ESM 803: Climate Change Impacts and Adaptation in the Pacific

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ESM 803: Final Exam - Solution

Section A – Short Answers -Solution

A-1 Carbon sequestration

Carbon sequestration secures carbon dioxide to prevent it from entering the Earth's atmosphere. Besides, the idea is to stabilize carbon in solid and dissolved forms so that it doesn't cause the atmosphere to warm. The process shows tremendous promise for reducing the human "carbon footprint."

Two important facts:

- ✓ To achieve the global warming targets set by the Paris climate change conference it may be necessary to actively remove and store greenhouse gas currently in the atmosphere.
- ✓ The capture and storage of carbon will be key to reducing future greenhouse gas emissions.

A-2 UNFCCC

The UNFCCC - United Nations Framework Convention on Climate Change - The ultimate objective of this convention and any related legal instruments that the Conference of the Parties may adopt is to achieve, in accordance with the relevant provisions of the Convention, stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.

Two important facts:

- ✓ The Parties should protect the climate system for the benefit of present and future generations of humankind, on the basis of equity and in accordance with their common but differentiated responsibilities and respective capabilities. Accordingly, the developed country Parties should take the lead in combating climate change and the adverse effects thereof.
- ✓ The Parties have a right to, and should, promote sustainable development. Policies and measures to protect the climate system against human-induced change should be appropriate for the specific conditions of each Party and should be integrated with national development programmes, considering that economic development is essential for adopting measures to address climate change.

A-3 Milankovitch cycles

Milankovitch cycles include the shape of Earth's orbit **(its eccentricity)**, the angle that Earth's axis is tilted with respect to Earth's orbital plane **(its obliquity**), and the direction that Earth's spin axis is pointed **(its precession)**.

Two important facts:

- ✓ Milankovitch cycles operate on long time scales, ranging from tens of thousands to hundreds of thousands of years.

- ✓ Milankovitch cycles are just one factor that may contribute to climate change, both past and present

As a result, the extent of ice sheets, for example, affects how much of the Sun's incoming energy is reflected back to space, and in turn, Earth's temperature.

A-4 Keeling Curve

Basically, Charles David Keeling of Scripps Institution of Oceanography was the leading authority in establishing the global atmospheric carbon dioxide (CO_2) record. Initially, in 1958, Keeling began measuring atmospheric CO2 con-centrations from Hawaii's Mauna Loa Observatory. Using rigorous analytical procedures, he revealed new information about natural and man-caused carbon trends. The precision, accuracy and continuity of Keeling's research over the span of decades provided one of the most important scientific linkages between fossil fuel combustion and global climate change due to the greenhouse effect.

Two important facts:

- ✓ **The Keeling Curve serves** as a link between modern CO_2 concentrations and those of the past
- ✓ **The Keeling Curve was** among the earliest charts showing that carbon dioxide levels in Earth's atmosphere were on a steady uptick.

A-5 'Urban Heat Island'

An urban heat island occurs when a city experiences much warmer temperatures than nearby rural areas. In addition, the difference in temperature between urban and less-developed rural areas has to do with how well the surfaces in each environment absorb and hold heat.

Two important facts:

- ✓ Urban heat islands are one of the easiest ways to see how human impact can change our planet.
- ✓ Scientists can use this information to track hotspots in cities across the planet. NASA scientists, with their global satellite views, are working to understand urban heat islands and help urban planners to build more energy efficient, cooler and safer cities.

A-6 Carbon Trading

Carbon trading is a market-based system aimed at reducing greenhouse gases that contribute to global warming, particularly carbon dioxide emitted by burning fossil fuels. Particularly, carbon trading is the process of buying and selling permits and credits that allow the permit holder to emit carbon dioxide. Alternatively, of greater significance have been the so-called **cap** and **trade schemes**, at regional, national and international levels. They work by setting an overall limit or cap on the amount of emissions that are allowed from significant sources of carbon, including the power industry, automotive and air travel.

Two important facts:

- ✓ Clearly, it has been a central pillar of the EU's efforts to slow climate change.
- ✓ Cap and trade schemes have been very effective in tackling environmental problems in the past, with trading in sulphur dioxide permits helping to limit acid rain in the US.

A-7 The Koppen Climate Classification System

The Koppen climate classification system is a widely-utilized vegetation-based climate classification system that was created by the German botanist and climatologist Wladimir Koppen. The Koppen climate classification system is an attempt to come up with a formula to delineate climatic boundaries in correspondence with vegetation zones or biomes across the globe.

Two important facts:

- ✓ The Koppen climate classification system, sometimes called the Koppen-Geiger climate classification system, is a terrestrial classification of climactic zones into five major types, which Koppen represented through the letters A, B, C, D, and E.
- ✓ The present system of Koppen climate classification is based on the classification of climactic zones as based on both precipitation and temperature along with the corresponding vegetation. Temperature defines all the climactic zones except for B, as the determining factor for vegetation here is dryness, which can be categorized under precipitation

The five major climactic zones defined by Koppen;

A – Tropical Moist Climates (average temperature above 18oC in all months)
B – Dry Climates (deficient precipitation for most of the year)
C – Moist Mid-Latitude Climates with Mild Winters
D – Moist Mid-Latitude Climates with Cold Winters
E – Polar Climates (extremely cold summers and winters)

A-8 Dendrochronology

Dendrochronology is the science that deals with the dating and study of the annual growth increments, or tree rings, in woody trees and shrubs.

Two important facts:

Dendrochronology Defining Principles

- ✓ *Limiting factors* - that certain weather and climate conditions have an effect on the tree ring growth in any given year or season.
- ✓ *Ecological amplitude* - Certain tree species will only grow in certain areas. Some like wet, salty soil and others prefer dry, acidic soil; there are preferences for temperature, humidity and most have an elevation limit. The best records are those taken from the margins of the land that the species prefer because it is here we see the most variations in tree ring growth.

A-9 Ocean acidification

Particularly, ocean acidification is sometimes called "climate change's equally evil twin," and for good reason: it's a significant and harmful consequence of excess carbon dioxide in the atmosphere that we don't see or feel because its effects are happening underwater.

Two important facts:

- ✓ Ocean acidification is a global issue, caused by the build-up of carbon dioxide in the atmosphere, that affects marine ecosystems broadly.
- ✓ The primary direct impacts of concern are damage to shellfish, reef-building corals, some plankton, and impacts on other marine species such as tuna.

Ocean acidification could also impact industries and economies via losses in tourism, food security, livelihoods, aquaculture (jobs), and increased hazard vulnerability due to reduced shoreline protection from coral reefs.

A-10 Climate and weather

The term weather refers to short-term activity in the atmosphere, such as rainfall, storms, humidity and wind. Climate, on the other hand, is the average weather in a large area over a long period of time 30 years or more.

Two important facts:

- ✓ Climate scientists measure an area's temperature and precipitation over time to describe its climate.
- ✓ Weather is a specific event like a rainstorm or hot day that happens over a few hours, days or weeks.

Climate is what you expect, weather is what you get.

Section B – Solution

B-1 Common but differentiated responsibilities

Using examples, explain what the above statement means:

Common but differentiated responsibilities (CBDR), is the principle of international environmental law establishing that all states are responsible for addressing global environmental destruction yet not equally responsible.

For instance, **the principle**: "In view of the different contributions in global environmental degradation. States have common but differentiated responsibilities. The developed countries acknowledge the responsibility that they bear in the international pursuit of Sustainable Development in view pressures their societies place on the global environment and of the technologies and financial resources they command."

Explain the significance of the Kyoto Protocol in this matter:

Common but Differentiated Responsibilities and Respective Capabilities (CBDR–RC) is a principle within the United Nations Framework Convention on Climate Change (UNFCCC) that acknowledges the different capabilities and differing responsibilities of individual countries in addressing climate change.

Basically, the Convention, the Kyoto Protocol and the Paris Agreement call for financial assistance from parties with more financial resources to those that are less endowed and more vulnerable. As a result, this recognizes that the contribution of countries to climate change and their capacity to prevent it and cope with its consequences vary enormously. However, climate finance is needed for mitigation, because large-scale investments are required to significantly reduce emissions. Thus, climate finance is equally important for adaptation, as significant financial resources are needed to adapt to the adverse effects and reduce the impacts of a changing climate.

In accordance with the principle of "common but differentiated responsibility and respective capabilities" set out in the Convention, developed country Parties are to provide financial resources to assist developing country parties in implementing the objectives of the UNFCCC. The Paris Agreement reaffirms the obligations of developed countries, while for the first time also encouraging voluntary contributions by other parties. Besides, developed country parties should also continue to take the lead in mobilizing climate finance from a wide variety of sources, instruments and channels, noting the significant role of public funds, through a variety of actions, including supporting country-driven strategies, and considering the needs and priorities of developing country parties. Such mobilization of climate finance should represent a progression beyond previous efforts.
Indeed, it is important for all governments and stakeholders to understand and assess the financial needs of developing countries, as well as to understand how these financial resources can be mobilized. Provision of resources should also aim to achieve a balance between adaptation and mitigation.

B-2 IPPC AR6 – Weather and Climate

Explain three key findings on weather and climate extremes, as reported in the IPCC AR6:

Evidently, report addresses changes in weather and climate events relevant to extreme impacts and disasters. Since, an extreme (weather or climate) event is generally defined as the occurrence of a value of a weather or climate variable above (or below) a threshold value near the upper (or lower) ends ('tails') of the range of observed values of the variable.

However, some climate extremes (e.g., droughts, floods) may be the result of an accumulation of weather or climate events that are, individually, not extreme themselves (though their accumulation is extreme). As well, weather or climate events, even if not extreme in a statistical sense, can still lead to extreme conditions or impacts, either by crossing a critical threshold in a social, ecological, or physical system, or by occurring simultaneously with other events. Hence, a weather system such as a tropical cyclone can have an extreme impact, depending on where and when it approaches landfall, even if the specific cyclone is not extreme relative to other tropical cyclones. Conversely, not all extremes necessarily lead to serious impacts.

Moreover, many weather and climate extremes are the result of natural climate variability (including phenomena such as El Niño), and natural decadal or multi-decadal variations in the climate provide the backdrop for anthropogenic climate changes. Even if there were no anthropogenic changes in climate, a wide variety of natural weather and climate extremes would still occur.

A changing climate leads to changes in the frequency, intensity, spatial extent, duration, and timing of weather and climate extremes, and can result in unprecedented extremes.

ANU Factsheet:

Certainly, the Sixth Assessment Report (AR6) comprises three Working Group contributions: Working Group I **(the physical science basis),** Working Group II **(impacts, adaptation and vulnerability)** and Working Group III **(mitigation)** and a Synthesis Report.

- *The Working Group I*: will address the most updated physical understanding of the climate system and climate change, bringing together the latest advances in climate science, and combining multiple lines of evidence from paleoclimate, observations, process understanding, global and regional climate simulations.
- *Working Group II*: will assess the impacts of climate change, from a world-wide to a regional view of ecosystems and biodiversity, and review the implications for humans and their diverse societies, cultures and settlements.
- *Working Group III*: will assess progress in limiting emissions, and the range of available mitigation options in energy and urban systems, and in sectors such as agriculture, forestry and land use, buildings, transport and industry.

B-3 The Climate system consists of five components

Five systems and discuss the interactions among them that have stabilised the global climate over time:

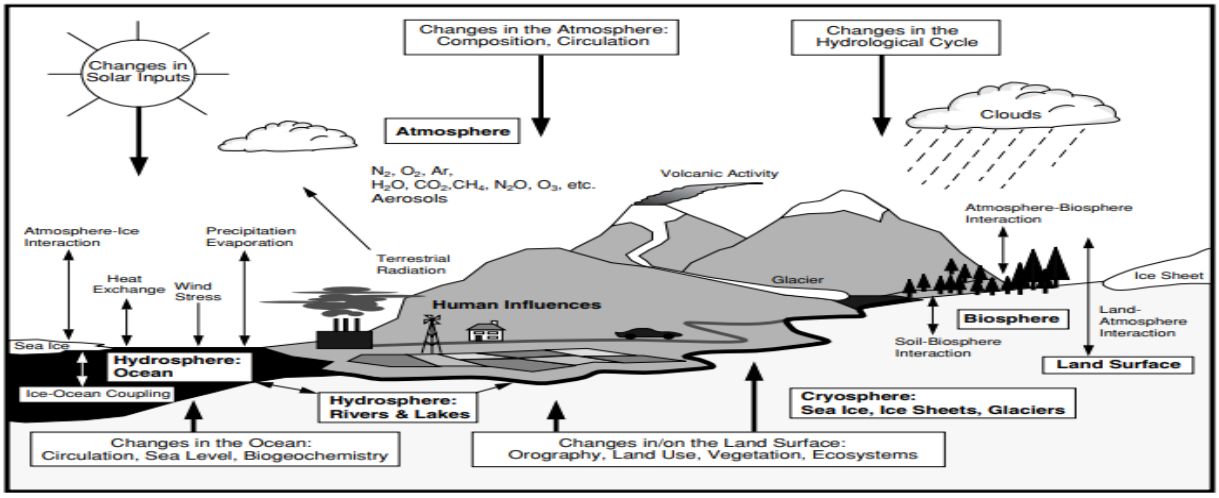
The Climate System

Its components

The climate system define as an interactive system consisting of five major components: **the atmosphere, the hydrosphere, the cryosphere, the land surface and the biosphere**, forced or influenced by various external forcing mechanisms, the most important of which is the Sun. Hence, the direct effect of human activities on the climate system is considered an external forcing.

In addition, the atmosphere is the most unstable and rapidly changing part of the system. Its composition, which has changed with the evolution of the Earth, is of central importance to the problem assessed in this Report. The Earth's dry atmosphere is composed mainly of nitrogen (N2, 78.1% volume mixing ratio), oxygen (O2, 20.9% volume mixing ratio, and argon (Ar, 0.93% volume mixing ratio). These gases have only limited interaction with the incoming solar radiation and they do not interact with the infrared radiation emitted by the Earth.

However, there are a number of trace gases, such as carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O) and ozone (O3), which do absorb and emit infrared radiation. These so-called greenhouse gases, with a total volume mixing ratio in dry air of less than 0.1% by volume, play an essential role in the Earth's energy budget.



IPCC, 1994

Moreover, atmosphere contains water vapour (H2O), which is also a natural greenhouse gas. Its volume mixing ratio is highly variable, but it is typically in the order of 1%. Because these greenhouse gases absorb the infrared radiation emitted by the Earth and emit infrared radiation up- and downward, they tend to raise the temperature near the Earth's surface. Water vapour, CO2 and O3 also absorb solar short-wave radiation.

B-5 Causes of climate change

Discuss the natural and anthropogenic causes of climate change:

Climate change is any change occurring to the planet's climate either permanently or lasting for long periods of time. It is the cumulative total of two related sources: anthropogenic climate change and natural climate change. Clearly, anthropogenic climate change is defined by the human impact on Earth's climate while natural climate change are the natural climate cycles that have been and continue to occur throughout Earth's history.

Natural Climate Change:

Earth's climate has always been driven by the amount of incoming and outgoing energy. Without the influence of humans, the Earth has natural cycles that drive the climate. The major factors contributing to Earth's natural climate change are determined by the [Axial tilt Earth's orbit around the sun], the output of energy from our sun, the ocean's natural cooling and warming cycles and the constant variability in volcanic activity. Another factor to consider are the glacial advances and retreats that occur throughout Earth's history.

Anthropogenic Climate Change:

Human induced climate change is directly linked to the amount of fossil fuels burned, aerosol releases and land alteration from agriculture and deforestation. The beginning of the Industrial Revolution shows a major spike in temperature levels and climate influences. The product of fossil fuel burning is the emission of a greenhouse gas: carbon dioxide which traps heat.

Explain the main GHGs, and their sources:

To bring some understandable reason to the family of GHGs, scientists speak in terms of carbon dioxide equivalent – CO2e. That approach in effect makes carbon dioxide, CO2, the prevailing "currency" of greenhouse gases and global warming.

Types of Greenhouse Gases

GHG Categories	GWP Value*	Major Sources
Carbon dioxide (CO_2)	1	Fossil fuel combustion, deforestation
Methane (CH_4)	25	Landfills, rice paddies, digestive tracts of cattle and sheep
Nitrous oxide (N_2O)	298	Fertilizer, animal waste
Hydrofluorocarbons (HFCs)	Varies (up to 14,800)	Semiconductor manufacturing and other industrial processes
Perfluorocarbons (PFCs)	Varies (up to 12,200)	Same as HFCs, plus aluminum smelting
Sulfur hexafluoride (SF_6)	22,800	Electrical transmission systems, magnesium and aluminum production

* Global warming potential

Source: U.S. Environmental Protection Agency

B-7 Sea level rise

Discuss the main causes of sea level rise and the main impacts that are being felt by these islands:

Causes & Impacts:

Sea level rise is a major consequence of climate change. Since, the global sea level rise is due to a combination of the **thermal expansion of the oceans (because of their warming), and an increase in runoff from the melting of continental glaciers (which adds water to the oceans)**.

Basically, the rate of global mean sea level (GMSL) has likely accelerated during the last century, and projections predict that sea level will be 0.4 to 0.8 m higher at the end of this century around the Pacific islands. Regional variations in sea level also exist and are due to large scale current or climate features. In addition, the sea level experienced on Pacific islands can also be affected by vertical land movements that can either increase or decrease the effects of the rise in GMSL.

Moreover, Pacific islands are extremely vulnerable to climate change. The most substantial impacts of climate change include losses of coastal infrastructure and land, more intense cyclones and droughts, failure of subsistence crops and coastal fisheries, losses of coral reefs and mangroves, and the spread of certain diseases. Climate change will affect the Pacific way of life and the sustainable development of our islands in profound ways:

- *Ice melting sea rising-as the ice caps melt, and the sea temperatures increase, the oceans expand, and sea levels rise.*
- *Extreme weather events-climate change will intensify extreme weather events, such as storms, cyclones, floods, droughts and heat waves.*
- *Water shortages Rises in sea level-rises in sea level, and storm surges will result in saltwater entering freshwater supplies (saline intrusion), which means that there will be less water available to drink and to grow plants and food.*
- *Increase in drought- droughts for a long period can have other effects such as placing forests at high risk from fires.*
- *Health issue-the changes in the climate, and the effects of climate change such as the increases in temperature, flooding, and contaminated water, will increase the level of waterborne and vector-borne diseases, such as cholera, typhoid, malaria and dengue.*
- *Production of food Tropical cyclones- this will affect diet, income generating activities for communities and economies - in essence the food security of the Pacific Islands*
- *Affecting unique Pacific- The impacts of climate change, including cyclones and changes in temperature due to drought, can lead to changes in the habitats of plants and animals.*
- *Erosion-Flooding of lowland and coastal areas, and severe coastal erosion will impact on coastal infrastructure.*

*The **impacts of climate change** will affect the sustainable development of the Pacific islands by affecting industries such as agriculture and tourism. Each year, millions of tourists visit the region for its 'Pacific paradise' image. The effects of climate change on tourism will likely include loss of beaches, degradation of the coastal ecosystems, saline intrusion and damage to critical infrastructure.*

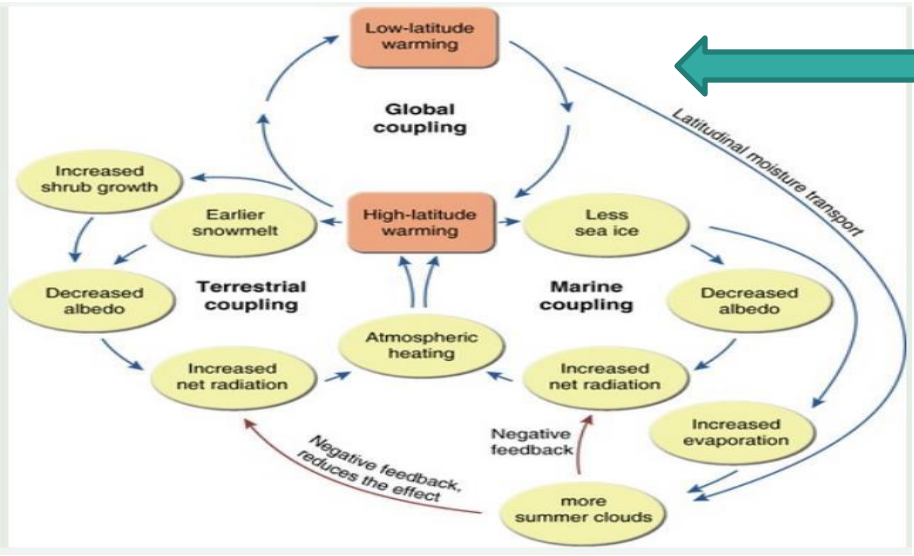
B-8 Albedo and 'positive feedback'

Discuss using diagrams what is meant by the albedo positive feedback mechanism:

Albedo is the amount of sunlight (solar radiation) reflected by a surface. When talking about albedo, the surface is almost always the surface of a planet like Earth. For a given area, albedo is determined by more than just the composition of soil, it's impacted by soil moisture, type of vegetation, and levels of urbanization. Different surfaces on the earth have different albedos and that albedo varies with time.

In addition, changes in albedo occur as the amount of cloud cover changes. Likewise, changes in any surface cover, like snow, ice, and vegetation, shift the albedo. Albedo is one of the major properties that controls how much energy is absorbed by the surface of the Earth, the cloudiness and ground cover are important factors in climate models.

Accordingly, feedback refers to the modification of a process by changes resulting from the process itself. Positive feedbacks accelerate the process, while negative feedbacks slow it down. Initially, part of the uncertainty around future climates relates to important feedbacks between different parts of the climate system: air temperatures, ice and snow albedo (reflection of the sun's rays), and clouds. Basically, an important positive feedback is the ice and snow albedo feedback. Sea ice and snow have high albedo. This means that it reflects most of the solar radiation. **Moreover, with warmer polar temperatures, the area of sea ice and snow cover decreases, exposing new expanses of ocean and land surfaces that absorb an increased amount of solar radiation.**



Positive Ice/Snow Albedo Feedback

All in all, albedo plays a central role in the climate change energy budgeting, but its generic use (from the astronomy tradition) creates problems of many kinds. Thus, albedo is one of the major properties that controls how much energy is absorbed by the surface of the Earth, the cloudiness and ground cover are important factors in climate models.

B-9 Deforestation and climate change

Explain how deforestation can lead to both a warming effect and a cooling effect for global temperatures:

Deforestation refers to the decrease in forest areas across the world that are lost for other uses such as agricultural croplands, urbanization, or mining activities. Deforestation has been an issue for decades, leading to massive loss of species and biodiversity. Earlier, deforestation greatly accelerated by human activities since 1960, deforestation has been negatively affecting natural ecosystems, biodiversity, and the climate. Studies, have indicated that deforestation happens all over the world. However, the vast majority of deforestation takes place in rainforest around the globe, mostly concentrated mainly in the tropics.

In addition, deforestation has thus many causes. Population pressures, profits, and internal social and political forces can also all push up the rate of forest loss. Generally, the removal or destruction of significant areas of forest cover has resulted in a degraded environment with reduced biodiversity. Tropical forest trees, like all green plants, take in carbon dioxide and release oxygen during photosynthesis. Plants also carry out the opposite process known as respiration in which they emit carbon dioxide, but generally in smaller amounts than they take in during photosynthesis. The surplus carbon is stored in the plant, helping it to grow. When trees are cut down and burned or allowed to rot, their stored carbon is released into the air as carbon dioxide and this is how deforestation and forest degradation contribute to warming effect.

Certainly, deforestation is a key contributor to human caused climate change. When forests are cleared or burnt, they release the carbon they store. Removing trees also diminishes an important carbon "sink" that takes up carbon dioxide from the atmosphere. Moreover, deforestation can also affect temperatures through its effect on a range of different physical processes. These effects occur at local and regional scales, but can have global repercussions. Clearly, such process is evapotranspiration, a term describing the exchange of water between the land and the atmosphere. **As part of this process, forests absorb water from the soil through their roots and later release it into the air as moisture, which has a cooling effect on the air above. When trees are cut down, this cooling effect disappears**.

In conclusion, deforestation is continuing at an alarming rate. Reducing deforestation and degradation is a highly cost-effective way of reducing Green House Gases (GHG), one that can be done immediately if the drivers of deforestation are addressed strategically and if it done right, it can also benefit biodiversity conservation and people. Therefore, reducing deforestation and forest degradation must be part of the solution to the Global Climate Solution. **For this reason, the forests of the world can still be saved. The next generation, environmentally conscious and ready to make a change, may be the final key to unlocking the preservation and protection of forests**.

B-10 IPCC Fifth Assessment Report (AR5) and the 4 RCPs

Explain what is the main subject of the IPCC AR5:

The IPCC Fifth Assessment Report (AR5) provides an overview of the state of knowledge concerning the science of climate change, emphasizing new results since the publication of the IPCC Fourth Assessment Report (AR4) in 2007.

Write down what RCP stand for:

RCP stands for **'Representative Concentration Pathway'**. To understand how our climate may change in future, we need to predict how we will behave**. For example, will we continue to burn fossil fuels at an ever-increasing rate, or will we shift towards renewable energy.** Particularly, the RCPs try to capture these future trends. They make predictions of how concentrations of greenhouse gases in the atmosphere will change in future as a result of human activities.

Discuss what the 4 RCPs are:

There are four main topics-RCP addressed on IPPC AR5;

Topic 1 - Observed Changes and their Causes:

Human influence on the climate system is clear, and recent anthropogenic emissions of greenhouse gases are the highest in history. Recent climate changes have had widespread impacts on human and natural systems.

Topic 2 - Future Climate Changes, Risks and Impacts:

Continued emission of greenhouse gases will cause further warming and long-lasting changes in all components of the climate system, increasing the likelihood of severe, pervasive and irreversible impacts for people and ecosystems. Limiting climate change would require substantial and sustained reductions in greenhouse gas emissions which, together with adaptation, can limit climate change risks.

Topic 3 - Future Pathways for Adaptation, Mitigation and Sustainable Development:

Adaptation and mitigation are complementary strategies for reducing and managing the risks of climate change. Substantial emissions reductions over the next few decades can reduce climate risks in the 21st century and beyond, increase prospects for effective adaptation, reduce the costs and challenges of mitigation in the longer term and contribute to climate-resilient pathways for sustainable development.

Topic 4 - Adaptation and Mitigation:
Many adaptation and mitigation options can help address climate change, but no single option is sufficient by itself. Effective implementation depends on policies and cooperation at all scales and can be enhanced through integrated responses that link adaptation and mitigation with other societal objectives.

Section C – Essay – Solution

C-1 Climate change is already affecting the small island developing states such as Fiji

Climate Change and the Forestry Sector

The effects of climate change and climate variability on forest ecosystems are evident around the world and further impacts are unavoidable, at least in the short to medium term. In some cases, climate change is impairing the ability of forests to deliver critical goods and ecosystem services, such as wood and non-wood products and clean water, to the detriment of the livelihoods of forest dwellers, forest-dependent communities and others. Initially, during the last decade of the 20th century, deforestation in the tropics and forest regrowth in the temperate zone and parts of the boreal zone remained the major factors responsible for emissions and removals, respectively.

Certainly, climate change poses crucial challenges but may also **create new opportunities for the forest sector**. Policy-makers and forest managers will wish to take these into consideration. They will also need to consider responses to climate change in the context of the multiple goods and ecosystem services that forests provide to meet the diverse needs of a wide range of stakeholders. In addition, it is important that climate change strategies and plans relevant to forests are integrated into a country's existing forest policy framework and other sectoral frameworks that influence forests; this can help to ensure that climate change objectives are balanced with other forest sector objectives and that trade-offs are weighed and collaborations captured.

Particularly, forests are a stabilizing force for the climate. They regulate ecosystems, protect biodiversity, play an integral part in the carbon cycle, support livelihoods, and supply goods and services that can drive sustainable growth. As a result, forests are important carbon pools which continuously exchange CO2 with the atmosphere, due to both natural processes and human action. Understanding forests' participation in the greenhouse effect requires a better understanding of the carbon cycle at the forest level.

Climate Change Impacts on forests:

Climate changes **directly and indirectly** affect the growth and productivity of forests through changes in **temperature, rainfall, weather, and other factors**. Furthermore, elevated levels of carbon dioxide have an effect on plant growth. These changes influence complex forest ecosystems in many ways. In conjunction with the projected impacts of climate change, forests face impacts from land development, suppression of natural periodic forest fires, and air pollution. Although it is difficult to separate the effects of these different factors, the combined impact is already leading to changes in our forests. As these changes are likely to continue in the decades ahead, some of the valuable goods and services provided by forests may be compromised.

Impacts on Forest Growth and Productivity

Many aspects related to climate change are likely to affect forest growth and productivity. Three examples are described below: increases in temperature, changes in precipitation, and increases in carbon dioxide (CO2).

Soil and water protection

Climate change may make the role of forests in water regulation and soil protection more important, but the capacity of forests to fulfil this role may also be affected. Reductions in rainy-season flows and increases in dry-season flows are of little value when total annual rainfall is low and significant quantities of water are lost through evapotranspiration and are consumed by forests.

Socio-economic impacts

Climate change may increase forest growth in some areas and decrease it in others. The expected global increase in wood production could lead to lower prices, which would benefit consumers. However, lower prices and regionally differentiated impacts on productivity will have varying effects on incomes and employment derived from timber (Osman-Elasha *et al*., 2009).

Vulnerabilities of forest-dependent poor

The expected increases in extreme weather events, such as heat waves, droughts and floods, and the increased risk of fire, pests and diseases will cause additional stress for large forest-dependent populations. The forest-dependent poor, who often rely directly on forests for their livelihoods and for meeting domestic needs related to energy, food and health, will be most vulnerable to these stresses.

Impacts of Disturbances

Climate change could alter the frequency and intensity of forest disturbances such as insect outbreaks, invasive species, wildfires, and storms. These disturbances can reduce forest productivity and change the distribution of tree species. In some cases, forests can recover from a disturbance. In other cases, existing species may shift their range or die out. In these cases, the new species of vegetation that colonize the area create a new type of forest.

Impacts on human health

In many parts of the world, climate change scenarios project that forest fires will be more frequent and that fire seasons will be longer. The intensity of the fires is also expected to be greater, which could have significantly harmful effects on human health.

Impact of Climate Change on Forest Sector:

Change in Supply

Yield models demonstrate that climate change can increase global timber production through location changes of forests, i.e., through a polar ward shift of the most important for forestry species. Climate change can also accelerate vegetation growth caused by a warmer climate, longer growth seasons, and elevated atmospheric CO2 concentrations. Changing timber supply will affect

the market, generally lowering prices. It will also impact supply for other uses, e.g., enhancing the potential of using various types of wood biomass energy.

Change in Demand

Climate change affects the use of wood for fuel and biomass energy could dramatically escalate in the face of rising energy prices and new technologies, particularly if incentives are created to shift away from carbon-emitting fossil fuels and toward biofuels, which are viewed as recycling the emitted carbon.

Timber Production

The future trend of fuel wood is more problematic depending in large part on the use to which wood is put to substitute for high-priced carbon-emitting fossil fuels.

Moreover, forests play many important ecological roles. From helping to mitigate climate change; providing homes for many species of plants and animals (some endemic to forested regions); providing food, medicine and livelihoods for people around the globe; to the intrinsic values of forests, these essential ecological powerhouses are irreplaceable and at risk.

All in all, forests play major roles in mitigate climate change. They contribute carbon emissions when destroyed or degraded and they suffer from changing climate, drought and extreme weather. Managed sustainably, they can provide a unique environmental service by removing excess carbon from the atmosphere, storing it in biomass, soils and products.

C-4 Adaptation to Climate change – Ecosystem-based Adaptation (EbA)

Explain what EbA means and what it involves:

Ecosystem-based adaptation is a strategy for adapting to climate change that harnesses nature-based solutions and ecosystem services. For instance, protecting coastal habitats like mangroves provides natural flood defenses; reforestation can hold back desertification and recharge groundwater supplies in times of drought; and water bodies like rivers and lakes provide natural drainage to reduce flooding. Basically, ecosystem-based adaptation (EbA), **involving** the **conservation, sustainable management and restoration of ecosystems** can help people adapt to the impacts of climate change.

Additionally, shifting weather patterns as a result of climate change, affecting rainfall and temperature, are likely to impact the ecosystem goods and services such as clean water and food on which people rely. Clearly, ecosystem-based adaptation is a nature-based solution that harnesses biodiversity and ecosystem services to reduce vulnerability and build resilience to climate change.

Three international agreements or conventions initiated at the Rio Earth summit in 1992:

The 1992 Rio Earth Summit gave rise to the three Rio Conventions:

1. **the Convention on Biological Diversity (CBD),**
2. **the United Nations Framework Convention on Climate Change (UNFCCC), and**
3. **the United Nations Convention to Combat Desertification (UNCCD).**

EbA have significantly contributed to the above mentioned conventions include: restoring coastal ecosystems to lower the energy of tropical storms and protect local communities against erosion and wave damage; wetland and floodplain management to prevent floods and to maintain water flow and water quality in the face of changing rainfall patterns; conservation and restoration of forests and natural vegetation to stabilise slopes and prevent landslides, and to regulate water flows preventing flash flooding; and, establishment of diverse agroforestry systems to help maintain crop yields under changing climates.

Certainly, key attributes of effective ecosystem-based approaches to adaptation (EbA) involves;

- ✓ *Human-centric:* EbA emphasizes human adaptive capacity or resilience in the face of climate change.
- ✓ *Harnesses the capacity of nature to support long-term human adaptation:* It involves maintaining ecosystem services by conserving, restoring or managing ecosystem structure and function, and reducing non-climate stressors. This requires an understanding of ecological complexity and how climate change will impact ecosystems and key ecosystem services.
- ✓ *Draws on and validates traditional and local knowledge:* Humans have been using nature to buffer the effects of adverse climatic conditions for millennia. Traditional knowledge about how best to do this should thus be drawn upon when implementing EbA.

- ✓ *Based on best available science*: An EbA project must explicitly address an observed or projected change in climate parameters, and as such should be based on climatic projections and relevant ecological data at suitable spatial and temporal scales.
- ✓ *Can benefit the world's poorest*: many of whom rely heavily on local natural resources for their livelihoods.
- ✓ *Community-based and incorporates human rights-based principles*: Like community-based adaptation (CBA), EbA should use participatory processes for project design and implementation.
- ✓ *Involves cross-sectoral and intergovernmental collaboration*: Ecosystem boundaries rarely coincide with those of local or national governance. Moreover, ecosystems deliver services to diverse sectors. As such, EbA requires collaboration and coordination between multiple sectors (e.g. agriculture, water, energy, transport) and stakeholders.
- ✓ *Operates at multiple geographical, social, planning and ecological scales*: EbA can be mainstreamed into government processes (e.g. national adaptation planning) or management (e.g. at the watershed level), provided that communities remain central to planning and action.
- ✓ *Integrates decentralized flexible management structures: that enable adaptive management*:
- ✓ *Minimizes trade-offs and maximizes benefits with development and conservation goals*: to avoid unintended negative social and environmental impacts.
- ✓ *Involves longer-term 'transformational' change*: to address new and unfamiliar climate change-related risks and the root causes of vulnerability, rather than simply coping with existing climate variability and 'climate-proofing' business-as-usual development.

Discuss three examples of Ecosystem-based adaptation strategies:

Alternatively, these are the various strategies of EbA to mitigate climate change in small developing nation;

- coastal defense through the maintenance and/or restoration of coastal vegetation (mangroves especially). The vegetation reduces the strength of waves before they reach the shore and therefore reduces coastal flooding and coastal erosion;
- sustainable management of wetlands and floodplains for maintenance of water flow and quality, acting as floodwater reservoirs and providing important stores of water in times of drought;
- conservation and restoration of forests and natural vegetation to stabilize slopes and regulate water flows, preventing flash flooding and landslides as rainfall levels and intensity increases;
- establishment of healthy and diverse agroforestry systems (the integration of food production into forests) to cope with changed climatic conditions.

Moreover, healthy and functional ecosystems help reduce climate change vulnerability and disaster risk by:

- Reducing physical exposure to hazards by serving as protective barriers or buffers and so mitigating hazard impacts, including in wetlands, forests and coastal ecosystems; and
- Reducing socioeconomic vulnerability to hazard impacts: In addition to protective and hazard regulatory functions of ecosystems, they also sustain human livelihoods and provide essential goods such as food, fibre, medicines and construction materials, which strengthen people's resilience to disasters.

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Finally, because of the important role of forests in mitigating the risks posed by natural hazards, these programmed aims to improve the stability and functionality of forest stand structures, foster adapted species mixtures, promote natural regeneration, prevent forest fires and/or control pests and diseases. **Thus, ecosystem-based adaptation (EbA) should be integrated into broader adaptation and development strategies to maintain and increase resilience and reduce vulnerability of ecosystems and people to adverse effects of climate change.**

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