

# Chapter 12

## The World Climate and Climate Change

### Koeppen's Climate Classification

- Koeppen's Classification of climate is the most commonly used classification of climate.
- This climate classification scheme was developed by Wladimir Peter Koeppen in 1884.
- He recognized a close relationship between the distribution of vegetation and climate.
- The categories are based on the data of annual and monthly averages of temperature and precipitation.
- He selected specific values of temperature and precipitation and related them to the distribution of vegetation and used these values for classifying the climates.
- The Koeppen climate classification system recognizes five major climatic types and each type is designated by a capital letter- A, B, C, D, E, and H.
  - f -no dry season
  - m - Monsoon climate
  - w- Winter dry season

- s - Summer dry season
- The small letters a, b, c, and d refer to the degree of severity of temperature.

The capital letters: A, C, D and E delineate humid climates and B dry climates.

The climatic groups are subdivided into types, designated by small letters, based on seasonality of precipitation and temperature characteristics.

The seasons of dryness are indicated by the small letters : f, m, w and s, where f corresponds to no dry season

### Climate Groups According to Koeppen

Group	Characteristics
A – Tropical	Average temperature of the coldest month is 18 C or higher
B – Dry Climates	Potential evaporation exceeds precipitation
C – Warm Temperate	The average temperature of the coldest month of the (Mid-latitude) climates years is higher than minus 3oC but below 18oC
D – Cold Snow Forest Climates	The average temperature of the coldest month is minus 3° C or below
E – Cold Climates	Average temperature for all months is below 10' C
H – High Land	Cold due to elevation

# Climate Types According to Koeppen

Group	Type	Letter code	Characteristics
A -Tropical Humid Climate	Tropical wet Tropical monsoon Tropical wet and dry	Af Am Aw	No dry season Monsoonal, short dry season Winter dry season
B-dry climate	Subtropical steppe Subtropical desert Subtropical steppe Mid-latitude desert	BSH BWH BSK BWK	Low-latitude semi arid or dry Low-latitude arid or dry Mid-latitude arid or dry
C-Warm temperate (Mid-latitude) Climates	Humid subtropical Mediterranean Marine west coast	Cfa Cs Cfb	No dry season, warm summer Dry hot summer No dry season, warm and cool summer
D-cold snow forest Climate	Humid continental Subarctic	Df Dw	No dry season. Severe winter Winter dry and very severe
E-cold climate	Tundra Polar ice cap	ET EF	No true Perennial ice
H-highland	Highland	H	Highland with snow cover

The above mentioned major climatic types are further subdivided depending upon the seasonal distribution of rainfall or degree of dryness or cold.

a: hot summer, average temperature of the warmest month over  $22^{\circ}\text{C}$

c: cool summer, average temperature of the warmest month under  $22^{\circ}\text{C}$

f: no dry season

w: dry season in winter

s: dry season in summer

g: Ganges type of annual march of temperature; hottest month comes before the solstice and the summer rainy season.

h: average annual temperature under  $18^{\circ}\text{C}$

m (monsoon): short dry season

The capital letters **S** and **W** are employed to designate the two subdivisions of dry climate:

1. semi-arid or **Steppe (S)** and
3. arid or desert (**W**).

Capital letters **T** and **F** are similarly used to designate the two subdivisions of polar climate

1. tundra (**T**) and
3. icecap (**F**).

- Koeppen divided India into nine climatic regions making use of the above scheme.

### 1. Koeppen's Scheme – Climatic Regions of India

Climate type	Region	Annual rainfall
<b>Amw</b> <b>(Monsoon type with short dry winter season)</b>	Western coastal region, south of Mumbai	over 300 cm
<b>As</b> <b>(Monsoon type with dry season in high sun period)</b>	Coromandel coast = Coastal Tamil Nadu and adjoining areas of Andhra Pradesh	75 – 100 cm [wet winters, dry summers]
<b>Aw</b> <b>(Tropical Savanah type)</b>	Most parts of the peninsular plateau barring Coromandel and Malabar coastal strips	75 cm
<b>BShw</b> <b>(Semi-arid Steppe type)</b>	Some rain shadow areas of Western Ghats, large part of Rajasthan and contiguous areas of Haryana and Gujarat	12 to 25 cm
<b>BWhw</b> <b>(Hot desert type)</b>	Most of western Rajasthan	less than 12 cm

<b>Cwg</b> <b>(Monsoon type with dry winters)</b>	Most parts of the Ganga Plain, eastern Rajasthan, Assam and in Malwa Plateau	100 – 200 cm
<b>Dfc</b> <b>(Cold, Humid winters type with shorter summer)</b>	Sikkim, Arunachal Pradesh and parts of Assam	~200 cm
<b>Et</b> <b>(Tundra Type)</b>	Mountain areas of Uttarakhand The average temperature varies from 0 to 10°C	Rainfall varies from year to year.
<b>E</b> <b>(Polar Type)</b>	Higher areas of Jammu & Kashmir and Himachal Pradesh in which the temperature of the warmest month varies from 0° to 10°C	Precipitation occurs in the form of snow

## Koppen Climate Classification

- Koppen's Group-A climates are found in the unbroken belt around the Earth at low latitudes, typically within 15° North and South.
- Group A climates are regulated largely by the seasonal variations of the trade winds, the Inter-Tropical Convergence Zone (ITCZ), and the Asian monsoon.

### Group A: Tropical Humid Climates

- Tropical humid climates exist between Tropic of Cancer and Tropic of Capricorn.
- Inter-Tropical Convergence Zone makes the climate hot and humid.
- The annual range of temperature in this region is very low whereas the annual rainfall is high.
- The tropical group is divided into three types. They are:
  - Af - Tropical wet climate
  - Am - Tropical monsoon climate
  - Aw - Tropical wet and dry climate

#### Tropical Wet Climate (Af)

- Tropical wet climate is seen near the equator.
- The chief areas that lie in this climate are
  - Amazon Basin in South America
  - Western Equatorial Africa ◦ The islands of East Indies

- A substantial amount of rainfall occurs in every month of the year.
- These regions receive thundershowers in the afternoon.
- The temperature is uniformly high.
- The annual range of temperature is negligible.
- The maximum temperature during daytime is about  $30^{\circ}\text{C}$  whereas the minimum temperature is about  $20^{\circ}\text{C}$ .
- The region is bestowed with Tropical evergreen forests and large biodiversity.

### Tropical Monsoon Climate (Am)

- Tropical monsoon climate (Am) is found over:
  - The Indian sub-continent
  - North Eastern part of South America
  - Northern Australia
- These regions receive heavy rainfall in summer.
- Winter in this area seems to be dry

### Tropical Wet and Dry Climate (Aw)

- Tropical wet and dry climate is found in north and south of Tropical Wet Climate (Af) type climate regions.
- It borders with Cf or Cw on the eastern part and dry climate on the western part of the continent.

Extensive Aw climate is found in

- Sudan
- South of Central Africa

- North and South of the Amazon forest in Brazil
- Connecting parts of Bolivia and Paraguay in South America
  - The annual rainfall in Tropical Wet and Dry Climate is significantly less than that in Af and Am climate types.
  - The wet season is shorter in this region.
  - The dry season is longer with the drought being more severe.
  - The diurnal ranges of temperature are extreme in the dry season.
  - Temperature is high throughout the year.
  - Deciduous forest and tree-shredded grasslands main flora found in this region.

### Group B: Dry Climates

The Group-B Climates of Koppen's Climate Classification are Dry Climates

- These arid and semiarid climates cover about a quarter of the land surface of the Earth.
- This region lies between 50° North and 50° South.
- But these regions are predominantly seen in the 15-30° latitude belts in northern and southern hemispheres.
- These regions have intense solar radiation and clear skies.
- **These regions experience**
- Low precipitation
- Great variability in precipitation from year to year
- Low relative humidity

- High evaporation rates

- **Dry climates are divided into:**

- Steppe or semi-arid climate (BS)
- Subtropical steppe (BSh)- Latitudes from 15° - 35°
- Mid-latitude steppe (BSk)
- Desert climate (BW)
- Subtropical desert (BWh) - Latitudes between 35°- 60°
- Mid-latitude desert (BWK)

### **Subtropical Steppe (BSh) and Subtropical Desert (BWh) Climates**

Subtropical steppe (BSh) and subtropical desert (BWh) have common temperature and precipitation characteristics.

- The maximum temperature in this region in summer is very high.
- The annual and diurnal ranges of temperature are also high.
- The highest temperature of 58°C was recorded at Libya in 1922 at Al Aziziyah.
- This region is positioned in the transition zone between dry climates and humid.
- Subtropical steppe region receives slightly more rainfall than the subtropical desert which is sufficient enough for the growth of meager grasslands.
- The rainfall in both the climates is highly variable.
- Rain occurs in short intense thundershowers in deserts and is futile in building soil moisture.

- The inconsistency in the rainfall distresses the life in the steppe much more than in the desert, more frequently causing famine.
- Fog is common in coastal deserts neighbouring cold currents.

### Group C-Warm Temperate

Warm temperate (mid-latitude) climates stretch from  $30^{\circ}$  -  $50^{\circ}$  of latitude mainly on the western and eastern margins of continents.

- These climates usually have warm summers with mild winters.

They are classified into four types:

1. Humid subtropical - Cwa
2. Mediterranean Climate - Cs
3. Humid subtropical climate - Cfa
4. Marine west coast climate - Cfb

#### Humid Subtropical Climate (Cwa)

The Humid subtropical climate is found in the poleward of Tropic of Cancer and Capricorn.

This climate is predominantly found in the North Indian plains and interior plains of South China.

The Humid Subtropical Climate is similar to Tropical Wet and Dry Climate (Aw) climate excluding that the temperature in winter is warm

#### Mediterranean Climate (Cs)

- Mediterranean climate is found around Mediterranean sea, along the west coast of continents in subtropical latitudes between  $30^{\circ}$  -  $40^{\circ}$  latitudes

- The climate is predominantly found in the
  - Central Chile
  - Central California
  - Along the coast in South Eastern
  - South Western Australia
- These areas come under the influence of westerly wind in winter and sub-tropical high in summer.
- Therefore, the climate is characterized by hot, dry summer and mild, rainy winter.
  - The monthly average temperature in winter below  $10^{\circ}\text{C}$  and in summer is around  $25^{\circ}\text{ C}$ .
  - The annual precipitation ranges from 35 - 90 cm

### Humid Subtropical Climate (Cfa)

- The Humid subtropical climate is found in the Eastern parts of the continent lying in the subtropical latitudes.
- In this area, the air masses are usually uneven and cause rainfall throughout the year.
- This Climate is found in:
  - The Eastern United States of America
  - Southern and eastern China
  - Southern Japan
  - North-eastern Argentina
  - Coastal South Africa

- Eastern coast of Australia
  - The annual average of precipitation stretches from 75-150 cm.
  - Frontal precipitation in winter and thunderstorms in summer are usual.
  - The average monthly temperature in winter it differs from 5°-12° C and in summer is about 27°C.

### Marine West Coast Climate (Cfb)

- Marine west coast climate is situated poleward from the Mediterranean climate on the west coast of the continents.
- The main areas are:
  - North-western Europe
  - West coast of North America
  - North of California
  - Southern Chile
  - South-eastern Australia
  - New Zealand • The temperature is moderate and in winter, it is warmer than for its latitude due to marine influence.
  - The mean temperature in winter 4°-10°C and in summer months ranges from 15°-20°C.

### Group D-Cold Snow Forest Climates

Cold snow forest climate is found in the large continental area in the northern hemisphere between 40°-70° North latitudes.

- The regions lying in this climate are:

- Europe ◦ Asia
- North America
- Cold snow forest climates are divided into two types:
- Df- cold climate with humid winter.
- Dw- cold climate with dry winter.
- The severity of winter is more pronounced in higher latitudes.

### Cold Climate with Humid Winters (Df)

- Cold climate with humid winters is found in the poleward of mid-latitude steppe and marine west coast climate.
- The winters are snowy and cold.
- The frost-free season is short.
- The annual ranges of temperature are high.
- The weather changes are unexpected and short.
- Poleward, the winters are extreme.

### Cold Climate with Dry Winters (Dw)

- Cold climate with dry winter mainly found over North-Eastern Asia.
- Precipitation occurs in summer.
- The annual precipitation is low from 12-15 cm.
- The progress of pronounced winter anticyclone and its weakening in summer sets in the monsoon-like reversal of the wind in this area.
- Poleward summer temperatures are poorer and winter temperatures are very low with several locations experiencing below freezing point temperatures.

## Group E - Cold Climates

- Group E climates are regulated by the polar and arctic air masses of high latitudes which lie above 60° North and South latitudes.

### Polar Climates (E)

- Polar climates are found in the poleward beyond 70° latitude
- Polar climates consist of two types:
  - Tundra (ET)
  - Ice Cap (EF)

### Tundra Climate (ET)

- The tundra climate (ET) is so called after the types of vegetation, such as lichens, low-growing mosses, and flowering plants.
- The regions experiencing this climate are:
  - Mount Rainier
  - Macquarie Island
  - Crozet Islands
  - Campbell Island
  - Kerguelen Islands
  - Prince Edward Islands
- This is the region of permafrost.
- The subsoil in this region is permanently frozen.
- The waterlogging and short growing season support only low growing plants.

- The tundra regions have a very long period of daylight during summer.

### **Ice Cap Climate (EF)**

- The ice cap climate (EF) found in the interior Greenland and Antarctica.
- The regions experiencing this climate are:
  - Vostok Station, Antarctica ◦ Mount Ararat, in Turkey
  - Mount Everest
  - Scott Base, Antarctica
  - Summit Camp, Greenland
  - Plateau Station, Antarctica
- The temperature is below freezing point even in summer.
- This region receives very little precipitation.
- The ice and snow get amassed and the increasing pressure causes the deformation of the ice sheets and they break.
- These broken pieces move as icebergs and float in the Antarctic and Arctic waters

### **Group H-Highland Climates**

- Group H climate contains all highland areas not easily categorized by other climate types.
- Highland climates are dominated by topography.
- In high mountains, large changes in average temperature occur over short distances.

- Precipitation types and intensity of the precipitation also differ spatially across highlands.
- There is vertical zonation of layering of climatic types with elevation in the mountain environment

## What is Climate Change?

Climate change refers to changes in average weather conditions of a given area observed over an extended period of time.

The term Climate change was used by World Meteorological Organization in the 1960s to refer to climate variability observed on a time scale of over 10 years irrespective of causes, but in later years the term became associated with human-induced changes in weather patterns.

Climate Change, which is today a cause for worry, has been evidenced by rising temperatures since the mid-20th century, retreating glaciers and melting of polar ice caps, increased frequency of extreme weather events such as droughts, heavy rainfall, cyclones, heat waves etc.

## Causes

Factors that shape climate are called climate forcing . These could be grouped into natural and anthropogenic Natural Causes

**Biotic processes:** Processes pertaining to living beings shape and influence water cycle and nutrient cycles (Carbon, nitrogen etc.) and thereby shape climate. For instance glaciation in the past occurred on earth with the evolution of plants that depleted atmosphere of Carbon dioxide (using it in photosynthesis)

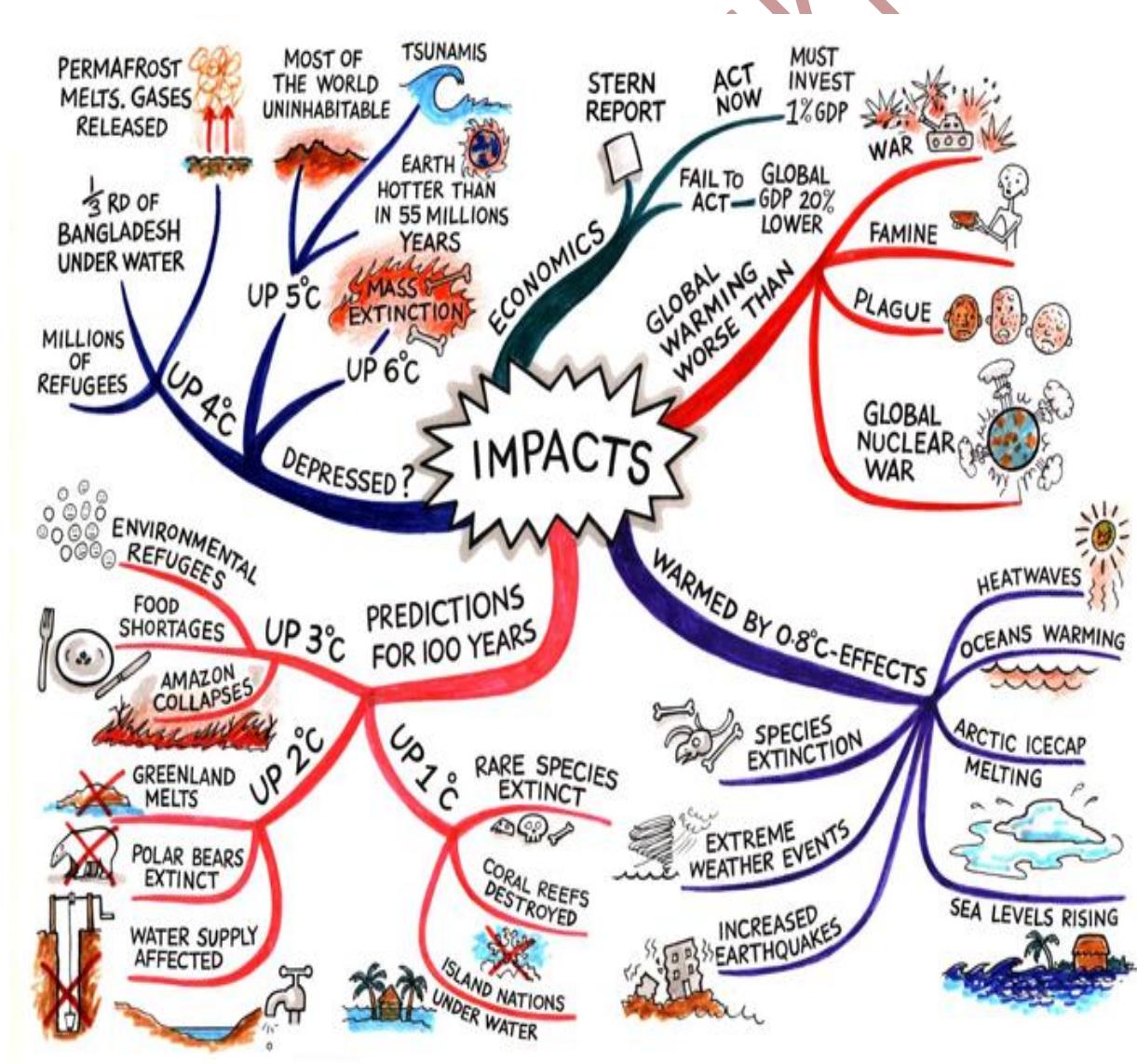
- **Variations in solar radiation received by Earth:** Sunspot cycle (periodic variation in the number of sunspots) amounts to changes in incoming solar radiation that have a bearing on climate.
- **Plate tectonics:** The location of continents and seas across the globe has a bearing on ocean circulation and atmospheric circulation which brings about the meridional transfer of heat. Changes in these dynamics can induce climate changes
- **Volcanic eruptions:** These inject sulfate aerosols into the atmosphere which induce cooling by reflecting solar radiations.
- **Variations in the Earth's orbit:** Changes in earth's axial tilt cause changes in incident solar radiation and result in climate change.
- **Changes in the albedo** or reflectivity of the continents, atmosphere, and oceans

### **Anthropogenic causes**

- **Emissions of Greenhouse gases:** Build-up of heat-trapping gases such as CO<sub>2</sub>, Water vapour, HFCs, Nitrous oxides etc in the atmosphere is a major factor behind rising global temperatures and consequent climate variability. CO<sub>2</sub> concentration in the atmosphere has increased from 288 ppm in 1870 to 404 ppm (2016).
- **The World Resource Institute (WRI)** in its report estimates that the world produces 31,000 million tonnes of Carbon dioxide every year and the earth naturally assimilates 17,500 mt of CO<sub>2</sub> annually, leaving a substantial amount of CO<sub>2</sub> to accumulate in the atmosphere.

- **Ozone depletion:** Caused by the release of ODS (Ozone depleting substances) used in refrigerants, coolants, sprays, dyes and paints etc
- **Agriculture and Animal Husbandry**
- **Deforestation:** Clearing of forests has removed natural carbon sinks and facilitated an increase in CO<sub>2</sub> concentration in the atmosphere. Deforestation has also adversely impacted rainfall patterns in monsoon regions.

### Impact of Climate Change



## Global Warming

Average surface temperature has risen by 0.95 degree Celsius since 1880 (as per NOAA). NASA records show that the world witnessed 16 of its hottest years post year 2000. Current levels of Emissions, global temperatures are predicted to rise by up to 5.4%. Scientists have also observed that spring seasons now begin early and last longer causing disruptions in ecology and economy (agriculture, fisheries etc.).

## Sea Level Rise and Glacier Retreat

Each ton of CO<sub>2</sub> emitted is known to melt 32 square feet of arctic ice. Globally sea levels have risen by 8 to 9 inches since 19th Century. Arctic ice caps have reduced from nearly 3 million square miles to less than 2 million square miles. Further ice melts could raise sea levels to dangerous degrees leading to coastal submergence and displacements. In addition to this, Himalayan glaciers have lost 21-30% of their cover in the last 40 years (CSE).

## Climate-related disasters

Average number of climate-related disasters such as droughts, floods, cyclones and heat waves etc. has tripled since 1980 from an average of 218 to 700 in 2016. Researchers have observed that warming of 0.85 degree Celsius in the present day is responsible for 75% of daily heat extremes and 18% of precipitation extremes. If global temperature rises by 2 degree Celsius, 40 percent of rainfall extremes would then be a result of anthropogenic climate disruptions.

## Impact on Biosphere

47 percent of species are reported to have gone extinct due to human-induced climate change and many have come under stress.

Rising temperatures have caused a reduction in plant and animal populations, distress migrations, coral bleaching and die-offs.

### Self-reinforcing

Increasing temperatures have caused an increase in demand for cooling appliances refrigerants, air conditioners etc. Energy use for cooling is predicted to witness a 90% jump on 2017 levels which is likely to reinforce global warming by raising CO<sub>2</sub> concentrations in the atmosphere by nearly 2.5 Gt by 2050.

### On civilization

A renowned epidemiologist, McMichael in his book Climate Change and health of nations observes that novel infectious disease could appear in future due to cross-species microbial traffic in response to climate change. He cites Kawasaki disease occurring in Japan as an example and states that change in wind patterns could widen the geographical range of the disease affecting greater number of people in near future, thus threatening human civilization. One may note here that collapse of Mesopotamian and Harappan Civilizations is also often associated with climate change.

### Impact on India Climate

- Warming of Tibetan plateau is associated with the instability of western winds resulting in variability in western Disturbances. This changes the pattern of winter rainfall witnessed in northern and north-western India.
- The Indian Ocean is showing signs of large warming as compared to suppressed warming of the Indian subcontinental landmass. This will result in weakening of summer monsoons.

• By 2100, the temperature in tropics might rise by more than 4 degree Celsius.

• IMD study shows a rise of about 1 degree Celsius in mean temperatures in the Himalayan cold arid zone since 1950.

### Agriculture and Food security

• Temperature rise beyond the biological limit for food crops could spell agrarian crisis and jeopardize food security in the country.

• Declining yield: By 2030, a 10 percent drop in rice yield is expected in South Asia. By 2050, this will impact wheat and maize

• Fish catch is expected to reduce by 60 percent owing to habitat destruction and fish migrations

### Economy

• Agriculture is the mainstay of economy employing nearly 50% of the population, the country's economy will come under stress due to climate change. The Economic Survey points out that climate change could cause a 25% drop in agricultural incomes in the next 7 decades.

• Fiscals will come under stress due to rising spate of disasters and disease burden.

### Others

• The rise in water stress

• Resource conflicts

• Displacements

• Impoverishment

## What is Global Warming?

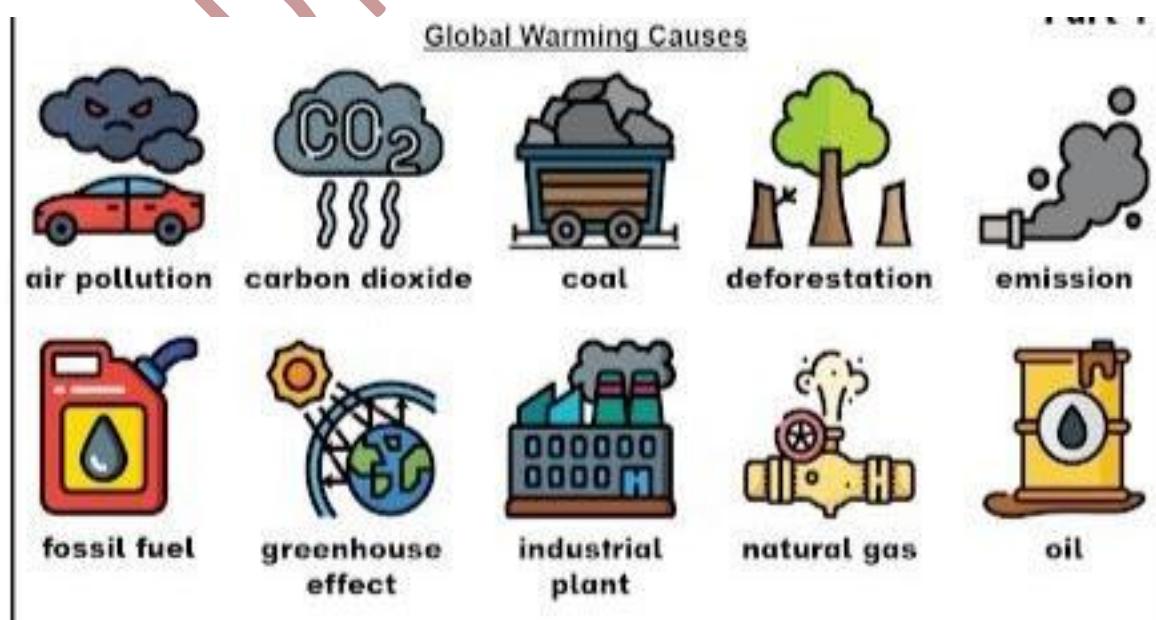
Global warming is the phenomenon of gradual increase in temperature near the Earth's surface. This phenomenon has been observed over the past one or two centuries. This change has disturbed the climatic pattern of the earth. However, the concept of global warming is quite controversial. But, the scientists have provided relevant data in support of the fact that the temperature of the Earth is rising constantly.



There are several causes of global warming which have a negative effect on human, plant and animal lives. These causes may be natural or might be the outcome of human activities. In order to curb the issues, it is very important to understand the negatives of global warming.

### Causes of Global Warming

Following are the major causes of global warming: Man-made Causes of Global Warming



## Deforestation

Plants are the main source of oxygen. They take in carbon dioxide and release oxygen thereby maintaining environmental balance. The forests are being depleted for many domestic and commercial purposes. This has led to an environmental imbalance thereby giving rise to global warming

## . Use of Vehicles

The use of vehicles even for very short distances results into various gaseous emissions. Vehicles burn fossil fuels which emit a large amount of carbon dioxide and other toxins into the atmosphere resulting in a temperature increase

## Chlorofluorocarbon

With the excessive use of air conditioners and refrigerators, humans have been adding CFCs into the environment which affects the atmospheric ozone layer. The ozone layer protects the earth surface from the harmful ultraviolet rays emitted by the sun. The CFCs has led to ozone layer depletion making way for the ultraviolet rays, thereby increasing the temperature of the earth.

## Industrial Development

With the advent of industrialization, the temperature of the earth has been increasing rapidly. The harmful emissions from the factories add to the increasing temperature of the earth. In 2013, the Intergovernmental Panel for Climate Change reported that the increase in the global temperature between 1880 and 2012 has been 0.9 degrees Celcius. The increase is 1.1 degrees Celcius when compared to the preindustrial mean temperature.

## Agriculture

Various farming activities produce carbon dioxide and methane gas. These add to the greenhouse gases in the atmosphere and increase the temperature of the earth.

## Overpopulation

Increase in population means more people breathing. This leads to an increase in the level of carbon dioxide, the primary gas causing global warming, in the atmosphere

## Natural Causes of Global Warming

### Volcanoes

Volcanoes are one of the largest natural contributors to global warming. The ash and smoke emitted during volcanic eruptions goes out into the atmosphere and affects the climate.

### Water Vapour

Water vapour is a kind of greenhouse gas. Due to the increase in earth's temperature more water gets evaporated from the water bodies and stays in the atmosphere adding to global warming.

### Melting Permafrost

Permafrost is there where glaciers are present. It is a frozen soil that has environmental gases trapped in it for several years. As the permafrost melts, it releases the gases back into the atmosphere increasing the earth's temperature.

### Forest Blazes

Forest blazes or forest fires emit a large amount of carbon-containing smoke. These gases are released into the atmosphere and increase the earth's temperature resulting in global warming

## Effects of Global Warming

Following are the major effects of global warming:

### Rise in Temperature

Global warming has led to an incredible increase in earth's temperature. Since 1880, the earth's temperature has increased by 1.4 degrees. This has resulted in an increase in melting of glaciers which have led to an increase in the sea levels. This could have devastating effects on coastal regions.

### Threat to the Ecosystem

Global warming has affected the coral reefs that can lead to a loss of plant and animal lives. Increase in global temperatures has made the fragility of coral reefs even worse.

### Climate Change

Global warming has led to a change in climatic conditions. There are droughts at some places and floods at some. This climatic imbalance is the result of global warming

### Spread of Diseases

Global warming leads to a change in the patterns of heat and humidity. This has led to the movement of mosquitoes that carry and spread diseases.

### Decrease in the Human Population

Due to an increase in floods, tsunamis and other natural calamities, the population of humans tend to decrease. Also, the spread of diseases leads to a decrease in the human population.

## Loss of Natural Habitat

A global shift in the climate leads to the loss of habitats of several plants and animals. In this case, the animals need to migrate from their natural and many of them even get extinct. This is yet another major impact of global warming on biodiversity

