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Research Paper

Climate Change: History, Causes, Evidences, Impacts and Adaptation Measures

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***Abstract**: Climate change refers to the long-term shifts in temperatures and weather patterns. A report, "Climate India 2024: An assessment of extreme weather events," demonstratesthedevastatingeffects of climate change.It reveals that India faced extreme weather events on 322 days in the last year (2024) alone, surpassing the records of previous years. The year 2024 was marked by extreme events of heat, forest fires, cold waves, cyclones, lightning, heavy rain, floods, and landslides, resulting in large-scale death and destruction. The presentpaper examines the natural and anthropogenic causes andevidence of climate change.It tries to visualize the possibleeffects of global climate change on mankind. It also highlights the different methods of mitigationin addressing climate change.*
***Key words**: Climate change, Cyclones, Forest fires, Anthropogenic causes*

I. INTRODUCTION:

Climate change refers to long-term shifts in temperatures and weather patterns. Such shifts can be natural, due to changes in the sun's activity or large volcanic eruptions. But since the 1800s, human activities have been the main driver of climate change, primarily due to the burning of fossil fuels like coal, oil, and gas**.** It is one of the most pressing global challenges faced by mankind in recent times. Though it is a natural phenomenon, but has been aggravated due to anthropogenic causes like increased production of trace gases, burning of fossil fuels and has resulted in severe implications for food production, water supply, natural ecosystem, health, air quality etc. At global level it has led to rising global sea level, increase in global temperature and melting of ice. Since India has a vast geography that supports large population which is dependent on activities associated with climate like agriculture, forestry thus to tackle with climate change and to make people and infrastructure adaptable with changing environment Indian government needs to take prompt short term and long-term measures. Taking into consideration the criticality of climate changes the paper discusses elaborately the impact, evidence, causes and measures to adapt with climate change.

The objective of this research is to assess several natural causes of climate change and to view how they have impacted the earth's atmosphere over the years and how climate change has intensified after industrial revolution. The various implications of climate at global, regional and local levels are discussed. Furthermore, the paper aims to assess mitigation and adaptation strategies employed by various nations and international organisations to address climate change.

Research methodology: This research paper uses secondary data to analyse the impact, causes and evidences of climate change. The study relies on data obtained from sources like International organizations such as the Intergovernmental Panel on Climate Change (IPCC), World Bank, and United Nations Framework Convention on Climate Change (UNFCCC), Reports like "Global Climate Highlights 2024- Copernicus", "State of the Global Climate 2024-WMO", "Emissions Gap Report 2024- UNEP" etc, Climate databases, academic publications and government reports and policy documents.

Structure of paper:
The paper is divided into following sections-
A. History of climate change discoveries
B. Causes of climate change
C. Evidences of climate change
D. Impacts
E. Adaptation and Mitigation measures

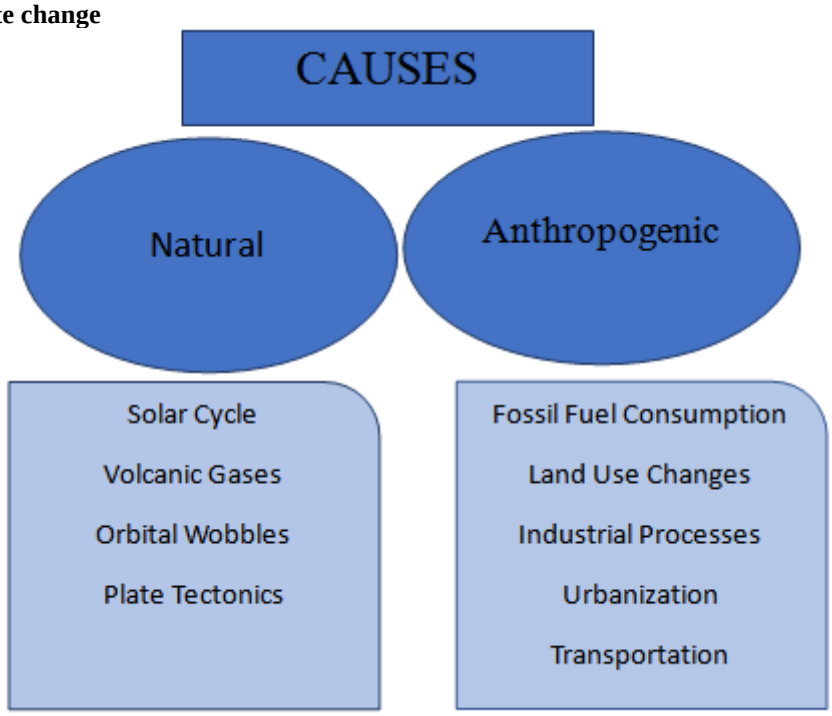
History of climate change Discoveries:

Dating back to ancient times many people have proposed that Humans could change temperatures and influence rainfall. In 1820s, French mathematician Joseph Fourier proposed greenhouse effect which was further worked on by Eunice Newton Foote, John Tyndall. Their studies suggested that global temperature would increase by 5 degrees C.

Dr. Charles keeling provided first evidence that carbon dioxide levels are increasing. Using computer model of planet earth's climate scientists predicted doubling concentration of carbon dioxide could raise global temperature by 2-degree C. After predictions of melting ice cap, ozone hole discovery in 1988 the Intergovernmental Panel on Climate Change(IPCC) started a new era of climate research.

Timeline of Climate Change Discoveries

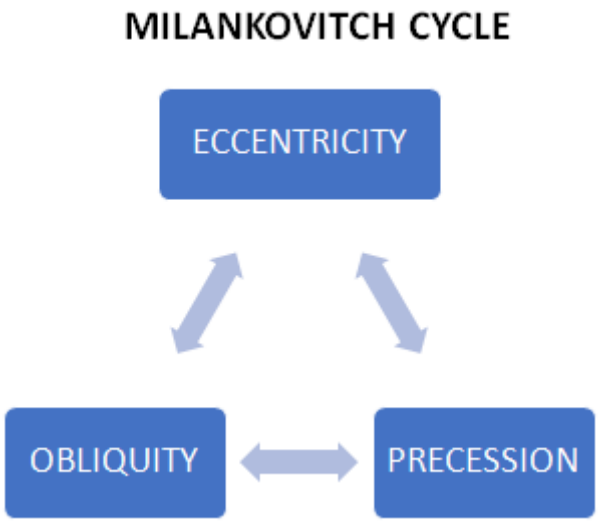
Causes of climate change



Sun Cycle: The Sun doesn't always shine at same level of brightness, it brightens and dims slightly, taking 11 years to complete one solar cycle during which sun undergoes various changes. From solar minimum to solar maximum (e.g. - 1996 to 2001) global temperature increase 0.18 degrees C due to an increase in the Total Solar Irradiance. Conversely. From solar maximum to minimum (e.g. - 2001 to 2007), the reducedforcing from the sun cools global temperature by 0.18 degree Thus, it can be concluded that solar cycle does impact the atmosphere of earth but the change it brings is not phenomenal to cause climate change.

Volcanic Gases: During volcanic eruption huge amount of volcanic gas, aerosol droplets, and ash are injected into the atmosphere. Volcanic gases like sulphur dioxide can cause global cooling while gases like Carbon dioxide has potential to promote global warming. There's no debate that the Tobas Super Volcanic eruption 74000 years ago is Earth's largest known explosive eruption. The 1815 Tambora eruption, one of the most destructive eruptions in known geological history, was 1/12 the size. the Toba catastrophe theory is that ash from the eruption caused a volcanic winter of almost a decade and initiated a 1000 year long cooling period across the planet.

Orbital Wobbles:Orbital wobble refers to the slow, gradual shift in the direction of a planet's axis of rotation. A century ago, Serbian scientist Milankovitch hypothesized that changes in Earth's position relative to the Sun are a strongdriver of Earth's long-term climate.

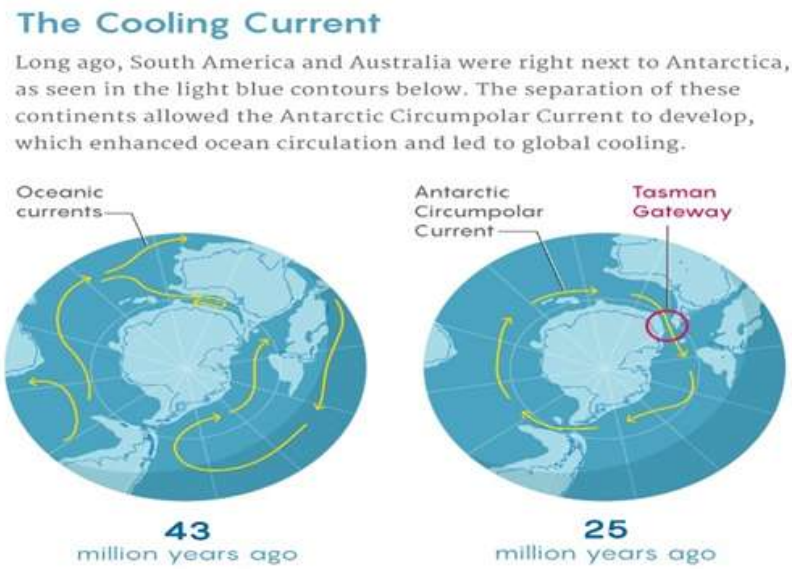


Eccentricity reference to departure of shape of Earth's orbit from a perfect circle to elliptical forming perihelion (when earth is closest to sun) and aphelion (when earth is farthest from sun). Changes in eccentricity due to pull of gravity from Jupiter and Saturn, brings change in global annual insolation but the total change is very small since variation in eccentricity are small.

The tilt in angle of earth's axis of rotation is known as obliquity. The angle varies by some degree over certain years. The greater Earth's axial tilt angle, the more extreme our seasons are.

Axial precession is the slow, gradual change in the orientation of Earth's axis over time. The cycle of axial precession spans about 25,771.5 years.

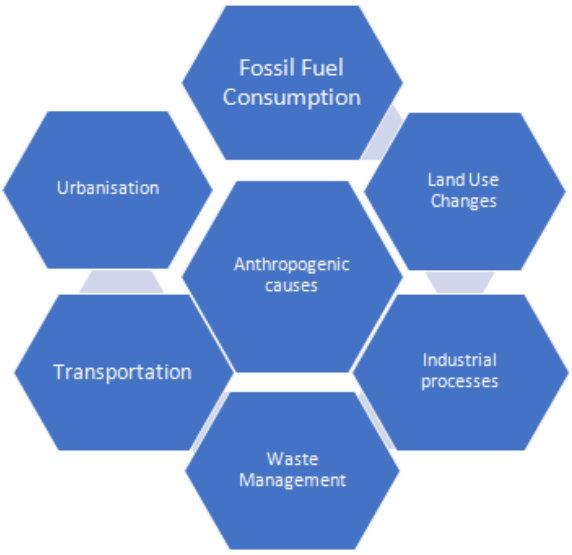
Plate Tectonics: Plate tectonic refers to dynamic movement of large plates that constitute the earth's lithosphere. They have brought roughly 30 degrees Celsius change in temperature over the past 500 million years.



Samuel Velasco/Quanta Magazine; source: doi.org/10.1016/j.palaeo.2005.07.033

There is no doubt that certain natural phenomenon has their impact on Earth's climate but they are not drivers of Climatic Change that we are witnessing now. So, the major causes that have led to changes or variation in the climate are human activities.

Anthropogenic factors causing Climate Change



Evidences of Climate Change

There is unequivocal evidence that Earth is warming at an unprecedented rate. Human activity is the principal cause says NASA

Various evidences of changing climate

1. Rising Global Temperature
2. Coastal glaciers are retreating
3. Mountain glaciers are disappearing
4. Ocean is getting warmer
5. Sea ice is shrinking
6. Sea level is rising
7. Extreme events

Global temperature is rising: Due to large emission of carbon dioxide into the atmosphere and other human activities, the global temperature has risen about 1°C from pre-industrial levels. The warmest year on record is 2024. It has been confirmed by the World Meteorological Organization (WMO).

Concentration of various gases in atmosphere

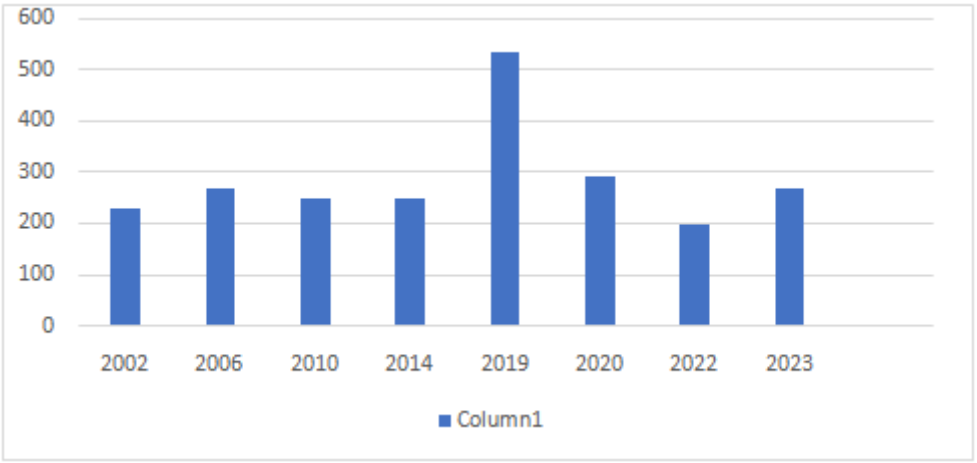
Greenhouse Gas	Pre 1750 Tropospheric concentration	Recent Tropospheric concentration	Change in Tropospheric Concentration
Carbon dioxide	280ppm	400ppm	40%
Methane	700ppb	1874ppb	168%
Nitrous oxide	270ppb	324ppb	20%
chlorofluorocarbon	0	21-529ppb	NA

The ocean is getting warmer: Oceanacts as a heat sinkthe excess heat present in the atmosphere driven by rising greenhouse gases is trapped by ocean water due to its high heat capacity. The top 100m of ocean showing warming of 0.33°C since 1969.

Shrinking ice sheets: Data from NASA's Gravity Recovery and Climate Experiment show Greenland lost an average of 279 billion tons of ice per year between 1993 and 2019.

The table above indicates the ice sheet mass loss in Greenland, the highest loss mass of up to 532 Gigatons is recorded in 2019.

Greenland Ice Sheet Mass Loss by years

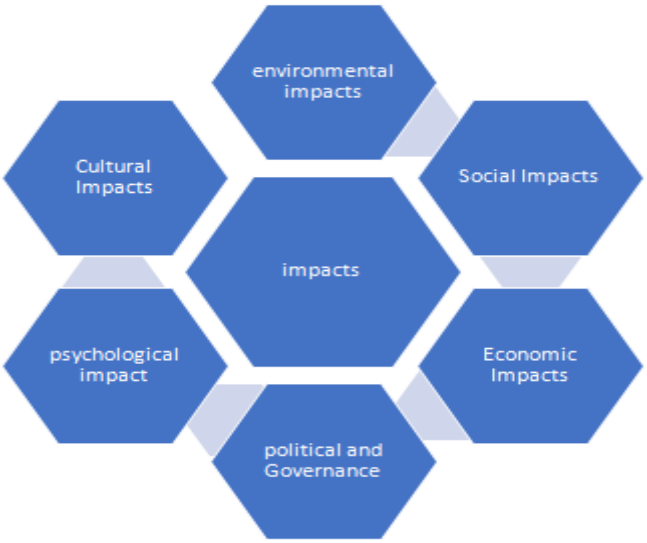


Glaciers are retreating almost everywhere around the world.

Extreme Events are increasing in frequency: flooding in Tanzania, a heatwave in Saudi Arabia, wildfires in Chile, landslide in India

Sea level is rising: Global sea level rose about 8 inches in the last century says NASA.
Ocean acidification is increasing: since the beginning of industrial revolution acidity of surface ocean water has increased by about 30%, NASA.

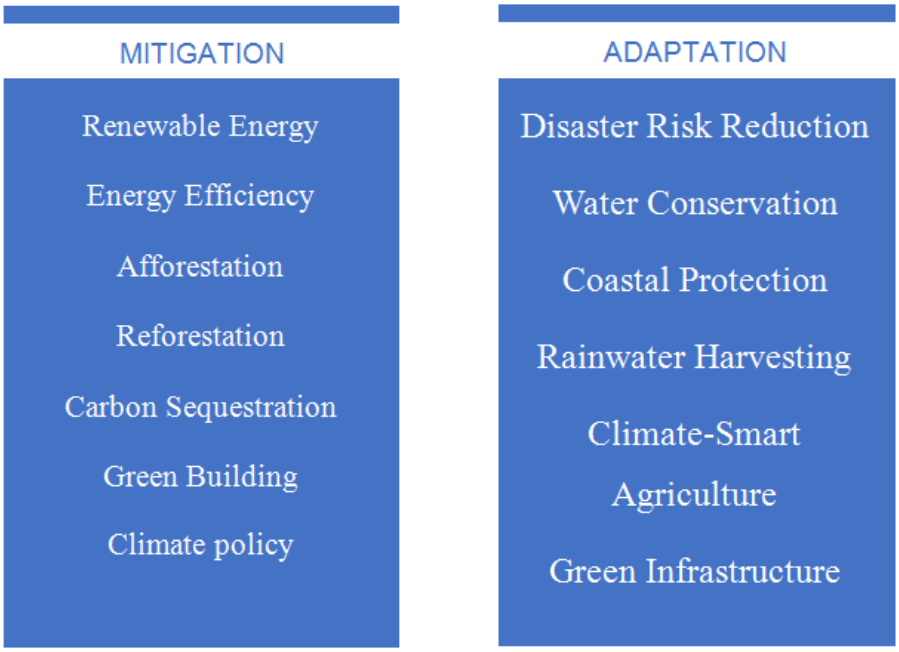
Multidimensional Impacts of Climate Change



Environmental impacts of climate change: Rising temperatures, increased sea level, Extreme weather events, shrinking ice sheets etc are profound environmental impacts of changing climate.
Economic impacts: Due to change in climate, the rainfall patterns are also changing and the temperature is rising as a result crop yield is impacted which in turn rises concern regarding food security. Heavy rainfalls can lead to more soil erosion, which is a major environmental threat to sustainable crop production. Apart from this disaster like flooding, storm, heat stress led to infrastructure damage.
E.g. 2023 Flash flood in Himachal Pradesh damaged roads and railway including National Highway 5, collapsed bridges and disrupted communication network as per Sphere India Situation Report.
Social impact: Calamities caused due to Climate Change result in large number of Migration and Displacement.
e.g. The gradual submergence of low-lying islands such as Ghoramara, Lohachara (now fully submerged) and Parts of Sagar Island in west Bengal has forced thousands to migrate inland, says UNDP India Report.
Scarcity of resources like water, arable land caused due to changing climate can intensify conflicts.
Political and governance impacts: Climate change has now become a key issue in diplomacy, trade and global cooperation amongst which Paris Agreement is a landmark international climate treaty to reduce emission of greenhouse gases. The treaty emphasized on differentiate but common responsibility. India has also taken active role in climate diplomacy since its large population is dependent on climate related activities the most significant amongst which is international solar alliance founded by India and France.
Psychological impacts: climate related disasters have created havoc in past leading many to migrate and displace from their origin place and this has become major cause of anxiety, depression and trauma among the victims.
Cultural impacts: Climate change doesn't just affect the environment and the economy. It also deeply influences culture, tradition and identities
e.g. Rising sea level threatened sacred groves, temples and community lands in Sundarbans. As a result of coastal erosion and changing climate world heritage sites located at coasts like Venice (Italy), Easter Island (Chile) are also at risk.

Mitigation and Adaptation Strategies

Mitigation refers to actions aimed at reducing greenhouse gas emissions to lessen the impacts of climate change, while adaptation focuses on adjusting to the unavoidable impacts of climate change that are already happening or are expected. [Wikipedia]



Nation wise Climate Policies:

INDIA: National Action Plan on Climate Change was released by Prime Minister on 30th June 2018.It outlines a national strategy that aims to enable the country to adapt to climate change and enhance the ecological sustainability of India's development path. There are eight National Missions that form the core of this action plan.

EUROPEAN UNION: European union came up with European Green Deal which aims for climate neutrality by 2050.

CHINA: China is world's largest investor in solar and wind energy. It has its National Emission Trading System launched in 2021.

SOUTH AFRICA: To shift from coal to renewables they came up with Just Energy Transition Investment Plan

Climate Change is Global issue as a result country are working not only at national level but are also collaborating at international level. Humankind has realised that it is no longer a distant threat but a present reality. The time for debate is over and the time for action is now.