**UNIT TWO**

**CLIMATE CHANGE**

**KEY TERMS:** Climate Change, Global warming, Greenhouse gases, IPCC, Carbon dioxide

* **Climate** refers to the **conditions of the atmosphere** in a certain place **over many years**.The average climate around the world is called **global climate**.
* When scientists talk about **global climate change**, they are talking about the global climate and a pattern of change that’s happening over many years.
* The **average temperature of the Earth**, which has been **increasing** for many years. This is called **global warming**.
* **Rising global temperatures lead to** other changes around the world, such as stronger **hurricanes**, **melting glaciers**,and the **loss of wildlife habitats**.
* According to the **Intergovernmental Panel on Climate Change** (IPCC), **Climate change refers** to a change in the state of the climate that can be **identified by changes** in the mean and/or the variability of its properties and that persists for an extended period, typically **decades** or **longer**.



Figure 2.2: Climate change: an integrated framework

* The atmospheric concentrations of important **green-house gases** such as **carbon dioxide** (CO2), **methane** (CH4), and **nitrous oxide** (N2O) have increased over the last few centuries.

**2.2. Trends in Global Climate Change**

**KEY TERMS**: Reducing emissions, Deforestation, Aerosols, Human activities

* **The Earth’s climate** has always **changed and evolved**. Some of these changes have been due to **natural causes**, but others can be attributed to **human activities.**
* **Human activities** such as **deforestation**, atmospheric **emissions** from **industry** and **transport**, which resulted in the storage of **gases** and **aerosols** in the atmosphere.
* **Greenhouse gases** (GHGs)trap heat and raise air temperatures near the ground.
* **The Intergovernmental Panel on Climate Change** (IPCC) pointed out in its 2001 Third Assessment Report :
* The **1990s** had been the **warmest decade worldwide**.
* **1998** the **warmest year** since instrumental records had begun in 1861.
* The report also indicated that the **twentieth century** was likely to have been **the warmest century** in the last 1,000 years.
* Most of the **warming experienced** over the past 50 years had **resulted from human activities.**
* **Global warming** has begun to **affect** the **sea level**, **snow cover**, **ice sheets and rainfall.** Shifts in regional patterns of climate marked by rising air temperatures are already affecting **watershed**s and **ecosystems** in many parts of the world.
* According to **IPCC 2001 report** the average **global surface temperature has warmed** **0.800C in the past century** and **0.600C in the past three decades**.
* **The IPCC has projected** that to rise, the **mean global temperatures will increase** from **1.40C to 5.80C** by the **end of the 21st century** (IPCC 2001).

**2.3. Natural and Human Induced Climate Change**

**KEY TERMS**: Variations in Solar Output, Climate variations, Milankovitch Theory, Composition of the atmosphere, Incoming solar radiation

* One of the great **environmental concerns** of our time is the **climate change** **now unfolding** as a result of **greenhouse gases** being added to our atmosphere.
* **Consequences of climate change include**
* Glaciers are melting,
* Sea level is rising,
* Precipitation is becoming more intense in many areas
* Global temperature is increasing each decade.
* **The primary cause of climate changes** over the last few decades is **human(anthropogenic)** activity, mainly the **burning of fossil fuels**.
* **IPCC** has produced the world’s most **comprehensive reports on climate change** for more than 25 years. It published in-depth climate assessments in **1990, 1995, 2001, 2007, 2013,** and again in **2021**.
* **IPCC 2013, Fifth Assessment Report**, states that it is extremely likely that **human influence has been the dominant cause** of the observed warming **since the mid-twentieth century**. In the report, “extremely likely” means a probability of at least **95 percent**

**I. Climate Change Caused by Natural Events**

What are the natural causes of climate change?

There are three **“external” causes of climate change**. These are changes in:

1. Incoming solar radiation;

2. The composition of the atmosphere; and

3. The Earth’s surface.

* **Natura**l phenomena can cause climate to **change by all the three mechanisms**, whereas **human activities** can change climate by the **second and third mechanisms**.
* **Internal” causes of climate change**, manifested interms of **circulation patterns of the ocean and atmosphere,** which redistribute energy within the climate system rather than altering the total amount of energy it holds.
* **If temperature changes**, many other elements may be altered as well. The **interactions** among the **atmosphere,** the **oceans**, and the **ice** are extremely complex and the number of possible interactions among these systems is enormous. **No climatic element within the system is isolated from the others**

**a). Variations in the Earth’s Orbit**:

* **A theory** ascribing climatic changes to **variations in the Earth’s orbit** is the **Milankovitch theory**(1930).
* The basic idea of **Milankovitch theory** is that, as the Earth travels through space, **three separate cyclic movements** combine to produce variations in the amount of solar energy that reaches the Earth.
* **The Milankovitch cycles** that combine to produce variations in solar radiation received at the Earth’s surface include:

1. **Eccentricity:** changes in the shape of the Earth’s orbit about the sun. Eccentricity earth encounters **more variation in the energy** that it receives from the sun when **earth’s orbit is elongated** than it does when Earth’s is more circular.
2. **Precession of the Earth’s axis of rotation, or wobbling**. A gradual change or ‘’wobble’’ in the orientation of Earth’s axis affects the relationship between Earth’s tilt and eccentricity.
3. **Changes in the tilt (obliquity)** of the Earth’s axis. The tilt of Earth’s axis varies between **22.0** and **24.50**. The greater the tilt angle is ,the more solar energy the pole receive

**Variations in Solar Output**

* Solar energy measurements made by sophisticated instruments aboard satellites show that the **sun’s energy output (called brightness)** varies slightly by a fraction of 1 percent with sunspot activity.
* **Sunspots** are **huge magnetic storms** on the sun that show up as **cooler (darker)** regions on the sun’s surface. **They occur in cycles**, with the number and size reaching a maximum approximately **every 11 years**.



* During periods of **maximum sunspots**, the **sun emits more energy** (about 0.1 percent more) contrasted to periods of sunspot minimums.

**b). Atmospheric Particles**

* Microscopic **liquid** and **solid particles** **(aerosols)** that enter the **atmosphere** from both **natural** and **human-induced** sources can have an effect on climate.

**c). Particles near the surface /the lower atmosphere**/**:** through natural means include

* Wildfires/ smoke particles/
* Dust storms sweep tons of fine particles
* Flaming volcanoes/ sulphur rich aerosols/
* The overall effect they have is to **cool the surface of the earth** by preventing sunlight from reaching the surface.

**d). Volcanic eruptions**

* **Volcanic eruptions** can have **a major impact on climate**. During volcanic eruptions, fine particles of **ash** and **dust** (as well as **gases**) can be **ejected into the atmosphere**.
* **Scientists agree** that the **volcanic eruptions** having the greatest impact on climate are those **rich in sulphur gases**.
* **Sulphur gases**, when ejected into the stratosphere, **combine with water vapour** in the presence of **sunlight** to produce tiny, reflective **sulphuric acid particles** that grow in size, forming a dense layer of **haze**.
* The **haze** may reside in the **stratosphere** for several years, **absorbing** and **reflecting** back to space a portion of the **sun’s incoming energy**.
* The **reflection of incoming sunlight** by the **haze** tends **to cool the air at Earth’s surface**

**II. Human (Anthropogenic) Induced Climate Change**

1. **Aerosols Injected into the Lower Atmosphere:**

* **The human-induced sources** include emissions from factories, autos, trucks, aircraft, power plants, home furnaces and fireplaces...etc
* Many of **the particles that reduce the amount of sunlight** reaching Earth’s surface tend to cause **a net cooling of the surface air during the day**.

**b). Land use changes**:

* All climate models predict that, as **fossil fuels** continue to spew **greenhouse gases** into the air, the climate will change and **the Earth’s surface will warm**.
* **Modification of Earth’s surface** taking place right now could potentially be **influencing the immediate climate of certain regions**. Example :
* Clearing large areas of tropical rain forests such as Amazon.
* overgrazing and excessive cultivation of grasslands in semi-arid regions
* Causing an increase in desert conditions (a process known as **desertification**).

**c). Increasing Greenhouse Gases Emission**

* **Greenhouse gases include: Carbon dioxide (CO2), Nitrous Oxide (N2O) and Methane (CH4)**
* **Carbon dioxide** is one of a greenhouse gas that **strongly absorbs infrared radiation** and **plays a major role in the warming** of the lower atmosphere.
* **CO2** has been increasing steadily in the atmosphere, **primarily due to human activities**, such as
* The burning of fossil fuels like coal, oil, and natural gas.
* Deforestation.
* The CO2 is stored in leaves, branches, and roots. When the trees are cut and burned, or left to decay, the **CO2 goes back into the atmosphere**.
* **Nitrous Oxide** (N2O) and **Methane** (CH4) are greenhouse gases that causes for climate change.
* **These three gases** are differ in how they **absorb energy** (preventing it from escaping to space) and **how long the gas stays** (life time) in the atmosphere.

For example,

* **CO2 stays for over 100 years** while, the others **two gases** last relatively for **short time**.
* **NH3 causes 21 times** as much warming as an **equivalent mass of CO2** over 100 years.
* Naturally, atmospheric **GHGs are important to maintain life on earth**. The role of **water vapour**, **Co2** and other GHGs play keeping the earth’s mean surface temperature higher than it otherwise would be.
* **If the GHGs were absent** earth’s average **atmospheric temperature would be 330C less.** These affect all ecosystems on earth.
* **The problem of GHGs effects are increasing in the amount** of those gases in the atmosphere due to human causes that resulted for deviation from the natural or normal conditions.

**Global Warming**

* The average global surface air temperature **since the late 1800s has risen by about 10C**.Moreover, the global average for **each decade since the 1980s** has been **warmer than that of the preceding decade.**
* **Signs of increasing global warmth** are the **amount of water locked in the world’s glaciers** and **ice sheets** is steadily **decreasing**, and **sea level is steadily rising**.



**2.4. Consequences of Climate Change**

**KEY TERMS:** Sea level rise, sea ice melt, Food security

* **Climate models predict** that land areas will warm more rapidly than the global average, particularly **in the northern high latitudes in winter**.
* As high-latitude regions of the Northern Hemisphere continue to warm, **modification of the land may actually enhance the warming.**
* If **warming allows the boreal forests to expand into the tundra**, the forests may accelerate the warming in that region.
* As the temperature rises, **organic matter** in the soil should **decompose at a faster rate**, **adding more CO2 to the air**, which might **accelerate the warming** even more.
* Changes in temperature will affect people in many ways such as:
* **Heat-related deaths** are expected to **increase**, although there could be some compensating **decrease in cold-related illnesses**.
* In the **lower latitude**, there are more **frequent droughts** and **unpredictable rainfall** due to global warming.

**Precipitation**

* Since the middle of the twentieth century, **precipitation** has generally **increased** over the **middle- and high-latitude** land areas of the Northern Hemisphere, while **decreasing** over **some subtropical land areas.**
* The changes in precipitation **adversely affect** by placing added **stress on agriculture**.
* **Warming temperatures** will tend to **cause soil to dry out more quickly**, exacerbating the impact of drought when it occurs.

**Sea Level Rise**

* As land-based **ice sheets** and **glaciers** retreat (melt), the **oceans** continue to expand and **get warm**.
* During the twentieth century, average global **sea level rose by about 17 cm**. From **1900** to **2010**, globally averaged **sea level rose about 19 cm**.
* **Globally averaged sea level has risen about twice as quickly since 1993**, roughly 3.4 cm per decade, as it did during the twentieth century as a whole.
* **Rising ocean levels could also have a damaging influence on coastal ecosystems**, such as **coral reefs**. In addition, **coastal groundwater supplies might become contaminated with saltwater**

**Effects on Polar Regions**

* Over **Greenland,**which is experiencing **rapid melting of ice and snow**.
* **Sea ice** has been **shrinking** and **thinning rapidly** across the **Arctic Ocean**. During the summer of 2007, and again in the summer of 2012, the extent of **Arctic sea ice dropped dramatically to new record lows.**

**Effects on ecosystems**

* Increasing levels of CO2 in a warmer world could have many other consequences.
* In some ecosystems, certain plant species could become so dominant that others are eliminated.
* **In tropical areas** **decrease crop yield**, whereas **higher latitudes might benefit** from a longer growing season and an earlier snowmelt.
* **Wildfires** may continue to become **more prevalent** during dry spells in forested **high-latitude areas**.
* **The impact of climate change** on **agriculture** and **ecosystems** may become increasingly **negative** by later in this century.

**2.5. Adaptation and Mitigation Strategies to Climate Change**

**KEY TERMS**: Adaptation, Mitigation, Strategies, Reactive, Anticipatory, Planned, Autonomous

* **The United Nations Framework Convention on Climate Change** (UNFCCC) highlights two fundamental response strategies: **mitigation** and **adaptation**.
* While **mitigation** seeks to limit climate change by **reducing the emissions of greenhouse** gases and by **enhancing ‘sink’** opportunities, **adaptation** aims to **alleviate the adverse impacts** through a **wide-range of system-specific actions**.
* **Adaptation has now emerged as an urgent policy priority**, prompting action both within and outside the climate change negotiations.( particularly after the IPCC Third Assessment Report)

**Climate Change Adaptation**

* According to IPCC, **adaptation** to climate change refers to, “**adjustments in ecological, social or economic systems** in response to actual or expected stimuli and their effects or impacts’’.
* **The most commonly identified** **adaptation strategies in Ethiopia** include soil conservation, terracing, water harvesting, crop diversification, changing crop planting date, planting trees and irrigation

**Types of Adaptation**

* Depending on its **timing**, **goal** and **motive of its implementation**, adaptation can either be **reactive or anticipatory**, **private or public**, **planned or autonomous**. Adaptations can also be **short/long term**, **localized or widespread** (IPCC 2001).

**I. Reactive or Anticipatory Adaptation**

* **Reactive adaptation** is the one that takes place **after the initial impacts** of climate change have occurred.
* **Anticipatory adaptation** takes place **before impacts become apparent**. In natural systems, there is no anticipatory adaptation.

**II.Private or Public Adaptation**

* **The distinction is based** on whether adaptation is motivated by **private** (individual) **household**s and **companies or public interest** (government).

**III.Planned or Autonomous Adaptation**

* **Planned adaptation** is consequence of **deliberate policy decision**, based on the awareness that conditions have changed or are expected to change.
* **Autonomous adaptation** involves changes that systems will undergo in response to changing climate **irrespective of any policy, plan or decision**

**Climate Change Mitigation**

* It refers **avoiding** and **reducing emission** of heat trapping **greenhouse gases** in to the atmosphere to prevent the planet from warming to more extreme temperatures.
* **Reducing source** of heat trapping GGs the **burning of fossil fuels for electricity**, heat or transport and **enhancing the sinks** (such as the **oceans, forests** and **soil**).
* Climate change **mitigation** (Forests as sinks and wind power as source of green energy)

**2.6. International Conventions and Agreements on Climate Change**

**KEY TERMS:** Toronto Conference, Kyoto Protocol, Buenos Aires Plan of Action,

Marrakesh Accords

* **The First World Climate Conference (1979)** identified climate change as an urgent world problem and issued a declaration calling on governments to anticipate and guard against potential climate hazards.
* **A World Climate Programme** was set up, directed by the World Meteorological Organization (WMO), the United Nations Environment Programme (UNEP) and the International Council of Scientific Unions (ICSU).
* **The Toronto Conference on the Changing Atmosphere (1988)** advanced public debate, when more than 340 participants from 46 countries all recommended developing a comprehensive global framework convention to protect the atmosphere.
* Following a **proposal by Malta**, the **United Nations General Assembly** addressed climate change for the first time by **adopting Resolution 43/53.** This recognized that “**climate change is a common concern of mankind, since climate is an essential condition which sustains life on earth**”.
* **The IPCC published the First Assessment Report on the state of the global climate (1990)** which had a potent effect on policy makers and on public opinion.
* **The Second World Climate Conference met in Geneva** in November, and, unlike the 1979 Climate Conference, included **minister**s as well as **scientists.**
* **The IPCC finalized its Second Assessment Report in time for COP 2 in Geneva in June 1996**.It recommended cost-effective steps, consistent with sustainable development and designed to provide “no regrets” safeguards against such risks.
* **COP 6 (2001) resumed in Bonn** in late July and reached an **outline agreement** – the so-called **Bonn Agreements** – on an **emissions trading system**, on a **Clean Development Mechanism** (CDM), on rules for accounting for **emissions reductions from carbon** “sinks” and on a compliance regime.
* **COP 7, held in Marrakesh in late 2001**. COP 7 adopted the respective decisions, the so-called Marrakesh Accords.
* **COP 8 (2002) , held in New Delhi** in November It marked a new phase of negotiations as the focus shifted to **implementation of the Marrakesh Accords** and to **Convention issues**. COP 8 adopted the Delhi Ministerial Declaration on Climate Change and **Sustainable Development** as well as the New Delhi work programme on education, training and public awareness.
* **COP 9 (2003) , held in Milan** in December, adopted decisions on **afforestation** and **reforestation** activities under the CDM.
* **COP 10 (2004) , held in Buenos Aires** in December, the predominant issue was **adapting to climate change** and one of the outcomes was the Buenos Aires programme of work on **adaptation** and **response measures**
* The **Kyoto Protocol (2005) came into force on 16 February**. The first Conference of the Parties serving as the meeting of the Parties to the Kyoto Protocol (COP/MOP 1) was held with **COP 11 in Montreal in November and December**.
* **The international agreement called the Kyoto Protocol** was adopted in 1997 and put into force in February 2005. The Protocol set **mandatory targets** for **reducing greenhouse gas emissions** in countries that adopt the plan.
* The overall goal of **Kyoto Protocol** was to reduce greenhouse gas emissions in developed countries by **at least 5 percent** below existing 1990 levels during the five-year period of 2008 through 2012.
* **The** **United States** did not ratify the **Kyoto Protocol**, and many developing nations such as **China** were not required to carry out emission reductions.
* The Kyoto Protocol has been followed by **the Paris Agreement**, which was introduced in **2015** and adopted by virtually every one of the world’s nations.In mid-2017, the United States announced its intention to **withdraw from the Paris Agreement.**
* **The cutting down on the emissions of greenhouse gases** and pollutants has several potentially **positive benefits**. These are, it:
* Could slow down the enhancement of Earth’s greenhouse effect,
* Reduce global warming,
* Reduce acid rain,
* Diminish haze,
* Slow the production of photochemical smog, and
* Produce significant health benefits.
* **To fight climate change**, we must first **reduce our greenhouse gases** (GHG) emissions. to accomplish this, the first step is to **embrace renewable energy** that are naturally replenished on a human timescale, such as **sunlight, wind, rain, tides, waves, and geothermal heat**, and avoid creating energy by the burning of fossil fuels

**2.7. Pillars of Climate Resilient Green Economy of Ethiopia**

**KEY TERMS**: Climate resilient, Green Economy, Carbon stocks, Energy-efficient technologies

* **Ethiopia’s plan** is to follow a green growth path that fosters development and sustainability. The **Climate Resilient Green Economy** (CRGE) strategy follows a sectoral approach.
* Ethiopia’s green economy plan is based on **four pillars discussed**:

1. **Improving crop and livestock production practices for higher farmer income and food security while reducing emissions**:

* This pillar recognizes that **agriculture will remain a core sector of the economy** that provides employment to the majority of the Ethiopian population.
* Prioritizes initiatives that **limit soil-based emissions from agriculture** and **limits pressure on forests** by limiting expansion of land under cultivation.
* Prioritizes initiatives that increase the resource efficiency and productivity of the **livestock sector.**

1. **Protecting and re-establishing forests for their economic and ecosystem services including carbon stocks**:

* Prioritized strategies to **reduce** demand for fuel wood, and **increase** afforestation, reforestation, and forest management **to increase** **carbon sequestration in forests** and **woodlands** as well as the promotion of area closure, which would result in increased storage of carbon in Ethiopian forests.

1. **Expanding electricity generation from renewable sources of energy for domestic and regional markets**:

* This pillar recognizes **electricity as a fundamental enabler of modern economic development** for powering cities, fuelling industrial activity and pumping irrigation water for agriculture.
* Its plan is to exploit its **vast potential** for hydro, geothermal, solar and wind power – all of which would deliver electricity at virtually **zero GHG emissions**.
* a possibility of exporting its clean energy to neighboring countries.

1. **Leapfrogging to modern and energy-efficient technologies in transport, industrial**

**sectors and buildings:**

* This pillar **recognizes the opportunity to gear development of key sectors** including transport, and industrial sub-sectors like cement, textile, leather and fertilizer industries, to contribute to the sustainable development pathway.
* The strategy **introduces initiatives** that include introduction of **stricter fuel efficiency standards**, construction of an **electric rail network** powered by renewable energy, **improvement of modern transport**.

**REVIEW QUESTIONS**

**I. Multiple Choice Questions**

Choose the correct answer from the given alternatives.

1. Which of the following is important greenhouse gas?

A. Carbon dioxide (CO2) B. Methane (CH4), C. Nitrousoxide (N2O) D. All

2. According to the Third Assessment Report of IPCC which decade had been the warmest decade worldwide?

A.1990s B.1950s C. 1920s D.1970s

3. What is a feasible method to reduce the release of the greenhouse gases without decreasing the production of these gases?

A. Mitigation B. Adaptation C. Resilience D. Exposure

4. The type of adaptation that takes place after the initial impacts of climate change has occurred is:

A. Anticipatory B. Reactive C. Planned D. Autonomous

5. Which of the following country had an intention to withdraw from the Paris Agreement in mid-2017:

A. United States of America B. Russia C. China D. France

**II. Short Answer Questions**

1. What is the state of today’s average global temperature compared with the average temperature during most of the past 1000 years?

2. Describe the Milankovitch theory of climatic change by explaining how each of the three cycles alters the amount of solar energy reaching the Earth.

3. Do volcanic eruptions rich in sulfur tend to warm or cool the Earth’s surface? Explain.

4. Explain how variations in the sun’s energy output might influence global climate.

5. How could Climate models predict that increasing levels of CO2 will cause the mean global surface temperature to rise?