[redacted]

Impact of Climate Change on Plants, Animals & Man (I)

1. Introduction

The Earth's climate has changed throughout history. The current warming trend is of particular significance because most of it is extremely likely (greater than 95 percent probability) to be the result of human activity since the mid-20th century, and it is proceeding at a rate that is unprecedented over decades to millennia. The oceans have absorbed much of this increased heat. Global sea level rose about 8 inches in the last century, with the rate in the last two decades nearly double that of the last century. The Greenland and Antarctic ice sheets have decreased in mass, glaciers are retreating almost everywhere around the world — including in the Alps, Himalayas, Andes, Rockies, Alaska and Africa. With climate change, extreme weather events, stress on freshwater supplies and ocean acidification are also observed.

2. Learning Outcomes

(a) Identify and explain the human activities over the last few centuries that have contributed to climate change through increased emission of greenhouse gases (limited to CO_2 and methane) including burning of fossil fuels linked to increasing energy usage, clearing of forests and food choices (increasing consumption of meat).

(b) Explain the effect of climate change as a result of greenhouse gas emissions, including the melting of polar ice caps, rising sea levels, stress on fresh water supplies, heat waves and heavy rains, death of coral reefs, migration of fishes and insects and release of greenhouse gases in frozen organic matter.

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3. Greenhouse Gases & Greenhouse Effect

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What are Greenhouse Gases?

A greenhouse gas (GHG) is a gas that both **absorbs and emits radiation in the infrared range**. When present in the atmosphere, these gases trap radiation in the form of heat, causing a **warming process** called the **greenhouse effect**.

Greenhouse gases include water vapour, **carbon dioxide**, **methane**, nitrous oxide, and fluorinated gases. The greenhouse gases in the Earth's atmosphere keep the average temperature of the Earth at 15°C, whereas without the greenhouse effect the average temperature would be a frosty -18°C. Some concentration of greenhouse gases in the atmosphere is normal, and is therefore necessary for life on Earth. It is also normal for the concentrations of these gases to fluctuate over time, causing the average global temperature to vary over a period of hundreds of thousands or millions of years.

The "**greenhouse effect**" of the atmosphere is named by analogy to greenhouses which become warmer in sunlight.

How do greenhouses work?

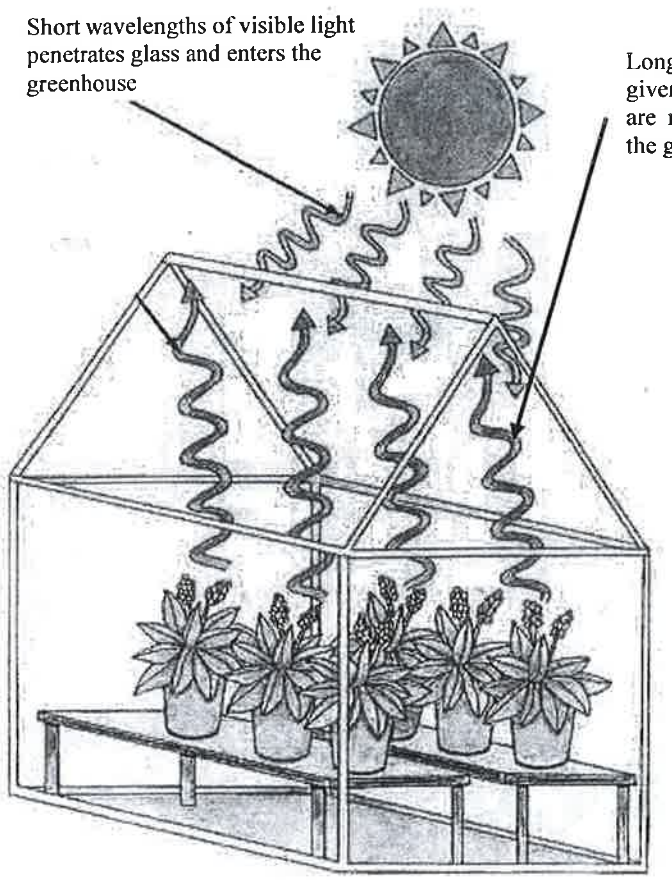


Fig. 1: Diagram showing how greenhouses trap heat

Short wavelength of light from the sun passes through the glass.

↓

Everything in the greenhouse, such as plants, surfaces and ground, absorbs the short wavelength light and becomes warmer.

↓

Warmed objects now give off long wavelength infrared light.

↓

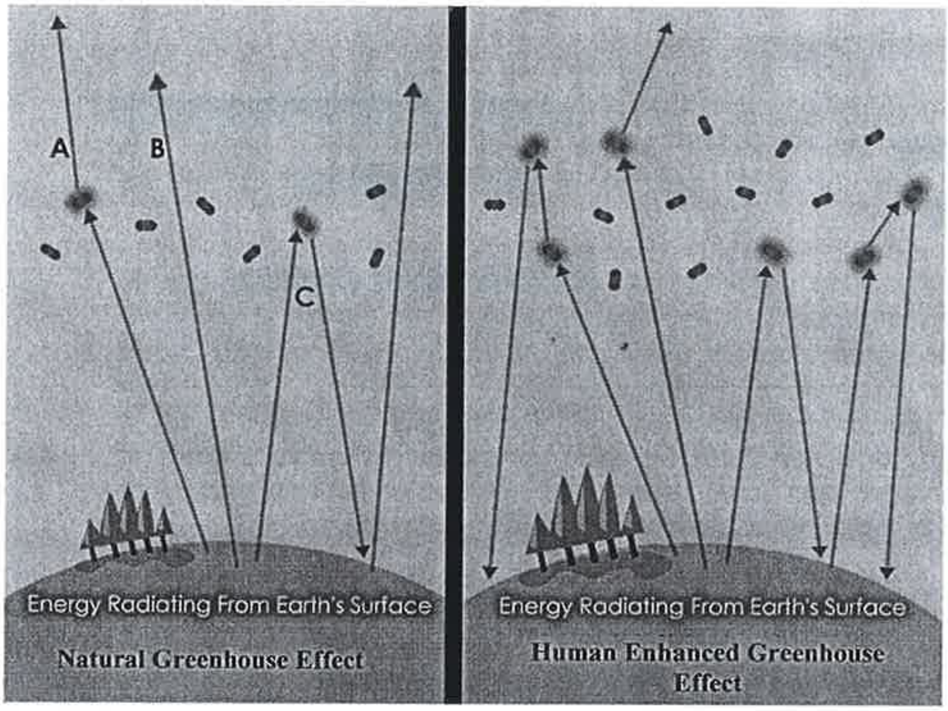
Glass of greenhouse absorbs the long wavelength infrared light and warms up.

↓

Glass gives off long wavelength infrared light which mostly shines back into the greenhouse, thus warming the interior of the greenhouse.

The Earth's Greenhouse Effect

Notes to self



The Earth's surface, warmed by the Sun, radiates heat into the atmosphere. Some heat is absorbed by greenhouse gases like carbon dioxide and then radiated to space (**A**). Some heat makes its way to space directly (**B**). Some heat is absorbed by greenhouse gases and then radiated back towards the Earth's surface (**C**). With more carbon dioxide in the atmosphere due to human activities, more heat will be trapped by greenhouse gases, warming the planet more significantly.

Fig. 2: Diagram showing the natural greenhouse effect and human enhanced (anthropogenic) greenhouse effect

The greenhouse effect is a natural process by which **heat** radiated from Earth's surface is **trapped by greenhouse gases** as such water vapour, carbon dioxide, nitrous oxide, methane and others.

Solar radiation passes through the atmosphere, and some of the solar radiation is reflected by the clouds, atmosphere and surface of the Earth. About half of the solar radiation is absorbed by the Earth's surface and warms it. The Earth's greenhouse effect maintains Earth's average surface temperature at a life-sustaining 15°C.

While water vapour is present mainly due to natural factors, vast amounts of the other greenhouse gases, i.e. **carbon dioxide, methane**, nitrous oxide, and fluorinated gases, have been added to the atmosphere as a **result of human activity**. **Strengthening of the greenhouse effect** through human activities is known as the enhanced (or **anthropogenic**) greenhouse effect.

4. Human Activities & Increase in Greenhouse Gas Emissions

Notes to self

Anthropogenic greenhouse gas emissions have increased since the pre-industrial era, driven largely by economic and population growth, and are now higher than ever. This has led to atmospheric concentrations of carbon dioxide and methane that are unprecedented in at least the last 800,000 years.

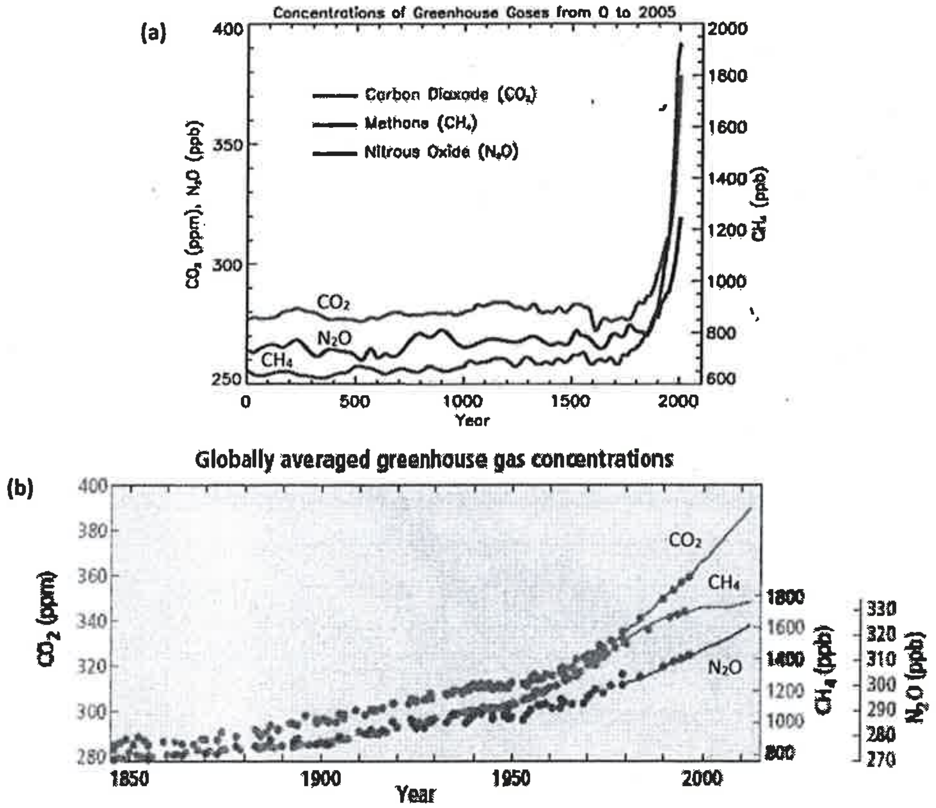
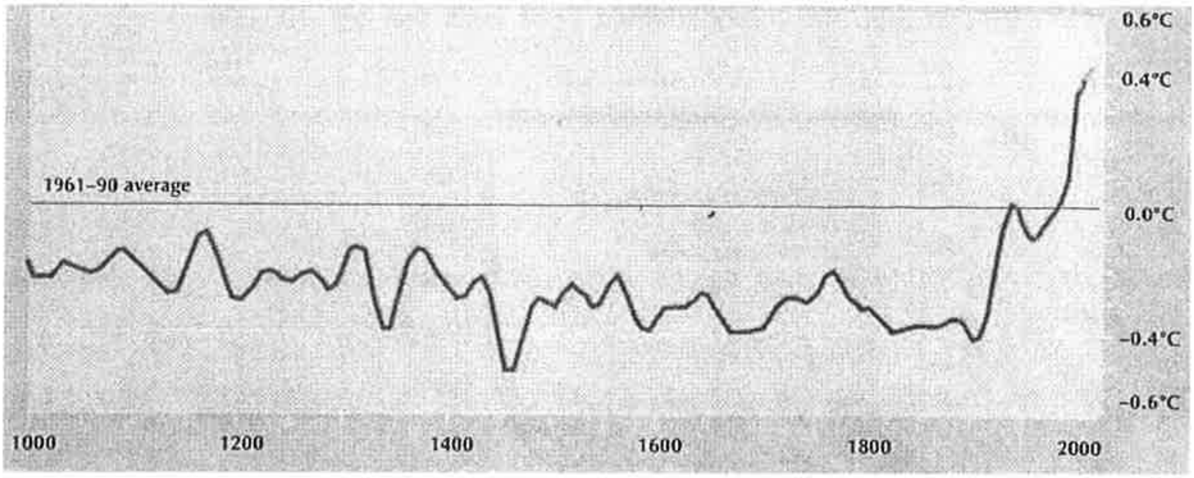


Fig. 3: Diagram showing global greenhouse gas concentrations
(a) Average greenhouse gas concentrations from Year 0 to 2005. (b) Average greenhouse gas concentrations from 1850 to 2010. Both (a) and (b) show the significant rise in greenhouse gas concentrations from around 1850 to current time.

Notes to self

Each of the last three decades has been successively warmer at the Earth's surface than any preceding decade since 1850. The period from 1983 to 2012 was likely the warmest 30-year period of the last 1400 years in the Northern Hemisphere.

(a) Departure from 1961-90 average



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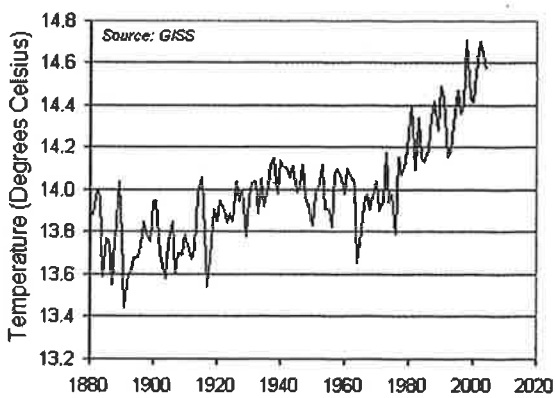
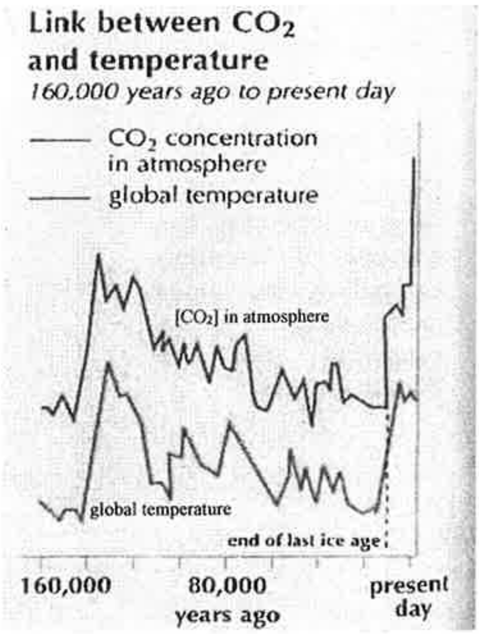


Fig. 4: Diagram showing temperature at Earth's surface
(a) Temperature from 1000 to beyond 2000 in the northern hemisphere, showing a generally upward trend from about 1960. Over the period from 1880 to 2012, there is a warming of 0.85°C. (b) Average global temperature from 1880 to 2004. While there are fluctuations in temperature due to the natural warming and cooling cycles (of several years to a decade), there is an overall increasing trend. Both (a) and (b) show the rise in temperature at the Earth's surface in recent times.

Notes to self

The increase in greenhouse gas emissions that have been detected throughout the climate system are extremely likely to have been the dominant cause of the observed warming.

(a)



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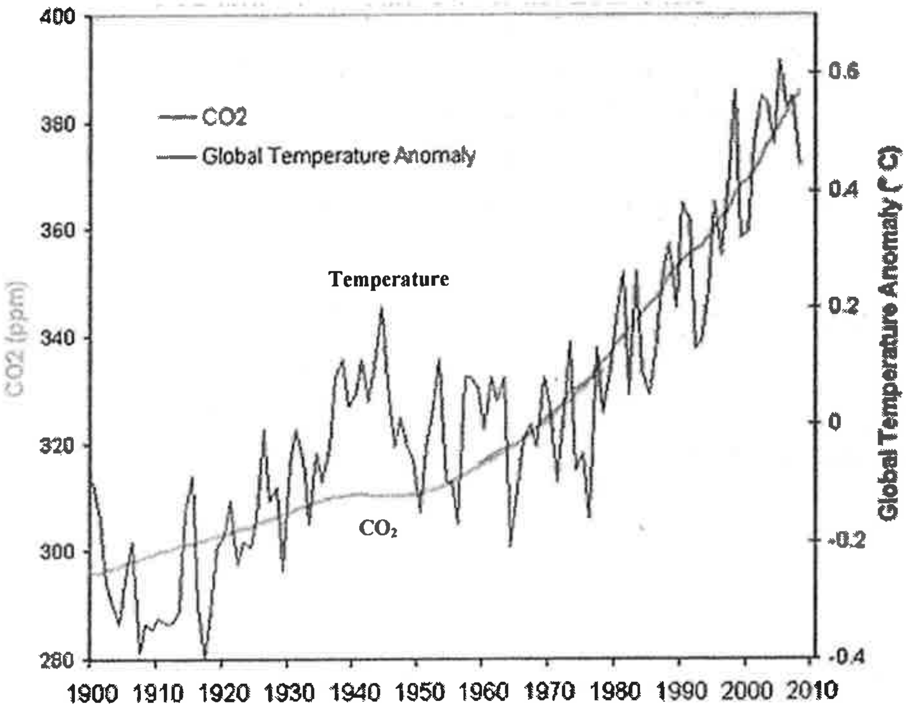
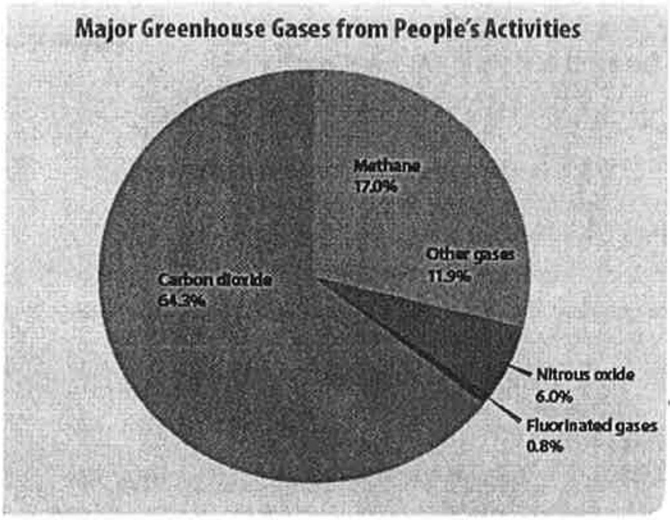


Fig. 5: Diagram showing the correlation between CO_2 levels and temperature
(a) Link between CO_2 levels and temperature from 160 000 years ago to present is evident from the similar trend in both graphs. (b) The relationship between CO_2 levels and the increase in the global temperature anomaly is visible in the increasing trend of both graphs. The CO_2 levels were measured in Antarctica from 1900 to 1980 and in Mauna Loa from 1960 to present day. The global temperature anomaly is calculated as a difference between the combined average temperature over global land and ocean surfaces and the 20th century average of 14.8°C.

Notes to self



The size of each piece of the pie represents the amount of warming that each gas is currently causing in the atmosphere as a result of emissions from people's activities.
Source: *Intergovernmental Panel on Climate Change, Fifth Assessment Report (2014).*

Fig. 6:
Diagram showing the amount of warming caused by the major greenhouse gases produced due to human activity

Global greenhouse gas emissions can also be broken down by the economic activities that lead to their production.

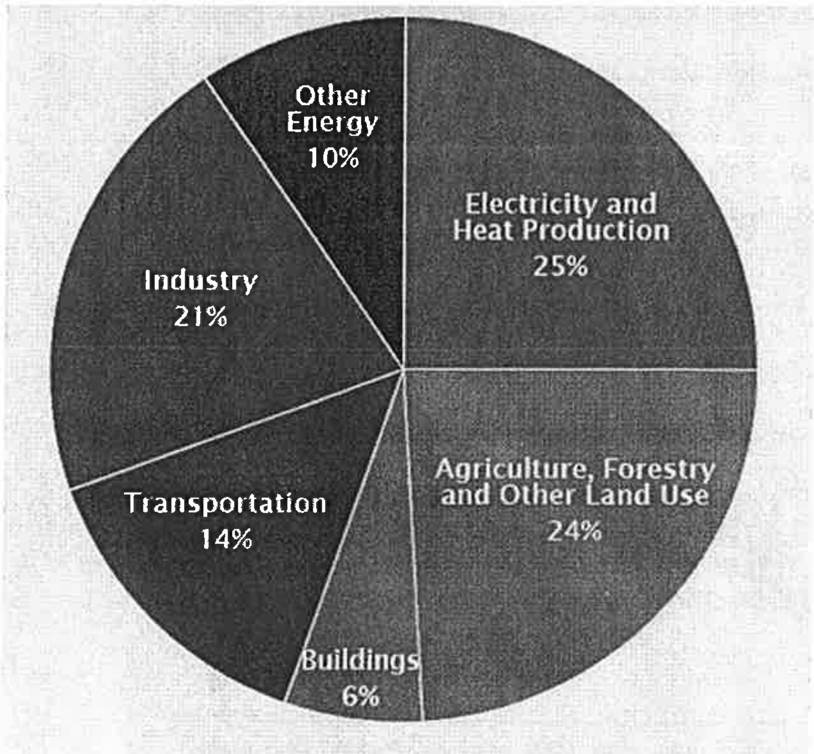


Fig. 7: Diagram showing the greenhouse gas emissions by various sectors. Industry: primarily involve fossil fuels burned on-site at facilities for energy. Buildings: burning of fossil fuels for on-site energy generation and for e.g. cooking in homes. Others: emissions from the Energy sector which are not directly associated with electricity or heat production, such as fuel extraction, refining, processing, and transportation.

Combustion of Fossil Fuels

Notes to self

Burning of fossil fuel is the primary source of CO_2:

Burning of fossil fuels for electricity and heating

Coal, petrol and natural gas are burnt to produce electricity and heat buildings and this is the **largest single source of global greenhouse gas emissions**. Electricity is a significant source of energy used to power homes, business, and industry. The type of fossil fuel used to generate electricity will emit different amounts of greenhouse gases. To produce a given amount of electricity, burning coal will produce more CO_2 than oil or natural gas. Generation of electricity and heat worldwide relies heavily on coal, the most carbon-intensive fossil fuel. Countries such as Australia, China, India, Poland and South Africa produce over two-thirds of their electricity and heat through the combustion of coal.

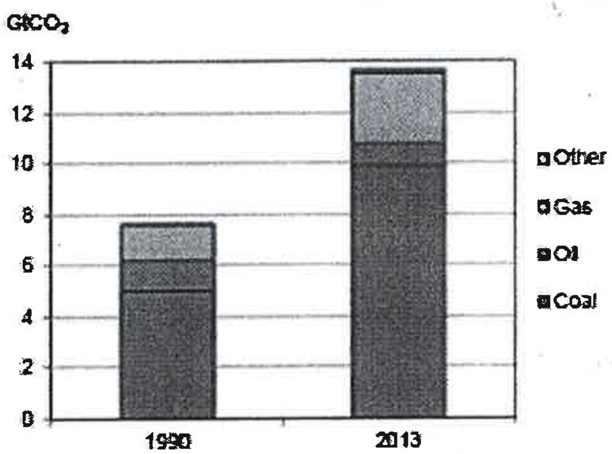


Fig. 8: Diagram showing CO_2 emissions from electricity and heat generation

CO_2 emissions from electricity and heat almost doubled between 1990 and 2013, driven by the large increase of generation from coal.

Burning of fossil fuels for transportation

The combustion of fossil fuels such as gasoline and diesel to transport people and goods is the fourth largest source of greenhouse gas emissions. Almost all (95%) of the world's transportation energy comes from petroleum based fuels, largely gasoline and diesel. Fossil fuels are burnt to run vehicles, which includes road, rail, air and marine transportation. For transport, the fast emissions growth was driven by emissions from the road sector, which increased by 68% since 1990 and accounted for three quarters of transport emissions in 2013.

Many industrialised nations are beginning to curb their carbon dioxide emissions, by more efficient fuel use or by using alternative sources of fuel. However, in many of the newly industrialising countries emissions have increased markedly over recent decades. While petroleum reserves are limited, there are still hundreds of years of coal reserves worldwide, which could remain a significant source of greenhouse gas emissions. Currently, coal fills much of the growing energy demand of those developing countries (such as China and India) where energy-intensive industrial production is growing rapidly and large coal reserves exist with limited reserves of other energy sources.

Notes to self

Note:
Natural gas is also a fossil fuel used as a source of energy for heating, cooking and electricity generation. Natural gas is made mostly of methane and this can be released if there are even small leaks in gas pipes during the production and transportation of the natural gas.

Deforestation

Trees play a huge role in the carbon cycle. They convert the CO_2 in the air to O_2, through the process of photosynthesis, and in this way, they can be looked at as a natural regulator of CO_2. The more trees, the less CO_2 in the atmosphere and the more O_2.

Plants absorb CO_2 from the atmosphere as they grow, and they store some of the carbon throughout their lifetime. Soils can also store CO_2, depending on how the soil is managed. This storage of carbon in plants and soils is called biological carbon sequestration. Because biological sequestration takes CO_2 out of the atmosphere, it is also called a greenhouse gas "sink."

Since CO_2 is very abundant in the atmosphere, released through man-made inventions, such as cars, factories, and power plants, it is vital, more than ever, that trees fulfill their part in the environment and take some of the excess CO_2 out of the air.

Unfortunately, deforestation is preventing this job to be fully accomplished, and with half of all the Earth's forests gone, and four million trees cut down each year just for paper use, the amount of CO_2 is rising. Additionally, undisturbed waterlogged peatlands (organic soils) store a large amount of carbon and act as small net sinks. Drainage of peatlands for agriculture and other uses results in a rapid increase in decomposition rates and increased risk of peatland fires, leading to increased emissions of CO_2 and N_2O.

In summary, clearing of forests and mangroves removes the trees that can sequester CO_2. If these forests are on waterlogged peatlands, draining of these peatlands prevent them from storing carbon. The subsequent decomposition and burning of biomass from the cleared forests releases more greenhouse gases. Thus overall, **clearing of forests results in significant greenhouse gas emissions**.

With more CO_2 in the atmosphere, more of the sun's radiation is being reflected back to earth, instead of space, and this is causing our average temperature to rise. In this way, deforestation is a major issue when it comes to global warming.

In the United States overall, since 1990, land use, land-use change, and forestry activities have resulted in more removal of CO_2 from the atmosphere than emissions. Because of this, the land use, land-use change, and forestry sector in the United States is considered a net sink, rather than a source, of CO_2 over this period. In many areas of the world, the opposite is true: In countries where large areas of forest land are cleared, often for agricultural purposes or for settlements, the land use, land-use change, and forestry sector can be a net source of greenhouse gas emissions.

Food Choices

Notes to self

Agriculture, is one of the main contributors to the emission of greenhouse gases and thus has a potential impact on climate change. Most studies attribute 10 to 35 percent of all global greenhouse gas emissions to agriculture.

As the economy in some countries slowly grew, industrial style agriculture replaced traditional small-scale farming. Pasturage and use of animal manure as fertilizer was abandoned. The increasing efficiency of industrial agriculture has led to reduced prices for many of our daily products. It helped to reliably nourish large populations, and turned a food that was an occasional meal - meat - into an affordable, every day product for many.

While the average meat consumption globally is 115 grams per day (42 kg per year), meat supply varies enormously from region to region, and large differences are visible within regions. The USA leads by far with over 322 grams of meat per person per day (120 kg per year), with Australia and New Zealand close behind. Europeans consume slightly more than 200 grams of meat (76 kg per year); almost as much as do South Americans (especially in Argentina, Brazil and Venezuela). Although Asia's meat consumption is only 25 per cent of the U.S. average (84 grams per day, 31 kg per year), there are large differences, for example, between the two most populous countries: China consumes 160 grams per day, India only 12 grams per day.

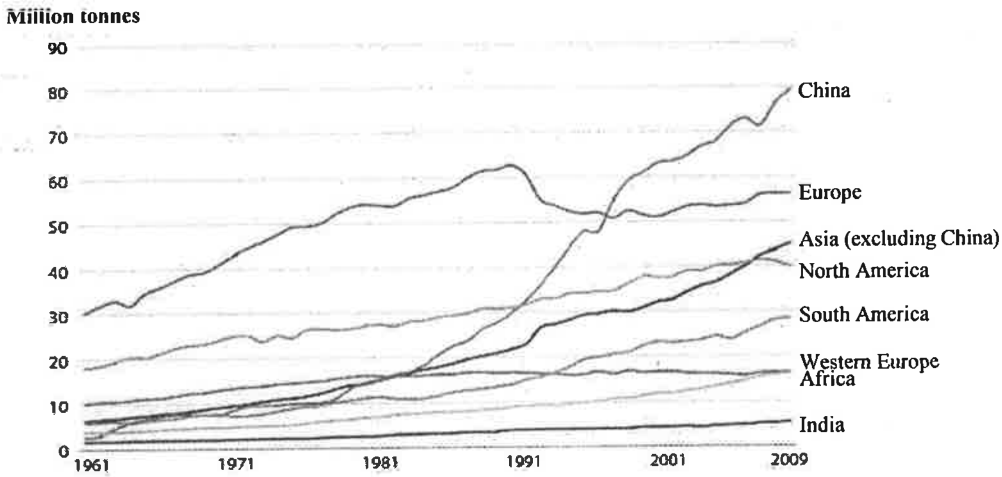


Fig. 9: Diagram showing trends in meat supply for selected countries/regions between 1961 and 2009

Notes to self

The growth in per capita consumption is strongly linked to increasing levels of income in many countries of the world. One of the fastest growing meat consuming regions is Asia, particularly China. Total meat consumption has increased 30-fold since 1961 in Asia, and by 165 per cent since 1990 in China. Per capita meat consumption has grown by a factor of 15 since 1961 in Asia and by 130 per cent since 1990 in China.

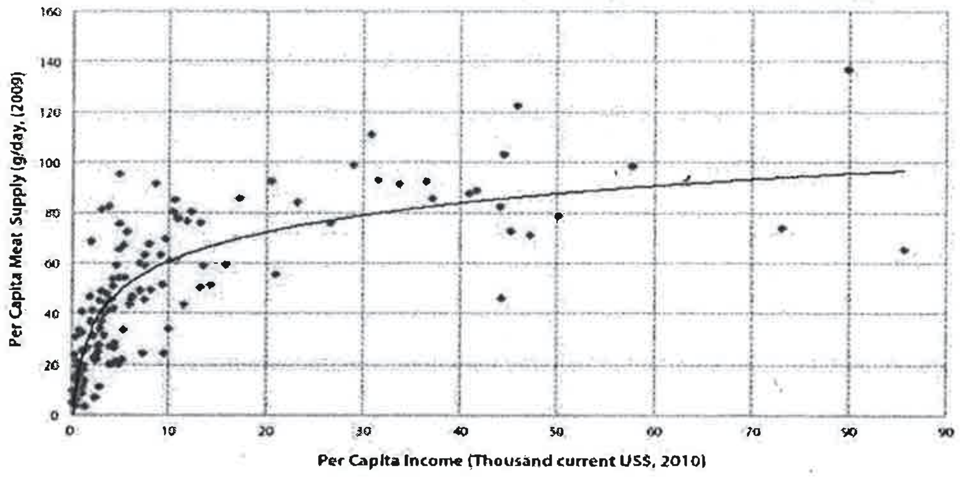


Fig. 10: Diagram showing per capita income versus meat consumption

Not only has per capita consumption grown, there are also millions more consumers of meat. The global human population grew from around 5 billion in 1987 to 7 billion in 2011, and is expected to reach 9 billion people in 2050. Thus, the total amount of meat produced climbed from 70 million tonnes in 1961 to 160 million tonnes in 1987 and to 278 million tonnes in 2009, an increase of 300 per cent in 50 years. The FAO expects that global meat consumption will rise to 460 million tonnes in 2050, a further increase of 65 per cent within the next 40 years.

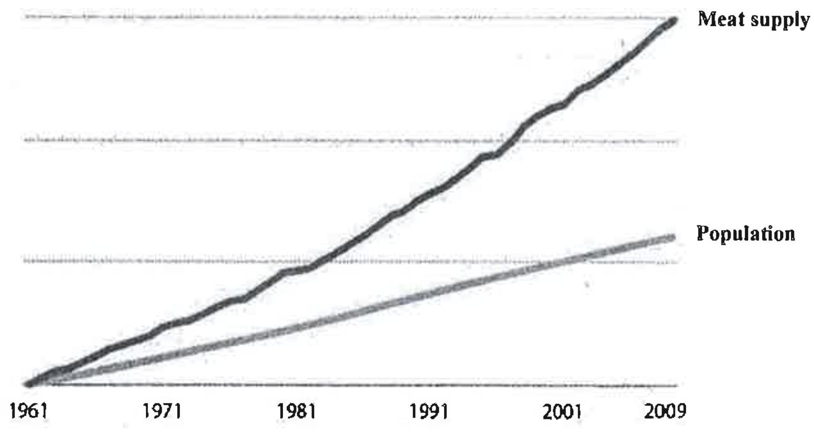


Fig. 11: Diagram showing growth of population and meat supply

However, the true costs of industrial agriculture, and specifically "cheap meat", have become more and more evident. Today, "the livestock sector emerges as one of the top two or three most significant contributors to the most serious environmental problems". This includes environmental stresses such as deforestation, desertification, excretion of polluting nutrients, overuse of freshwater, inefficient use of energy, diverting food for use as feed and emission of greenhouse gas.

Sources of greenhouse gas emissions from raising livestock:

Notes to self

Source of greenhouse gas	How is the greenhouse gas produced?	Greenhouse gas produced
i. Enteric fermentation	• Certain animals – especially cows and sheep – produce methane as they digest food. Enteric fermentation is a digestive process by which carbohydrates are broken down by microorganisms into simple molecules for absorption into the bloodstream of an animal.	• Methane
ii. Nitrogenous fertilisers	• Application of chemical nitrogenous fertilisers to increase production of animal feed for livestock • Production of chemical nitrogenous fertilisers	• Nitrous oxide • CO_2 and nitrous oxide
iii. Manure	• Stored manure from livestock. Manure releases methane when it decays. • Application of manure as fertilisers	• Methane • Nitrous oxide
iv. Deforestation and conversion of grassland into agricultural land	• Decomposition of carbon and nitrogen-rich humus	• CO_2 and nitrous oxide

	Enteric fermentation (CH_4)	Manure (N_2O)	Manure (CH_4)	Soils (N_2O)
Latin America	460	11	17	394
Africa	280	6	14	361
China	259	69	22	536
India	218	0	23	58
Asia (except China	175	35	24	192
Western Europe	160	26	69	257
North America	136	22	43	300
Non Eu former Sov	97	28	12	76
Australia/New Zeal	88	1	3	32
Eastern Europe	28	12	7	43
Middle East	27.3	0.7	1.6	50.7
World	1929	211	235	2299

Fig. 12: Diagram showing regional emissions of major greenhouse gases (million tonnes of CO_2-eq/year)

Beef produces the highest greenhouse gas emissions in comparison to other products such as pork, poultry and milk. Emissions from beef amounts to 20 times that of wheat. Thus "it is more "climate efficient" to produce protein from vegetable sources than from animal sources. Beef is the least efficient way to produce protein, less efficient than vegetables that are not recognized for their high protein content, such as green beans or carrots.

Notes to self

Changes in human diet may be a practical tool to reduce greenhouse gas emissions. As a large percentage of beef is consumed in hamburgers or sausages, it has been suggested that the inclusion of protein extenders from plant origin would be a practical way to replace red meats. A switch to less "climate-harmful" meat may also be possible, as pigs and poultry produce significantly less methane than cows. They are however more dependent on grain and soy-products and may thus still have a negative impact on greenhouse gas emissions. Grass-fed meat and resulting dairy products may be more environmentally friendly than factory-farmed or grain-fed options.

Scientists agree that in order to keep greenhouse gas emissions to 2000 levels, the projected 9 billion inhabitants of the world (in 2050) need to each consume no more than 70 to 90 grams of meat per day. To meet this target, substantial reductions in meat consumption in developed countries and constrained growth in demand in developing ones would be required.

How much heat do CO_2 and methane trap?

Methane traps over **21 times more** heat than the same amount of carbon dioxide. Therefore, methane has a Global Warming Potential (GWP) of 21.

GWP is a measure of how much heat a substance can trap in the atmosphere. GWP can be used to compare the effects of different greenhouse gases.

For example, methane has a GWP of 21, which means over a period of 100 years, 1 pound of methane will trap 21 times more heat than 1 pound of carbon dioxide (which has a GWP of 1).

According to the latest Assessment Report from the Intergovernmental Panel on Climate Change, "*atmospheric concentrations of carbon dioxide, methane and nitrous oxide are unprecedented in at least the last 800,000 years. Their effects, together with those of other anthropogenic drivers, have been detected throughout the climate system and are extremely likely to have been the dominant cause of the observed warming since the mid-20th century*".

How long do CO_2 and methane stay in the atmosphere?

- CO_2: Between 50 to thousands of years
- Methane: About 12 years

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5. Climate Change Effects due to Greenhouse Gas Emissions

Notes to self

a. Melting of Polar Ice Caps & Rising Sea Levels

Global warming has resulted in the rise of sea levels due to:

- Melting of the Greenland and Antarctic ice sheets, glaciers and polar ice caps.

Over the past century, the sea level has slowly been rising, partly due to the addition of water to the oceans through the melting of the polar ice caps. The world's two major ice sheets – Greenland and Antarctica – contain about 75% of the world's fresh water, enough to raise the sea level by over 75 metres, if all the ice were returned to the oceans.

Research shows that glaciers are already declining. Mountain glaciers at all latitudes have retreated, including those in the Himalayas of Central Asia, the Andes of South America, and the Rockies and Sierras in the United States. Scientists project that, as a result of climate change, many mountain glaciers will be gone by the middle of the 21st century.

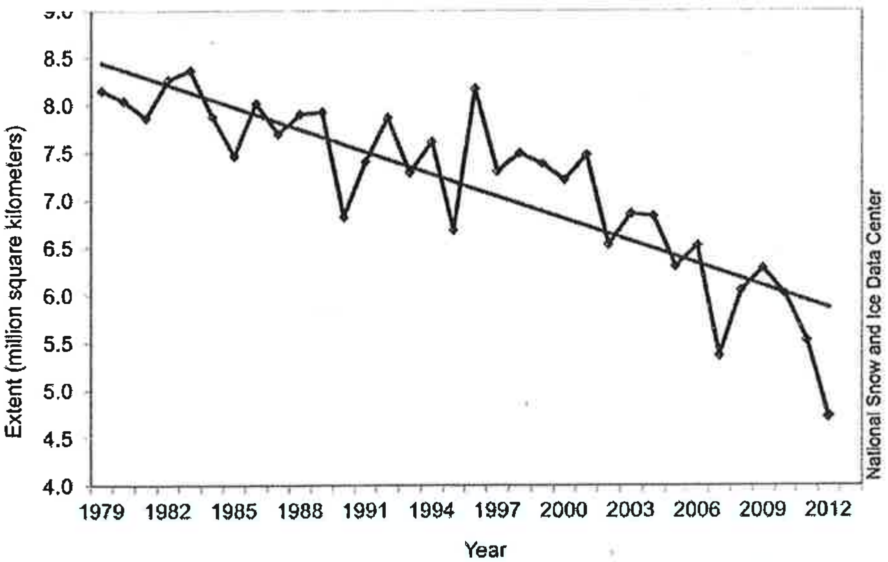

Fig. 13: Average monthly Greenland sea extent from Aug 1979 – 2012

Effects of melting of the Greenland and Antarctic ice sheets, glaciers and polar ice caps:

- The loss of Arctic sea ice is likely to have serious global implications. Many marine animals, such as seals, polar bears, and fish, depend on sea ice. With a loss of sea ice, these animals will lose access to their feeding grounds for long periods, which will make it difficult for these populations to be sustained.
- Glaciers serve as an important resource of fresh water that supports people and agricultural production. As glaciers retreat, these communities will lose this resource and they may also experience floods, avalanches, or landslides triggered by glacial melt.

Notes to self

- Thermal expansion of seawater

Thermal expansion occurs when the ocean temperature rises and the particles that make up the ocean start to move more vigorously. This causes expansion of water, increasing the overall volume of the ocean, causing a rise in average sea levels.

Effects of sea level rise:

- Almost 50% of the world's population lives close to the seashore, and rising sea levels will impact humans, animals, and plants living on or near the coast.

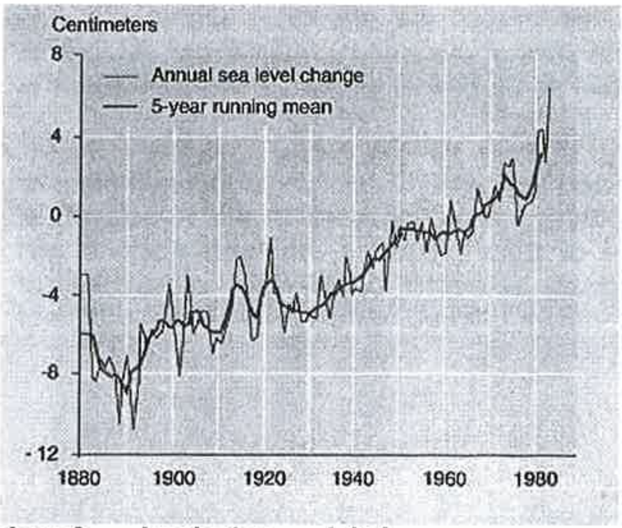

Fig. 14: Rising of sea levels due to global warming in the last century

b. Heat Waves & Heavy Rains

How global warming results in change in weather:

Rise in temperature and warmer air

↓

Greater evaporation from land and water into atmosphere

↓

More water vapour in the air

↓

Increased precipitation i.e. more rain and snow.

(Do note that this increase in precipitation is not spread evenly around the globe. Some places will get less precipitation due to shifts in air and ocean currents. This results in change in global weather patterns.)

Weather: refers to short term changes in the atmosphere.
Climate: describes the average daily weather for an extended period of time at a certain location.

Observed impact of climate change

Notes to self

- More precipitation:
  On average, the world is already getting more precipitation now than it did 100 years ago → nearly 2% more worldwide.

- Difference in levels of precipitation in different parts of the globe:
  Between 1900 and 2005, in parts of North and South America, northern Europe and northern and central Asia there has been towards increasing rain and snowfall precipitation. Other areas such as the Sahel, the Mediterranean, southern Africa and parts of southern Asia have tended towards less precipitation.

- Stronger storms and hurricanes:
  Hurricanes and other tropical storms get their energy from warm ocean water. As the top layer of the ocean gets warmer, hurricanes and other tropical storms grow stronger, with faster winds and heavier rain. Because of higher temperatures and increased evaporation, climate change causes other types of storms to get stronger, too.

- More areas affected by droughts:
  Since 1970 the area of the planet affected by drought appears to have increased.

Predicted impact of climate change

- Rainfall is likely to increase in the tropics and at high latitudes and decrease in the already dry subtropics.
  - Increased frequency and intensity of rainfall in some areas will produce more pollution such as erosion and sedimentation due to runoff.
  - Water-borne diseases and lower water quality likely to increase with heavy precipitation.
  - Increased risk of flooding in urban areas.

- The number of frost days is expected to decrease at high latitudes, increasing the growing season, thus increasing food production for the high latitudes.

- Increases in temperature will affect the amount and duration of snow cover which will in turn affect the timing of ice melting and water flowing into waterways, impacting groundwater recharge.

- Heatwaves are expected to become more frequent as average temperatures rise.
  - Increasingly intense and frequent heat-waves are likely to cause more heat-related deaths, particularly amongst the elderly, chronically ill and very young, though the occurrence of cold-related deaths is expected to fall.

c. Stress on Fresh Water Supplies

Notes to self

Fresh water (or **freshwater**) is any naturally occurring water except seawater and brackish water. Fresh water includes water in ice sheets, ice caps, glaciers, icebergs, bogs, ponds, lakes, rivers, streams, and even underground water called groundwater.

Freshwater supplies are scarce. The vast majority of the Earth's water resources are salt water, with only 2.5% being fresh water. Approximately 70% of the fresh water available on the planet is frozen in the ice sheets of Antarctica and Greenland leaving the remaining 30% (equal to only 0.7% of total water) available for consumption. From this remaining 0.7%, roughly 87% is allocated to agricultural purposes.

Scarcity of freshwater is expected to become an ever-increasing problem in the future, for the following reasons:

i. Groundwater depletion

Global warming will result in change in rainfall patterns. With shorter duration of rainfall combined with increased sum of evaporation and plant transpiration from the earth's land surface, replenishment of groundwater will be negatively affected. Also in some areas with less rainfall, there will be increased pumping of groundwater for irrigation. Overall, all these factors will lead to groundwater depletion.

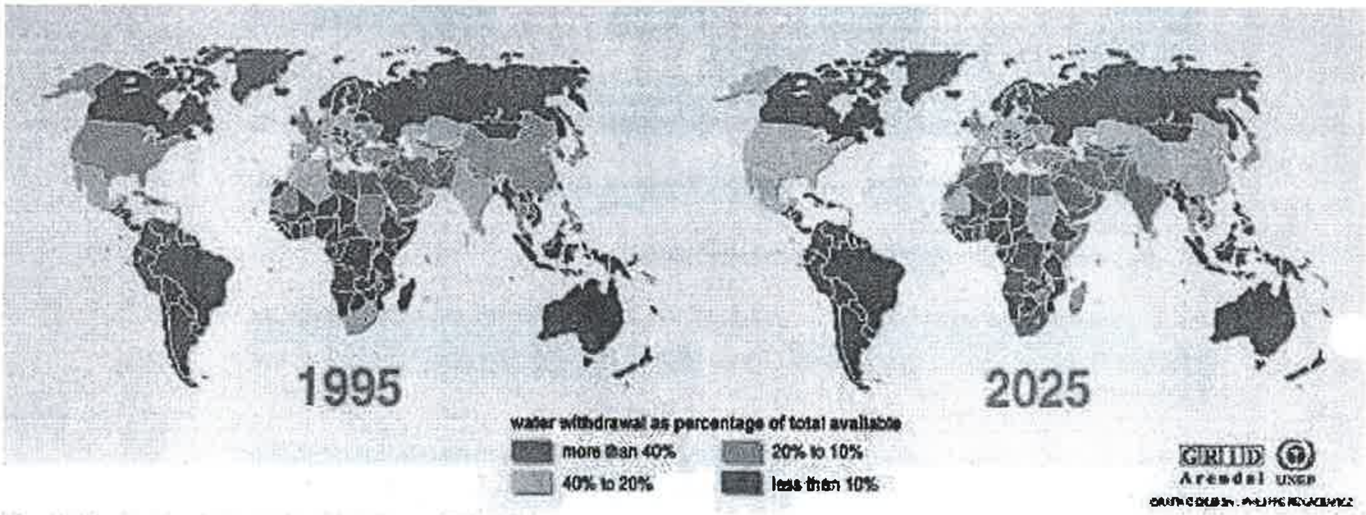

Fig. 15: Increasing stress on freshwater supplies by 2025
Water withdrawals are defined as freshwater taken from ground or surface water sources.
Water withdrawal will increase dramatically in many areas of the world by 2025.

ii. Decline in water quality

Notes to self

- Increase in precipitation leads to increase in runoff. The water will carry larger levels of sediment and contaminants which are flushed into waterways and drinking reservoirs.

- If drought conditions persist in certain areas, groundwater reserves may be depleted and the residual water that remains is often of inferior quality. This is a result of the leakage of saline or contaminated water from the land surface, or the adjacent water bodies that have highly concentrated quantities of contaminants. This occurs as decreased precipitation and runoff results in a high concentration of pollution and nutrients in the water. High level of nutrients tends to an increase load of microbes in waterways and drinking-water reservoirs.

- Increase in water temperatures can lead to a bloom in microbial populations in freshwater supplies.

- Increase in water temperatures can also reduce the amount of dissolved oxygen in the water. The health of a body of water, such as a river, is dependent upon its ability to effectively self-purify through biodegradation, which is hindered when there is a reduced amount of dissolved oxygen. This occurs when water warms and its ability to hold oxygen decreases.

- For coastal populations, water quality is likely to be affected by salinisation, or increased quantities of salt in water supplies. This will result from a rise in sea levels, which will increase salt concentrations in groundwater and estuaries. Sea-level rise will not only extend areas of salinity, but will also decrease freshwater availability in coastal areas.

d. Release of Greenhouse Gases in Frozen Organic Matter

Notes to self

Permafrost refers to a layer of soil or rock that is frozen all year round. Plants can still grow in the soil at the surface (active layer), which is not frozen during warmer parts of the year.

Fig. 16: Cross-section of layers of soil

The active layer is the top layer of soil that thaws during the summer and freezes again during the autumn. Beneath that is the permafrost which is a permanently frozen layer of soil. Beneath the permafrost or scattered among the permafrost can be sections of unfrozen soil and rock.

Permafrost is found throughout much of North America, Scandinavia, Russia and China.

Permafrost stores an immense amount of carbon and methane, twice as much carbon as contained in the atmosphere. In a warming environment, permafrost is expected to degrade, and these gases which have been in storage will be released. The degradation of the permafrost has already begun in some parts of the world, and is expected to increase in earnest by the year 2020.

Carbon stored in permafrost

- A third of the Earth's soil carbon is found in the permafrost of the Arctic, where the soil carbon is stored in frozen organic matter. If the high northern latitudes warm significantly, permafrost will thaw, allowing the organic matter within the permafrost to decompose. The decomposition will release carbon into the atmosphere. This already happens within the active layer each summer. As the active layer thaws, some organic matter decomposes. Under normal climate conditions (i.e. a cold arctic region), the ground remains cold enough to keep the decomposition very slow. But as air temperature increases and the ground warms, this process will speed up.

- It has been estimated that by 2200, 60% of the Northern Hemisphere's permafrost will probably have melted, which could release around 190 billion tonnes of carbon into the atmosphere. This amount is about half of all the carbon released in the industrial age.

Methane stored in the permafrost

Notes to self

- Methane has 20 to 25 times more warming power than carbon dioxide.
- Methane can exist in the form of methane hydrates which is methane gas frozen into ice structures. They are formed at cold temperatures and under high pressure—conditions that are both present beneath layers of frozen permafrost. The amount of methane hydrates in permafrost could range anywhere from 7.5 to 400 billion tons of carbon-equivalent.
- As the ground warms, methane will either be released directly into the atmosphere or bacteria will break it down into carbon dioxide, which will then be released. If areas of thawed permafrost exist between frozen layers of permafrost, it is possible that microbial activities will continue unabated, even during the winter, to create new methane from organic material.

Note:

Frozen permafrost soil is the perfect place to preserve bacteria and viruses. That means melting ice could potentially open a Pandora's box of diseases. The temperature in the Arctic Circle is rising quickly, about three times faster than in the rest of the world. As the ice and permafrost melt, other deadly, infectious agents may be released.