosphere, creating the so called “green-house” effect. The term “climate-forcers” refers to gas pollutants and particular matter affecting the Heart’s energy balance and producing changes in climate.

WHAT IS AIR POLLUTION?

Air pollution means the presence of substances in the atmosphere that are harmful to health of living beings and/or cause damages to environment or materials. As well as driving climate change, the main cause of CO_2 emissions – the extraction and burning of fossil fuels – is also a major source of air pollutants.

There are many different types of air pollutants, such as gases (e.g. ammonia, carbon monoxide, sulphur dioxide, nitrous oxides, methane and chlorofluorocarbons), particulates (both organic and inorganic), and biological molecules (pollen).

These short-lived climate-forcing pollutants (SLCPs) include methane, black carbon, ground-level ozone, and sulphate aerosols. They have significant impacts on the climate: black carbon and methane in particular are among the top contributors to global warming after CO2.

WHAT CAUSES AIR POLLUTION?

Both human activity and natural processes can generate air pollution.

“Most air pollution comes from energy use and production,” says John Walke, director of the Clean Air Project, part of the Climate and Clean Energy program at NRDC. “Burning fossil fuels releases gases and chemicals into the air.” In addition, in an especially destructive feedback loop, air pollution not only contributes to climate change but is also exacerbated by it. “Air pollution in the form of carbon dioxide and methane raises the earth’s temperature,” Walke says. “Another type of air pollution is then worsened by that increased heat: Smog forms when the weather is warmer and there’s more ultraviolet radiation.” Climate change also increases the production of allergenic air pollutants including mold (thanks to damp conditions caused by extreme weather and increased flooding) and pollen (due to a longer pollen season and more pollen production).

Pollutants

An air pollutant is a material in the air that can have adverse effects on humans and the ecosystem. The substance can be solid particles, liquid droplets, or gases. A pollutant can be of natural origin or man-made. Pollutants are classified as primary or secondary. Primary pollutants are usually produced by processes such as ash from a volcanic eruption. Other examples include carbon monoxide gas from motor vehicle exhausts or sulphur dioxide released from factories. Secondary pollutants are not emitted directly. Rather, they form in the air when primary pollutants react or interact. Ground level ozone is a prominent example of a secondary pollutant. Some pollutants may be both primary and secondary: they are both emitted directly and formed from other primary pollutants.

Schematic drawing, causes and effects of air pollution: (1) greenhouse effect, (2) particulate contamination, (3) increased UV radiation, (4) acid rain, (5) increased ground-level ozone concentration, (6) increased levels of nitrogen oxides.

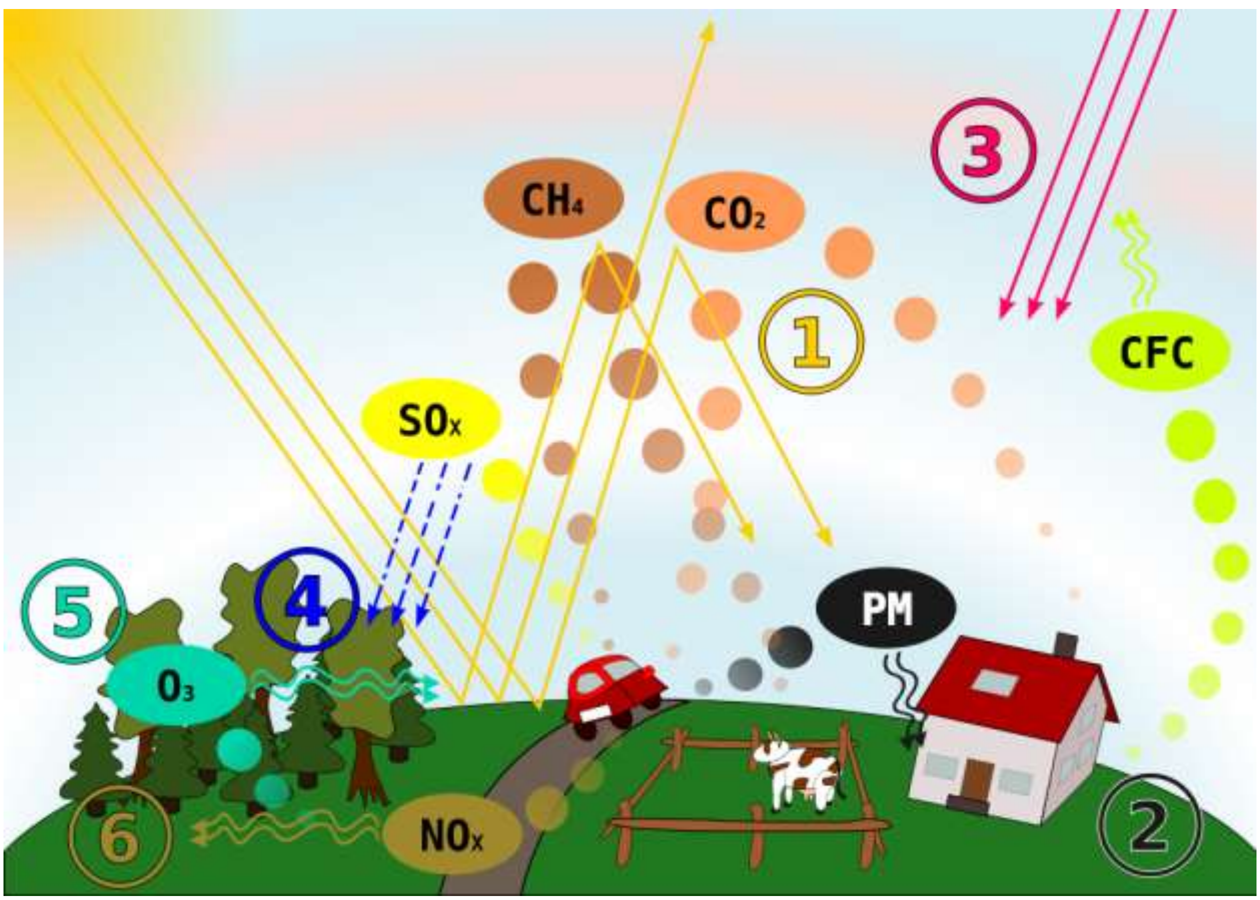
More on pollutants in the ANNEX.

SOURCES OF AIR POLLUTION

Anthropogenic (human-made) sources

These are mostly related to the burning of fuel.

- Stationary sources include smoke stacks of fossil fuel power stations, manufacturing facilities (factories) and waste incinerators, as well as furnaces and other types of fuel-burning heating devices. In developing and poor countries, traditional biomass burning is the major source of air pollutants; traditional biomass includes wood, crop waste and dung.
- Mobile sources include motor vehicles, marine vessels, and aircraft.



- Controlled burn practices in agriculture and forest management. Controlled or prescribed burning is a technique sometimes used in forest management, farming, prairie restoration or greenhouse gas abatement. Fire is a natural part of both forest and grassland ecology and controlled fire can be a tool for foresters. Controlled burning stimulates the germination of some desirable forest trees, thus renewing the forest.

Beijing air on a 2005-day after rain (left) and a smoggy day (right)

There are also sources from processes other than combustion

- Fumes from paint, hair spray, varnish, aerosol sprays and other solvents. Emissions from these sources was estimated to account for almost half of pollution from volatile organic compounds in the Los Angeles basin in the 2010s.
- Waste deposition in landfills, which generate methane. Methane is highly flammable and may form explosive mixtures with air.
- Fertilized farmland may be a major source of nitrogen oxides.

Natural sources

- Dust from natural sources, usually large areas of land with little vegetation or no vegetation
- Methane, emitted by the digestion of food by animals, for example cattle
- Radon gas from radioactive decay within the Earth's crust. Radon is a colourless, odourless, naturally occurring, radioactive noble gas that is formed from the decay of radium. It is a health hazard. Radon gas from natural sources can accumulate in buildings, especially in confined areas such as the basement and it cause of lung cancer.

- Smoke and carbon monoxide from wildfires. During periods of actives wildfires, smoke from uncontrolled biomass combustion can make up almost 75% of all air pollution by concentration.

- Vegetation, in some regions, emits environmentally significant amounts of Volatile organic compounds (VOCs) on warmer days. These VOCs react with primary anthropogenic pollutants—specifically, NOx, SO2, and anthropogenic organic carbon compounds — to produce a seasonal haze of secondary pollutants. Black gum, poplar, oak and willow are some examples of vegetation that can produce abundant VOCs. The VOC production from these species result in ozone levels up to eight times higher than the low-impact tree species.

- Volcanic activity, which produces sulphur, chlorine, and ash particulates

Environmental impacts

Though many living things emit carbon dioxide when they breathe, the gas is widely considered to be a pollutant when associated with cars, planes, power plants, and other human activities that involve the burning of fossil fuels such as gasoline and natural gas. That is because carbon dioxide is the most common of the greenhouse gases, which trap heat in the atmosphere and contribute to climate change. Humans have pumped enough carbon dioxide into the atmosphere over the past 150 years to raise its levels higher than they have been for hundreds of thousands of years.

Other greenhouse gases include methane —which comes from such sources as landfills, the natural gas industry, and gas emitted by livestock—and chlorofluorocarbons (CFCs), which were used in refrigerants and aerosol propellants until they were banned in the late 1980s because of their deteriorating effect on Earth's ozone layer.

Another pollutant associated with climate change is sulphur dioxide, a component of smog. Sulphur dioxide and closely related chemicals are known primarily as a cause of acid rain. But they also reflect light when released in the atmosphere, which keeps sunlight out and creates a cooling effect. Volcanic eruptions can spew massive amounts of sulphur dioxide into the atmosphere, sometimes causing cooling that lasts for years. In fact, volcanoes used to be the main source of atmospheric sulphur dioxide; today, people are.

EFFECTS OF AIR POLLUTION

Health effects

Compared to 2009, the number of premature deaths linked to air pollution in 2018 decreased by 13 % for $PM_{2.5}$ and by 54 % by NO_2, but increased by 24 % for ozone (for EU27 and the UK), according to EEA. According to WHO, ischaemic heart disease attributable to air pollution caused over 112 000 deaths in the EU-27 and the United Kingdom in 2016. Other significant diseases attributed to air pollution and leading to deaths, identified by WHO, include stroke, chronic obstructive pulmonary disease, trachea, bronchus and lung cancers, and lower respiratory infections.

These effects can result in increased medication use, increased doctor or emergency department visits, more hospital admissions and premature death. The human health effects of poor air quality are far reaching, but principally affect the body's respiratory system and the cardiovascular system. Individual reactions to air pollutants depend on the type of pollutant a person is exposed to, the degree of exposure, and the individual's health status and genetics. Children aged less than five years that live in developing countries are the most vulnerable population in terms of total deaths attributable to indoor and outdoor air pollution

Agricultural effects

In India in 2014, it was reported that air pollution by black carbon and ground level ozone had reduced crop yields in the most affected areas by almost half in 2011 when compared to 1980 levels

Economic effects

Air pollution costs the world economy $5 trillion per year as a result of productivity losses and degraded quality of life, according to a joint study by the World Bank and the Institute for Health Metrics and Evaluation (IHME) at the University of Washington. These productivity losses by deaths are due to diseases caused by air pollution. One out of ten deaths in 2013 was caused by diseases associated with air pollution and the problem is getting worse. "Children under age 5 in lower-income countries are more than 60 times as likely to die from exposure to air pollution as children in high-income countries". The report states that additional economic losses caused by air pollution, including health costs and the adverse effects on agricultural and other productive sectors were not calculated in the report, and thus the actual costs to the world economy are far higher than $5 trillion.

How to help reduce air pollution

The less gasoline we burn, the better we're doing to reduce air pollution and harmful effects of climate change. Make good choices about transportation. When you can, walk, ride a bike, or take public transportation. For driving, choose cars that get better miles per gallon of gas or choose an electric car. You can also investigate your power provider options—you may be able to request that your electricity be supplied by wind or solar. Buying your food locally cuts down on the fossil fuels burned in trucking or flying food in from across the country. And perhaps most important - Support leaders who push for clean air and water and responsible steps on climate change.

We need action on air pollution and greenhouse gases

To reach the Paris Agreement goal of limiting warming to 1.5 (or even 2) degrees Celsius, rapid reduction of CO2 emissions is necessary, but will not in itself sufficient. The IPCC special report on the impacts of global warming of 1.5 °C stresses that deep reductions in emissions of non-CO2 climate forcers, particularly the air pollutants methane and black carbon, are also crucial. And while the decarbonisation of the economy will generally reduce emissions of both CO2 and air pollutants, pursuing the phase-out of fossil fuels is not enough – for either air quality or climate. First, emissions from additional sectors are also important: for instance, methane and black carbon emissions from agriculture have important health and climate impacts, and emissions of coolants (particularly hydrofluorocarbons, or HFCs) from the cooling sector are especially potent climate warmers. Second, it is important to consider both CO2 and air pollutants when designing and selecting climate and air quality measures to ensure that the desired benefits can be achieved. Some technologies that are promoted as climate-friendly – combustion of biomass and other biofuels for home heating or transport, for example – may emit more particulate matter, including black carbon, than the technology it replaced, and thus continue to harm human health and potentially warm the climate.

If we are to achieve the goals of the Paris Agreement, then emissions of other climate drivers such as methane, black carbon, and ground-level ozone must be reduced alongside carbon dioxide. These reductions would benefit the climate and foster sustainable development by delivering better health outcomes through improved air quality, preventing crop losses, and ensuring that we avoid climate-tipping points that would exacerbate long-term impacts and impede efforts to adapt to climate change.

Multiple benefits for climate, air quality, health, and sustainable development

Aside from contributing to limiting global warming, strong reductions in methane, black carbon and ground-level ozone have other key benefits for sustainable development:

- they protect health and avoid premature deaths by improving air quality;
- they prevent millions of tonnes of crop losses yearly; and
- they can prevent the climate from reaching tipping points that can exacerbate long-term climate impacts and make adapting to climate change harder, especially for the poor and most vulnerable.

By acting on climate and air pollution together we take advantage of synergies between the Paris Agreement Climate Goals and the UN Sustainable Development Goals to improve lives now and limit future climate warming.

ANNEX - LIST OF MORE RECURRING POLLUTANTS EMITTED INTO THE ATMOSPHERE BY HUMAN ACTIVITY

Carbon dioxide (CO_2) – Because of its role as a greenhouse gas it has been described as "the leading pollutant" and "the worst climate pollutant". Carbon dioxide is a natural component of the atmosphere, essential for plant life and given off by the human respiratory system. CO_2 currently forms about 410 parts per million (ppm) of earth's atmosphere, compared to about 280 ppm in pre-industrial times, and billions of metric tons of CO_2 are emitted annually by burning of fossil fuels. CO_2 increase in earth's atmosphere has been accelerating.

Sulphur oxides (SO_x) – particularly sulphur dioxide, a chemical compound with the formula SO_2. SO_2 is produced by volcanoes and in various industrial processes. Coal and petroleum often contain sulphur compounds, and their combustion generates sulphur dioxide. Further oxidation of SO_2, usually in the presence of a catalyst such as NO_2, forms H_2SO_4, and thus acid rain is formed. This is one of the causes for concern over the environmental impact of the use of these fuels as power sources.

Nitrogen oxides (NO_x) – Nitrogen oxides, particularly nitrogen dioxide, are expelled from high temperature combustion, and are also produced during thunderstorms by electric discharge. They can be seen as a brown haze dome above or a plume downwind of cities. Nitrogen dioxide is a chemical compound with the formula NO_2. It is one of several nitrogen oxides. One of the most prominent air pollutants, this reddish-brown toxic gas has a characteristic sharp, biting odour.

Carbon monoxide (CO) – CO is a colourless, odourless, toxic gas. It is a product of combustion of fuel such as natural gas, coal or wood. Vehicular exhaust contributes to the majority of carbon monoxide let into our atmosphere. It creates a smog type formation in the air that has been linked to many lung diseases and disruptions to the natural environment and animals.

Volatile organic compounds (VOC) – VOCs are a well-known outdoor air pollutant. They are categorized as either methane (CH4) or non-methane (NMVOCs). Methane is an extremely efficient greenhouse gas which contributes to enhanced global warming. Other hydrocarbon VOCs are also significant greenhouse gases because of their role in creating ozone and prolonging the life of methane in the atmosphere. This effect varies depending on local air quality. The aromatic NMVOCs benzene, toluene and xylene are suspected carcinogens and may lead to leukaemia with prolonged exposure. 1,3-butadiene is another dangerous compound often associated with industrial use.

Particulate matter / particles, alternatively referred to as particulate matter (PM), atmospheric particulate matter, or fine particles, are tiny particles of solid or liquid suspended in a gas. In contrast, aerosol refers to combined particles and gas. Some particulates occur naturally, originating from volcanoes, dust storms, forest and grassland fires, living vegetation, and sea spray. Human activities, such as the burning of fossil fuels in vehicles, power plants and various industrial processes also generate significant amounts of aerosols. Averaged worldwide, anthropogenic aerosols—those made by human activities—currently account for approximately 10 percent of our atmosphere. Increased levels of fine particles in the air are linked to health hazards such as heart disease, altered lung function and lung cancer. Particulates are related to respiratory infections and can be particularly harmful to those already suffering from conditions like asthma.

Chlorofluorocarbons (CFCs) – harmful to the ozone layer; emitted from products are currently banned from use. These are gases, which are released from air conditioners, refrigerators, aerosol sprays, etc. On release into the air, CFCs rise to the stratosphere. Here they come in contact with other gases and damage the ozone layer. This allows harmful ultraviolet rays to reach the earth's surface. This can lead to skin cancer, eye disease and can even cause damage to plants.

Ammonia – emitted mainly by agriculture sector. Ammonia is a compound with the formula NH3. It is normally encountered as a gas with a characteristic pungent odour. Ammonia contributes significantly to the nutritional needs of terrestrial organisms by serving as a precursor to foodstuffs and fertilizers. Ammonia, either directly or indirectly, is also a building block for the synthesis of many pharmaceuticals. Although in wide use, ammonia is both caustic and hazardous. In the atmosphere, ammonia reacts with oxides of nitrogen and sulphur to form secondary particles.

Radioactive pollutants – produced by nuclear explosions, nuclear events, war explosives, and natural processes such as the radioactive decay of radon.

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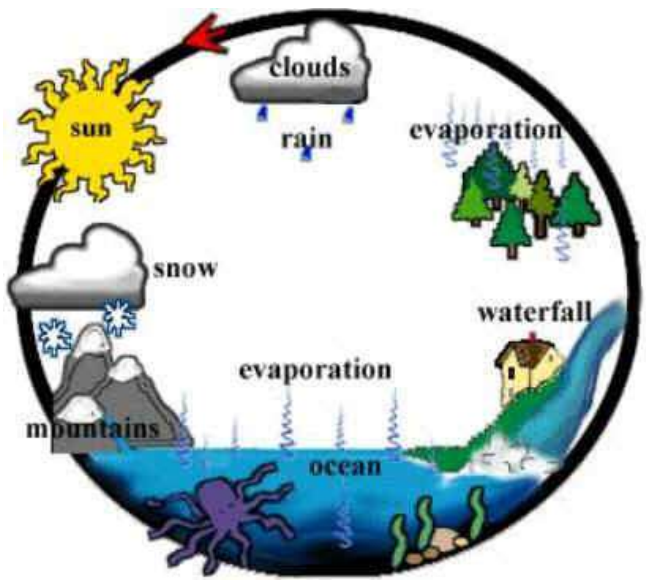
AQUATIC ECOSYSTEMS

Aquatic ecosystems are critical components of the global environment. In addition to being essential contributors to biodiversity and ecological productivity, they also provide a variety of services for human populations, including water for drinking and irrigation, recreational opportunities, and habitat for economically important fisheries. However, aquatic systems have been increasingly threatened, directly and indirectly, by human activities. In addition to the challenges posed by land-use change, environmental pollution, and water diversion, aquatic systems are expected to soon begin experiencing the added stress of global climate change.



HYDROLOGICAL CYCLE

Oceans and seas are mostly affected by the process of change caused by global warming since they constitute a large portion of our planet and have rich biodiversity. A temperature increase of only a few degrees does not only cause an increase in the temperature of large water masses such as oceans, seas, lakes, and ponds but it also causes hydrological events that cause a change in the physical and chemical characteristics of water. Water temperature is the most important environmental parameter that affects the life cycle, physiology and behaviours of aquatic living beings (Tekinay ve Güroy, 2007). Therefore, to what extent the oceans and seas will be affected by global warming on a worldwide scale, how global warming will affect the distribution of species, the relationship between global warming and biodiversity, and the impact of climate change on water resources which can renew themselves but are limited are topics that need to be considered carefully.

Approximately 70% of the earth's surface is covered by water. Climate change is already changing the distribution and abundance of aquatic ecosystem. Even minor changes to water temperature will result in changes to the currents that flow across the earth's surface. An aquatic ecosystem is broadly fall in to two categories (a) Marine ecosystem and b) Fresh water ecosystem.

Climate change within the ocean

The increase in greenhouse gases within the earth's atmosphere is set to change three fundamental variables:

(i). Reduced Total Carbonate alkalinity

Total carbonate alkalinity of seawater will decrease as CO2 increases within the earth's atmosphere (Gattuso et al., 1998; kleypas et al., 1999). This particular variable is expected to substantially change the acidity and carbonate ion pool of the global ocean. Doubling carbon dioxide concentrations in the atmosphere will decrease the aragonite saturation state in the tropics by 30% by 2050.

ii) Increased Sea level

Changes in sea level have had major impacts on the abundance and particularly the distribution of both marine and terrestrial diversity. Sea level will rise as climate changes pushes planetary temperature higher. This occurs due to the thermal expansion of ocean water, the melting of glaciers, and changes to the distribution of ice sheets. The expected increase in sea level is approximately 9 - 29 cm over the next 40 years or 28 - 29 cm by 2090 (Church et al., 2001; IPPC 2001). According to Nichols and colleagues (1999), sea level rise could cause the loss of up to 22% of the world's coastal west lands by 2080. Combined with other human impacts, this number is likely to climb to a loss of 70% of the world's coastal wetlands by the end of the 21st century.

iii) Sea temperature increase

Significant increase in heat content has not been distributed evenly. Sea temperature in turn influences of the marine environment. Due to its direct effects on the density of seawater, changes in global temperatures can play directly upon the rates and directions of ocean water movement.

Deep-sea biodiversity

The deep sea is increasingly recognized as a major reservoir of biodiversity. It is believed that the deep seabed support more species than all other marine environment. Marine biodiversity and ecosystem are threatened by pollution, shipping, military activities and climate change, but today fishing presents the greatest threat.

The greatest threat to biodiversity in the deep sea is bottom trawling. This type of high seas fishing is more damaging to seamounts and the cold-water corals they sustain. These habitats are home for several commercial bottoms- dwelling fish species.

Fish populations

Coastal fisheries are critical resources for hundreds of millions of people. Many scientists now point to the dramatic over exploitation of fisheries and the subsequent decline in fish stocks as the major factor in ecosystem change over the past two centuries (Jackson et al., 2001). Recent evidence has revealed that oceanographic and climatic variability may play a dominant role in fish stocks (Klyashtorein, 1998; Babcock Hollowed et al., 2001; Attrill and Power, 2002). The relationship between climate variability and fish stocks is probably complex. In some cases, subtle changes may affect conditions and crucial changes in the life history of the fish species. The most widespread effects of climate occur on the primary and secondary production in marine ecosystems.

Coral Reef

Tropical intertidal and sub tidal regions are dominated by ecosystems that are characterized by a framework of Scleractinia corals. They have undergone major changes over the past 20 years, much of which has been associated with climate change and other stresses. (Bryant et al., 1998). Despite the lack of external nutrients, these ecosystem from rich and complex food chains that support large populations of fish, birds, turtles and marine mammals. Light, temperature and the carbonate alkalinity of seawater decrease in a pole ward direction, making the formation of carbonate reefs more difficult at higher latitudes. Coral reefs have already experienced major impact from climate changes. Major disturbances to coral reefs have increased dramatically over the past 30 years and have been linked irrefutably to periods of warmer than normal sea temperatures.

Coral bleaching occurs when corals rapidly lose the cells. Bleaching results in colonies turning from brown to while, often with spectacular host pigments being exposed. Reef building corals that lose these important symbionts may experience mortality rates that may exceed 90% changes in reef building coral communities are likely to have huge impacts on marine biodiversity. Corals form the essential framework within which a multitude of other species makes their home. Fish that depend on corals for food, shelter or settlement cares may experience dramatic changes in reef building coral communities are likely to have huge impacts on marine biodiversity. Corals form the essential framework within which a multitude of other species makes their home. Fish that depend on corals for food, shelter or settlement cures may experience dramatic changes in abundance or go extinct. Thousands of other organisms are also vulnerable impacts on marine biodiversity. Corals form the essential framework within which a multitude of other species makes their home. Fish that depend on corals for food, shelter or settlement cares may experience dramatic changes in reef building coral communities are likely to have huge impacts on marine biodiversity. Corals form the essential framework within which a multitude of other species makes their home. Fish that depend on corals for food, shelter or settlement cures may experience dramatic changes in abundance or go extinct. Thousands of other organisms are also vulnerable.

FRESHWATER ECOSYSTEM

The threats to freshwater fauna fall into several broad categories: nutrient enrichment, hydrological modifications, habitat loss and degradation, pollution, and the spread of invasive species. A changing climate and increasing levels of UV light pose additional risks that superimpose upon existing threats. The combination of rapid land use change, habitat alteration and a changing climate is viewed as a particular serious challenge to aquatic ecosystems.

Importance of freshwater ecosystems

Surface freshwater are a small fraction of global water. Healthy freshwater ecosystems provide vital ecosystem services to human societies including the provision of clean water for drinking for agriculture, for fisheries, and for recreation. Many regions, in the world have insufficient clean water to meet even the minimal demands for human survival.

Climate change and the hydrologic cycle

Freshwater ecosystems will naturally be sensitive to change in the hydrologic cycle and these are difficult to predict. A warmer climate will result in greater evaporation from water surfaces and greater transpiration by plants which will result in a more vigorous water cycle. Future climate change will directly affect lake ecosystems through warmer temperature and changes to the hydrologic cycle.

Biological impacts

Rapid climate change has many negative implications for the biodiversity of rivers and streams. Climate change may cause extinction at several taxonomic levels. At the species level, those species that are highly restricted in their geographic ecologically are vulnerable to global extinction. This is true for fish where there are regional differences in the proportional occurrence of specialized species are vulnerable to global extinction.

CONCLUSION

Human demands for aquatic ecosystem quantity and quality now pose severe threats. The multiple human stressors of aquatic ecosystems will interact with future climate change. Current biodiversity changes are still largely driver by anthropogenic alteration of habitat. Biodiversity is sensitive to even small changes in the earth's climate. Every man need more wants, when this need should single want

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and then only we can develop a sustainable biodiversity.

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EXTREME WEATHER PHENOMENA

Climate change affects all regions around the world. Extreme weather phenomena are becoming more and more frequent and common, as extreme heat waves and water shortage with consequent droughts. Extreme weather can have a severe impact on society and Countries will face with significant policy and technological challenges.

Extreme weather, shifting rainfall patterns

Picture - REUTERS/Phil Noble

Heavy rain and other extreme weather events can lead to floods, decreasing water quality, but also decreasing availability of water resources in some regions. Europe and areas of Russia experienced unprecedented heat waves during the summers of 2003 and 2010. In 2013, record-breaking floods affected Germany, Hungary and other countries. During summer 2007, the United Kingdom experienced a series of destructive floods across the country. These brief examples illustrate that extreme weather may affect lives and livelihoods, agriculture, ecosystems and cause large-scale damages to property and loss of lives. These examples also reveal the need for adaptation to climate variability; extreme weather events must be considerated a part of normal life where societies have learnt to some extent to deal and adapt.

Popular images of global warming are often based on a mental model of a uniformly distributed gradual change. However, potential outcomes for a given location and time may range from hardly any warming to very rapid temperature increases, as we are currently observing in the increase in Arctic temperatures. Thus, adaptation has to address impacts of climate change at local to global levels. Adapting to climate change is not just a matter of average changes but much more of potential changes in the occurrence of extremes and their frequency, intensity and duration. In particular, policy making at the European Union (EU) level covers many countries with a combined population of over 500 million. The EU countries are spread over several very different climate zones from the Mediterranean sub-tropical to the Arctic. Changes in the frequency or intensity of extreme events have considerable implications for vulnerable communities across the continent.

Extreme weather and trends in Europe

Data collected since 1980 by the insurance industry provide one indicator of trends in extreme events. Data show weather-related catastrophes recorded worldwide to have increased from an annual average of 335 events from 1980 to 1989, to 545 events in the 1990s and to 716 events for 2002–2011.

Floods and the ‘climatological’ perils like **heat waves, droughts and wild fires** show the most pronounced upward trend, followed by **storms**. The analysis presents a clear distinction between all weather-related perils and geophysical hazard events like earthquakes, volcano eruptions and tsunamis, with the latter group showing only a slight and statistically non-significant increase.

Compared with other continents, the increase in loss-relevant natural extreme events in Europe has been moderate, with an increase of about 60% over the past three decades. The highest increases have occurred in North America, Asia and Australia/Oceania with today about 3.5 times as many events as at the beginning of the 1980s.

The humanitarian effects are exemplified by the record-breaking heat waves over Central and Western Europe during the summer of 2003 and over Russia during the summer of 2010, which led to tens of thousands of heat-related deaths across Europe, crop shortfalls, extensive forest fires and record high prices on the energy market among many other effects. In the winters of 2005/2006 and 2009/2010, parts of Europe experienced unusually cold temperatures that caused travel disruption, cold-related mortality and high energy consumption.

Flood damage has strongly increased owing to a wide range of factors, and floods are an increasingly urgent problem. Flood risk and society’s vulnerability increase because of a range of climatic and non-climatic factors, with a high dependence on site-specific conditions and a combination of these different factors. Losses caused by floods have increased and the death toll continues to be high.

The economic loss burden of extreme weather events has been considerable, estimated to be €405 billion since 1980 (in 2011 values). The most costly hazards have been storms and floods, amounting to a combined total loss of more than €308 billion. The most affected countries were Germany (455 events), France (425), United Kingdom (415), Switzerland (360), Italy (355) and Spain (317).

In agriculture, the 2003 and 2010 heat waves and associated dry conditions resulted in major regional crop shortfalls. The drought conditions and associated fires in the 2010 heat wave also caused a 25–30% drop in the forecast of Russia’s annual grain crop production, compared with 2009.

Connections between global warming and extreme weather

The robust warming signal projected by global climate models is already acknowledged in global risk reports such as those of the World Economic Forum (2013) and the International Risk Governance Council (Renn, 2006). An IPCC Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (IPCC/SREX, 2012) also provides a global overview of current knowledge about extreme weather events and changing climate, and their implications for society.

The recent 5th Assessment of Climate Change (IPCC, 2013) concluded that 'warming of the climate system is unequivocal' and that 'it is extremely likely that human influence has been the dominant cause of the observed warming since the mid-20th century'. The statistics described in section 2 above indicate that the frequency of climatological events overall and the resulting damage are increasing. Recent studies have also been able to attach probabilities to the extent to which inherent natural variability is involved and the extent to which climate change associated with global warming is exacerbating this situation.

Assessing the contribution of climate change and natural variability to extreme events

The NAS and NMI (2013) report reviews recent studies that allow us to assess the contribution of climate change associated with global warming to the probability of extreme events. These analyses do not seek to relate any event only to climate change and global warming, but allow the probability that such events would have occurred in a non-warming world to be assessed and compared with events under current global warming conditions. The main insights include the following:

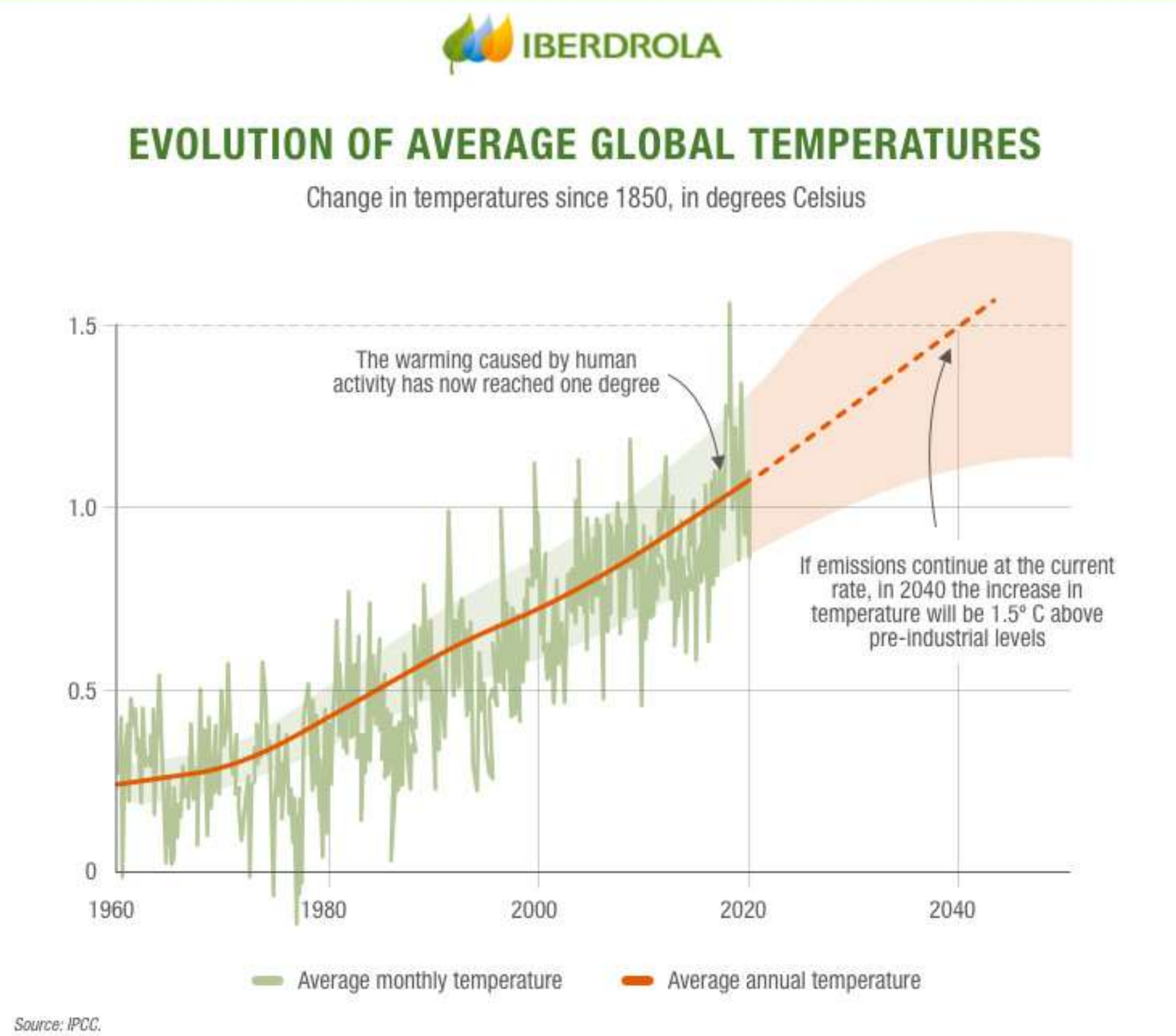
- Warming increases the water vapour in the lower ~10 km of the atmosphere.
- Warming increases the high sea-surface temperatures.
- Extreme summertime temperatures experienced are more than three standard deviations* warmer than would be expected from the climatological record. These high temperature extremes typically covered areas less than 1% of Earth's land surface between 1951 and 1980, but under the current situation these events may affect areas of about 10% of the Earth's land surface. Some of the hot anomalies during 2006–2011, including in Europe, exceeded three, four and five standard deviations of the 1951–1980 observations.
- The relative influence on these extreme heat waves of natural internal fluctuations is still under investigation. One model indicates that it is unlikely that the extreme hot summers in Western and Central Europe in 2003 and in Russia in 2010 would have occurred in the absence of global warming and, for a future global warming of at least 1 °C, anomalies exceeding three standard deviations would be the norm and five standard deviations should be occasionally expected. However, another study suggests that, at least for Russia in 2010, natural internal fluctuations may have been mainly responsible.

Source:

https://ec.europa.eu/clima/change/consequences_en
Report by Trends in extreme weather events in Europe: implications for national and European Union adaptation strategies - Building science into EU policy - www.easac.eu

INCREASE IN AVERAGE GLOBAL TEMPERATURE

The world is getting warmer. Thermometer readings around the world have been rising since the Industrial Revolution, and the causes are a blend of human activity and some natural variability—with the preponderance of evidence saying humans are mostly responsible.



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 a little more than 1° Celsius (2° Fahrenheit) since 1880. Two-thirds of the warming has occurred since 1975, at a rate of roughly 0.15-0.20°C per decade.

But why should we care about one degree of warming? After all, temperatures fluctuate by many degrees every day.

The global temperature record represents an average over the entire surface of the planet. The temperatures we experience locally and in short periods can fluctuate significantly due to predictable cyclical events (night and day, summer and winter) and wind and precipitation patterns. But the global temperature mainly depends on how much energy the planet receives from the Sun and how much it radiates back into space. The amount of energy radiated by the Earth depends significantly on the chemical composition of the atmosphere, particularly the amount of heat-trapping greenhouse gases.

A one-degree global change is significant because it takes a vast amount of heat to warm all the oceans, atmosphere and land by that much. In the past, a one- to two-degree drop was all it took to plunge the Earth into the Little Ice Age. A five-degree drop was enough to bury a large part of North America under a towering mass of ice 20,000 years ago.

Global temperature records start around 1880 because observations did not sufficiently cover enough of the planet prior to that time. The period of 1951-1980 was chosen largely because the U.S. National Weather Service uses a three-decade period to define "normal" or average temperature. The GISS temperature analysis effort began around 1980, so the most recent 30 years was 1951-1980.

2019 was the end of a *decennium horribilis* for the planet's climate. The verdict of the World Meteorological Organisation (WMO) during COP25 was unequivocal: the warmest decade since records began (1850).

These are bad times for the planet's climate. The exponential increase in CO2 emissions as a result of human activity since the end of the 19th century has sent the earth's temperature rocketing to unimaginable levels. We are now getting dangerously close to the 2 °C thresholds, and if we exceed it, we will be forced to face the irreversible effects of a climate crisis unprecedented in history.

CLIMATE REPORT DATA

If the latest climate report from the World Meteorological Organisation (WMO) is accurate we have just endured the hottest decade since records began (1850). Never before we had seen a decade marked by such an extraordinary rise in the average temperature of the Earth, which, in 2019 was around 1.1 ºC higher than at pre-industrial levels.

The year 2019 will be remembered as one of the hottest in history — the hottest still being 2016 — and an especially sad chapter as regards the melting of the poles, with the Arctic's worst summer of the century. Other areas of the world such as **Asia, South America, Africa, Europe and Oceania have also seen an increase in average temperatures,** which have risen continuously, breaking records decade after decade since 1980.

Global warming is the cause of increasingly frequent and violent extreme natural phenomena.

2019 CLIMATE SUMMARY

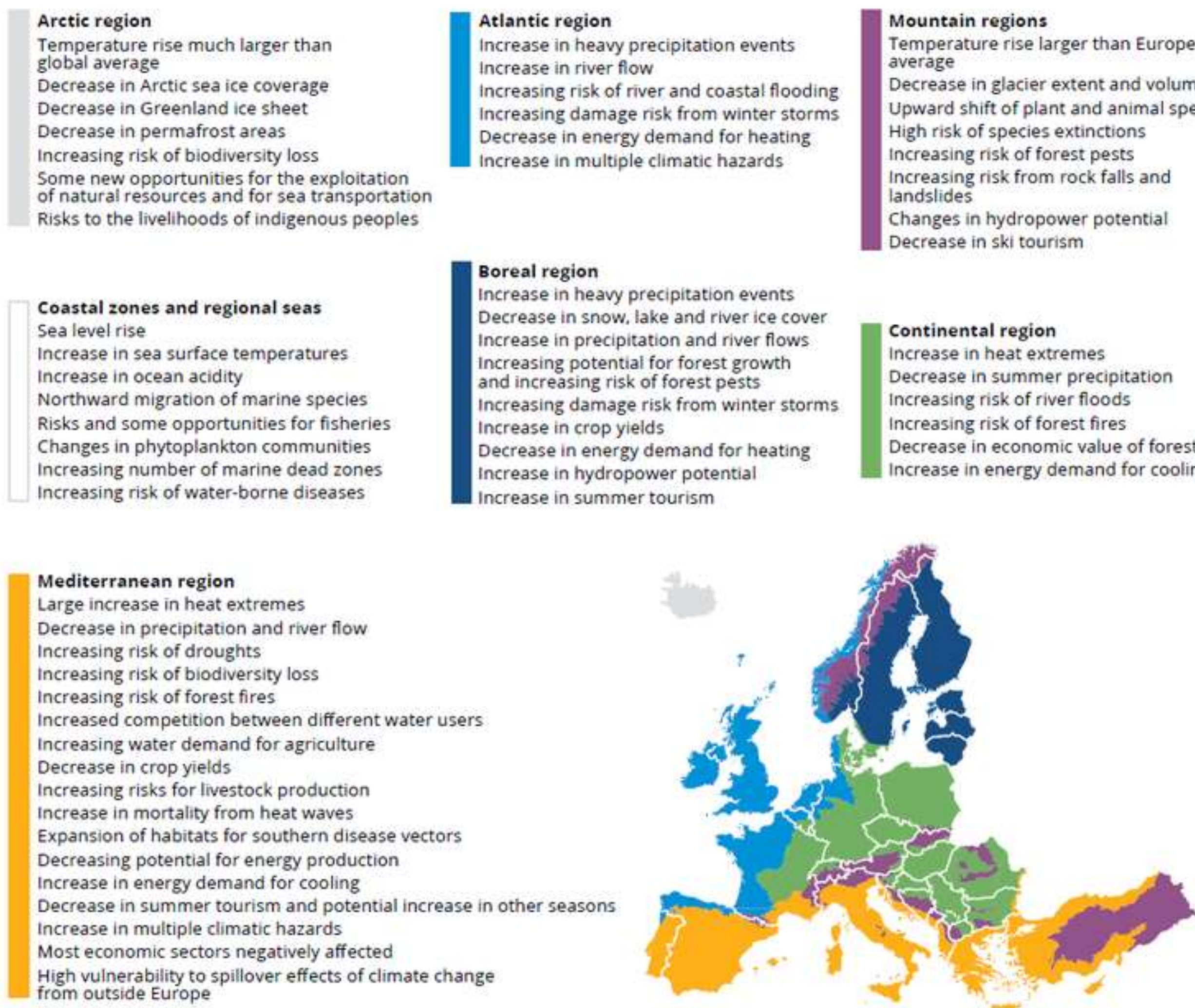
The US National Oceanic and Atmospheric Administration (NOAA) produced a list of the main global climate events in 2019. These are among the most significant:

Europe - Europe experienced several heatwaves, the one in Germany being the most worrying, and the second warmest year ever recorded.

Africa - This region faced the third hottest year of all time and produced cyclones like Idai and extreme droughts in countries like Ethiopia, Somalia, Kenya and Uganda.

Asia - This continent went through the third hottest year of the last century, with three cyclones in the same period with winds of over 185 km/h.

North America - Alaska broke its high-temperature record and several rivers — like Missouri and Mississippi — burst their banks between March and July.



Central and South America - Mexico experienced its hottest August on record and South America had its second-hottest year since 1909. The region also endured hurricanes and tropical storms such as Iba.

Oceania Australia - Australia endured a year of extreme temperatures and one of the worst outbreak of fires in its history.

CAUSES AND CONSEQUENCES OF THE INCREASE IN THE PLANET'S TEMPERATURE

The rise in the average World temperature over the last decade has had serious consequences for the planet. The following are the greatest concern:

The rise in the oceans and melting of the poles and glaciers

In October, the sea reached its highest level since precise measurements began in 1993. The Arctic is thawing and has been joined by the Antarctic, a process that has accelerated since 2016, particularly in 2019.

Warming and acidification of the oceans

There were record-breaking high ocean temperatures from 2016 to 2019. This warming has increased ocean acidification by 26% since 1750 and is destroying our marine ecosystems.

Extreme meteorological phenomena

Over the last decade droughts, floods and other climate catastrophes have intensified, causing thousands of deaths and leaving seven million people homeless in areas like Africa, Asia and the Caribbean.

Endangering the health and food security

In 2019, unprecedented heatwaves affected much of the world together with a notable increase in cases of dengue fever compared to 2018. Food security has been affected in parts of Africa and Asia by drought and floods.

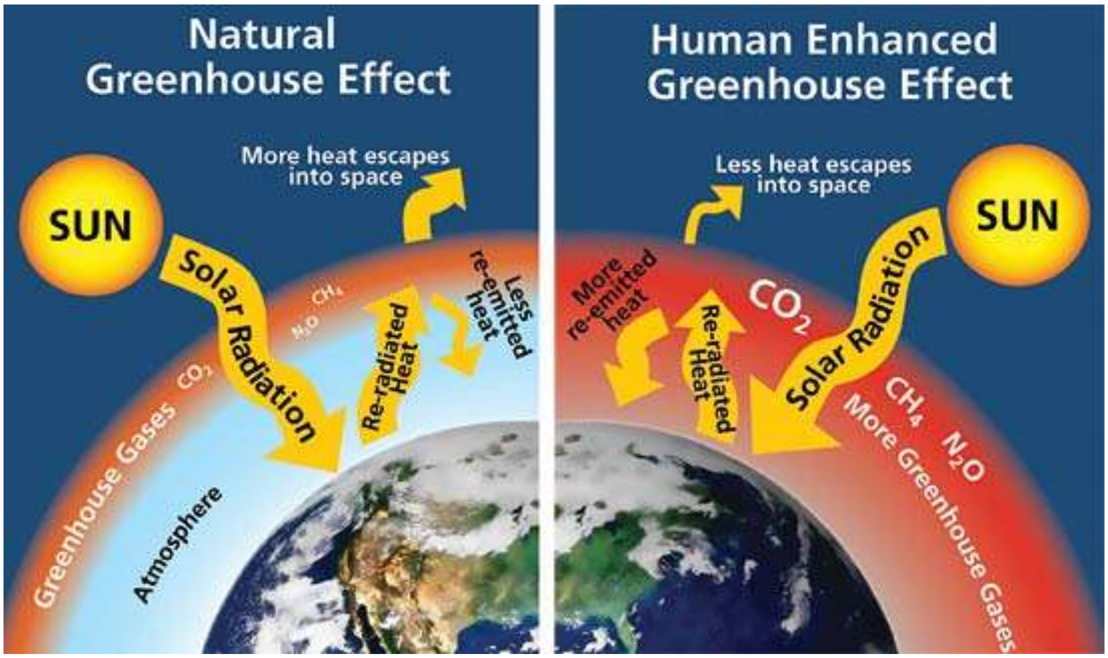
Source

https://www.iberdrola.com/environment/increase-average-temperature-on-earth

https://climate.nasa.gov/vital-signs/global-temperature/

https://climate-adapt.eea.europa.eu/knowledge/tools/urban-ast/step-0-2

CARBON AND GREENHOUSE GAS



ANTHROPOGENIC GREENHOUSE GAS EMISSIONS

What are the specific greenhouse gases involved, other than the obvious culprit - CO2, and where are these emissions actually coming from? What are the sectors of society and economy responsible for these emissions, the potential for reducing emissions in these various sectors, and the larger economic, political, and ethical considerations surrounding these issues?

First, let us tackle the first question. In terms of the net increase in the greenhouse effect due to human-produced greenhouse gases, CO2 is responsible for the lion's share. CO2 from fossil fuel burning alone is more than half the net force. If you add CO2 from fossil fuel burning, deforestation, and other minor sources, this comes to a little more than three-fourths of the net greenhouse radiative forcing by human-caused emissions. That means, however, that a non-trivial fraction of the effect is coming from other gases. What are they?

Well, roughly 14% is methane, mostly from agriculture, livestock raising, and damming projects (which create an artificial breeding ground for methanogenic bacteria), though some also escapes during natural gas recovery attempts. Another 8% is nitrous oxide—also a from agriculture, and the remaining 1.1% is chlorofluorocarbons (CFCs). It is tempting to simply lump the contribution of these greenhouse gases together with that of CO_2, representing the net impact in terms of an effective CO_2 concentration called "CO_2 equivalent". Some of these gases (like methane) are considerably more short-lived in the atmosphere than CO_2, persisting for decades rather than centuries. Such complications are often dealt with through the concept of global warming potential (GWP), which takes into account both the radiative properties of a particular greenhouse gas molecule and the lifetime that such a molecule typically has in the atmosphere, once emitted. In any case, such details represent a complication for greenhouse emissions mitigation policies. If we need to avoid a dangerous near-term climate tipping point, we might focus more effort on reducing methane because it is a particularly potent, if short-lived, greenhouse gas. On the other hand, if our goal is to stabilize long-term greenhouse gas concentrations, we would be better served by focusing purely on CO_2 emissions.

So, where are these greenhouse gas emissions coming from? They come from literally every sector of our economy. The largest single source is energy supply—primarily coal fired power plants, and natural gas—used by consumers for electricity and heating. The next largest contribution comes from industry, which includes electricity and heating used by the industrial sector and greenhouse gases released as a by product of cement production, chemical processing, and other industrial processes. Energy supply and industry combine for nearly half of the greenhouse gas emissions.

Next, accounting for about 17% of emissions, is forestry—mostly the carbon released from forest clearing and forest burning, followed by agriculture and transport, each of which accounts for around 13% of emissions. Agricultural emissions are mostly in the form of methane released by ruminants such as cows used as livestock, and by cultivation of rice paddies which provide breeding grounds for methanogenic bacteria. Transport-related emissions are mostly in the form of petroleum-based fuels used for personal (i.e., cars and motorcycles, minivans, SUVs, small trucks, buses, airplanes) and commercial (large trucks, ships, airplanes) transportation. Finally, residential buildings (including both construction and maintenance, electricity requirements, etc.) and waste management are responsible for about 8% and 3% of emissions respectively.

While it is useful to know what the historical contributions to our emissions have been from the various sectors, looking forward towards the future it is also important to know which sectors are growing most rapidly in their contribution to anthropogenic greenhouse emissions. By comparing emissions rates during the middle of the past decade with those at the beginning of the 1990s, we see that the largest absolute increase (an increase of nearly 3 gigatons/year of CO_2 released) has been in the energy sector, though other sectors such as transport and forestry have shown similar (35-40%) increases in emissions over this time frame. It is logical to conclude that these sectors might demand special attention in considering possible emissions mitigation approaches.

CARBON EMISSIONS POLICIES

Personal responsibility is hardly enough to effect major changes in carbon emissions. In a market-based economy only proper market incentives can insure major changes in collective behaviour. Ultimately, to solve the climate change problem, we need to fundamentally reshape our incentive structure, increasing investment for renewable sources of energy, while subsidizing development of fossil fuel sources. Putting a price on the emission of carbon is the only way to do that. And whether it is a carbon tax or emissions permits, only governmental policies coordinated among the nations of the world can implement such a system.

Kyoto Accord

Given the global nature of our carbon emissions, negotiated international treaties are essential if we are to stabilize greenhouse gas concentrations. Awareness of the need for such treaties was recognized by the early 1990s, in the form of the United Nations Framework Convention on Climate Change (UNFCCC), which was first put forward at the 1992 Earth Summit in Rio de Janeiro. The framework convention was updated at an international summit held in Kyoto, Japan in 1997 to constitute the now-famous Kyoto Protocol, which had as its stated goal, holding greenhouse gas concentrations below a level that would constitute dangerous anthropogenic interference (DAI) with the climate system. This was, indeed, the first reference to the now-familiar concept of DAI. The Kyoto Protocol went into effect 8 years later, in 2005.

While putting a price on carbon emissions is the only way that free market forces will insure stabilization of greenhouse gas concentrations, the Kyoto accord did not mandate a particular approach (i.e., carbon tax, or tradable emissions), nor did it define DAI in terms of a particular CO2 equivalent stabilization level or amount of warming. However, by 2007, the European Union had taken such initiative, defining DAI as 2°C warming relative to pre-industrial time, and implementing its own pilot program in emissions trading.

By the end of 2008, all industrial nations had ratified the treaty except the U.S. (though Canada withdrew from the treaty in 2012 under a new administration). Many developing nations also ratified the protocol, but were not held to mandated reductions due to the financial hardships the reductions might have imposed upon their fragile economies. While ultimately 192 nations signed on to the Kyoto Accord before it expired in 2012 (and many were willing to sign on to even stricter controls on carbon emissions), the two largest emitters of all ”the United States and China” remained holdouts. This is, perhaps, unsurprising. Both countries, as we have seen, rely upon a fossil fuel energy economy and—in the case of the U.S., politicians are lobbied heavily by fossil fuel industry groups not to pass legislation that might put a price on carbon emissions. Progress in mitigation of global carbon emissions is unlikely to occur without the participation of these two nations, placing much of the global political pressure on the U.S. and China to agree to an emissions reductions treaty.

Some nations, for example low-lying island regions and tropical nations most likely to be impacted in the near-term by climate change, argued that Kyoto did not go nearly far enough, and that for them DAI is already around the corner, and they do not have the resources to implement a program of wide-scale adaptation that richer nations have. Other supporters of Kyoto pointed out that it was just a first step in a process that will hopefully lead to more stringent reductions in the future. Critics on the other side argued that the impacts of climate change are overstated, and that passing the Kyoto accord would cost the economy. However, as we saw earlier in this lesson, sober cost-benefit analyses indicate that the costs of inaction are likely to greatly exceed the cost of action, so the credibility of this particular argument might be called into question.

Other complications arose due to the politics of differing interests of the two major holdouts, China and the U.S. China's net greenhouse emissions are now greater than those of the U.S., but their per capita emissions (due in large part to their extremely large population) are lower. Not surprisingly, the U.S. argued that the required emissions reductions be based on total emissions, while China argued it should be based on per capita emissions. Another complication is that western nations, like the U.S. and Europe, have enjoyed the benefits of more than a century of access to cheap fossil energy, while emerging industrial nations like China and India are only now exploiting fossil fuel energy reserves. These nations argue that the developed world already had its turn, and that that they deserve their fair share. There are consequently substantial political tensions that make progress in achieving a negotiated emissions treaty slow and difficult.

Paris Agreement and Future Policy

Little progress was made in achieving a binding international climate treaty in the years following Kyoto. No such agreements were reached during either the 2007 Bali summit, or the 2009 Copenhagen summit. The primary obstacles seemed to be those cited above, namely the differing interests of various major players such as the U.S. and China, and more generally between the developed, developing, and undeveloped world. The reticence of the U.S. in committing to mandatory carbon reductions is, too, in part a product of political pressures. Those favouring U.S. participation have had to fight a coordinated, massively funded publicity campaign by the fossil fuel industry and trade groups representing it, which has successfully prevented passage of energy legislation dealing with climate change by attacking its scientific underpinnings, and by opposing politicians who support such legislation by funding their opponents in political campaigns, among other tactics.

This lack of progress and the apparent lack of will to confront the climate change threat has caused many to become discouraged over prospects for a meaningful carbon emissions policy. However, there is some cause for cautious optimism as well. While China is the single largest net emitter of carbon on the planet now, this country has shown signs of commitment to developing renewable and clean energy, investing far more money in this area in recent years that other countries, such as the U.S. In November 2014, General Secretary Xi Jinping, along with President Obama, created a plan to limit greenhouse gas emissions. Meanwhile, the Obama administration pursued executive actions via the EPA to reduce U.S. carbon emissions, including calling for higher automobile fuel-efficiency standards and regulations on coal-fired power plants such as the Clean Power Plan, with a target of reducing U.S. electrical power generation emissions by 32% by 2030. While the U.S. Congress failed to pass a comprehensive climate bill, many states and localities have implemented their own greenhouse gas reduction schemes.

There are past examples of success we can look to, where nations came to agreement on policies to mitigate other emerging global environmental threats, whether it be the passage of the Clean Air Acts in the 1970s to deal with the threat of acid rain, or passage of the Montreal Protocol in 1984 to ban the production of CFCs, which were known to be damaging the stratospheric ozone layer. These past examples show that nations can join together in binding agreements to confront emerging global environmental threats before these threats reach catastrophic magnitudes. Dealing with climate change is admittedly more difficult, as carbon emissions are at the very heart of our current global energy economy, and simple solutions (such as installing scrubbers in smokestacks in the case of acid rain), or ready substitutes (replacing CFCs with other non-ozone-destroying substitutes as propellants in spray cans) are far more challenging to come by. Clearly, confronting global climate change will require greater will and greater global cooperation than has ever been called for before. Nonetheless, we can look with guarded optimism at these past successes and use them as instructive road maps as we seek to deal with the problem of global climate change.

Finally, at the Paris summit in December 2015, the Paris Agreement was composed by consensus of the nearly 200 attending parties of the UNFCCC (countries plus the EU), and became legally binding in November 2016 after sufficient parties representing enough of the world's greenhouse gas emissions ratified the agreement - including, in particular, the United States and China. Each participating party has been required to set an emission reduction target - a Nationally Determined Contribution (NDC) - but the chosen amount is voluntary, and no enforcement mechanism is in place. It was agreed that the goal would be to limit global warming to "well below 2° C above pre-industrial levels", but also "to pursue efforts to limit the temperature increase to 1.5 °C above pre-industrial levels"

From a global perspective, there is evidence that mitigation policy is having a noticeable effect. After steady growth in recent decades, global CO2 fossil-fuel emissions nearly stabilized 2014 to (less than 1% growth per year) despite substantial worldwide GDP growth, in large part due to the phasing out of coal power plants in China and the United States. However, global emissions rose again in 2017 and 2018.(link is external) The European Union and 174 world states have ratified the Paris Agreement, and after Syria in 2017, every country in the world except the United States is now a party to the Paris agreement. Course author Michael Mann argues that not only would the proposed agenda of the Trump administration be disastrous for worldwide climate change mitigation, but that the United States needs to remain deeply committed to clean energy research and development for its own economic self-interest, to remain a world leader in clean energy research and technology.

Ethical Considerations

While the economics of climate change get much attention, the ethical considerations of climate change often get short shrift by comparison.

One of the challenges of applying traditional economics and cost benefit analysis to the problem of climate change is that the costs and benefits are simply not borne by the same individuals. There is a disaggregation of the costs and benefits with respect to both generation and region. We have seen that those who live in the undeveloped and developing world, largely in the tropics, and have had little role in the carbon emissions that have led to climate changes thus far, are likely to see the most devastating impacts in key areas such as agriculture and freshwater availability and—in the case of low-lying island nations—loss of habitability. Because of their relative lack of wealth, the nations of the undeveloped and developing world are least able to implement adaptations that might better allow them to cope with climate change. One possible solution is a system that would provide for a transfer of funds from industrial nations to poorer nations to allow them to implement adaptive measures.

Aside from the regional disparities, there is a fundamental generational disparity associated with climate change. The generation that is creating the problem—us—is unlikely to see the most severe impacts of climate change. Instead, it is future generations who will see the greatest impacts of the carbon we are emitting today, e.g., inundation due to sea level rise, stronger hurricanes, worsened drought. The economic discounting typically used in purely economic evaluations of the climate change problem, one might argue, does a grave injustice to future generations by placing lesser value on their world than ours.

There is, finally, the even more fundamental ethical question of whether it is ethical to be playing "Russian roulette" with the future of the planet. We have discussed the potential harm to the climate associated with ongoing carbon emissions. But there are other even more immediate and more visceral reminders of the hidden costs—the externalities—of our current reliance on fossil fuel sources that are increasingly more difficult, and more dangerous, to recover. Recent accidents over the past decade, like the Deepwater Horizons (link is external)oil disaster, which cost human lives and did potentially irreparable harm to the ecosystems of the Gulf of Mexico, or the Upper Big Ranch Coal Mine(link is external) explosion and collapse, which killed 25 miners (the company, Massey Energy, that runs the mine had been cited for over 500 violations in the past year; this is the same company responsible for the extremely controversial(link is external) practice of mountain top removal) are reminders of the true cost of our continuing reliance on fossil fuel energy.

The recent Japanese nuclear meltdown, resulting from a major earthquake off the coast of Japan and devastating tsunami, serve as further warnings regarding the dangers of some other non-carbon energy sources that have been proposed as alternatives to fossil fuel energies. One can make a fairly compelling argument that there are no magic bullets. The only safe way of meeting our current and future energy requirements is to put far greater investment into clean, renewable energy sources—like wind, solar, hydro-power, bio-fuels, etc.

We have talked previously about the so-called precautionary principle. There is only one Earth, and if we choose to perform an uncontrolled experiment with it, and that experiment goes awry--there is no going back. There is no restoring the Greenland and Antarctic Ice Sheets, which took millions of years to form, once they have collapsed. There is no restoring species, who evolved over many millions of years, once they go extinct because of human-caused environmental changes. Naive economic analyses of climate change damages can by surprisingly dismissive of the costs of such catastrophic outcomes. Critics have pointed out, for example, that one widely used economic model for performing carbon emissions cost-benefit analysis places a disturbingly low cost on ecosystem damages: the model favours the elimination of 99% of species going extinct within 40 years because it only values the net loss of those species at $250/capita! (the costs of lost species are valuated only in terms of the fact that humans like having them around, i.e., there is no intrinsic value ascribed to animal and plant species, functioning ecosystems, etc.—arguably a fundamental weakness in the way such damages are treated in these sorts of models in general).

Is this outcome defensible from a moral or ethical point of view? Could we rationalize leaving our children and our grandchildren not only a severely degraded environment, but a world lacking most of the wonder and beauty of our world —charismatic creatures like the polar bear and the now-extinct Golden Toad, and Hemingway's magnificent "Snows of Kilimanjaro"?

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Understanding the Change in Sea Level

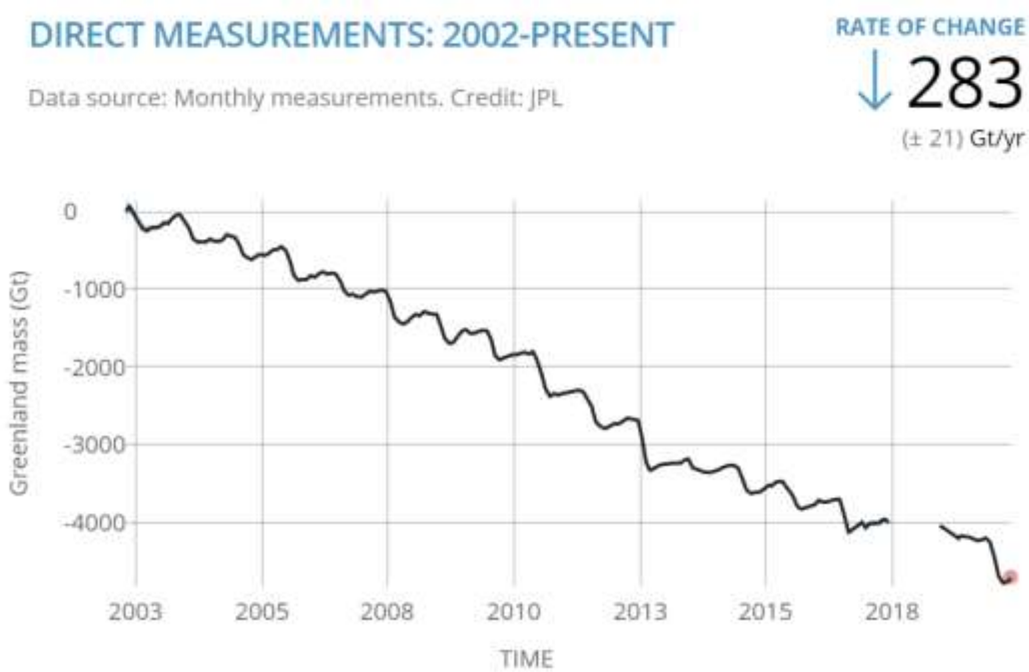
Earth's seas are rising, a direct result of a changing climate. Ocean temperatures are increasing, leading to ocean expansion. And as ice sheets and glaciers melt, they add more water. An armada of increasingly sophisticated instruments, deployed across the oceans, on polar ice and in orbit, reveals significant changes among globally interlocking factors that are driving sea levels higher.

Contributing Factors

The globally averaged trend toward rising sea levels masks deeper complexities. Regional effects cause sea levels to increase on some parts of the planet, decrease on others, and even to remain relatively flat in a few places, including, in recent decades, on the California coast. Thermal expansion of seawater can be the product of regional phenomena, such as El Niño, the periodic warming of the eastern tropical Pacific. But some of these regional cycles so far show no direct link to long-term global climate change—despite, at times, independently exerting a powerful short-term influence on global climate.

Ice Melt

Ice melt: the loss of ice mass in response to warming. Ice loss near the poles from glaciers and ice sheets is one of the most significant contributions to global sea level rise; the largest single source is Greenland, with the island's losses increasing by the decade.



Greenland

Data from NASA's GRACE and GRACE Follow-On satellites show that Greenland has been losing mass since 2002. The GRACE mission concluded science operations in June 2017. GRACE Follow-On began data collection in June 2018 and is now continuing the mass change data record for Greenland.

This dataset contains the Greenland mass time series generated from the GRACE and GRACE Follow-On JPL RL06Mv2 data, which includes the latest data processing improvements. The 1-dimensional time series of ice mass averaged over the Greenland ice sheet from GRACE and GRACE Follow-On is expressed in equivalent ice mass (Gt). 1 mm of sea level equivalent equals approximately 360 Gt of ice. The time series starts in April 2002 and is continuously updated as more data are collected, with a lag of up to 2 months.

An animation of the spatial variations can be found here. These data are available in ASCII format (Reference: Watkins et al., 2015, doi: 10.1002/2014JB011547).

Satellite gravimetric

The advent of gravimetric measurements with the twin GRACE satellites in 2002, along with more recent deployment of floating Argo sensors, opened the way to "closure" of the sea level budget—that is, when the sum of observed ocean mass and density changes equals total sea level change [Leuliette and Willis, 2011].

GRACE measures changes in water mass, including terrestrial storage in the form of groundwater, rivers, snow and ice, and mass changes within the ocean itself, as well as the movement of water between land and ocean.

Early attempts did not achieve closure of the sea level budget for four-year trend lines [Willis et al., 2008, Chang et al., 2010], leading to concerns about possible instrument drift. More recent efforts, however, led to reports of closure for more extended periods, including a NOAA report covering 2005 to 2013 ("The Budget of Recent Global Sea Level Rise, 2005-2013," by Eric Leuliette).

To capture changes in water mass accurately, shifts in atmospheric mass must be subtracted from GRACE's gravitational measurements—along with changes in the mass of ocean basins, the lingering rebound effect from the loss of Ice Age glaciers [Tamisiea and Mitrovica, 2011].

One approach to achieving a high-precision dataset is the mass concentration (mascon) method, which breaks up GRACE's gravitational measurements into discrete regions of higher mass. This allows more precise resolution of mass changes in smaller regions than more traditional "harmonic" solutions, which smooth gravitational measurements into a larger whole [Watkins et al., 2015].

Greenland & Antarctica

Ice loss near the poles is one of the most critical changes pushing sea levels higher, a conclusion supported by data of increasing weight and accuracy. Greenland's contribution to global sea-level rise is the largest, and increases every decade. Studies suggest that its melt grew from 0.09 millimetres per year between 1992 and 2001, expressed as the global sea-level rise equivalent, to 0.59 millimetres per year between 2002 and 2011 [Velicogna et al, 2014].

Measurements by the twin GRACE satellites (Gravity Recovery and Climate Experiment) show that most of the losses between 2003 and 2013 were coming from the southeast and northwest portions of the island, while the southwest is responsible for more than half of the acceleration of ice loss. The estimated total loss is in the range of more than 200 to more than 300 gigatons per year (1 gigaton is approximately 264 billion gallons of water. Melting 365 gigatons of ice would add 1 millimeter to global sea level; there are 25.4 millimeters in an inch). It is essential to understand, particularly on these short time scales, what part of the mass loss is due to changes in precipitation and surface melting and what part to changes in glacial discharge.

The measurements show that the pace of ice loss in Antarctica, while more moderate, remains sizable. Although East Antarctica has little mass loss, West Antarctica's is significant. The Amundsen Sea region and the Antarctic Peninsula, both in West Antarctica, account for 64 percent of the total, some 180 gigatons per year between 2003 and 2013 (a loss offset by mass gains in East Antarctica, for a total loss for the continent of 67 gigatons per year [Velicogna et al, 2014]). And the Amundsen Sea area was the dominant contributor to the acceleration of ice loss, which increased about 11 gigatons each year.

Antarctica's contribution to sea-level rise increased from 0.08 millimeters per year between 1992 and 2001 to 0.40 millimeters per year between 2002 and 2011 [Velicogna et al, 2014]. Together, Greenland and Antarctica contribute about one third of present-day sea level rise [Chen et al., 2013].

A 2012 study relying on altimetric, interferometric and gravimetric satellite data, as well as modeling [Shepherd et al., 2012], found that the Greenland ice sheet lost 142 gigatons per year between 1992 and 2011, though with an uncertainty of 49 gigatons per year. The same study saw 71 gigatons of ice loss in Antarctica, also with a large uncertainty factor. That adds up to a polar ice-sheet contribution of about 0.59 millimeters of sea-level rise per year for the study period.

And a recent reprocessing of GRACE data [Watkins et al., 2015] found 289 gigatons per year of ice-mass loss for Greenland between 2002 and 2014, and 141 gigatons for Antarctica.

Another study [Rignot et al., 2014] found a rapid rate of retreat for Amundsen Sea glaciers between 1992 and 2011, with their grounding lines, which separate ice on bedrock from floating ice, receding from 10 to 35 kilometers. These authors concluded that the ice retreats along regions of "retrograde bed elevation"—where the bedrock slopes downward, and farther away from the grounding line, in the inland direction. Ice-sheet numerical models find this configuration to be unstable.

Yet Antarctica illustrates the ability of broad-scale averaging to mask highly variable rates of change across regions. Some parts of the frozen continent, shielded by isolation and deep cold, are seemingly impervious to global warming—at least for the present. Queen Maud Land in East Antarctica even appears to be gaining ice mass—some 63 gigatons per year from 2003 to

2013 [Velicogna et al, 2014]. While not enough to overcome the continent's net loss of ice, such gains do show that some regions can manage a shift toward higher ice mass, due to greater precipitation and fewer losses.

Modeling Ice

Ice sheet modeling is critical to any projection of future sea level rise but remains in its early stages. Still, recent attempts to model surface mass balance of the Greenland and Antarctic ice sheets during the latter half of the 20th century agree well with observations—an important step in validating projections of future changes in mass balance and their sea level equivalent [Shepherd et al., 2012]. Such projections are typically derived from regional climate models or downscaled atmosphere-ocean general circulation models [Flato et al., 2013].

The Ice Sheet System Model (ISSM), an impressive tool developed in recent years, integrates data from a variety of sources to simulate the higher-order physics of ice flow, and to develop mass-balance projections for the Greenland and Antarctic ice sheets [Larour et al., 2012]. This high-resolution model, which includes three-dimensional capability, represents an improvement over previous "hybrid" models (these combine Shallow Ice Approximation and Shallow Shelf Approximation simulations with simplified ice-flow mechanics, but do not always capture ice sheets and ice shelves realistically). The ISSM was shown to model ice flow surface velocities in good agreement with observations for Greenland [Larour et al., 2012], and has been used to improve Antarctic ice-shelf velocity modeling [Larour et al., 2014].

For the Greenland ice sheet, a variety of models show no trend of statistical significance from the 1960s to the 1980s, then a significant trend toward an increasing contribution to sea-level rise beginning in the 1990s [Flato et al., 2013]. By 2011, Rignot et al. were using the Regional Atmospheric Climate Model (RACMO2) to show that changes in surface mass balance could account for roughly 60 percent of loss in ice mass since 1992 [Rignot et al., 2011, Flato et al., 2013].

Antarctic simulations come with greater uncertainty, inspiring among the authors of the latest IPCC report only medium confidence in modeling results for the late 20th century, including a RACMO2 estimate of a negative contribution to global sea level rise: minus 5.5 millimeters per year, plus or minus 0.3, between 1979 and 2000 [Lenaerts et al., 2012].

A recently published evaluation of Antarctic climate modeling by 20 experts [Bracegirdle et al., 2015] included a number of recommended improvements:

- Elimination of large biases in positioning of the southern hemisphere mid-latitude tropospheric jet, which drives westerly winds, in CMIP 5 models, to better capture the effects of stratospheric ozone depletion and recovery.

- Better modeling of clouds over the Southern Ocean.
- Evaluation of energy fluxes over Antarctica in climate models, with the aim of developing a proper atmospheric energy budget.
- Using reconstructions of paleoclimate to create more effective simulations of the relative warming rate over the southern continent, known as "polar amplification."
- Reliably simulating connections between the tropical Pacific and Antarctica, especially the climatic effects of an expected eastward shift in southerly directed Rossby waves—a shift projected by most models.

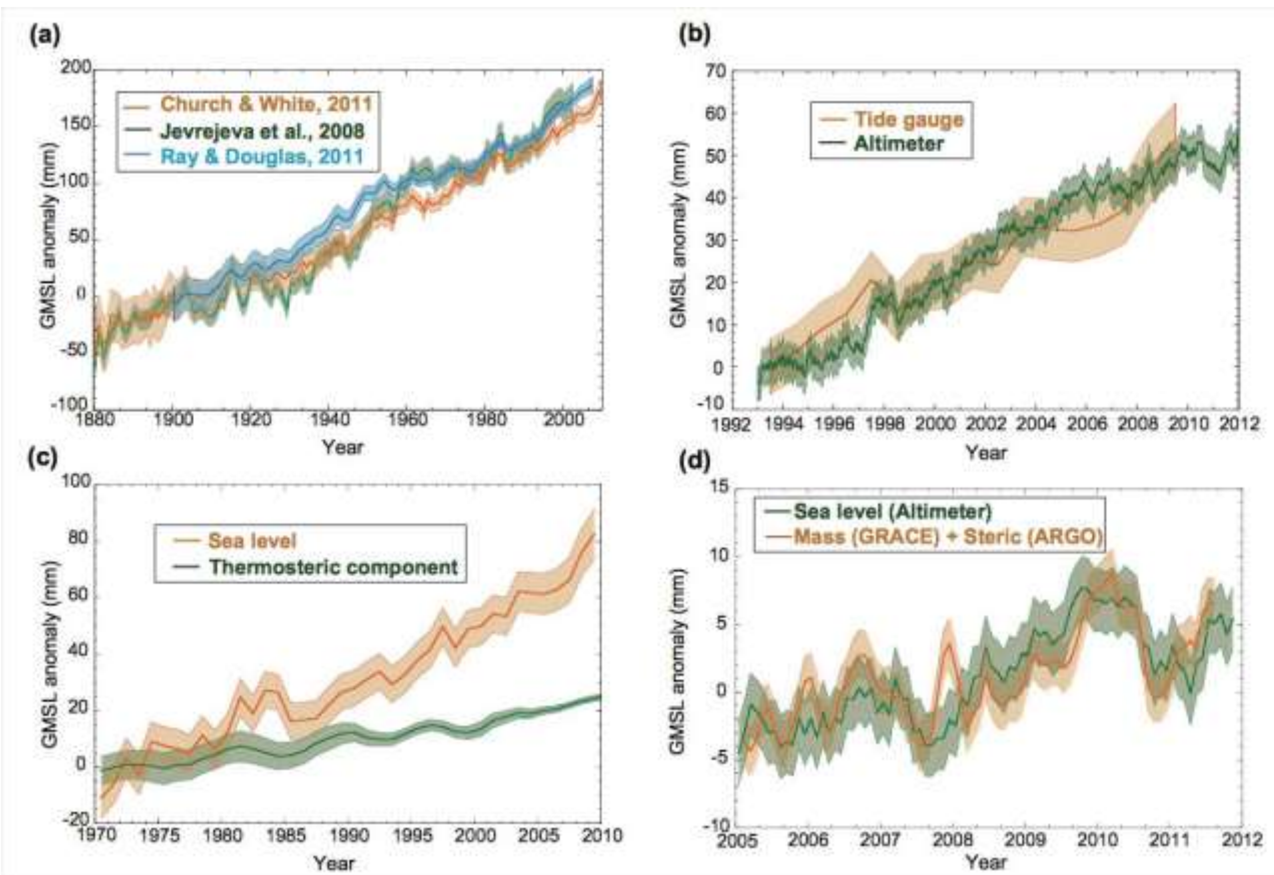
The evaluation also recommended improved modeling of Southern Ocean circulation.

THERMAL EXPANSION

Ocean water expands as it warms, filling larger volumes. The ocean absorbs more than 90 percent of the heat that greenhouse gases trap in Earth's atmosphere, making thermal expansion a significant contributor to global sea-level rise — about one-third of the total observed.

Global mean sea level anomalies (in mm) from the different measuring systems as they have evolved in time, plotted relative to 5-year mean values that start at (a) 1900, (b) 1993, (c) 1970 and (d) 2005. (a) Yearly average GMSL reconstructed from tide gauges (1900–2010) by three different approaches (Jevrejeva et al., 2008; Church and White, 2011; Ray and Douglas, 2011). (b) GMSL (1993–2010) from tide gauges and altimetry (Nerem et al., 2010) with seasonal variations removed and smoothed with a 60-day running mean. (c) GMSL (1970–2010) from tide gauges along with the thermosteric component to 700 m (3-year running mean) estimated from in situ temperature profiles (updated from Domingues et al., 2008). (d) The GMSL (nonseasonal) from altimetry and that computed from the mass component (GRACE) and steric component (Argo) from 2005 to 2010 (Leuliette and Willis, 2011), all with a 3-month running mean filter. All uncertainty bars are one standard error as reported by the authors. The thermosteric component is just a portion of total sea level and is not expected to agree with total sea level. (Source: IPCC Fifth Assessment Report)

The warming of Earth is primarily due to accumulation of heat-trapping greenhouse gases, and more than 90 percent of this trapped heat is being absorbed by the oceans. Water volume rises with temperature because of thermal expansion—another major driver of sea level rise. The estimated rate of thermal expansion, or thermosteric sea level rise, from 1971 to 2010 is 0.4 to 0.8 millimeters per year; the estimate carries a confidence level of 90 to 100 percent [Rhein et al., 2013]. This corresponds to a warming rate of 0.015 degrees Celsius per decade in the upper 700 meters of the global ocean between 1971 and 2010. By comparison, an estimate using Argo floats found the thermosteric component of sea level rise above a depth of 2000 meters to be 0.5 millimeters per year, plus or minus 0.5 millimeters, between January 2005 and September 2010 [Leuliette and Willis, 2013]. Temperature measurements of the sea surface, taken by ships, satellites and drifting sensors, along with subsurface measurements and observations of global sea-level rise, lead researchers to conclude that this warming of the upper ocean over four decades is virtually certain. A contribution to sea level rise of about 0.1 millimeter per year by warming of ocean waters at depth, 700 meters to 2,000 meters, is considered likely, with about another 0.1 millimeter caused by warming deeper than 2,000 meters also considered likely [Rhein et al., 2013].



The expansion record is a short one; before 1971, ocean measurements were too few to allow meaningful estimates. Still, the record is robust enough to reveal that temperature-driven changes in seawater volume vary seasonally, as well as across decades. Combined with seasonal movement of rainfall, which brings shifts in water mass, such changes can cause sea levels in a given hemisphere to fluctuate by amounts approaching a centimeter [Chen et al., 2005].

The magnitude of expansion's effect leads some researchers to urge adoption of sea level rise as the true "global warming number." While we might instinctively look to globally averaged, surface air temperature as the benchmark of climate change, the sea level signal, these scientists argue, closely tracks the vast majority of the planet's heat absorption.

Empirical Projections

Projections of global sea level rise by 2100, the year upon which climate modelers typically focus, vary widely depending on modeling methods and on assumptions—the rate of increase in greenhouse gas emissions, for example, and especially how ice sheets will respond to warming air and ocean water. Recent projections range from 0.2 meters to 2.0 meters (0.66 to 6.6 feet) [Melillo et al., 2014; see sections 13.5.1 and 13.5.2 of the 2013 IPCC report for detailed discussion].

The projections for the century ahead focus on the two largest contributors: thermal expansion of seawater and melting land ice. The consensus projections in the most recent IPCC report, called the Fifth Assessment or AR5, include dynamic changes in the great ice sheets—an improvement over the previous assessment, AR4, although much remains uncertain in the young field of ice sheet modeling [Church et al., 2013].

The latest assessment provides a range of projections for a variety of greenhouse gas emissions scenarios and associated radiative forcing (the energy injected into the climate system by the action of these gases). The four Representative Concentrated Pathway scenarios, or RCPs, rise from low to high emissions, each applied to CMIP 5 models to produce possible future sea-level changes.

AR5 expresses "medium confidence" in these projections, derived from process-based models—that is, attempts to simulate the mechanics and interactions of the factors driving sea level rise and land ice changes. But coupled general circulation numerical models—considered "process-based"—explain 90 percent of the observed sea level rise between 1971 and 2010, as well as that observed during a shorter period, 1993 to 2010 (see "By the Numbers"). This increases confidence that these models are reliable under present-day conditions, despite the fact that the models' current rate of rise, 3.7 millimetres per year, is significantly higher than shown by observations. Since these coupled models do not include ice sheet instabilities, their projections very likely represent a "lower bound" for future sea level rise.

Process-based models project a rise of 0.26 to 0.55 meters, with a median value of 0.4, for the RCP 2.6 scenario, in which gas emissions decline after a peak, while carbon dioxide levels remain below 500 parts per million. For the RCP 8.5 scenario, with its higher concentrations of greenhouse gases and with carbon dioxide above 700 parts per million, the projected rise is 0.52 to 0.98 meters, with a median value of 0.6. [Church et al., 2013].

Ocean warming and ice-sheet losses are "very likely" to drive the rate of sea level rise higher in the 21st century than the rate measured from 1971 to 2010, according to AR5 [Church et al., 2013]. For the 2081-2100 period, compared to 1986-2005, the report considers it likely, with medium confidence, that global mean sea-level rise will fall between five and 95 percent of the range projected by process-based models. Only the collapse of marine-based portions of the Antarctic ice sheet could drive sea level above these "likely" ranges, the authors concluded, and no more than a few tenths of a meter [Church et al., 2013].

And while the IPCC report acknowledges a newer, alternative approach known as semi-empirical modeling, its projections earn only "low confidence" from the IPCC [Church et al., 2013]. The report's authors could not evaluate the probability that semi-empirical models, or SEMs, would come true, and believed the scientific community lacked consensus on their reliability.

SEMs [Rahmstorf et al., 2012 and references therein] take a simple approach—a kind of shortcut—to simulating future sea level rise. Instead of trying to model the processes underlying sea level change, these models rely on sea-level changes observed in previous decades and their relationship to global temperature. Then they apply that same relationship to the century to come. The resulting projections tend to be significantly higher than those derived from process-based modeling.

An illustrative example can be found in a recent study contrasting the projections of process-based and semi-empirical models [Perrette et al., 2013]. Global mean sea level rise from major sources—thermal expansion, glaciers, and the Greenland and Antarctic ice sheets—total 0.42 meters by 2100 in the process based RCP 6.0 model, considered a mid-range, standard-type emission scenario. But updated with the semi-empirical approach, the same model yields a total of 0.86 meters, more than twice the process-based value.

For scenario RCP 2.6, the median projection of the SEMs is about 0.75 meters by century's end, and about one meter for scenario RCP 8.5. At the high end of the confidence intervals (95%), sea level reaches above 1.5 meters for the latter scenario, mostly based on the works of Rahmstorf and of Jevrejeva. Another study of modeling reliability, in which Rahmstorf et al. performed an extensive analysis of their SEMs [[Rahmstorf et al., 2012], concluded that a rise of about one meter, produced by a warming of 1.8 degrees Celsius, represented a robust result, derived from published data and their model.

Since the publication of AR5, newer ice-sheet observations also are suggestive of the higher values for sea level rise. Measurements of grounding line retreat in West Antarctic glaciers [Rignot et al., 2014] yielded evidence of rapid retreat between 1992 and 2011. More importantly, the researchers did not find a "major bed obstacle that would prevent the glaciers from further retreat and draw down the entire basin [Rignot et al., 2014]." Bedrock along the discharge channels grows deeper in the inland direction, helping the grounding line move farther inland. A complementary study [Morlighem et al., 2014] found that the glacial valleys through which Greenland discharges ice to the ocean are deeper than previously believed, making them more vulnerable to melting by adjacent, warmer ocean waters.

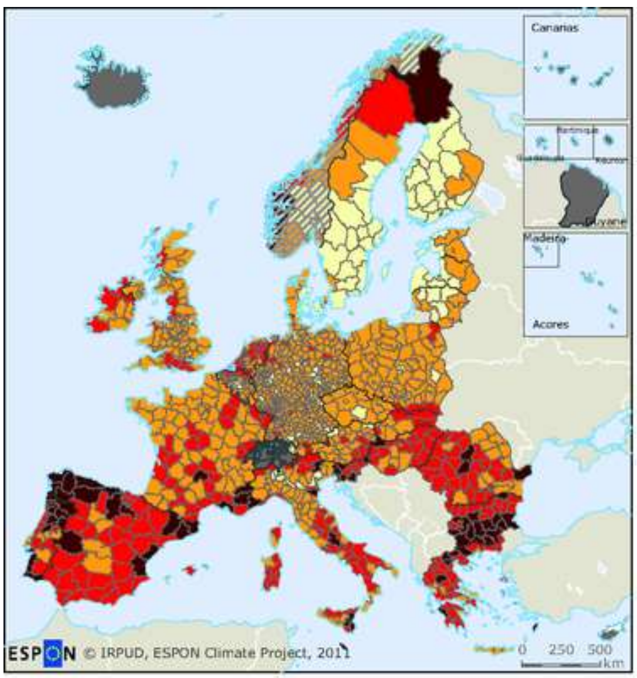
Source

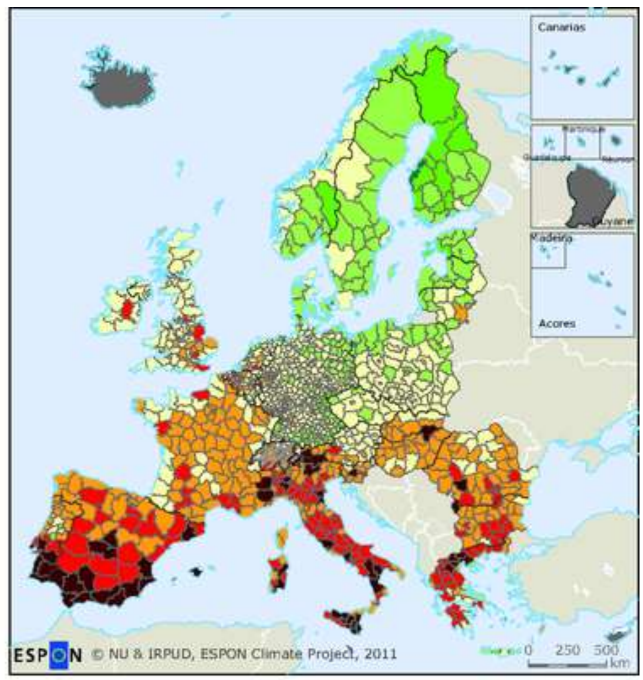
https://sealevel.nasa.gov/understanding-sea-level/overview

Funded by the Erasmus+ Programme of the European Union

Climate change and humans

UNDERSTANDING OF ECONOMIC IMPLICATIONS OF CLIMATE CHANGE





Potential environmental impact of climate change

- Highest negative impact
- Medium negative impact
- Low negative impact
- No/marginal impact
- No data
- Reduced data

Potential economic impact of climate change

- Highest negative impact
- Medium negative impact
- Low negative impact
- No/marginal impact
- Low positive impact
- Medium positive impact
- High positive impact
- No data
- Reduced data

Source Potential environmental and economic impact of climate change — European Environment Agency (europa.eu) Created 14 Nov 2012 Published 29 Nov 2012 Last modified 21 Dec 2016

Combined potential impacts of changes in summer and winter precipitation, heavy rainfall days, annual mean temperature, summer days, frost days, snow cover days and annual mean evaporation on soil erosion, soil organic carbon content, protected natural areas and forest fire sensitivity.

Combined potential impacts of changes in annual mean evaporation, summer days, snow cover days, frost days, changes in inundation heights of a 100 year river flood event and a sea level rise adjusted 100 year coastal storm surge event on agriculture, forestry, summer and winter tourism, energy supply and demand.

Despite a general agreement on the need to reduce GHG emissions, the debate among economists about climate change has been unusually bitter, perhaps as a reflection of the wider polarization of climate research and climate policy. In particular, estimates of the marginal impact of climate change vary so widely that the initial carbon price is more a matter of politics than economics.

The impacts of climate change are many and diverse. Determining whether these impacts are beneficial or detrimental, small or large, depends on the sector, location, and time being considered. Unfortunately, a reading of the literature on the impacts of climate change (Field and Canziani 2014) is likely to leave a lay reader confused. It is very difficult to make sense of the many and different effects: crops hit by worsening drought, crops growing faster because of carbon dioxide fertilization, heat stress increasing, cold stress decreasing, sea levels rising, increasing energy demand for cooling, decreasing energy demand for heating, infectious disease spreading, species going extinct. Thus, we need aggregate indicators to assess whether climate change is, on balance, a good thing or a bad thing and whether the climate problem is small or large relative to the many other problems that society faces. We focus in this and the next section on two aggregate indicators (Smith et al. 2001): the impact of climate change on total economic welfare and the distribution of those welfare impacts.

ESTIMATES OF THE TOTAL IMPACT OF CLIMATE CHANGE

Trying to understand what climate change may mean for the future of our economies is daunting. It is not simply the case of coming up with a point estimate of what climate change might cost world Gross Domestic Product (GDP). What we need is a more nuanced understanding of how climate change impacts sectoral and regional economic activity, how these impacts propagate through our economic system, and what the downside risks are to long term economic growth. These insights are invaluable in informing policy makers how to manage the significant and accumulating risk of serious climatic disruption

The simulations carried out for a study by OECD on THE ECONOMIC CONSEQUENCES OF CLIMATE CHANGE in 2015 suggests that in the absence of further action to tackle climate change, the combined negative effect on global annual GDP could be between 1.0% 3.3% by 2060. As temperatures could continue to rise to a projected 4°C above pre-industrial levels by 2100, GDP may be hurt by between 2% and 10% by the end of the century relative to the no-damage baseline scenario. Most importantly, the net economic consequences would be negative in 23 of the 25 regions modelled in the analysis and particularly severe in Africa and Asia, where the regional economies are vulnerable to a range of different climate impacts.

The analysis in the report is not a prediction of what will happen, nor a synthesis of all the social costs of climate change. There is still a lot we cannot quantify, particularly with regard to the economic consequences of triggering important tipping points in the climate system which could be catastrophic for our economies. However, just like the build-up of risks before the financial crisis, uncertainty should not be an excuse for inaction. The report also demonstrates how early and ambitious action on adaptation and mitigation can significantly reduce these downside risks.

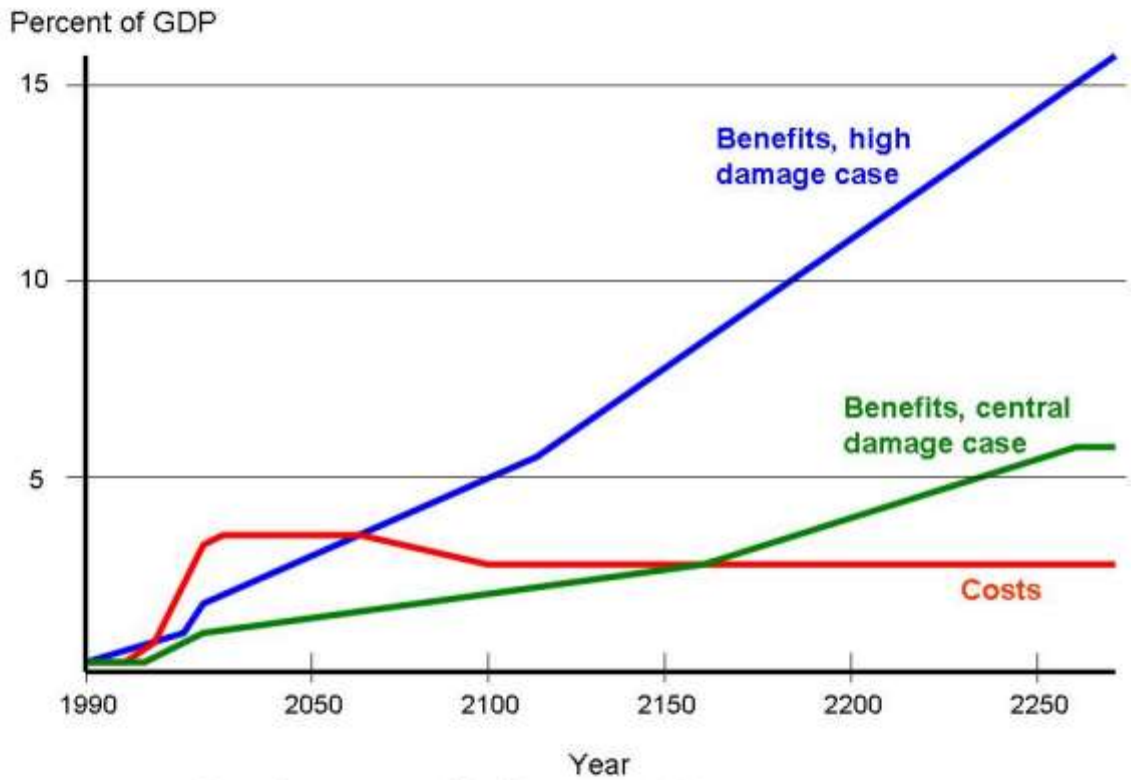
ANALYSING LONG TERM ENVIRONMENTAL EFFECTS

Economists evaluate future costs and benefits by the use of a discount rate. The problems and implicit value judgments associated with discounting add to the uncertainties that we have already noted in valuing costs and benefits. This suggests that we should consider some alternative approaches – including techniques that incorporate ecological as well as economic costs and benefits.

The present value (PV) of a long-term stream of benefits or costs depends on the discount rate. A high discount rate will lead to a low present valuation for benefits that are mainly in the longer-term, and a high present valuation for short-term costs. On the other hand, a low discount rate will lead to a higher present valuation for longer-term benefits. The estimated net present value of an aggressive abatement policy will thus be much higher if we choose a low discount rate.

An ecologically oriented economist would argue that the fundamental issue is the stability of the physical and ecological systems that regulate the global climate. This means that stabilization of the global climate should be the goal, rather than economic optimization of costs and benefits. Stabilizing greenhouse gas emissions is not sufficient, since at the current rate of emissions carbon dioxide and other greenhouse gases will continue to accumulate in the atmosphere. Stabilizing the accumulations of greenhouse gases will require a significant cut below present emission levels.

Figure 1 - Long-term Costs and Benefits of Abating Climate Change



Source: Cline, *The Economics of Global Warming*, 1992.

Any measure taken to prevent global climate change will have economic effects on GDP, consumption, and employment, which explains the reluctance of governments to take drastic measures to reduce significantly emissions of CO_2. But these effects may not necessarily be negative.

A comprehensive review of economic models of climate change policy shows that the economic outcomes predicted for carbon reduction policies are very much dependent on the modeling assumptions that are used. The predicted effects of stabilizing emissions at 1990 levels range from a 2 percent decrease to a 2 percent increase in GDP.

The outcomes depend on a range of assumptions including:

- The efficiency or inefficiency of economic responses to energy price signals.
- The availability of non-carbon “backstop” energy technologies.
- Whether or not nations can trade least-cost options for carbon reduction.
- Whether or not revenues from taxes on carbon-based fuels are used to lower other taxes.

- Whether or not external benefits of carbon reduction, including reduction in ground-level air pollution, are taken into account.

Thus, policies for emissions reduction could range from a minimalist approach of slightly reducing the rate of increase in emissions to a dramatic CO2 emissions reduction of 40 to 50%. Most economists who have analysed the problem agree that action is necessary, but there is a wide scope of opinion on how drastic this action should be, and how soon it should occur. The nations of the world have acknowledged the problem and are negotiating over plans to achieve emissions reductions. The scope of the reductions now being discussed, however, falls well short of what would be required for climate stabilization.

Whatever the outcome of these negotiations, any serious effort to reduce carbon emissions will require the kinds of economic policies to deal with negative externalities. We will now turn to an analysis of some possible policies.

Source

https://www.fte.org/teachers/teacher-resources/

https://blogs.ei.columbia.edu/2019/06/20/climate-change-economy-impacts/

https://www.brookings.edu/research/ten-facts-about-the-economics-of-climate-change-and-climate-policy/

https://www.epa.gov/environmental-economics/economics-climate-chang

FOOD SHORTAGE

Creator: UN Photo/Logan Abassi

Climate change will affect all four dimensions of food security: food availability, food accessibility, food utilization and food systems stability. It will have an impact on human health, livelihood assets, food production and distribution channels, as well as changing purchasing power and market flows. Its impacts will be both short term, resulting from more frequent and more intense extreme weather events, and long term, caused by changing temperatures and precipitation patterns. People who are already vulnerable and food insecure are likely to be the first affected.

Agriculture-based livelihood systems that are already vulnerable to food insecurity face immediate risk of increased crop failure, new patterns of pests and diseases, lack of appropriate seeds and planting material, and loss of livestock. People living on the coasts and floodplains and in mountains, drylands and the Arctic are most at risk.

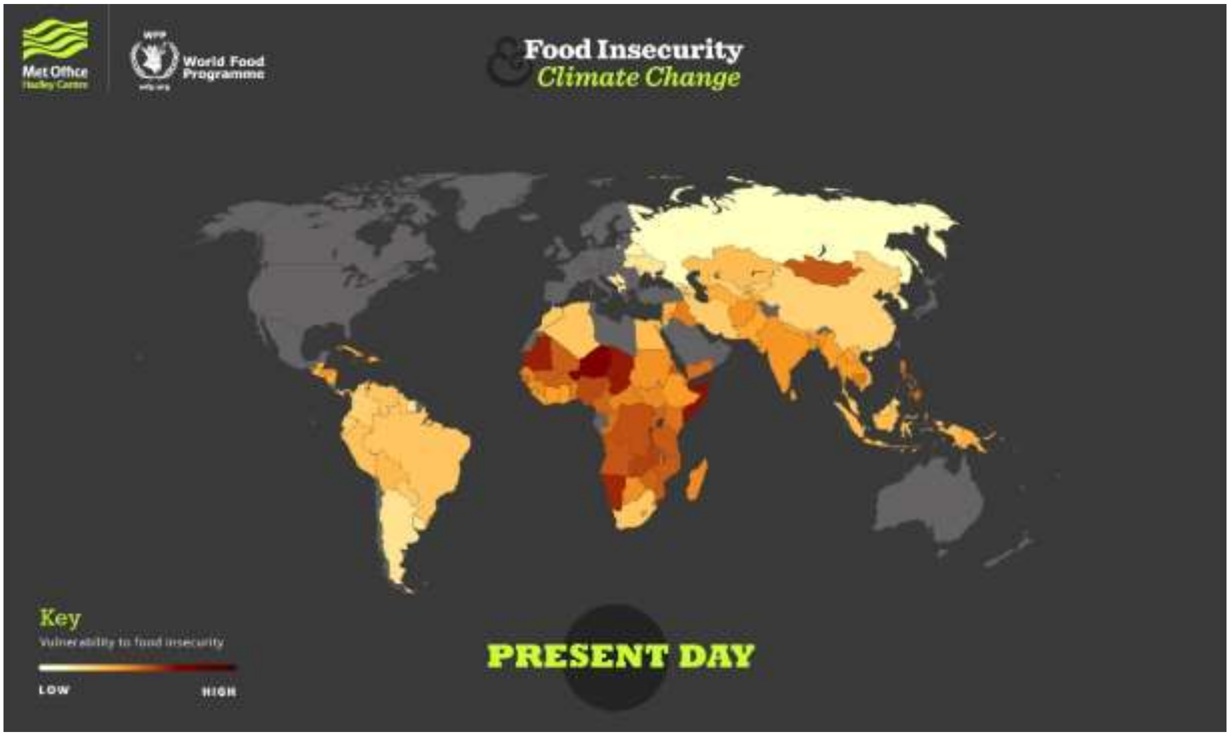
As an indirect effect, low-income people everywhere, but particularly in urban areas, will be at risk of food insecurity owing to loss of assets and lack of adequate insurance coverage.

This may also lead to shifting vulnerabilities in both developing and developed countries. Food systems will also be affected through possible internal and international migration, resource- based conflicts and civil unrest triggered by climate change and its impacts.

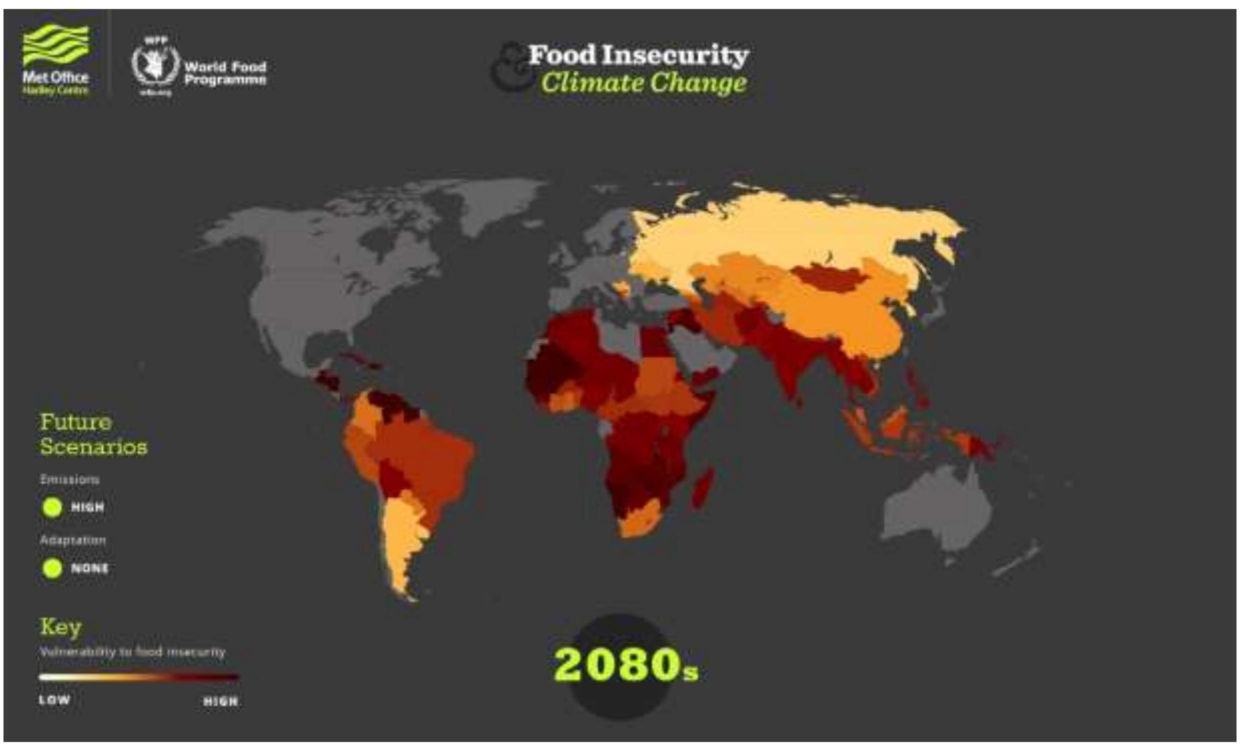
Agriculture, forestry and fisheries will not only be affected by climate change, but also contribute to it through emitting greenhouse gases. They also hold part of the remedy, however; they can contribute to climate change mitigation through reducing greenhouse gas emissions by changing agricultural practices.

At the same time, it is necessary to strengthen the resilience of rural people and to help them cope with this additional threat to food security. Particularly in the agriculture sector, climate change adaptation can go hand-in-hand with mitigation. Climate change adaptation and mitigation measures need to be integrated into the overall development approaches and agenda.

Vulnerability to food insecurity: present day



Vulnerability to food insecurity: 2080s projection



https://www.metoffice.gov.uk/food-insecurity-index/

A WIDER POINT OF VIEW

Mean global temperatures have been increasing since about 1850. The process of global warming shows no signs of abating and is expected to bring about long-term changes in weather conditions.

Effects are already being felt in global food markets and are likely to be particularly significant in specific rural locations where crops fail and yields decline.

Until about 200 years ago, climate was a critical determinant for food security. Since the advent of the industrial revolution, however, humanity's ability to face the forces of nature and manage its own environment has grown enormously. As long as the economic returns justify the costs, people can now create artificial microclimates, breed plants and animals with desired characteristics, enhance soil quality, and control the flow of water.

Advances in storage, preservation and transport technologies have made food processing and packaging a new area of economic activity. This has allowed food distributors and retailers to develop long-distance marketing chains that move produce and packaged foods throughout the world at high speed and relatively low cost. Where supermarkets with a large variety of standard-quality produce, available year-round, compete with small shops selling high-quality but only seasonally available local produce, the supermarkets generally win out. The consumer demand that has driven the commercialization and integration of the global food chain derives from the mass conversion of farmers into wage-earning workers and middle-level managers, which is another consequence of the industrial revolution. Today, food insecurity persists primarily in those parts of the world where industrial agriculture, long-distance marketing chains and diversified non-agricultural livelihood opportunities are not economically significant.

At the global level, therefore, food system performance today depends more on climate than it did 200 years ago; the possible impacts of climate change on food security have tended to be viewed with most concern in locations where rainfed agriculture is still the primary source of food and income.

However, this viewpoint is short-sighted. It does not take account of the other potentially significant impacts that climate change could have on the global food system, and particularly on market prices. These impacts include those on the water and energy used in food processing, cold storage, transport and intensive production, and those on food itself, reflecting higher market values for land and water and, possibly, payments to farmers for environmental services.

Rising sea levels and increasing incidence of extreme events pose new risks for the assets of people living in affected zones, threatening livelihoods and increasing vulnerability to future food insecurity in all parts of the globe. Such changes could result in a geographic redistribution of vulnerability and a relocalization of responsibility for food security – prospects that need to be considered in the formulation of adaptation strategies for people who are currently vulnerable or could become so within the foreseeable future.

The potential impacts of climate change on food security must therefore be viewed within the larger framework of changing earth system dynamics and observable changes in multiple socio-economic and environmental variables.

CLIMATE CHANGE AND FOOD SECURITY

Agriculture is important for food security in two ways: it produces the food people eat; and (perhaps even more important) it provides the primary source of livelihood for 36 percent of the world's total workforce. In the heavily populated countries of Asia and the Pacific, this share ranges from 40 to 50 percent, and in sub-Saharan Africa, two-thirds of the working population still make their living from agriculture (ILO, 2007).

Agriculture, forestry and fisheries are all sensitive to climate. Their production processes are therefore likely to be affected by climate change. In general, impacts are expected to be positive in temperate regions and negative in tropical ones, but there is still uncertainly about how projected changes will play out at the local level, and potential impacts may be altered by the adoption of risk management measures and adaptation strategies that strengthen preparedness and resilience.

The food security implications of changes in agricultural production patterns and performance are of two kinds:

- Impacts on the production of food will affect food supply at the global and local levels. Globally, higher yields in temperate regions could offset lower yields in tropical regions. However, in many low-income countries with limited financial capacity to trade and high dependence on their own production to cover food requirements, it may not be possible to offset declines in local supply without increasing reliance on food aid.

- Impacts on all forms of agricultural production will affect livelihoods and access to food. Producer groups that are less able to deal with climate change, such as the rural poor in developing countries, risk having their safety and welfare compromised.

Other food system processes, such as food processing, distribution, acquisition, preparation and consumption, are as important for food security as food and agricultural production are. Technological advances and the development of long-distance marketing chains that move produce and packaged foods throughout the world at high speed and relatively low cost have made overall food system performance far less dependent on climate than it was 200 years ago.

However, as the frequency and intensity of severe weather increase, there is a growing risk of storm damage to transport and distribution infrastructure, with consequent disruption of food supply chains. The rising cost of energy and the need to reduce fossil fuel usage along the food chain have led to a new calculus – "food miles", which should be kept as low as possible to reduce emissions. These factors could result in more local responsibility for food security, which needs to be considered in the formulation of adaptation strategies for people who are currently vulnerable or who could become so within the foreseeable future.

FOOD SECURITY AND CLIMATE CHANGE: A CONCEPTUAL FRAMEWORK

Climate change variables influence biophysical factors, such as plant and animal growth, water cycles, biodiversity and nutrient cycling, and the ways in which these are managed through agricultural practices and land use for food production. However, climate variables also have an impact on physical/human capital – such as roads, storage and marketing infrastructure, houses, productive assets, electricity grids, and human health – which indirectly changes the economic and socio-political factors that govern food access and utilization and can threaten the stability of food systems. All of these impacts manifest themselves in the ways in which food system activities are carried out. The framework illustrates how adaptive adjustments to food system activities will be needed all along the food chain to cope with the impacts of climate change. The climate change variables considered are:

- the CO2 fertilization effect of increased greenhouse gas concentrations in the atmosphere;
- increasing mean, maximum and minimum temperatures;
- gradual changes in precipitation: increase in the frequency, duration and intensity of dry spells and droughts;
- changes in the timing, duration, intensity and geographic location of rain and snowfall;
- increase in the frequency and intensity of storms and floods;
- greater seasonal weather variability and changes in start/end of growing seasons.

In addition, less immediate impacts are expected to result from gradual changes in mean temperatures and rainfall. These will affect the suitability of land for different types of crops and pasture; the health and productivity of forests; the distribution, productivity and community composition of marine resources; the incidence and vectors of different types of pests and diseases; the biodiversity and ecosystem functioning of natural habitats; and the availability of good-quality water for crop, livestock and inland fish production. Arable land is likely to be lost owing to increased aridity (and associated salinity), groundwater depletion and sea-level rise. Food systems will be affected by internal and international migration, resource-based conflicts and civil unrest triggered by climate change.

POTENTIAL IMPACTS OF CLIMATE CHANGE ON FOOD AVAILABILITY

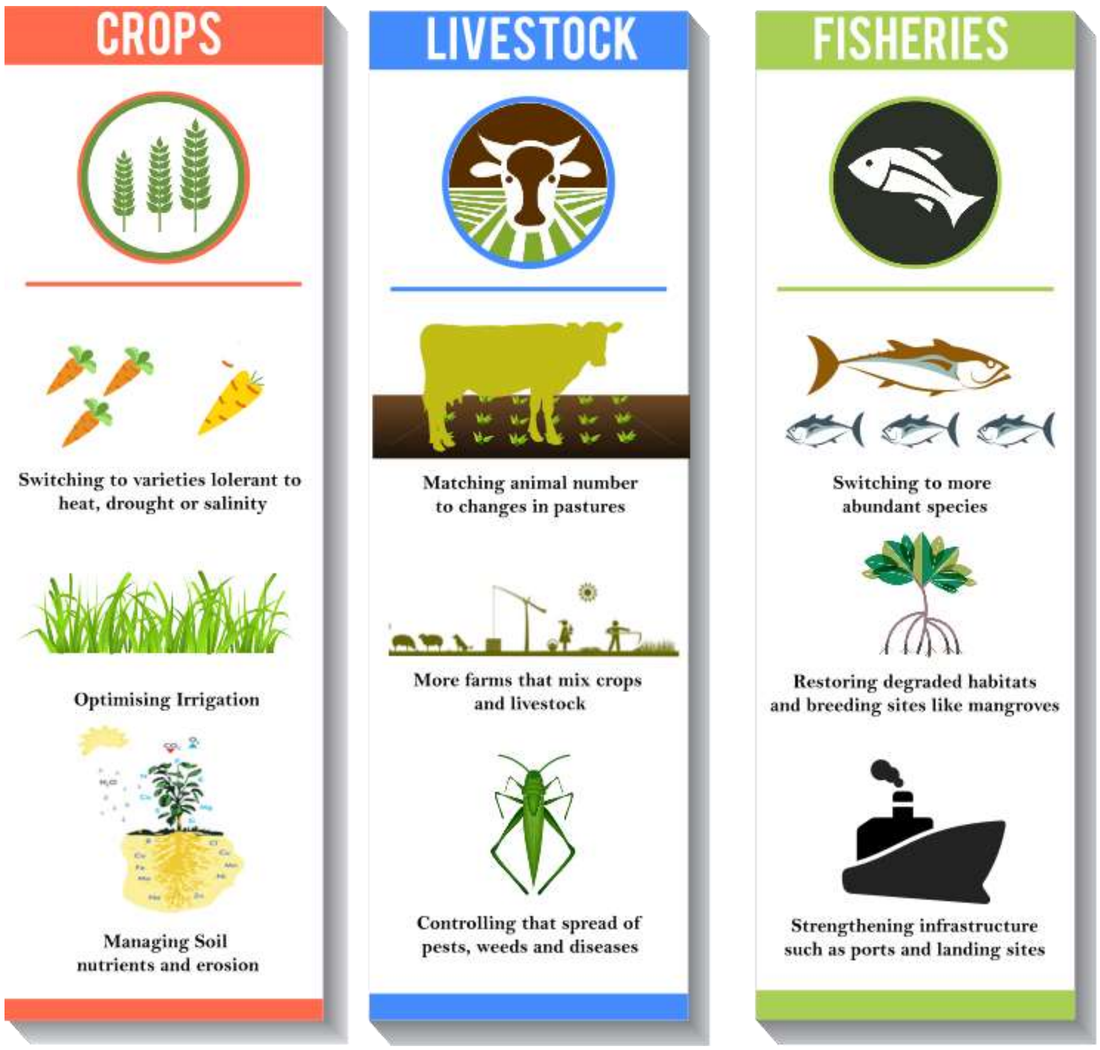
Production of food and other agricultural commodities may keep pace with aggregate demand, but there are likely to be significant changes in local cropping patterns and farming practices. There has been a lot of research on the impacts that climate change might have on agricultural production, particularly cultivated crops. Some 50 percent of total crop production comes from forest and mountain ecosystems, including all tree crops, while crops cultivated on open, arable flat land account for only 13 percent of annual global crop production. Production from both rainfed and irrigated agriculture in dryland ecosystems accounts for approximately 25 percent, and rice produced in coastal ecosystems for about 12 percent (Millennium Ecosystem Assessment, 2005).

Creator: Alfonso Cortes / Copyright: CIMMYT Int.

The evaluation of climate change impacts on agricultural production, food supply and agriculture-based livelihoods must take into account the characteristics of the agro-ecosystem where particular climate-induced changes in biochemical processes are occurring, in order to determine the extent to which such changes will be positive, negative or neutral in their effects.

The so-called “greenhouse fertilization effect” will produce local beneficial effects where higher levels of atmospheric CO2 stimulate plant growth. This is expected to occur primarily in temperate zones, with yields expected to increase by 10 to 25 percent for crops with a lower rate of photosynthetic efficiency (C3 crops), and by 0 to 10 percent for those with a higher rate of photosynthetic efficiency (C4 crops), assuming that CO2 levels in the atmosphere reach 550 parts per million (IPCC, 2007c); these effects are not likely to influence projections of world food supply, however (Tubiello et al., 2007). Mature forests are also not expected to be affected, although the growth of young tree stands will be enhanced (Norby et al., 2005).

The impacts of mean temperature increase will be experienced differently, depending on location (Leff, Ramankutty and Foley, 2004). For example, moderate warming (increases of 1 to 3 ºC in mean temperature) is expected to benefit crop and pasture yields in temperate regions, while in tropical and seasonally dry regions, it is likely to have negative impacts, particularly for cereal crops. Warming of more than 3 ºC is expected to have negative effects on production in all regions (IPCC, 2007c). The supply of meat and other livestock products will be influenced by crop production trends, as feed crops account for roughly 25 percent of the world's cropland.



Source Climate change and food security – The Institute for Policy, Advocacy, and Governance (ipag.org)

For climate variables such as rainfall, soil moisture, temperature and radiation, crops have thresholds beyond which growth and yield are compromised (Porter and Semenov, 2005). For example, cereals and fruit tree yields can be damaged by a few days of temperatures above or below a certain threshold (Wheeler et al., 2000). In the European heat wave of 2003, when temperatures were 6 ºC above long-term means, crop yields dropped significantly, such as by 36 percent for maize in Italy, and by 25 percent for fruit and 30 percent for forage in France (IPCC, 2007c). Increased intensity and frequency of storms, altered hydrological cycles, and precipitation variance also have long-term implications on the viability of current world agroecosystems and future food availability.

Wild foods are particularly important to households that struggle to produce food or secure an income. A change in the geographic distribution of wild foods resulting from changing rainfall and temperatures could therefore have an impact on the availability of food. Changes in climatic conditions have led to significant declines in the provision of wild foods by a variety of ecosystems, and further impacts can be expected as the world climate continues to change. For the 5 000 plant species examined in a sub-Saharan African study (Levin and Pershing, 2005), it is predicted that 81 to 97 percent of the suitable habitats will decrease in size or shift owing to climate change. By 2085, between 25 and 42 percent of the species' habitats are expected to be lost altogether. The implications of these changes are expected to be particularly great among communities that use the plants as food or medicine. Constraints on water availability are a growing concern, which climate change will exacerbate. Conflicts over water resources will have implications for both food production and people's access to food in conflict zones (Gleick, 1993). Prolonged and repeated droughts can cause loss of productive assets, which undermines the sustainability of livelihood systems based on rainfed agriculture.

For example, drought and deforestation can increase fire danger, with consequent loss of the vegetative cover needed for grazing and fuelwood (Laurence and Williamson, 2001Food production varies spatially, so food needs to be distributed between regions. The major agricultural production regions are characterized by relatively stable climatic conditions, but many food-insecure regions have highly variable climates. The main grain production regions have a largely continental climate, with dry or at least cold weather conditions during harvest time, which allows the bulk handling of harvested grain without special infrastructure for protection or immediate treatment.

Sources

http://www.fao.org/3/k2595e/k2595e00.pdf

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Climate Change and Human Health

Human health has always been influenced by climate and weather. Climate change, together with other natural and human-made health stressors, threatens human health and well-being in numerous ways.

Given that the impacts of climate change are projected to increase over the next century, certain existing health threats will intensify and new health threats may emerge. Connecting our understanding of how climate is changing with an understanding of how those changes may affect human health can inform decisions about mitigating (reducing) the amount of future climate change, suggest priorities for protecting public health, and help identify research needs.

Key Facts

- Climate change affects the social and environmental determinants of health – clean air, safe drinking water, sufficient food and secure shelter.
- Between 2030 and 2050, climate change is expected to cause approximately 250 000 additional deaths per year, from malnutrition, malaria, diarrhoea and heat stress.

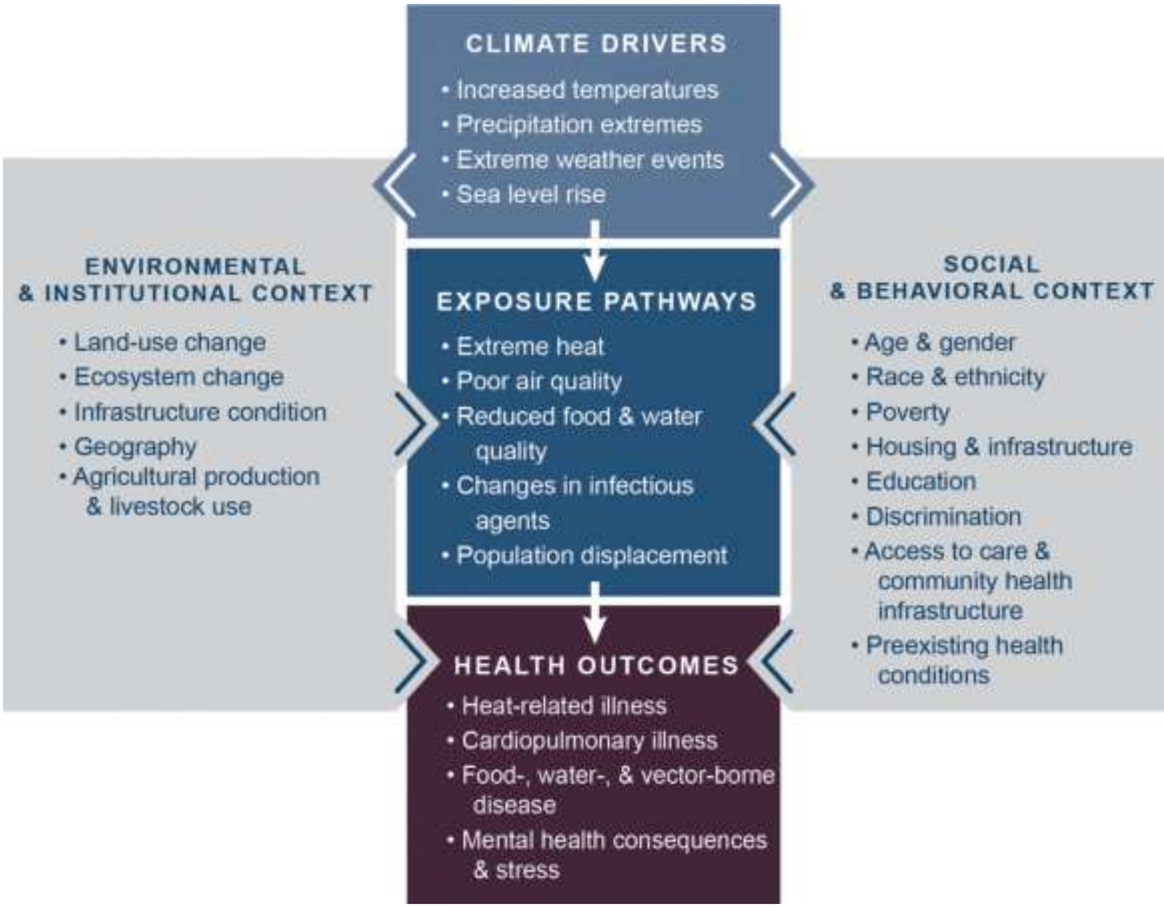
- The direct damage costs to health (i.e. excluding costs in health-determining sectors such as agriculture and water and sanitation), is estimated to be between USD 2-4 billion/year by 2030.
- Areas with weak health infrastructure – mostly in developing countries – will be the least able to cope without assistance to prepare and respond.
- Environmental policies can result in improved health, particularly through reduced air pollution.

Understanding the Connections Between Climate Change and Human Health

Climate change poses many threats to the health and well-being, from increasing the risk of extreme heat events and heavy storms to increasing the risk of asthma attacks and changing the spread of certain diseases carried by ticks and mosquitoes. Some of these health impacts are already happening in the United States.

What is the impact of climate change on health?

Climate change can exacerbate existing health threats or create new public health challenges through a variety of pathways. Figure 1 summarizes these connections by linking climate impacts to changes in exposure, which can then lead to negative effects on health (health outcomes). This figure also shows how other factors—such as where people live and their age, health, income, or ability to access health care resources—can positively or negatively influence people's vulnerability to human health effects. For example, a family's income, the quality of their housing, or their community's emergency management plan can all affect that family's exposure to extreme heat, the degree to which their health is affected by this threat, and their ability to adapt to impacts of extreme heat (for more examples, see Figure 4).



(Figure 1) Conceptual diagram illustrating the exposure pathways by which climate change affects human health. Exposure pathways exist within the context of other factors that positively or negatively influence health outcomes (gray side boxes). Key factors that influence vulnerability for individuals are shown in the right box and include social determinants of health and behavioural choices. Key factors that influence vulnerability at larger scales, such as natural and built environments, governance and management, and institutions, are shown in the left box. All of these influencing factors can affect an individual's or a community's vulnerability through changes in exposure, sensitivity, and adaptive capacity and may also be affected by climate change.

Extreme heat

Extreme high air temperatures contribute directly to deaths from cardiovascular and respiratory disease, particularly among elderly people. In the heat wave of summer 2003 in Europe for example, more than 70 000 excess deaths were recorded[1].

Natural disasters and variable rainfall patterns

Globally, the number of reported weather-related natural disasters has more than tripled since the 1960s. Every year, these disasters result in over 60 000 deaths, mainly in developing countries.

Rising sea levels and increasingly extreme weather events will destroy homes, medical facilities and other essential services. More than half of the world's population lives within 60 km of the sea. People may be forced to move, which in turn heightens the risk of a range of health effects, from mental disorders to communicable diseases.

Increasingly variable rainfall patterns are likely to affect the supply of fresh water. A lack of safe water can compromise hygiene and increase the risk of diarrhoeal disease, which kills over 500 000 children aged under 5 years, every year. In extreme cases, water scarcity leads to drought and famine. By the late 21st century, climate change is likely to increase the frequency and intensity of drought at regional and global scale.

Floods and extreme precipitations are also increasing in frequency and intensity. Floods contaminate freshwater supplies, heighten the risk of water-borne diseases, and create breeding grounds for disease-carrying insects such as mosquitoes. They also cause drownings and physical injuries, damage homes and disrupt the supply of medical and health services.

Rising temperatures and variable precipitation are likely to decrease the production of staple foods in many of the poorest regions. This will increase the prevalence of malnutrition and undernutrition, which currently cause 3.1 million deaths every year.

Patterns of infection

Climatic conditions strongly affect water-borne diseases and diseases transmitted through insects, snails or other cold-blooded animals.

Changes in climate are likely to lengthen the transmission seasons of important vector-borne diseases and to alter their geographic range. For example, climate change is projected to widen significantly the area of China where the snail-borne disease schistosomiasis occurs[2].

Malaria is strongly influenced by climate. Transmitted by Anopheles mosquitoes, malaria kills over

[1] https://pubmed.ncbi.nlm.nih.gov/18241810/
[2] https://pubmed.ncbi.nlm.nih.gov/18256410/

400 000 people every year – mainly children under 5 years old in certain African countries. The Aedes mosquito vector of dengue is also highly sensitive to climate conditions, and studies suggest that climate change is likely to continue to increase exposure to dengue.

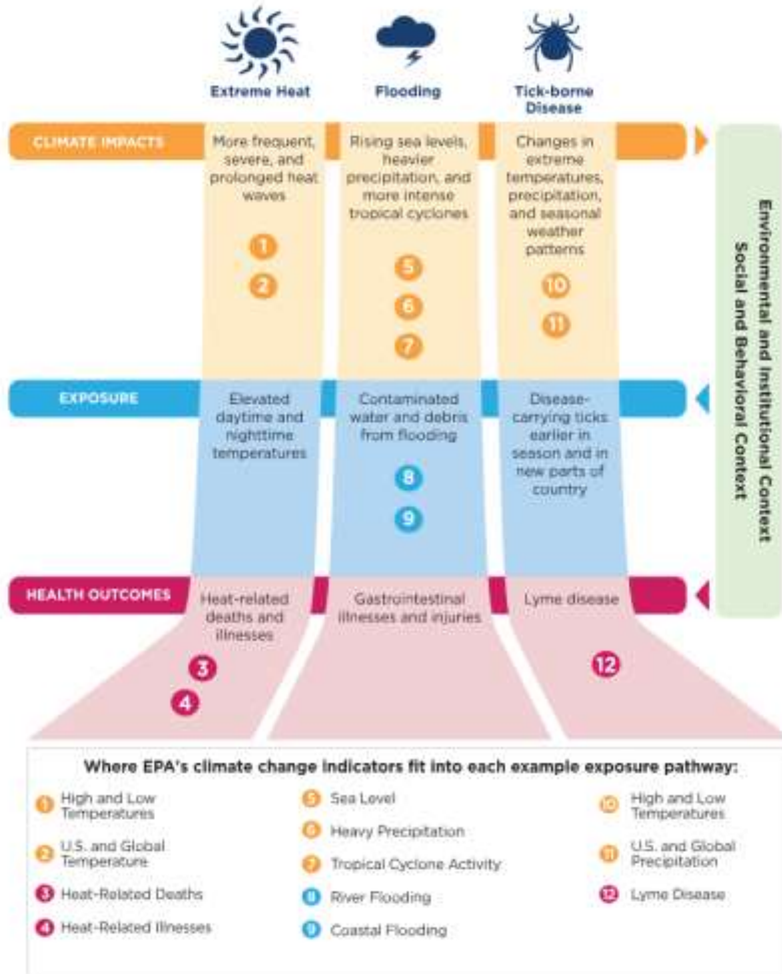
MEASURING THE HEALTH EFFECTS

Measuring the health effects from climate change can only be very approximate. Nevertheless, a WHO assessment, taking into account only a subset of the possible health impacts, and assuming continued economic growth and health progress, concluded that climate change is expected to cause approximately 250 000 additional deaths per year between 2030 and 2050; 38 000 dues to heat exposure in elderly people, 48 000 dues to diarrhoea, 60 000 dues to malaria, and 95 000 dues to childhood undernutrition.

What can Indicators Tell Us About Climate Change and Human Health?

As shown in Figure 1, the impacts of climate change on health are complex, often indirect, and dependent on multiple societal and environmental factors. Tracking changes in climate impacts and exposures improves understanding of changes in health risk, however, even if the actual health outcome is difficult to quantify. For example, the flooding pathway in Figure 2 shows how indicators of certain climate impacts like Sea Level, Heavy Precipitation, and Coastal Flooding could be used by state and local health officials to better understand changes in human exposure to contaminated waters (a health risk). By recognizing changing risks, these officials can better understand how climate change affects the number of people who get sick with gastrointestinal illnesses (a health outcome). Thus, even where health data or long-term records are unavailable or where the links between climate and health outcomes are complex, indicators play an important role in understanding climate-related health impacts.

(Figure 2) The three examples above show how climate impacts can affect health. The numbered circles identify where climate change indicators provide key information on changes occurring at different points along the pathways. Other factors can play a role in determining a person's vulnerability to climate-related health outcomes; see Figure 1 and Figure 4.



"The effects of climate change also affect people's mental health. In particular, climate- or weather-related disasters can increase the risk of adverse mental health consequences, especially if they result in damage to homes and livelihoods or loss of loved ones. The mental health impacts of these events can range from minimal stress and distress symptoms to clinical disorders, such as anxiety, depression, and post-traumatic stress"

WHO IS AT RISK?

All populations will be affected by climate change, but some are more vulnerable than others. People living in small island developing states and other coastal regions, megacities, and mountainous and

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polar regions are particularly vulnerable.

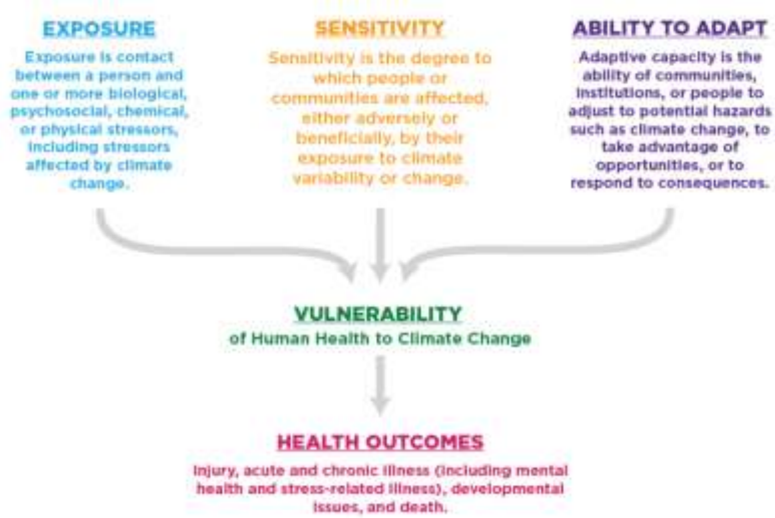
Children – in particular, children living in poor countries – are among the most vulnerable to the resulting health risks and will be exposed longer to the health consequences. The health effects are also expected to be more severe for elderly people and people with infirmities or pre-existing medical conditions.

Areas with weak health infrastructure – mostly in developing countries – will be the least able to cope without assistance to prepare and respond.

Figure 4 shows some examples of how certain populations are more vulnerable to health impacts because of differences in their exposure, sensitivity, or ability to adapt to climate-related stresses.

It is important to remember that the different health impacts identified here do not occur in isolation; people can face multiple threats at the same time, at different stages in their lives, or accumulating over the course of their lives. Risks may increase as people are exposed to multiple health threats. For example, extremely hot days can lead to heat-related illness as well as poor air quality, by increasing the chemical reactions that produce smog. In addition, many of the factors that influence whether a person is exposed to health threats or whether they become ill, such as an individual's personal habits, living conditions, and access to medical care (see Figure 1), can also change over time.

Figure 4



EXPOSURE

Low-income populations may be exposed to climate change threats because of socioeconomic factors. For example, people who cannot afford air conditioning are more likely to suffer from unsafe indoor air temperatures.

Occupational groups such as first responders and construction workers face more frequent or longer exposure to climate change threats. For example, extreme heat and disease-carrying insects and ticks particularly affect outdoor workers.

People in certain locations may be exposed to climate change threats, such as droughts, floods, or severe storms, that are specific to where they live. For example, people living by the coast are at increased risk from hurricanes, sea level rise, and storm surge.

SENSITIVITY

Pregnant women are sensitive to health risks from extreme weather such as hurricanes and floods. These events can affect their mental health and the health of their unborn babies by contributing to low birthweight or preterm birth.

People with pre-existing medical conditions, such as asthma, are particularly sensitive to climate change impacts on air quality. People who have diabetes or who take medications that make it difficult to regulate body temperature are sensitive to extreme heat.

Children are more sensitive to respiratory hazards than adults because of their lower body weight, higher levels of physical activity, and still-developing lungs. Longer pollen seasons may lead to more asthma episodes.

ABILITY TO ADAPT

Older adults may have limited ability to cope with extreme weather if, for example, they have difficulty accessing cooling centers or other support services during a heat wave. Heat-related deaths are most commonly reported among adults aged 65 and over.

People with disabilities face challenges preparing for and responding to extreme weather events. For example, emergency or evacuation instructions are often not accessible to people with learning, hearing, or visual disabilities.

Indigenous people who rely on subsistence food have limited options to adapt to climate change threats to traditional food sources. Rising temperatures and changes in the growing season affect the safety, availability, and nutritional value of some traditional foods and medicinal plants.

WHO'S RESPONSE

Many policies and individual choices have the potential to reduce greenhouse gas emissions and produce major health co-benefits. For example, cleaner energy systems, and promoting the safe use of public transportation and active movement – such as cycling or walking as alternatives to using private vehicles – could reduce carbon emissions, and cut the burden of household air pollution, which causes some 4.3 million deaths per year, and ambient air pollution, which causes about 3 million deaths every year.

In 2015, the WHO Executive Board endorsed a new work plan on climate change and health. This includes:

- **Partnerships:** to coordinate with partner agencies within the UN system, and ensure that health is properly represented in the climate change agenda.
- **Awareness raising:** to provide and disseminate information on the threats that climate change presents to human health, and opportunities to promote health while cutting carbon emissions.
- **Science and evidence:** to coordinate reviews of the scientific evidence on the links between climate change and health, and develop a global research agenda.
- **Support for implementation of the public health response to climate change:** to assist countries in building capacity to reduce health vulnerability to climate change, and promote health while reducing carbon emissions.

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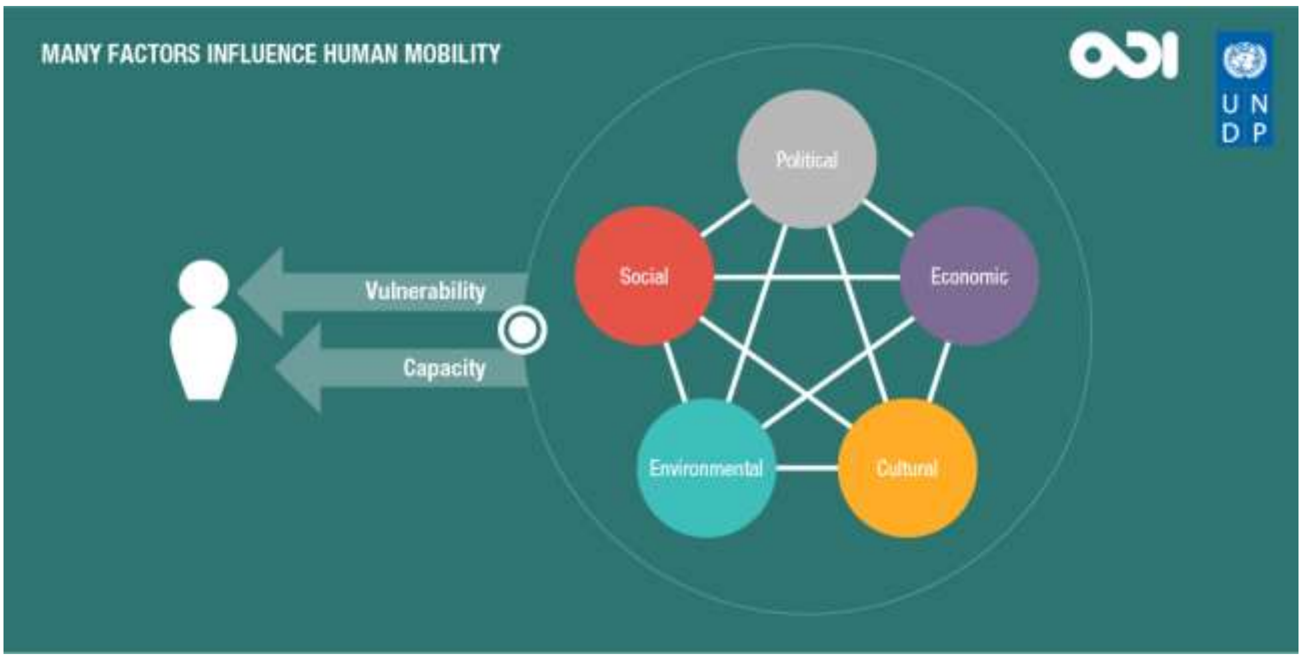
MIGRATION AND CLIMATE CHANGE

In 1990, the Intergovernmental Panel on Climate Change (IPCC) noted that the greatest single impact of climate change could be on human migration—with millions of people displaced by shoreline erosion, coastal flooding and agricultural disruption.

Since then various analysts have tried to put numbers on future flows of climate migrants (sometimes called "climate refugees")—the most widely repeated prediction being 200 million by 2050.



Impact of climate change

The meteorological impact of climate change can be divided into two distinct drivers of migration; climate processes such as sea-level rise, salinization of agricultural land, desertification and growing water scarcity, and climate events such as flooding, storms and glacial lake outburst floods. But non-climate drivers, such as government policy, population growth and community-level resilience to natural disaster, are also important. All contribute to the degree of vulnerability people experience.

The problem is one of time (the speed of change) and scale (the number of people it will affect). But the simplistic image of a coastal farmer being forced to pack up and move to a rich country is not typical. On the contrary, as is already the case with political refugees, it is likely that the burden of providing for climate migrants will be borne by the poorest countries—those least responsible for emissions of greenhouse gases.

https://refugeepathways.medium.com/

WHO IS IMPACTED MOST BY CLIMATE MIGRATION?

Climate migration has disproportionately impacted people living in poverty, disabled populations, the elderly and women. More often than not, the most extreme weather events and environmental degradation often happen in the Global South, where countries impacted are less able to cope due to structural constraints. Meaning, countries which are already located in a precarious environment are more likely to experience climate disasters and in turn, are more seriously impacted when an emergency occurs. The same situation is multiplied for vulnerable populations within the climate impacted countries. Those living with disabilities may already be more vulnerable to environmental degradation due to compromised health conditions.

Elderly populations are more vulnerable when disaster hits as their mobility may be limited and are often less likely to flee. Women also experience climate change differently than men and are more likely to be vulnerable in terms of protection and livelihoods when forced to migrate. This is due to factors including lack of access to emergency plans, opportunities for relocation within their means, and mobility. This leads to people being chronically hungry, un-housed and un-employed as a result of environmental destruction.

CLIMATE CHANGE AND FORCED MIGRATION

Put simply, climate change will cause population movements by making certain parts of the world much less viable places to live; by causing food and water supplies to become more unreliable and increasing the frequency and severity of floods and storms. While people are forced to migrate due to changing weather patterns now, experts predict that the situation will only worsen over the next few decades. The United Nations forecasts “that there could be anywhere between 25 million and 1 billion environmental migrants by 2050.” With numbers this striking, it is past time that climate change is centred in discussions of migration.

For an example of climate change affecting migration, look no further than Syria. A devastating drought, the worst in 900 years, affected the livelihoods of over 1.5 million farmers in rural Syria almost fifteen years ago. The drought led farmers to migrate from rural to urban areas of the country. It also led to a decimated water supply and disrupted food chains that became widespread in the country. While climate change is not the only factor that impacted migration in Syria, it certainly exacerbated already existing failures in social systems within the country and the extra stressor of the drought acted as a threat multiplier when it comes to political stability. Syria is not isolated in the climate migration phenomenon — people are forced to flee their homes due to changing weather conditions globally. For years, there has been incessant flooding in India, Nepal and Bangladesh, the degradation of local ecosystems in Central America, and detrimental drought in the Lake Chad Basin in west-central Africa. In 2018, 28 million new internal displacements accounted for in the World Migration Report. A staggering “sixty one percent (17.2 million) of these new displacements were triggered by disasters, and 39% (10.8 million) were caused by conflict and violence.”

According to Nicholls and Lowe (2004), using a mid-range climate sensitivity projection, the **number of people flooded** per year is expected to increase by between 10 and 25 million per year by the 2050s and between 40 and 140 million per year by 2100s, depending on the future emissions scenario.

CLIMATE DRIVERS

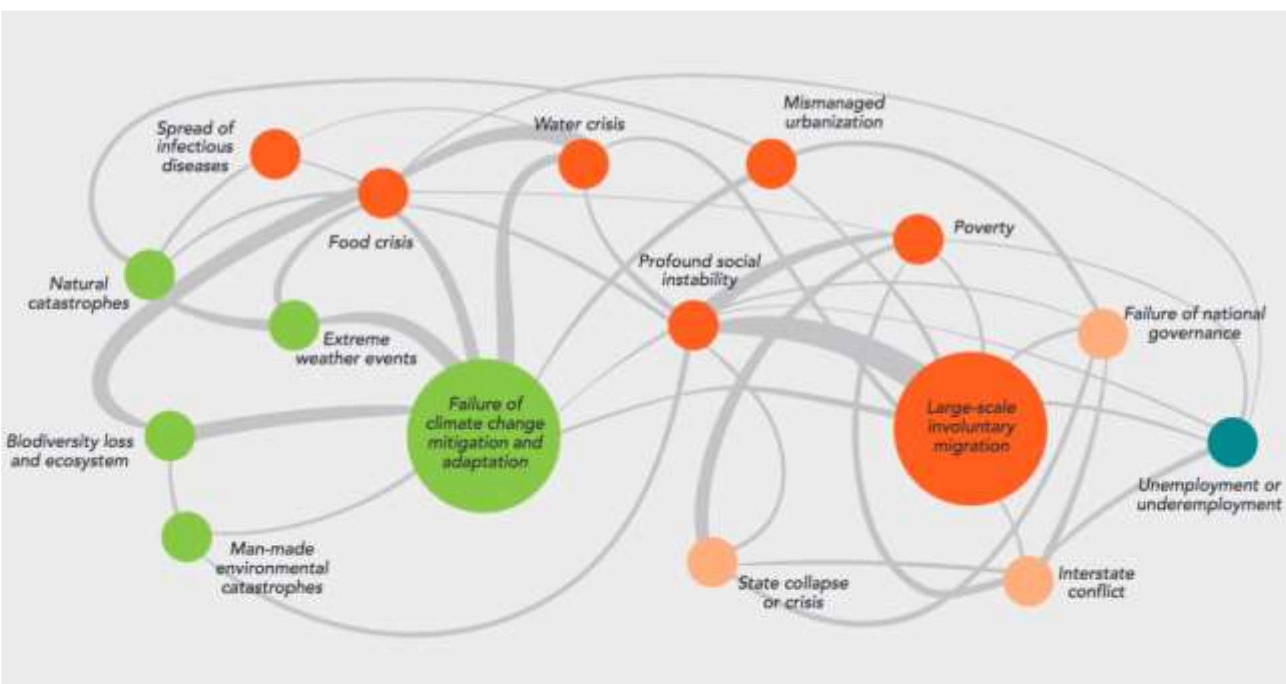
Robert McLeman of the University of Ottawa, unpacks the drivers of forced migration into two distinct groups. First, there are the climate drivers. These themselves are of two types – climate processes and climate events.

Climate processes

Climate processes are slow onset changes such as sea-level rise, salinization of agricultural land, desertification, growing water scarcity and food insecurity. Sea level rise patently makes certain coastal areas and small island states uninhabitable. Cumulatively they erode livelihoods and change the incentives to "stick it out" in a particular location. On a national level sea level rise could have serious implications for food security and economic growth. This is a particular concern in countries that have a large part of their industrial capacity under the "one metre" zone. Bangladesh's Gangetic plain and the Nile Delta in Egypt, which are breadbaskets for both countries, are two such examples. Egypt's Nile Delta is one of the most densely populated areas of the world and is extremely vulnerable to sea level rise. A rise of just 1 metre would displace at least 6 million people and flood 4,500 km2 of farmland.

Climate events

Climate events, on the other hand, are sudden and dramatic hazards such as monsoon floods, glacial lake outburst floods, storms, hurricanes and typhoons. These force people off their land much more quickly and dramatically. Hurricanes Katrina and Rita, for example, which lashed the Gulf Coast of the United States in August and September 2005 left an estimated 2 million people homeless. The



2000 World Disasters Report estimated that 256 million people were affected by disasters (both weather-related and geo-physical) in the year 2000, up from an average of 211 million per year during the 1990s – an increase the Red Cross attributes to increased "hydro-meteorological" events.

NON-CLIMATE DRIVERS

Equally important though are the non-climate drivers. It is clear that many natural disasters are, at least in part, "man-made". A natural hazard (such as an approaching storm) only becomes a "natural disaster" if a community is particularly vulnerable to its impacts. A tropical typhoon, for example, becomes a disaster if there is no early warning system, the houses are poorly built and people are unaware of what to do in the event of a storm. A community's vulnerability, then, is a function of its exposure to climatic conditions (such as a coastal location) and the community's adaptive capacity (the capacity of a particular community to weather the worst of the storm and recover after it).

Different regions, countries and communities have very different adaptive capacities: pastoralist groups in the Sahel, for example, are socially, culturally and technically equipped to deal with a different range of natural hazards than, say, mountain dwellers in the Himalayas. National and individual wealth is one clear determinant of vulnerability – enabling better disaster risk reduction, disaster education and speedier responses. In the decade from 1994 to 2003 natural disasters in countries of high human development killed an average of 44 people per event, while disasters in countries of low human development killed an average of 300 people each.

On a national scale, Bangladesh has very different adaptive capacities and disaster resilience to the United States. In April 1991 Tropical Cyclone Gorky hit the Chittagong district of south-eastern Bangladesh. Winds of up to 260 kilometres per hour and a six-metre high storm surge battered much of the country killing at least 138,000 people and leaving as many as 10 million people homeless. The following year in August 1992, a stronger storm, the category five Hurricane Andrew, hit Florida and Louisiana with winds of 280 kilometres per hour and a 5.2-metre storm surge. But, while it left US$ 43 billion in damages in its wake, it caused only 65 deaths.

Climate change will challenge the adaptive capacities of many different communities, and overwhelm some, by interacting with and exacerbating existing problems of food security, water scarcity and the scant protection afforded by marginal lands. At some point that land becomes no longer capable of sustaining livelihoods and people will be forced to migrate to areas that present better opportunities. The "tipping points" will vary from place to place and from individual to individual. Natural disasters might displace large numbers of people for relatively short periods of time, but the slow-onset drivers are likely to displace permanently many more people in a less-headline grabbing way.

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Climate change and living organisms

PLANTLIFE AND CLIMATE CHANGE

Assessment of WHO stated that 60% of the world population depends on traditional medicines which are basically obtained from plants. Anthropogenic activities play important role and contributing towards climate change around the world (Mishra, 2016). Due to sessile nature, plants cannot move from adverse conditions like all of us. That's why plants have to go for other alternative mechanism. Metabolic changes more specifically we can say variation in secondary metabolites content is considered to be one of the plant's defence mechanism toward unfavourable conditions (Ober, 2005; Pichersky and Gang, 2000). Secondary metabolites are compounds are not essential for plant normal activities, but these compounds such as alkaloids, terpenes and cyangenic glycosides collectively makes plant immune system (Hartmann, 2007; Wink, 2003). Climate change can change the quality of natural product and its affect the taste and medicinal value of some Arctic plants (Gore, 2006). Although it was reported that such changes could either be positive or negative. Production of secondary metabolites is increased in stressed conditions; however, production of secondary metabolites is influenced by many factors such as competition between the plants, light, soil and humidity etc. (Dean, 2007; Das, 2016).

Medicinal and aromatic plants are less immune to the climate change as compare to the other living organisms. Climate changes are causing significant impact on lifecycles and distributions of plants, therefore many medicinal plants become endemic to particular geographic regions. Research student at University of Washington, Seattle, studied on coping mechanism of plants with their changing environment. In their research, they collected data of seven topographically distinguished regions across western North America, from the western Sierra Nevada mountain range in Nevada to the eastern Rocky Mountain Foothills of northern Canada, approximately 300 plant species were used in this work. After collection of data they compared their findings with changes in climate conditions, for example rain, temperature, and snowfall. The results obtained after the analysis were very much surprising, above 60% of plants changes their distributions and shifted towards warmer region, all plants within a region regardless of species moved in the same direction.

According to recent study published in Journal Nature Climate Change, climate change could lead to the globally widespread loss of plants occurred around the world. This study collected data of 50,000 common species plants as well as animals. They concluded that more than half of the plants would be get affected until 2080 due to continuous rise in greenhouse gas emissions. Main author of this study Rachel Warren, of the Tyndall Centre at University of East Anglia, United Kingdom said "average plant will experience significant range loss under climate change." A visiting fellow at the Tyndall Centre, Jeff Price (a coauthor of the study) stated that some common plants such as "chocolate, coffee, sugar maple, teak, pineapple and cotton all show large contractions in their climatic ranges under the baseline climate change scenario". The climactic range is defined as a habitat where species exist and faces lots of challenges to survive with competitors. The research concluded that reduction in emission of greenhouse gases is urgently needed and this could be minimized widespread losses that cause climate change. Climate scientists estimated that emission of carbon dioxide should prevent from crossing the 400 parts per million thresholds (Banerjee, 2013)

Climatic Factors

Plants are dependent on certain factor such as temperature, light, carbon dioxide (CO2), rainfall and moisture to produce the crop products which are essential for human nutrition as well as health. The amount of these factors varies between locations. Crop management is therefore a huge challenge because it is always highly dependent on climate and environmental factors. A successful rate of crop production affected the net exporters, net importers and consumers, as well as for national and global food security. Plant growth and its development are strongly dependent upon the temperature, each species has an optimum or specific temperature range to survive and flourish in particular environment (Hatfield, 2015). Crop production also provides the food, fodder and fiber for cloths. Continuous increases in population create plenty of burdens on earth and this is the one of the major factors affecting climate. Climate change has pronounced effect on biogeography, temperature, rainfall, soil and herbivory.

List of some climatic Factors

Climatic Factors	Effect of climate change	References
Rainfall	Due to climate change increase in rainfall and snowfall is reported all over the world.	Tollefson, (2016)
Drought	Extreme Droughts is related to climate change. Due to more release of greenhouse gases into the air, air temperature is increased. Rise in temperatures enhances the rate of evaporation. Dry soil is less capable to absorb water from soil.	https://www.climaterealityproject.org/blog/facts-about-climate-change-and-drought
Air Pollution	The CO2 emissions is the main source of atmospheric pollution, beside this some other air pollutant, also responsible for climate change. These pollutants are known as short-lived climate-forcing pollutants (SLCPs) such as black carbon, methane, sulfate aerosols and ground-level ozone. Black carbon and methane are significant contributors after CO2	https://www.iass-potsdam.de/en/output/dossiers/air-pollution-and-climate-change

List of plant species affected through drought

Name of plant	Description
Triticum aestivum L.	Total growth duration was reduced and decrease in substantial yield was occurred
Hordeum vulgare L	
Chenopodium quinoa Wild	Delay in pre-anthesis and delayed flowering in quinoa.
Triticum aestivum L.	Delay in pre-anthesis
Oryza sativa L.	Delay in flowering
Glycine max L.	Drought at the time of grain filling accelerate

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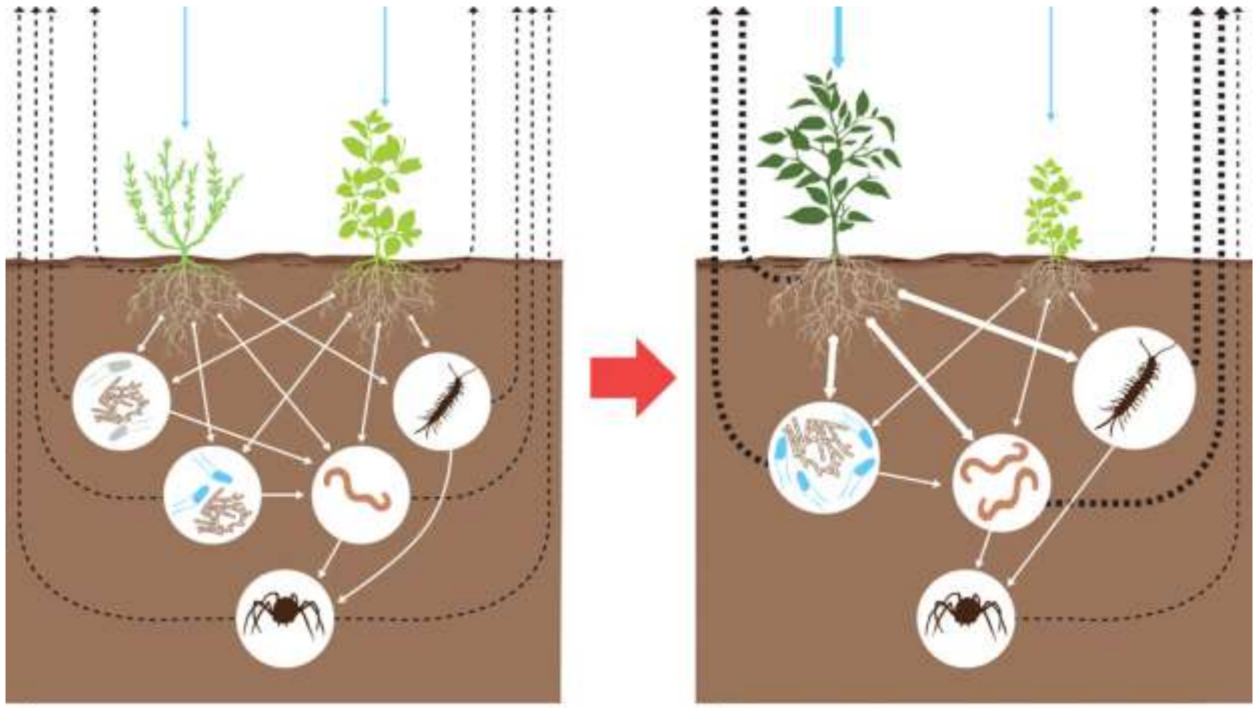
	the maturity and its down the yield.
Pennisetum glaucum L	Rate of ear abortion is increased.



Effect of Climate Change to Field Crops

Increase in root to shoot ratios was observed under elevated CO2condition; in this condition plant synthesize larger number of chloroplasts, mesophyll cell, longer stems and extended diameter, length and number of large roots, more lateral root production with changes in branching patterns (Qaderi and Reid, 2009). Some annual C3 field crops such as soybean, peanut, and rice cultivars etc. showed positive responses in high concentration of [CO2] growth and development of rice cultivar is increased and higher grain yield with improve quality was also obtained (Uprety, et. al., 2010). On contrary in maize, a C4 plant reduction in yield observed under elevated [CO2] condition (Alexadrov and Hoogenboom, 2000). Whereas a cotton crop showed increase in harvested yield (48%) and biomass yield (37%) in under elevated (550 ppm) [CO2] level. The different plant species responses towards elevated CO2 level might be due to variation in soil, water, temperature and nutrient availability (Amedie, 2013).

Effect of Climate Change to Forest Trees

Interaction of forest ecosystems with climate is a complex issue due to variation in different processes. An elevated ambient CO_2 concentration could reduce the stomata opening that subsequently reduce the rate of transpiration of the trees. These could increase the efficiency of water use by forest plants and increase productivity to some extent (Bolin, et. al., 1989). Trees have capacity to acclimatize according to warmer climate; however different species responded differently (Saxe, et. al., 2001). Usually forest trees are governed by the C3 photosynthetic pathway, so their productivity and need for nutrient is extremely affected through atmospheric CO_2 and temperature. Trees growing under high CO_2 level showed large productivity (if combination of absorption and increased nutrient use efficiency is achieved) as compare to crops (Lukac, et. al., 2010). In temperate bog and forest ecosystems, enhancement in temperature caused photo-inhibition stress and drought (Niinemets, 2010).

Threat on Health Sectors due to effect on plants

Global climate change is responsible for infectious and parasitic diseases and it is affecting badly or majorly our healthcare. Climate change specially temperature shifted the life cycle of pathogens and vectors, concentration of pathogens is also increasing in water because of changes in precipitation in urban settings (Confalonieri, 2015). These changes affected the natural flora of our ecosystem, and depletion in plant population creates a major threat to our health sector. The use of medicinal plants in health care practices is very high. Traditional Chinese medicine (TCM) is usually based on plant. India also has strong dependence on plant in modern medicines along with traditional system of Indian pharmacy. According to Hamilton, India has approximately 44% of medicinally important flora. India is considered as the “herbarium of world” due to the presence of its enormous natural flora. Variation in agro-climatic conditions is directly or severely affecting the growth and quality of natural products of medicinal plants. These natural products are used as raw material in various medicines. UVB radiation altered the physiological and developmental processes of plants. Although plants have mechanisms to cope up with environmental stresses but only with certain extent, further increase in radiation can directly affect the plant growth. Indirect changes caused by UVB affect the distribution of nutrients, secondary metabolism and timing of developmental phases and may be equally or sometimes more important than damaging effects of UVB (www.epa.gov/ozone-layer-protection/health-and-environmental-effects-ozone-layer-depletion)

Plants and Climate Change Considerations

Climate change isn’t only about warming. There are various aspects to consider on many fronts, but with plants, here are a few major factors that affect their life cycles.

Minimum, maximum, and average temperatures affect plant growth and distribution. Seasonal cycles are involved as well, but the timing of when regions warm up in the spring and cool down in the fall is changing. For example, warmer weather is setting up later during the spring in many places at high latitudes, where it is staying warmer later into the fall. Arctic areas are warming up the fastest, triggering a change in Arctic tree lines and vegetation growth, which are dependent on summer warmth.

A rising thermometer, however, doesn't deter all plants. A trend over the last 40 years has been for many North American plant species to move toward warmer areas, and even downhill. University of Washington, Seattle researchers studied 300 plant species in western North America; the 2014 study (published in Global Change Biology) found that 60 percent of plants studied shifted toward lower elevations as the climate warmed, although the availability of water from increased precipitation is thought to be a driving factor.

Rainfall impacts the balance of plant types in a specific area. Shifts in climate patterns can also alter soil type, affecting which plants thrive and don't in certain regions. As a result, some species are left behind, particularly ones that have long life cycles and disperse more slowly, such as arctic and alpine plants. The adaptability rates can cause some species to be lost, and others to move. There is also the impact of invasive species, which adapt more quickly to the environmental conditions where native species might struggle.

Temperature, rainfall, and the length of day affect phenophases, or the timing of plant life cycle phases. Seasonal variations impact these phases, but climate change is altering temperature and rainfall patterns, extending growing seasons and shifting them.

Changes in Leaf and Bloom Dates

For some species, such as honeysuckles and lilacs, first leaf and bloom dates vary from year to year. Such variability can make it difficult to measure major changes. The EPA's Climate Change Indicators show that, since the early 20th century, the growing season in the lower 48 states has increased by about two weeks. More rapid changes have been seen in the West, at a rate of about 2.2 days per decade. In the East, it is about one day per decade. Also, nearly every state has seen the growing season get longer, especially California and Arizona (However, southeastern states such as Alabama and Georgia have seen theirs get shorter). More recent data show earlier final spring frosts and later first fall frosts.

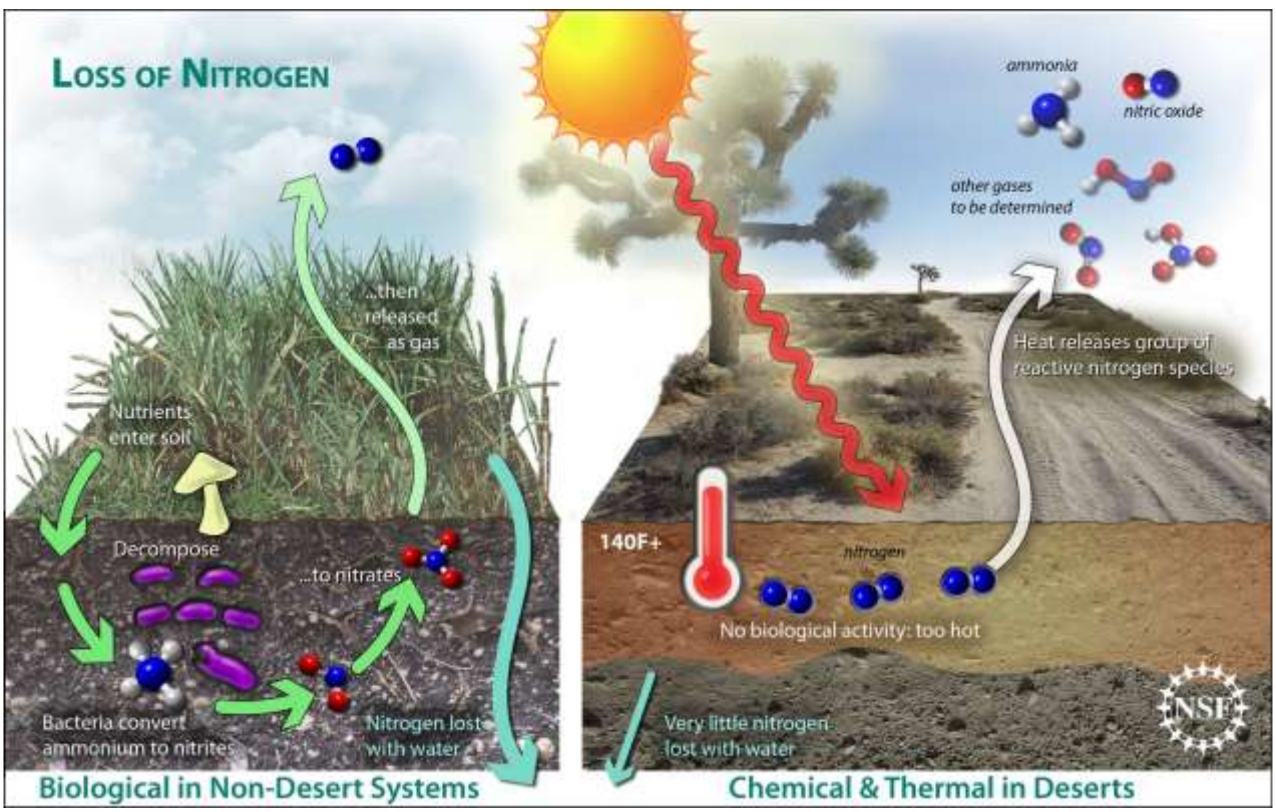
The blooming of plants earlier in the North and West is thought to be connected to this pattern. However, blooms have been occurring later in parts of the South. The pattern is even more pronounced in other places of the Northern Hemisphere.

Scientists are monitoring when first buds appear and when leaves start dropping to measure changes in seasonal patterns. [Project BudBurst](), implemented by the Chicago Botanical Garden, is facilitating this by enabling the public to report how plants in their city, town, park, or garden respond to the seasons.

EXTRA GREENERY, CLIMATE CHANGE, AND CO2

Colder regions have become increasingly more hospitable to plants. In satellite images, a greening effect has been seen across northern landscapes. A concern is that vegetation absorbs sunlight, rather than reflects it like snow and ice do, thereby causing more warming. The thawing of tundra may also release methane, a greenhouse gas. Warmer temperatures are thought to potentially kill off tropical forests, releasing more gases that can contribute to atmospheric warming.

However, a 2016 study in Nature Communications examined a stabilization of atmospheric carbon dioxide increases, which has been attributed to the additional intake of the ground. The belief is that plants being spurred on by climate change is causing it to slow, at least temporarily, because of more carbon dioxide being taken up. The study estimated in the late 20th century, 50 percent of human CO_2 emissions were being removed, but up to 60 percent may now be in the process of being absorbed by vegetation. Researchers also found that increased carbon dioxide concentrations help speed up photosynthesis by as much as 40 percent.



CLIMATE CHANGE AND POLLEN ALLERGIES

Longer plant seasons also equate to more pollen. One example is the ragweed pollen season. Typically peaking in late summer and early fall, ragweed plants can keep churning out pollen until the first frost. Given the current changes, pollen is being produced earlier in the spring and later in the fall. Therefore, pollen counts and allergy seasons are getting longer. In some parts of Europe, ragweed generates ~50% of the total pollen production.

Allergic disease is a key public health problem that has increased rapidly in recent decades in both developed and developing countries, and it is now recognized as a major global epidemic (Pawankar 2014; Platts-Mills 2015). The economic burden of allergic disease is considerable. In 2007, the total cost of allergic disease estimates for the European Union range from 55 to 151 billion EUR (Zuberbier et al. 2014). In terms of specific allergic diseases, the World Health Organization (WHO) estimates that 400 million people in the world suffer from allergic rhinitis and 300 million from asthma (Bousquet and Khaltaev 2007). Within Europe, the prevalence of pollen allergy in the general population is estimated at 40% (D'Amato et al. 2007).

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WILDLIFE AND CLIMATE CHANGE

Herd of elephants © Benh Lieu

For the past twenty years, climate change has been high on the international agenda. Together with desertification, soil degradation and biodiversity loss, it is widely recognized as the major environmental threat the world is facing. Evidence is increasing that warming and other climate-related changes are happening more quickly than anticipated, and prognoses are becoming worse.

The world already faces a biodiversity extinction crisis, and it is likely to be made worse by climate change. Therefore, terrestrial, freshwater and marine wildlife will be severely affected unless we manage to cope with climate changes through decisive planning and action. The main focus is on tropical terrestrial wildlife and its habitats, but other fauna, ecosystems and geographical regions are covered as well.

The impacts of climate change will include permanent changes in physical conditions, such as snow cover, permafrost and sea level along with increases in both the irregularity and severity of extreme weather events like droughts, floods and storms, which will lead to changes in ecosystems and ecosystem functioning.

The world is undergoing an extinction crisis – the most rapid loss of biodiversity in the planet's history – and this loss is likely to accelerate as the climate changes.

It has been estimated that 20–30 percent of plant and animal species will be at higher risk of extinction due to global warming and that a significant proportion of endemic species may become extinct by 2050 as a consequence. Some taxa are more susceptible than others. For example, 566 of 799 warm-water reef-forming coral species are at risk of becoming endangered because of the increasing climate change, as are about 35 percent of birds and 52 percent of amphibians. Moreover, the impact will likely be more severe on species that are already at risk of extinction: 70–80 percent of red-listed birds, amphibians and corals are considered susceptible to the effects of climate change (Vié, Hilton-Taylor and Stuart, 2008).

As average global temperatures rise, the impacts on habitats and species will depend on many factors, including local topography, changes in ocean currents, wind and rainfall patterns and changing albedo. In addition to variations in the rate and extent of temperature increases at different latitudes, there may be changes in the length and severity of seasons, including decreases in temperature in some areas. Rainfall patterns may likewise be affected in terms of overall annual quantity, seasonal distribution of precipitation and year-by-year regularity. Extreme weather events, such as droughts and floods, are expected to occur more often. In particular, droughts are projected to become more frequent and intense in subtropical and southern temperate forests; this will increase the prevalence of fire and predisposition to pests and pathogens (Seppälä, Buck and Katila, 2009).

Non-timber forest resources, such as fuelwood, charcoal, non-wood forest products and wildlife sustain the livelihoods of hundreds of millions of people in forest-dependent communities. Most rural and many urban populations in developing countries rely on woody biomass as their main energy source and depend on wild plant medicines for their healthcare. In many developing countries, bushmeat is an important source of protein, while for coastal communities or those living near freshwater, fish can be a major source of protein. In Central Africa, there is a very large and well-established trade in bushmeat products, which is driven mainly by consumer demand in major cities. Up to 5 million tonnes of bushmeat are believed to be consumed every year in the Congo Basin (Fa et al., 2002; Kleine, Buck and Eastaugh, 2010; Seppäla, Buck and Katila, 2009) in a trade that is recognized as unsustainable and often illegal. Despite their importance to local communities, about 13 million hectares (ha) of the world's forests are lost due to deforestation each year (FAO, 2010a) and further large areas are also degraded. Richardson & Robinson, 2005).

MAJOR CLIMATE-INDUCED CHANGES

Increased temperatures affect physical systems, as ice melts and snow cover is reduced, as well as affecting biological systems through a series of direct and indirect pressures. Physical systems include deep snow, glaciers and permafrost. Increases in temperature can lead to a drastic unbalancing of the physical system, causing irreversible losses.

The water cycle and hydrological systems are affected by changing temperatures, often indicated by dry riverbeds or floods due to increased runoff. In semi-desert areas, the decreased availability of water is already placing additional pressures on wildlife, which aggregate around limited water points and compete with domestic livestock (de Leew et al., 2001). Reduced plant production as a consequence of reduced precipitation increases the probability of soil degradation due to overgrazing by wildlife and domestic animals. Many freshwater species are under serious threat of extinction as a result of rising temperatures and the disappearance of ponds and coastal lagoons (Willets, Guadagno and Ikkala, 2010).

Rising sea levels are affecting coastal areas through shoreline erosion, the loss of coastal wetlands and modification of coastal vegetation. Marine and coastal ecosystems are also disrupted by storms that damage corals directly through wave action and indirectly through light attenuation by suspended sediment and abrasion by sediment and broken corals.

Higher temperatures also cause the expulsion of zooxanthellae (single-celled plants living in the cells of coral polyps), which leads to coral bleaching and has caused the loss of 16 percent of the world's corals (Wilkinson, 2004). Up to a third of corals are considered to be threatened with extinction due to climate change (Carpenter et al., 2008). In a chain reaction, the death of corals causes the loss of habitat for many species of tropical fish. Many studies report changes in fish populations, recruitment success, trophic interactions and migratory patterns related to regional environmental changes due to changing climatic conditions (e.g. Edwards and Richardson, 2004; Hays, Richardson & Robinson, 2005).

Photo Resources: © Global Warming Images/WWF; © Jurgen Freund/WWF; © Simon de Trey-White/WWF-UK; © Brent Stirton/WWF

Major threats to biodiversity

- Habitat destruction
- Overexploitation
- Invasive species
- Pollution
- Climate change

WHAT MAKES A SPECIES VULNERABLE TO CLIMATE CHANGE?

SENSITIVITY

- Geographic range
- Population size
- Temperature tolerance
- Reliance on environmental cues (for reproduction, migration, hibernation)
- Strong interactions with other species
- Diet
- Abundance of food source
- Freshwater requirements
- Habitat specialization
- Susceptibility to disease

The different traits are considered under the "sensitivity" category. Species with the following traits would be considered to have a HIGH vulnerability to climate change: Endangered on the IUCN Red list, narrow geographic range, small population size, narrow temperature tolerance, strong dependence on environmental cues for reproduction, migration and hibernation, strong interactions with one or more species (e.g. symbiosis), specialist diet, low abundance of food source, high freshwater requirements, specific habitat requirements, and high susceptibility to disease.

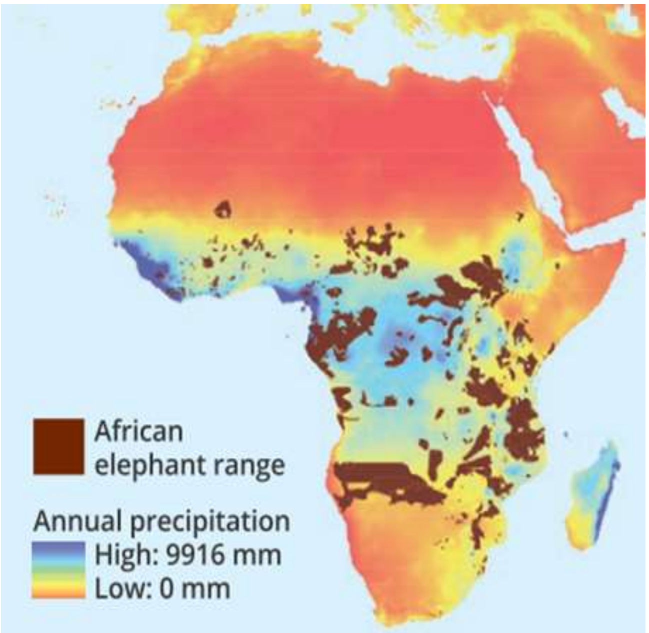
WHAT MAKES A SPECIES VULNERABLE TO CLIMATE CHANGE?

Adaptive capacity

- Dispersal ability
- Generation time
- Reproductive rate

- Genetic variation

ELEPHANTS AND WATER



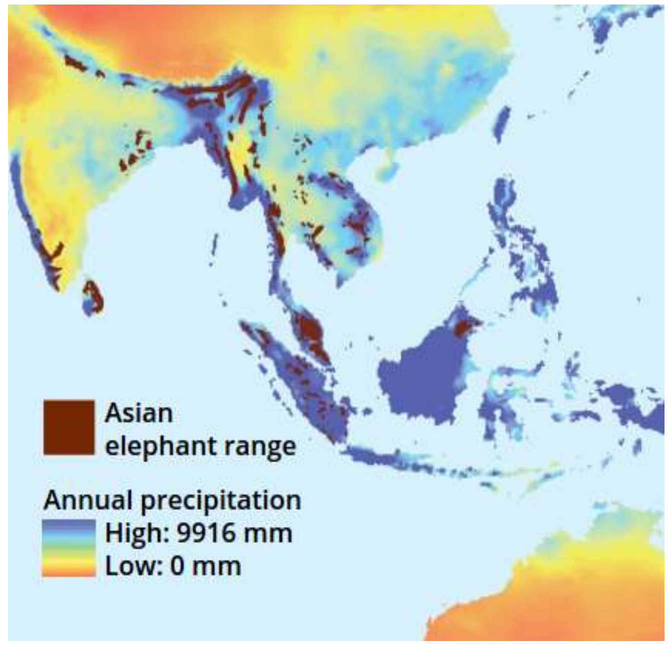
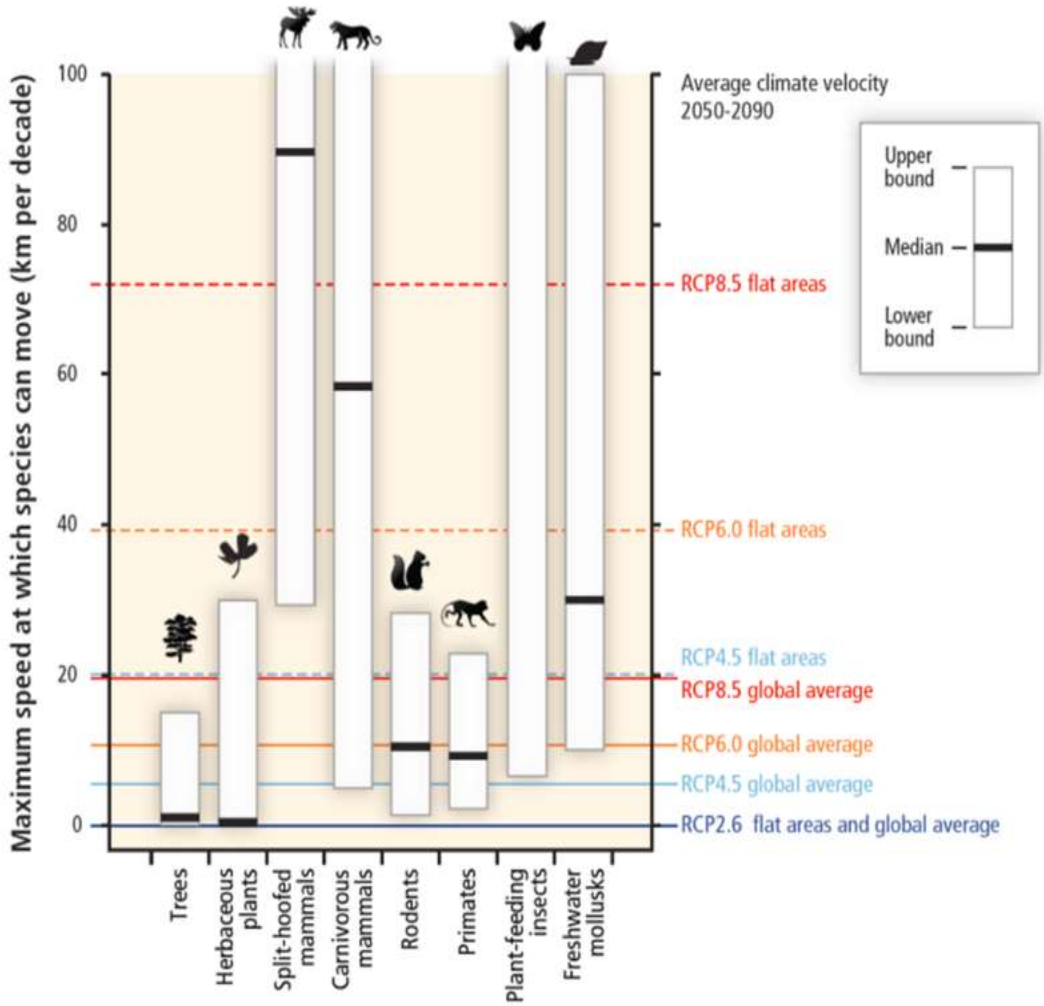


Photo Resources: © Nikhil Advani/WWF

CONSEQUENCES OF CLIMATE CHANGE

The IPCC has predicted that, as a result of changes in rainfall patterns and average global temperatures, “during the course of this century, the resilience of many ecosystems (their ability to adapt naturally) is likely to be exceeded by an unprecedented combination of change in climate and in other global change drivers (especially land use change and overexploitation), if greenhouse gas emissions and other changes continue at or above current rates. By 2100, ecosystems will be exposed to atmospheric CO2 levels substantially higher than in the past 650 000 years, and global temperatures at least among the highest as those experienced in the past 740 000 years. This will alter the structure, reduce biodiversity and perturb functioning of most ecosystems, and compromise the services they currently provide” (Parry et al., 2007).

Coastal inundation and salination is another landscape-level effect of climate change as sea levels steadily rise. Low-lying terrestrial ecosystems in the tropics will be increasingly exposed to storm surges as coral reefs decline.



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