Drishti IAS

Mains MARATHON

Important Q & A for Mains 2024

Geography and Disaster Management

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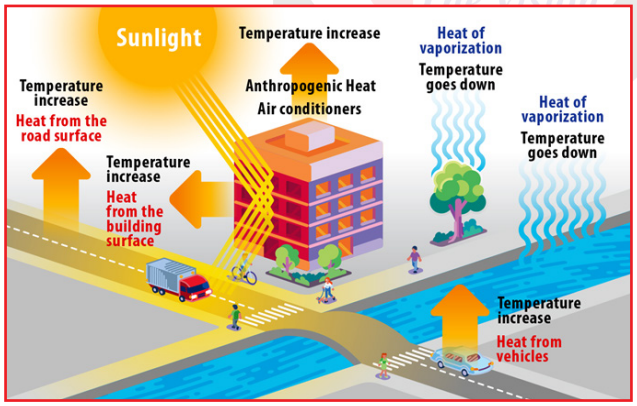
Q. What is the urban heat island effect and what are its causes and consequences? Suggest some measures to mitigate the urban heat island effect in Indian cities. (150 words)

Approach:

- **Introduction:** Briefly define Urban Heat Island and make a figure on it to make your introduction more elaborative.
- **Body:** Mention causes and consequences of Urban Heat Islands and discuss mitigation measures supported by some data or report.
- **Conclusion:** Summarize the key points and emphasize the importance of adopting measures to mitigate the urban heat island effect for sustainable urban development.

Introduction:

Urban heat island effect is a phenomenon where cities have higher air temperatures than the surrounding countryside. This effect can be noticeable, especially at night. This is due to a number of factors, including the use of dark, heat-absorbing materials in construction, the lack of vegetation, and the heat generated by human activity.



Body:

Causes:

- **Low albedo materials**: Albedo is the ratio of the reflected solar energy to the incident solar energy. Low albedo materials absorb more solar energy and store more heat, which increases the urban temperature.
- **Paved and impermeable surfaces:** Paved surfaces, such as roads and parking lots, can also absorb solar radiation as heat, and they are typically impermeable. They don't allow water to be absorbed by plants or water bodies, which can help cool the area.
- **Lack of vegetation:** Vegetation helps to cool the air by absorbing carbon dioxide and releasing oxygen. Areas typically having less vegetation are more vulnerable to the heat island effect.
- **Human activities:** Human activities, such as power generation, transportation, industry, and air conditioning, can also generate heat and greenhouse gas emissions that contribute to the urban heat island effect.

Consequences: The urban heat island effect can have several negative consequences, including:

- Increased energy consumption and costs for cooling buildings and vehicles.
- Increased air pollution and greenhouse gas emissions from fossil fuel combustion.
- Increased health risks such as heat stroke, heat exhaustion, and cardiovascular diseases.
- Reduced water quality due to increased runoff and evaporation.
- Reduced biodiversity and ecosystem services due to habitat loss and fragmentation.

Mitigation Measures:

- **Improving urban design and planning**: Urban design and planning can also help reduce the urban heat island effect by enhancing natural ventilation, reducing surface area exposed to sunlight, increasing albedo, and incorporating water features. For example, using porous materials for pavements, creating open spaces and corridors for air circulation, orienting buildings to maximize shade and breeze, and creating artificial lakes or ponds.
- **Increasing vegetation:** Vegetation can lower air temperatures by providing shade and cooling through evapotranspiration. Cities can expand parkland, plant street trees, and install green roofs and walls that harbour plant life. One study found that the presence of vegetation can lower nearby air temperatures by as much as around 4°F.
- **Using cool roofs and pavements:** Cool roofs and pavements feature bright coatings or materials that reflect more sunlight and absorb less heat. They can reduce the surface temperature of roofs and

Note:

pavements by up to 50°F and lower the ambient air temperature by several degrees.

- **Reducing Greenhouse gas emissions:** Promote sustainable transportation and improve energy efficiency in homes and businesses to reduce greenhouse gas emissions.

Conclusion:

The urban heat island effect is a serious problem that can have a number of negative consequences. However, there are a number of measures that can be taken to mitigate the urban heat island effect. By taking these measures, we can help to make our cities more livable and sustainable.

Q. What are the main types and causes of soil erosion in India? How does it affect the environment and the economy of India? (150 words)

Approach

- Start your answer with a brief introduction of soil erosion.
- Write its types and explain how it affect environment and economy.
- Conclude accordingly.

Introduction:

Soil erosion is the removal and displacement of the top layer of soil by various natural or human-induced agents. It is a serious environmental problem that affects the quality and productivity of land resources. It has the following main types and causes in India:

Body:

Types of soil erosion:

- **Water erosion:**
  - It is caused by the action of water, such as rainfall, runoff, streams, rivers, etc.
  - It results in the formation of rills, gullies, ravines, etc.
    - It is the most widespread and severe type of soil erosion in India.
- **Wind erosion:**
  - It is caused by the action of wind, especially in arid and semi-arid regions.
  - It results in the formation of sand dunes, deflation hollows, etc.
    - It is more common in western and northwestern parts of India.
- **Glacier erosion:**
  - It is caused by the movement of glaciers, which scrape and pluck the underlying rocks and soil.
  - It results in the formation of U-shaped valleys, cirques, moraines, etc.
    - It is more common in the Himalayan region of India.
- **Coastal erosion:**
  - It is caused by the action of waves, tides, currents, etc. along the coastline.
  - It results in the formation of cliffs, caves, arches, stacks, etc.
    - It is more common in the eastern and western coasts of India.

Causes:

- **Natural causes:**
  - These include climatic factors (such as rainfall intensity and distribution, temperature, wind speed and direction, etc.),
    - topographic factors (such as slope, aspect, relief, drainage pattern, etc.),
    - geological factors (such as rock type, structure, texture, etc.),
    - biological factors (such as vegetation cover, soil organisms, etc.).
- **Human-induced causes:**
  - These include deforestation, overgrazing, overcultivation, improper irrigation, mining, quarrying, construction activities, urbanization, industrialization, etc.

Soil erosion affects the environment and the economy of India in the following ways:

- **Environmental effects:**
  - Soil erosion reduces the fertility and water-holding capacity of soil. It leads to loss of organic matter and nutrients from soil.
  - It causes siltation and pollution of water bodies. It increases the risk of floods and droughts.
  - It affects the biodiversity and ecosystem services of soil.

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- **Economic effects:**
  - Soil erosion reduces the agricultural productivity and food security of India.
    - It increases the cost of soil conservation and reclamation.
  - It affects the hydroelectric power generation and navigation potential of rivers.
  - It damages the infrastructure and property along the coastlines.
  - It reduces the income and livelihood opportunities of rural people.

Conclusion:

Thus, soil erosion is a major threat to the sustainable development of India. It requires proper prevention and mitigation measures to conserve and enhance the soil resources of India.

Q. Discuss the concept of climate change and its implications on global ecosystems and human societies. Examine the key factors contributing to climate change and suggest measures to mitigate its adverse effects. (250 words)

Approach

- Start your answer by explaining the concept of climate change.
- Write implications of Climate Change on global ecosystems and human societies.
- Write key factors contributing to climate change.
- Suggest measures to mitigate adverse effects of Climate change.

Introduction:

Climate change refers to long-term shifts in temperature, precipitation patterns, wind patterns, and other aspects of the Earth's climate system. It poses significant challenges to both natural ecosystems and human societies, necessitating urgent action.

Body:

Concept and Implications of Climate Change:

- **Definition and Causes:**
  - Climate change is primarily caused by human activities, including the emission of greenhouse gases (GHGs) and deforestation.
  - GHGs trap heat in the Earth's atmosphere, leading to the greenhouse effect and resulting in global warming.
- **Implications on Global Ecosystems:**
  - Rising temperatures and changing precipitation patterns affect ecosystems and biodiversity.
  - Increased frequency and intensity of extreme weather events impact habitats, species distribution, and ecological balance.
  - Melting glaciers and polar ice caps threaten marine ecosystems and contribute to sea-level rise.
- **Implications on Human Societies:**
  - Climate change disrupts agriculture, leading to reduced crop yields, food insecurity, and loss of livelihoods for farming communities.
  - Changes in weather patterns affect water availability, leading to water scarcity and conflicts over resources.
  - Rising sea levels endanger coastal communities, resulting in forced migration and increased vulnerability to natural disasters.

Factors Contributing to Climate Change:

- **Greenhouse Gas Emissions:**
  - Burning fossil fuels (coal, oil, and natural gas) releases carbon dioxide (CO_2) into the atmosphere.
  - Industrial activities, transportation, and deforestation contribute to GHG emissions.
- **Deforestation:**
  - Clearing forests reduces the Earth's capacity to absorb CO_2 through photosynthesis, contributing to increased atmospheric concentrations.
- **Industrialization and Urbanization:**
  - Rapid industrial growth and urbanization lead to increased energy consumption and emissions.
  - Urban heat island effect exacerbates local warming in cities.

Measures to Mitigate Climate Change:

- **Transition to Renewable Energy:**
  - Promote the use of renewable energy sources such as solar, wind, and hydropower to reduce reliance on fossil fuels.
  - Encourage research and development of new technologies for efficient and clean energy production.

Note:

- **Forest Conservation and Reforestation:**
  - Implement sustainable forest management practices and promote reforestation efforts to enhance carbon sequestration.
- **Adoption of Sustainable Agriculture:**
  - Encourage climate-resilient farming techniques, agroforestry, and efficient water management practices.
  - Promote organic farming and reduce the use of synthetic fertilizers and pesticides.
- **International Cooperation:**
  - Strengthen global cooperation and agreements such as the Paris Agreement to reduce GHG emissions and promote sustainable development.

Conclusion:

Climate change poses substantial challenges to both ecosystems and human societies. By understanding its causes and implications, and implementing effective mitigation measures, we can work towards safeguarding the environment, ensuring sustainable development, and creating a resilient future for generations to come.

Q. Discuss the major factors that influence the distribution of temperature, precipitation, and wind on the Earth's surface. How do these factors vary across different climatic zones? (150 words)

Approach:

- Start the answer with factors which influence the distribution of temperature, precipitation, and wind on the Earth's surface.
- Explain the factors in detail and how these factors vary across different climatic zones.
- Conclude suitably.

Answer:

The distribution of temperature, precipitation, and wind on the Earth's surface is influenced by a complex interplay of various factors, both natural and anthropogenic. These factors vary across different climatic zones, creating distinct climate patterns worldwide. To discuss these major factors comprehensively, we can categorize them into natural and anthropogenic influences.

- **Natural Factors:**
  - **Latitude:** Latitude plays a crucial role in determining temperature distribution. Near the equator, where sunlight is more direct, temperatures tend to be higher, while at higher latitudes, the angle of sunlight is lower, resulting in cooler temperatures. This leads to the formation of the tropical, temperate, and polar climate zones.
  - **Altitude:** As elevation increases, the temperature typically decreases. This phenomenon is known as the lapse rate. Mountains can block or redirect wind patterns, leading to variations in precipitation and temperature on either side of the mountain range. This effect is evident in rain shadows.
  - **Ocean Currents:** Ocean currents transport heat across the globe, influencing the climate of coastal regions. Warm currents, such as the Gulf Stream, can raise temperatures in nearby coastal areas, while cold currents can have a cooling effect.
  - **Land-Water Distribution:** Water bodies like oceans and seas have a moderating influence on temperature, leading to milder climates near coastlines compared to inland areas. This effect is known as maritime influence.
  - **Topography:** The physical features of the Earth's surface, including mountains, valleys, and plains, can affect temperature, precipitation, and wind patterns. Wind patterns can be channeled and intensified or weakened by topographical features.
- **Anthropogenic Factors:**
  - **Urbanization:** Urban areas tend to have higher temperatures compared to rural areas due to the urban heat island effect, caused by buildings, roads, and other human-made structures that absorb and radiate heat.
  - **Deforestation:** The removal of forests can disrupt local climate patterns, leading to changes in temperature, precipitation, and wind patterns. Deforestation also contributes to climate change through the release of carbon dioxide.
  - **Industrialization:** The release of greenhouse gases from industrial processes and the burning of fossil fuels contributes to global warming, which in turn affects temperature and precipitation patterns on a global scale.
  - **Agriculture:** Changes in land use for agriculture, including irrigation practices, can alter local climate conditions, especially in arid and semi-arid regions.

Note:

Variation Across Different Climatic Zones:

- **Tropical Zones:** Near the equator, the primary driver of temperature is latitude, resulting in consistently warm temperatures year-round. Precipitation is influenced by the Intertropical Convergence Zone (ITCZ), and trade winds dominate wind patterns.
- **Temperate Zones:** These regions experience seasonal temperature variations due to the tilt of the Earth's axis. Prevailing westerlies and jet streams influence wind patterns, while precipitation varies seasonally.
- **Polar Zones:** High latitudes experience extremely cold temperatures due to the low angle of sunlight. These regions have low precipitation and are characterized by polar easterlies.
- **Mountainous Regions:** Altitude and topography play a significant role in temperature and precipitation variations, leading to diverse microclimates on mountain slopes.

The distribution of temperature, precipitation, and wind on Earth's surface is a result of a complex interplay of natural and anthropogenic factors. These factors vary significantly across different climatic zones, creating the diverse climate patterns we observe around the world. Understanding these influences is crucial for comprehending the Earth's climate system and its response to ongoing environmental changes.

Q. Discuss the primary and secondary factors that contribute to the formation of ocean currents. How do these factors interact and influence the characteristics of ocean currents, and what are the global implications of these interactions? (250 Words)

Approach:

- Begin with a concise introduction that provides an overview of what ocean currents are and their significance in the Earth's systems.
- Discuss the primary and secondary factors responsible for ocean current formation.
- Discuss how these factors interact and influence the characteristics of ocean currents. Highlight the far-reaching consequences of ocean currents on a global scale.
- You can conclude by summarizing the key points and emphasize the importance of understanding ocean currents and their multifaceted influences.

Introduction:

Ocean currents are the constant, directional flow of seawater, shaped by factors like wind, water density, tides, Earth's rotation, and ocean basin shapes. They create surface, deep-water, geostrophic, and tidal currents, impacting climate, ecology, and economies worldwide.

Body:

Some of the main factors that affect ocean currents are:

Primary Factors:

- **Wind:** Wind is a primary driving force for ocean currents. The friction between the wind and the ocean's surface generates momentum, pushing water in the direction of the prevailing winds.
- **Temperature and Density:** Differences in temperature and salinity (salt content) lead to variations in water density. Colder, denser water sinks, while warmer, less dense water rises. These density differences, known as thermohaline circulation, drive deep ocean currents. The sinking of cold, dense water in polar regions and the upwelling of warmer water in equatorial areas are crucial components of this process.

Secondary Factors:

- **Coriolis Effect:** The Coriolis effect influences the direction of ocean currents in each hemisphere. Coriolis effect causes ocean currents to veer to the right in the Northern Hemisphere and to the left in the Southern Hemisphere. It ensures that water masses move in a more circular pattern, creating the major gyres (circular currents) in the world's oceans, such as the North Atlantic Gyre and the South Pacific Gyre.
- **Continental Boundaries:** The shape and arrangement of continents play a significant role in directing and modifying ocean currents. For instance, when ocean currents encounter a continent, they are deflected, which can result in the creation of coastal currents or eddies.

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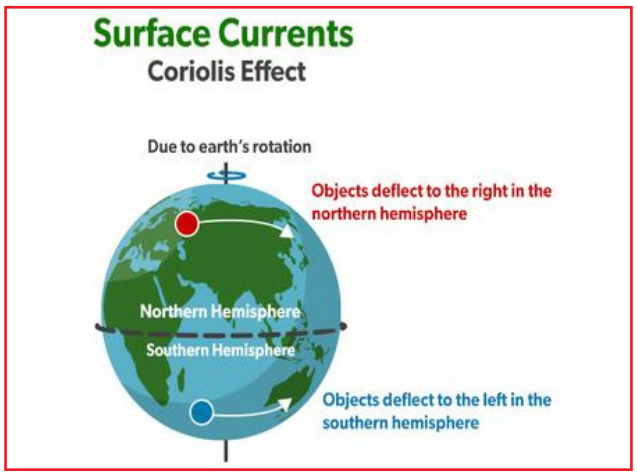


- **Tides:** Tidal forces, primarily caused by the gravitational pull of the Moon and the Sun, lead to the rise and fall of sea levels. These tidal changes can create tidal currents in coastal areas, affecting local ocean circulation patterns.

Interactions and Influence on Characteristics:

- These factors interact in complex ways. Wind-driven surface currents, for example, can transport warm or cold water to different regions, affecting local climates.
- The Coriolis effect influences the direction and speed of these currents, while temperature and density differences create vertical movement, influencing the deeper, slower currents.
- Continental boundaries and tides can further modify these patterns.

Global Implications:

- **Climate:** Ocean currents transfer heat and moisture, impacting regional climate. Warm currents increase evaporation and precipitation, while cold currents reduce them. They also influence weather patterns and events like El Niño-Southern Oscillation.
- **Ecology:** Ocean currents transport nutrients and organisms, influencing marine ecosystems. Upwelling currents support biodiversity by bringing nutrient-rich water to the surface. Downwelling currents maintain oxygen levels. They aid in the dispersal of marine life, enhancing connectivity and diversity.
- **Economy:** Ocean currents provide resources and opportunities. They support fisheries, offer renewable energy sources, and aid maritime transportation by reducing travel time and fuel consumption.

Conclusion:

The formation of ocean currents is a complex interplay of primary and secondary factors, with far-reaching implications for climate, ecosystems, and weather patterns. Understanding these dynamics is crucial for predicting and adapting to the consequences of ongoing climate change and other environmental challenges.

Q. From being a net food importer in the 1960's, India has emerged as a net food exporter to the world. Provide Reasons. (Answer in 250 words, UPSC Mains 2023)

Approach:

- Briefly introduce the historical context of India being a net food importer in the 1960s.
- Discuss major factors responsible for transforming India into a net food exporter from a net importer.
- Conclude with discussing the challenges that still pertain and significance of addressing those challenges.

Introduction:

Since the 1960s, when it was forced to rely on imports and food aid from other nations due to chronic food shortages, India has made great advancements in its ability to produce and export food.

According to WTO's Trade Statistical Review (2022), India was in the top 10 ranking of the global Agri exporters.

Body:

Some of the major factors are mentioned as below:

- **Green Revolution**: The green revolution initiated in the **mid 1960's** boosted agricultural productivity, food grain production and better **irrigation infrastructure.**
- **Government Policies**: Supportive government policies such as **Minimum Support Price** , **e-NAM**, subsidized inputs, better procurement system incentivised farmers to increase food production.
- **Research and Development**: Investment in agricultural research and development helped in adoption of better technologies and methods. E.g **Indian council for agriculture research.**
- **Private Sector Participation**: Private sector involvement in agriculture and allied fields such as **food processing industries** etc. lead to better infrastructure, better **market access** and better market prices e.g e-Choupal**, Tata Kisan Kendras.**

Note:

- **Diversification of Crops**: The government's focus on diversifying India's food supply e.g.Launching technology mission, Crop diversification programme (CDP) etc.
- **Trade liberalization**: Trade liberalization in the 1990's and thereafter too contributed to better exports.
- **Global Demand**: More global demand in the ever expanding world markets has also boosted the prospects of Indian agriculture.

Conclusion:

While India has made **significant strides** in becoming a net food exporter, certain challenges remain including **climate change, sustainable agriculture,water management** and to ensure that the benefit of the exports reaches to **small and marginal farmers** as well.

Addressing these challenges will enhance and **sustain India's position** in the global food market while at the same time ensure **national food security.**

Q. What do you understand about the "Glacial Lake Outburst Flood" (GLOF)? Discuss the causes and consequences of GLOFs in the Himalayan region? (250 Words)

Approach:

- Begin with a concise introduction that defines what a GLOF is and briefly mentions its relevance in the Himalayan region.
- Elaborate on the specific causes of GLOFs in the Himalayan region, emphasizing its unique geological and climatic characteristics.
- Describe the various consequences of GLOFs.
- You can conclude With a Way Forward approach and emphasis on the urgency of addressing GLOF risks in the Himalayas and the broader implications for climate change mitigation.

Introduction:

A Glacial Lake Outburst Flood (GLOF) is a catastrophic event that occurs when a glacial lake, typically dammed by a glacier, experiences a sudden release of water. This release can result in a rapid and massive flood downstream, posing significant threats to human settlements, infrastructure, and the environment. GLOFs are a particularly concerning phenomenon in the Himalayan region due to its complex topography, numerous glaciers, and vulnerable communities.

Body:

Causes of GLOFs in the Himalayan region:

- **Glacier Retreat:** One of the primary triggers of GLOFs is the melting and retreat of glaciers. As global temperatures rise, Himalayan glaciers are receding at an alarming rate. This retreat can expose and enlarge glacial lakes, increasing the likelihood of a GLOF.
- **Glacier Lake Formation:** Glacial lakes form as meltwater accumulates behind glacial moraines, ice dams, or other natural barriers. As these lakes grow, they become more unstable and susceptible to a GLOF.
- **Earthquakes:** The Himalayan region is seismically active, and earthquakes can rupture glacial dams or trigger landslides, leading to the sudden release of water from the glacial lakes.
- **Landslides:** Landslides, often triggered by heavy rainfall or earthquakes, can introduce large volumes of debris into glacial lakes, displacing the water and causing a GLOF.

Consequences of GLOFs in the Himalayan region:

- **Loss of Life and Property:** GLOFs can result in the loss of human lives, destruction of infrastructure, and damage to agricultural land. Entire villages can be swept away by the floodwaters.
- **Infrastructure Damage:** Roads, bridges, hydropower plants, and other critical infrastructure can be severely damaged or destroyed during GLOFs, disrupting essential services and transportation.
- **Ecological Impact:** GLOFs can have devastating effects on the local ecosystems, including the destruction of vegetation and habitats, sedimentation of rivers and streams, and contamination of water bodies.
- **Threat to Livelihoods:** Many communities in the Himalayan region depend on agriculture and livestock farming. GLOFs can damage agricultural fields, threaten livestock, and disrupt livelihoods, leading to food insecurity.
- **Downstream Flooding:** GLOFs release a massive volume of water, which can lead to downstream flooding, affecting communities far from the source of the flood. This poses additional risks to human lives and property.

Note:

Conclusion:

Early warning systems, hazard mapping, and infrastructure development in safer areas are among the strategies that could be employed to reduce the impact of these potentially catastrophic events. Additionally, addressing climate change and reducing greenhouse gas emissions remains crucial in slowing glacier retreat and mitigating the long-term risks of GLOFs in the Himalayas.

Q. Examine the role of climate and agroecological zones in influencing major crop cultivation. (150 Words)

Approach:

- Give a brief introduction underlining the wider impact of climate and agroecological zones
- Mention the Role of Climate in influencing Crop Cultivation
- Mention the Role of Agroecological Zones in influencing crop cultivation
- Mention the intersectional role of climate and agroecological zones
- Give a brief conclusion

Introduction:

Climate and agroecological zones play a pivotal role in shaping the patterns of major crop cultivation across the globe. The intricate interplay between environmental factors, such as temperature, precipitation, soil composition, and topography, significantly influences the choice of crops that can thrive in a particular region.

Body:

Role of Climate in influencing Crop Cultivation:

- **Temperature Regimes:**
  - Different crops have distinct temperature requirements for optimal growth.
  - Tropical regions favor heat-resistant crops like rice, sugarcane, and tropical fruits.
  - Temperate zones are suitable for cereals like wheat and barley, which thrive in cooler temperatures.
- **Precipitation Patterns:**
  - Rainfall influences crop selection, with water-intensive crops in regions with ample rainfall.
  - Arid and semi-arid areas may necessitate drought-resistant crops such as millets and sorghum.
- **Seasonal Variation:**
  - Monsoons and seasonal changes impact the cropping calendar.
  - Kharif and Rabi seasons in India exemplify the adaptation of crops to specific climatic phases.

Role of Agroecological Zones in influencing crop cultivation:

- **Soil Composition:**
  - Different crops thrive in distinct soil types (e.g., paddy fields for rice, well-drained soil for potatoes).
  - Soil fertility influences crop yields and quality.
- **Topography:**
  - Altitude affects temperature and atmospheric pressure, impacting crop varieties.
  - Mountainous regions may necessitate adapted crops due to challenging terrains.
- **Biotic Factors:**
  - Pests and diseases vary with agroecological zones, influencing crop selection and management practices.
  - Ecosystem diversity contributes to natural pest control in certain zones.

Interplay of Climate and Agroecological Zones:

- **Microclimates:**
  - Localized climate variations within a region impact micro-level farming decisions.
  - Farmers may select crops suited to specific microclimates for enhanced yields.
- **Climate Change Impacts:**
  - Shifts in climate patterns necessitate adaptive strategies in crop cultivation.
  - Sustainable agriculture practices become crucial to mitigate climate-related risks.

Conclusion:

Climate and agroecological zones play a crucial role in crop cultivation. With the ongoing challenges of climate change, it's urgent to adopt resilient and sustainable agricultural practices. A comprehensive understanding of these factors is essential for global food security and sustainable agriculture.

Note:

Q. Critically analyze the factors influencing the location of secondary sector industries in various parts of the world. (150 Words)

Approach

- Write a brief introduction about the secondary industries.
- Mention the pros and cons of factors responsible for determining the location of any industry.
- Write a conclusion.

Introduction

Secondary industries are those that process raw materials into finished or semi-finished products, such as manufacturing, construction, and power generation. The location of secondary industries is influenced by a combination of geographical and non-geographical factors, which vary depending on the type of industry, the region, and the time period.

Body

Some of the important geographical factors that affect the location of secondary sector industries:

Factors	Pros	Cons
Proximity to Raw Materials	➢ Cost-effective transportation.	➢ Limited flexibility in choosing the location.
Access to Transportation	➢ Efficient distribution of products. ➢ Access to a diverse market.	➢ High transportation costs in remote areas. ➢ Pollution and congestion in transport hubs.
Labor Availability	➢ Availability of a skilled workforce. ➢ Lower labor costs in certain regions.	➢ Competition for skilled labor in urban areas. ➢ Possible labor disputes or strikes.
Government Policies	➢ Incentives and tax benefits. ➢ Regulatory support for industries.	➢ Bureaucratic delays and red tape. ➢ Inconsistent policies over time.
Market Demand	➢ Proximity to the target consumer base. ➢ Faster response to changing market trends.	➢ Varied market demands in different regions. ➢ Risk of market saturation in certain areas.
Environmental Considerations	➢ Adherence to environmental standards. ➢ Sustainable practices for long-term growth.	➢ Potential conflicts with local communities. ➢ Cost implications of eco-friendly measures.

Conclusion:

These factors are not mutually exclusive, but rather interact and influence each other. The relative importance of each factor may change over time and space, depending on the changes in technology, economy, society, and environment. Therefore, the location of secondary industries is not static, but dynamic and complex.

Q. How do seismic shadow zones provide evidence for the existence of Earth's core? (150 Words)

Approach

- Write a Brief Introduction about the Seismic Shadow Zone.
- Mention about the seismic waves and shadow zones.
- Write how a seismic shadow zone provides evidence about the existence of a core.
- Write a conclusion.

Introduction

The existence of seismic shadow zones is primarily attributed to the refraction and reflection of seismic waves as they propagate through the Earth's interior. When an earthquake occurs, seismic waves are generated and travel in all directions through the Earth's layers, including the crust, mantle, and core. However, the density and composition of these layers cause seismic waves to undergo various changes in speed and direction, leading to the formation of shadow zones.

Body

There are two main types of seismic waves: primary (P-waves) and secondary (S-waves). P-waves are compressional waves that travel faster and can pass through both solid and liquid layers, whereas S-waves are shear waves that propagate slower and cannot travel through liquids.

Note:

The primary reasons for the existence of seismic shadow zones are:

- **Refraction:** As seismic waves encounter boundaries between different layers of the Earth's interior, such as the crust-mantle boundary or the mantle-core boundary, they undergo refraction, which causes them to bend. This bending effect results in the formation of regions where **seismic waves** are not detected or are significantly weakened, known as **shadow zones.**
- **Reflection:** Seismic waves can also undergo reflection when they encounter boundaries between layers at certain angles. Reflected waves can interfere with direct waves, leading to the cancellation or weakening of seismic signals in specific areas, creating shadow zones.
- **Differential behavior of P and S waves:**
  - **P-waves (compressional waves):** These waves can travel through both solids and liquids. When a P-wave encounters the core-mantle boundary, it bends (refracts) due to the change in material properties. This refraction creates a P-wave shadow zone between approximately 105° and 145° from the earthquake's epicenter. Within this zone, direct P-waves are absent, but they arrive later after traveling a longer path through the mantle.
  - **S-waves (shear waves):** These waves can only travel through solids and are completely blocked by liquids. When an S-wave encounters the liquid outer core, it cannot pass through and is entirely absorbed. This creates an S-wave shadow zone beyond approximately 105° from the epicenter. No S-waves are detected in this region, providing strong evidence for a liquid outer core.
- **Implications for Earth's Core:**
  - The observed absence of S-waves beyond the shadow zone conclusively indicates the presence of a liquid outer core that cannot transmit these waves.
  - The bending of P-waves and their delayed arrival within the P-wave shadow zone suggest a denser core material that alters their path. This further supports the existence of a distinct core composition.
  - The existence of different shadow zones for P and S waves also suggests a differentiation within the core, with a liquid outer core and a solid inner core.
    - The inner core, being solid, allows the transmission of S-waves, explaining their presence beyond the outer core's shadow zone.

Conclusion

The complex interaction of seismic waves with the Earth's heterogeneous interior, including variations in density, composition, and state (solid or liquid), contributes to the existence of seismic shadow zones. These shadow zones provide valuable insights into the Earth's internal structure and help scientists understand the behavior of seismic waves during earthquakes.

Q. What are the concepts behind El Niño and La Niña events? How do these phenomena impact the monsoon and air quality in India? (250 words)

Approach:

- Give a brief introduction to El Niño and La Niña events.
- Discuss the impacts of these phenomena on monsoon and air quality in India.
- Conclude suitably.

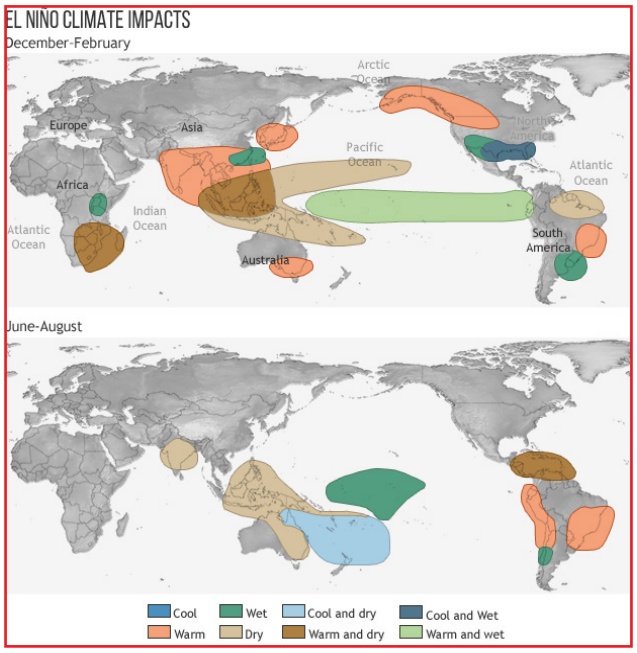
Introduction :

El Niño and La Niña are opposite phases of the El Niño-Southern Oscillation (ENSO) cycle, a natural climate phenomenon characterized by fluctuations in sea surface temperatures (SSTs) in the central and eastern tropical Pacific Ocean.

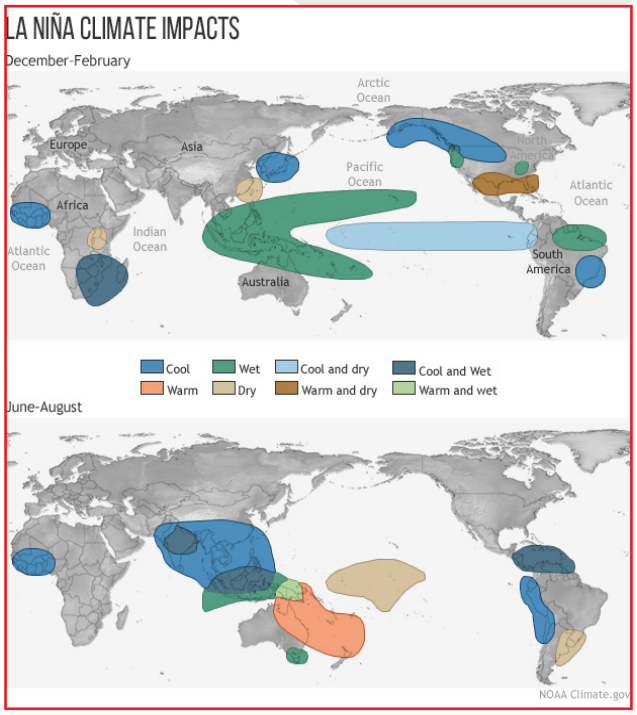
Body :

- **El Niño:**
  - During El Niño events, warmer-than-average sea surface temperatures develop in the central and eastern Pacific Ocean, disrupting normal atmospheric circulation patterns.
  - This disruption leads to changes in global weather patterns, including altered rainfall patterns and atmospheric circulation.
  - In India, El Niño generally tends to weaken the monsoon, resulting in drier-than-average conditions and reduced rainfall. This can lead to droughts, water shortages, and agricultural losses.

Note:



- **La Niña:**
  - La Niña events are characterized by cooler-than-average sea surface temperatures in the central and eastern Pacific Oceans.
  - La Niña typically strengthens the Indian monsoon, resulting in increased rainfall and wetter-than-average conditions in India. This can lead to flooding and waterlogging in some regions.



Impacts of these phenomena on air quality in India:

- **El Niño:** El Niño can **exacerbate air pollution** in India by contributing to stable atmospheric conditions and reduced rainfall, which can trap pollutants closer to the surface and lead to poor air quality.
- **La Niña**: La Niña can have varying impacts on air quality in India, depending on regional weather patterns. Increased rainfall associated with La Niña **can help to alleviate air pollution by removing pollutants** from the atmosphere through wet deposition. Nevertheless, these effects have experienced numerous anomalies.
  - In 2022, a study suggested that PM2.5 concentrations in Ghaziabad and Noida reduced significantly, while in contrast, Mumbai and Bengaluru experienced rises in PM2.5 levels.

Conclusion :

A thorough understanding of El Niño and La Niña phenomena is essential for India to effectively manage its water resources, agriculture, and air quality, as well as to develop adaptive strategies to mitigate the impacts of climate variability and extreme weather events on various sectors of the economy and society.

Q. Examine the factors that increase the Himalayan region's susceptibility to Glacial Lake Outburst Floods (GLOFs) and suggest strategies for mitigating the associated risks. (250 words)

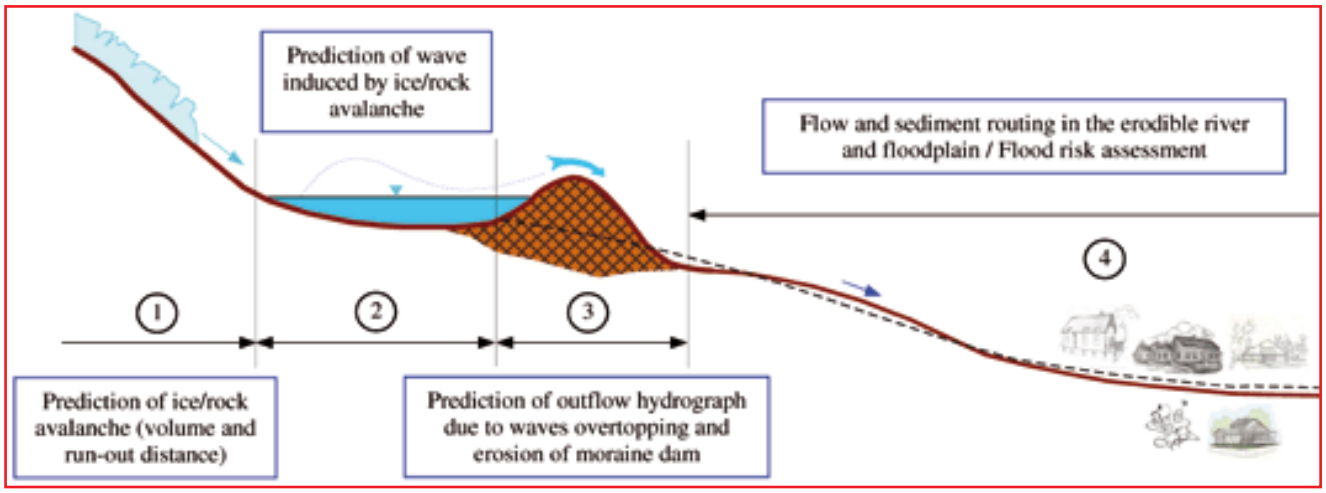
Approach:

- Give a brief introduction to Glacial Lake Outburst Floods (GLOFs).
- Discuss the factors that increase the Himalayan region's susceptibility to Glacial Lake Outburst Floods (GLOFs).
- Suggest strategies for mitigating the associated risks
- Conclude suitably.

Introduction :

Glacial Lake Outburst Flood (GLOFs) refers to a sudden release of water from a glacial lake, typically caused by the breaching or collapse of a natural dam, such as a moraine or ice barrier, that holds back the lake's water. The ISRO's National Remote Sensing Centre (NRSC) released a glacial lake atlas for the Himalayan River Basins which identified over 28,000 glacial lakes in the region.

Note:



Body :

The factors that increase the Himalayan region's susceptibility to Glacial Lake Outburst Floods:

- **Glacier Retreat:** The Himalayan glaciers are rapidly melting due to climate change, leading to the formation of glacial lakes. As glaciers retreat, the volume of meltwater increases, raising the risk of GLOFs.
- **Geological Vulnerability:** The Himalayan region is seismically active, with the potential for earthquakes and landslides. Seismic events can trigger GLOFs by destabilizing moraine dams or causing landslides that block river valleys and create temporary barriers for glacial lakes.
- **Steep Terrain and High Precipitation:** The rugged terrain of the Himalayas, coupled with high precipitation rates, accelerates the movement of water during GLOFs, amplifying the destructive power of floods downstream.
- **High Vulnerability Quotient:** The embankments of these lakes consist of loose deposits of glacier moraine, rocks, boulders, soil and ice. Since these embankments are not properly compacted, they have a high vulnerability quotient.
- **Human Activities:** Deforestation, infrastructure development, and mining activities in the Himalayan region can exacerbate the risk of GLOFs by destabilizing slopes, altering river courses, and obstructing natural drainage pathway.

Some measures that can be taken to Mitigate GLOF Disaster:

- **Monitoring and Data Collection:** Intense monitoring of meteorological events near the snout of vulnerable glacier lakes is an urgent necessity. Data should be gathered at observatories and communicated to a centralized office. It should be processed in real-time to forecast the behavior of glacial lakes and alert people.
- **Use of Technology**: A nationwide programme to regularly monitor vulnerable glacier lakes by satellites and drones should be initiated. This technology can complement ground-based observatories and enhance the overall understanding and prediction of GLOFs.
- **Revised Safety Standards:** Given the increased threats from GLOFs, safety standards for infrastructure projects in mountainous areas should be revised. This includes projects like dams, bridges, and highways. Quality control measures should be stringent to ensure the safety of such projects.
- **Regulation of Construction**: Infrastructure projects in mountains — dams, bridges and highways — must be subjected to stringent quality control measures. GLOFs and other floods in mountainous regions have shown that buildings constructed close to rivers were the first and the worst sufferers.
- **Comprehensive Risk Assessment:** The Himalayan region requires a comprehensive risk assessment that accounts for projected temperature rise, changes in precipitation patterns, and land-use/cover changes. This assessment should inform disaster risk-reduction strategies.

Note:

- **Reforestation and Watershed Management:** Protecting and restoring natural vegetation cover in the Himalayan region can help stabilize slopes, reduce soil erosion, and regulate water flow, thereby mitigating the risk of GLOFs and enhancing overall watershed resilience
- **Community Engagement and Capacity Building:** Engaging local communities in GLOF risk reduction efforts through awareness campaigns, training programs, and participatory planning initiatives can foster community resilience and empower residents to take proactive measures to protect themselves and their livelihoods.

Conclusion :

By adopting a holistic approach that integrates scientific knowledge, community engagement, and cross-border cooperation, it is possible to reduce the vulnerability of the Himalayan region to GLOFs and enhance its resilience to climate-related hazards.

Q. Evaluate the extent of the groundwater crisis in India and suggest strategies to mitigate its consequences. (250 words)

Approach:

- Start the answer with a discussion that sets a context for the question.
- Evaluate the extent of the groundwater crisis in India.
- Suggest strategies to mitigate its consequences
- Conclude suitably.

Introduction :

Bengaluru is facing a worsening **water crisis**, leading to significant shortages in various areas. According to the reports, 223 of the 236 talukas in Karnataka are affected by drought, including Mandya and Mysuru districts, the sources of Bengaluru's water.

Body :

The Current State of the Groundwater Crisis in India:

- **Lack of Water Availability:**
  - Despite supporting **17% of the world's population**, **India possesses only 4% of the world's freshwater resources**, making it challenging to meet the water needs of its vast populace.
  - A report titled **"Composite Water Management Index (CWMI)"**, published by **NITI Aayog** in June 2018, mentioned that India was undergoing the worst water crisis in its history; **that nearly 600 million people were facing high to extreme water stress**; and about 200,000 people were dying every year due to inadequate access to safe water.
- **Groundwater Overuse or Overexploitation:**
  - **India is the largest groundwater user in the world,** with an estimated usage of around 251 bcm per year, more than a quarter of the global total.
  - With more than 60% of irrigated agriculture and 85% of drinking water supplies dependent on it, and growing industrial/urban usage, groundwater is a vital resource.
  - It is projected that the per capita water availability will dip to around 1400 m^3 in 2025, and further down to 1250 m^3 by 2050.
- **Groundwater Contamination:**
  - Groundwater contamination is the presence of pollutants such as bacteria, phosphates, and heavy metals from human activities including domestic sewage.
  - The **NITI Aayog** report mentioned that India was placed at the rank of 120 amongst 122 countries in the water quality index, with **nearly 70% of water being contaminated.**
  - In parts of India, high levels of arsenic, fluoride, nitrate, and iron are also naturally occurring in groundwater, with concentrations likely to rise as water tables fall.
- **Lack of Access to Safe Drinking Water**:
  - Millions of Indians lack access to safe drinking water and improved sanitation, leading to a high incidence of waterborne diseases.
    - The water crisis in India is compounded by a growing demand for clean water, particularly from a fast-growing middle class, and widespread practices of open defecation, leading to health-related concerns.
  - A few numbers from the **World Bank** highlight the plight the country is facing:
    - 163 Million Indians lack access to safe drinking water.
    - 210 Million Indians lack access to improved sanitation.

Note:

- 21% of communicable diseases are linked to unsafe water.
- 500 children under the age of five die from diarrhoea each day in India.

➢ **Future Projections**:
  - The **NITI Aayog** report projected the country's water demand to be twice the available supply by 2030, implying severe scarcity for hundreds of millions of people and an eventual loss in the country's **GDP**.
  - **The rate of depletion of groundwater in India during 2041-2080 will be thrice** the current rate with global warming, according to a new report.
  - Across climate change scenarios, the researchers found that their estimate of **Groundwater Level (GWL)** declines from 2041 to 2080 is 3.26 times current depletion rates on average (from 1.62-4.45 times) depending on the Climate model and **Representative Concentration Pathway (RCP)** scenario.

Steps Ahaed to Address the Water Crisis in India :

➢ **Interlinking of Rivers:**
  - The **national interlinking of rivers (ILR)** is the idea that rivers should be interconnected, so that water from the surplus rivers and regions could be transferred to deficient regions and rivers to address the issue of **water scarcity**.

➢ **Promote Water Conservation:**
  - Implementing water conservation measures at individual, community, and national levels is crucial.
  - This includes promoting rainwater harvesting, efficient irrigation techniques, and minimising water wastage in domestic, industrial, and agricultural sectors.

➢ **Invest in Infrastructure:**
  - Allocate adequate financial resources for water infrastructure development, maintenance, and rehabilitation.
  - Explore innovative financing mechanisms such as public-private partnerships, water tariffs, and user fees to mobilise funding for water projects.

➢ **Promote Sustainable Agriculture:**
  - Encourage farmers to adopt water-efficient farming practices such as drip irrigation, precision agriculture, crop rotation, and agroforestry.
  - Providing incentives and subsidies for implementing water-saving technologies can facilitate this transition.
  - As per the **MS Swaminathan committee** report on **'More Crop and Income Per Drop of Water' (2006),** drip and sprinkler irrigation can save around 50% of water in crop cultivation and increase the yield of crops by 40-60%.

➢ **Address Pollution:**
  - Combat water pollution by enforcing strict regulations on industrial discharge, sewage treatment, and agricultural runoff.
  - Implementing wastewater treatment plants and adopting eco-friendly practices can help reduce pollution levels in rivers, lakes, and groundwater sources.

➢ **Legislation and Governance:**
  - Strengthen water governance frameworks by enacting and enforcing water-related legislation, policies, and regulatory mechanisms.
  - Establishing local, regional, and national water management authorities can facilitate coordinated decision-making and implementation of water management strategies.
  - Introducing **minimum support policies** for less water-intensive crops can reduce the pressure on agricultural water use.

➢ **Community Participation:**
  - Strengthening community participation and rights in groundwater governance can improve **groundwater management.**
  - **World Bank** projects for groundwater governance in peninsular India were successful on several fronts by implementing the **Participatory Groundwater Management approach (PGM).**

➢ **Adopt One Water Approach:**
  - **One Water Approach**, also referred to as **Integrated Water Resources Management (IWRM)**, is the recognition that all water has value, regardless of its source.
  - It includes managing that source in an integrated, inclusive, and sustainable manner by including the community, business leaders, industries, farmers, conservationists, policymakers, academics, and others for ecological and economic benefits.

Note:

Conclusion:

By fostering inclusive participation from all stakeholders, and implementing sound policies that prioritise long-term sustainability over short-term gains, India can pave the way toward a future where every Indian has access to safe and reliable groundwater.

Q. Discuss the role of tectonic activities in shaping landforms. How do erosion and deposition contribute to the formation of various geomorphic features? (250 Words)

Approach:

- Start the answer by introducing tectonic activities.
- Illustrate the role of tectonic activities in shaping landforms.
- Evaluate how erosion and deposition contribute to the formation of various geomorphic features.
- Conclude suitably.

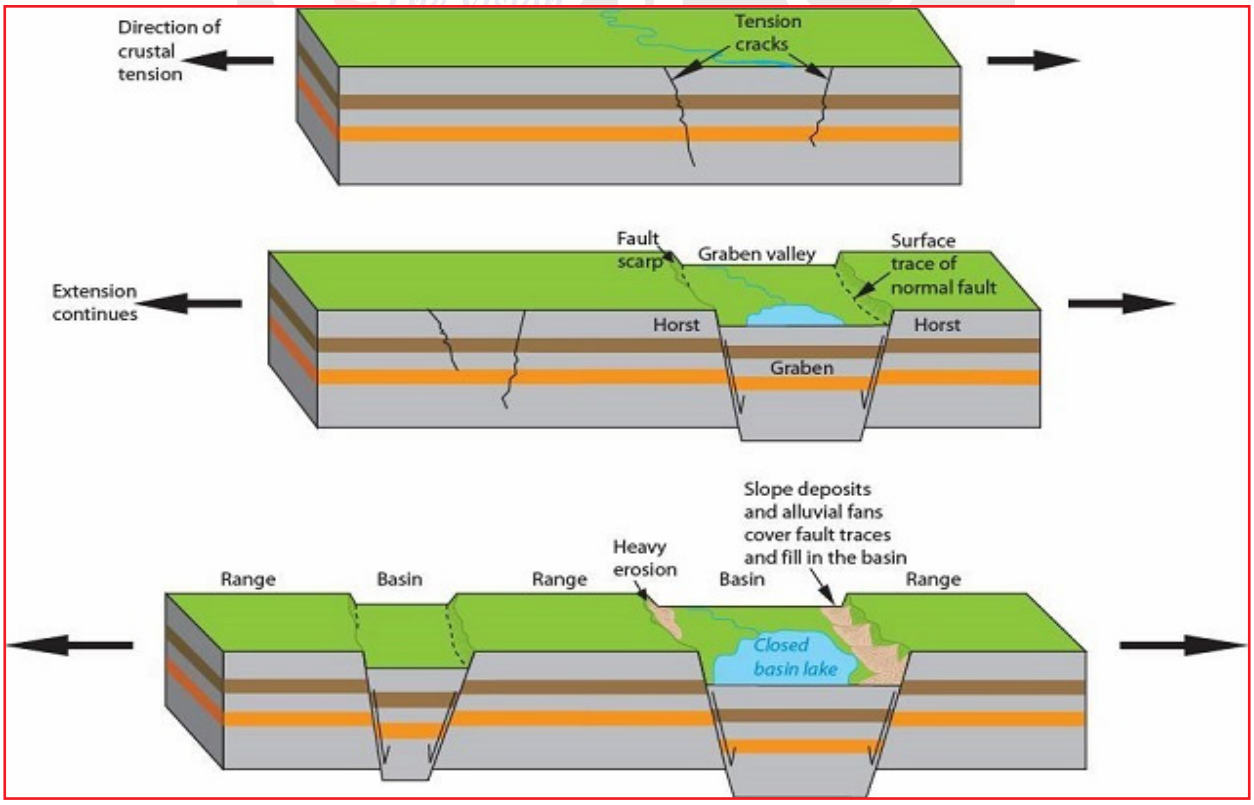
Introduction:

Tectonic activities, driven by the movement of Earth's lithospheric plates, play a pivotal role in shaping landforms across the globe. These processes encompass a range of geological phenomena, including earthquakes, volcanic eruptions, and the formation of mountain ranges.

Body:

Tectonic Activities and Landform Shaping:

- **Plate Tectonics:**
  - The Earth's lithosphere is divided into several large plates that float on the semi-fluid asthenosphere beneath them.
  - The movement of these plates, driven by processes like mantle convection, leads to tectonic activities such as subduction, collision, and divergence.
- **Mountain Building:**
  - Convergent plate boundaries, where plates collide, result in the formation of mountain ranges.
  - For instance, the Himalayas, the world's highest mountain range, are a result of the ongoing collision between the Indian and Eurasian plates.
- **Rift Valleys:**
  - Divergent plate boundaries, where plates move apart, create rift valleys. The East African Rift System is a prominent example, where the African Plate is splitting into smaller plates, leading to the formation of rift valleys like the Great Rift Valley.



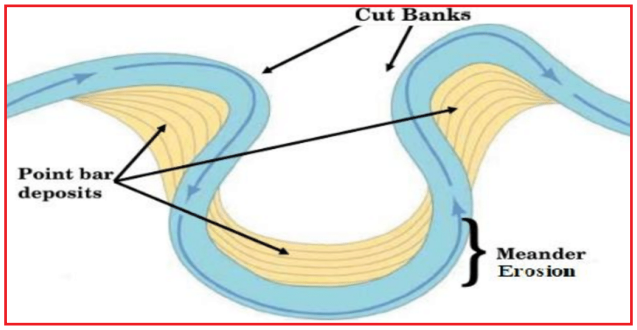
Note:

Erosion and Deposition Processes:

- **Weathering:**
  - Weathering, the breakdown of rocks at or near the Earth's surface, is a fundamental process in geomorphology.
  - Mechanical and chemical weathering weaken rocks, facilitating their erosion.
- **Erosion:**
  - Erosion involves the removal of weathered rock material by agents such as water, wind, ice, and gravity.
  - Rivers, glaciers, wind, and waves are major erosional forces that shape landscapes over time.
- **Deposition:**
  - Deposition occurs when eroded material is transported and deposited in new locations.
  - Sedimentary rocks, formed from the accumulation and compaction of deposited sediments, bear testimony to these processes.

Formation of Geomorphic Features:

- **River Valleys and Floodplains:**
  - Rivers erode their channels over time, forming valleys, meanders, canyons, and floodplains.
  - Deposition of sediment during floods contributes to the formation of fertile floodplains such as point bars, essential for agriculture.
- **Coastal Landforms:**
  - Coastal erosion and deposition sculpt diverse landforms such as beaches, cliffs, spits, and estuaries.
  - For example, the erosive action of waves and currents creates sea stacks and arches along coastlines.



- **Glacial Landforms:**
  - Glaciers, powerful agents of erosion, carve distinct landforms like cirques, U-shaped valleys, and moraines.
  - The retreat of glaciers leaves behind characteristic features that provide valuable insights into past climatic conditions.
- **Karst Topography:**
  - Karst landscapes, characterized by limestone dissolution and the formation of caves, sinkholes, and underground drainage systems, result from chemical weathering processes.

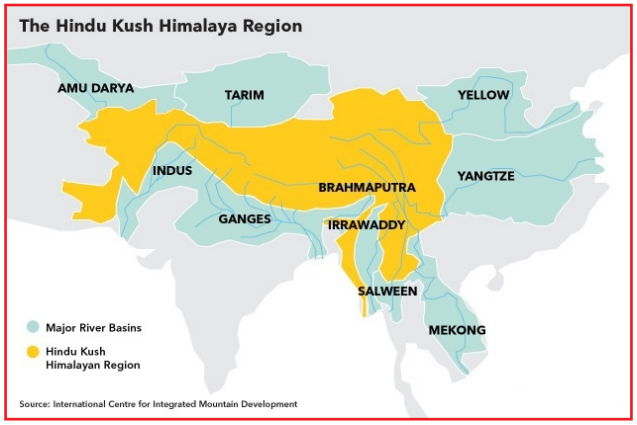
Conclusion:

Tectonic activities, erosion, and deposition are interconnected processes that shape Earth's surface over geological timescales. From towering mountain ranges to meandering river valleys, the dynamic interplay of these forces gives rise to the diverse geomorphic features that define our planet's landscapes.

Q. Examine the Himalayas' role as the 'Water Tower of Asia' and its impact on the regional climate and biodiversity of the Indian subcontinent. (250 words)

Approach:

- Introduce the answer with a emphasis on Hindu Kush Himalayas
- Delve into the role of himalayas as water tower of asia
- Mention impact of himalayas on regional Climate and biodiversity
- Conclude suitably.



Note:

Introduction:

The Himalayas or **Hindu Kush Himalaya** in particular is often referred to as the **'Water Tower of Asia',** playing a crucial role in shaping the regional climate and biodiversity of the Indian subcontinent as it is one of the largest volumes of ice and snow outside of the **Arctic and Antarctica.**

Body:

Role of Himalayas as Water Tower of Asia:

- **Glacial Reservoir and Release:** The Himalayas hold the largest concentration of glaciers outside the polar ice of the Arctic and Antarctica.
  - These glaciers act as giant natural reservoirs, storing **winter snowfall (e.g Gangotri Glacier)** and releasing meltwater during dry summers, feeding major rivers like the **Indus, Ganges, and Brahmaputra**.
  - This provides a crucial and consistent source of freshwater for millions in the Indian subcontinent.
- **Supporting Diverse Ecosystems:** The perennial rivers fed by the Himalayas nourish a vast network of ecosystems.
  - These rivers are lifelines for fertile plains (e.g, Indo-gangetic plains) and wetlands (e.g. **Sundarbans** mangrove forests).
  - This supports a rich tapestry of flora and fauna across the subcontinent.

Impact of Himalayas on Regional Climate and Biodiversity:

- **Impact on Regional Climate:**
  - **Temperature Moderation:** The Himalayas shield the Indo-Gangetic plains from the icy winds blowing from Central Asia, preventing extreme cold temperatures in the Indian subcontinent.
    - In contrast, the **Tibetan Plateau**, located on the leeward side of the Himalayas, experiences a much harsher and drier climate due to the rain shadow effect.
  - **Monsoon Formation:** The Himalayas play a crucial role in the formation of the Indian monsoon system.
    - They force **moisture-laden winds to rise,** leading to condensation and heavy precipitation on the subcontinent's southern slopes.
    - This seasonal phenomenon brings vital rainfall for agriculture and sustains ecosystems.
    - The Western Disturbances also interact with the Himalayas, affecting precipitation patterns in **northern India, Pakistan, and parts of Afghanistan.**
  - **Localized Weather Phenomena:** The complex topography of the Himalayas, with its deep valleys and gorges, creates localized weather phenomena, such as valley winds, mountain waves, and Foehn winds.
    - The **Brahmaputra Valley in Assam and the Kashmir Valley** experience distinct microclimatic conditions due to the influence of the surrounding Himalayan ranges.
- **Impact on Biodiversity:**
  - **Altitudinal Zonation:** The Himalayas exhibit a wide range of altitudinal zones, from tropical (e.g., Terai region) to alpine (e.g., Ladakh), supporting diverse ecosystems and species.
    - The **rhododendron forests** in the mid-hills of Nepal and Sikkim, the **alpine meadows of Gulmarg in Kashmir,** and the **cold deserts of Ladakh** are examples of unique habitats found at different elevations.
  - **Endemic Species:** The Himalayas are home to numerous endemic species, such as **Himalayan tahr, golden langur and pygmy hog.**
  - **Migratory Routes:** The Himalayas serve as a crucial migratory corridor for species like the **Demoiselle crane**.
    - The **Kanchenjunga Biosphere Reserve** is an important stopover for migratory water birds.

Conclusion:

The Himalayas are not merely a majestic mountain range but they are the very **lifeblood of the Indian subcontinent**, functioning as Asia's primary water source, climate regulator, and hub of unparalleled biodiversity. Preserving this iconic natural asset is essential not only for its beauty but also for ensuring the sustainable development and resilience of the entire region.

Note:

Q. What is Marine Cloud Brightening? Discuss its potential benefits and risks in the context of mitigating climate change. (250 words)

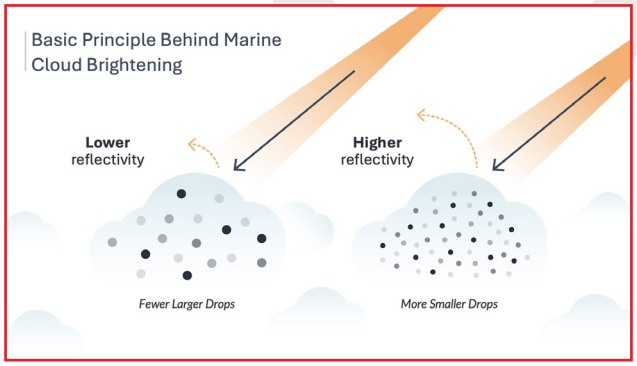
Approach:

- Introduce by defining Marine Cloud Brightening
- Delve into potential benefits of MCB
- Highlight significant risks associated with it
- Conclude positively.

Introduction:

Marine Cloud Brightening (MCB) is a proposed geoengineering technique that aims to mitigate the effects of climate change by increasing the reflectivity of **low-level marine clouds**, thereby reflecting more incoming sunlight back into space and **reducing the amount of solar radiation** absorbed by the Earth's surface.

- The process involves spraying a fine mist of **seawater particles** into the atmosphere, which act as **cloud condensation nuclei** and promote the formation of brighter, more reflective clouds.
- These clouds have a higher albedo (reflectivity) and can reflect more incoming sunlight, potentially cooling the Earth's surface.



Body:

Potential Benefits:

- **Cooling Effect:** MCB has the potential to **reduce global temperatures** by reflecting more sunlight back into space, potentially mitigating the effects of climate change caused by greenhouse gas emissions.
  - MCB could lessen extreme ocean heat, potentially safeguarding marine ecosystems like **coral reefs** facing bleaching threats.
- **Buying Time for Emissions Cuts:** MCB could provide a buffer while we transition to cleaner energy sources.
  - This **buying time** could allow for deeper cuts in emissions and avoid reaching catastrophic tipping points, like the **irreversible melting of polar ice caps**.
- **Localized Impact:** Unlike other geoengineering techniques that aim to achieve global cooling, MCB can be **targeted to specific regions**, allowing for more localized climate interventions.
  - For example, MCB could be deployed in areas particularly vulnerable to rising sea levels or extreme heat events.
- **Reversibility:** The effects of MCB are **relatively short-lived**, and if stopped, the Earth's climate would return to its previous state within a few years, making it a **potentially reversible technique.**
- **Cost-effectiveness**: Compared to other geoengineering techniques, MCB is considered relatively inexpensive and technologically feasible.

Potential Risks:

- **Unintended Consequences:** Like any large-scale intervention in the Earth's climate system, MCB carries the risk of unintended consequences that are difficult to predict, such as **changes in precipitation patterns, ocean circulation, and ecosystem disruptions.**
- **Limited Scope:** MCB might not be effective in all regions. Cloud types and atmospheric conditions can significantly impact its effectiveness.
  - Deploying **MCB in the tropics,** where clouds are already quite reflective, would likely have minimal impact on global warming.
- **Spatial Variability:** The cooling effects of MCB may **not be evenly distributed,** leading to regional disparities and potential conflicts over resource allocation and deployment.
- **Moral Hazard**: The perceived effectiveness of MCB could potentially **reduce the urgency to address the root causes of climate change,** such as reducing greenhouse gas emissions.
- **International Governance:** Deploying MCB unilaterally could **trigger international disputes**. Effective international agreements would be necessary for responsible implementation.

Note:

Conclusion:

While MCB holds promise as a potential climate change mitigation strategy, its deployment on a large scale would require careful consideration of the risks, as well as robust governance frameworks and international cooperation to ensure **responsible implementation and monitoring.**

Q. Identify the major causes and consequences of land degradation and desertification in different regions of India. Also, suggest strategies for sustainable land management practices. (250 words)

Approach:

- Introduce by defining land degradation
- Highlight the major causes of land degradation and desertification
- Delve into the consequences of land degradation and desertification
- Suggest strategies for sustainable land management
- Conclude by mentioning India's Land Degradation Neutrality Target

Introduction:

Land degradation refers to the deterioration or loss of the **productive capacity of land** resources, including soil, vegetation, and water resources.

- It is a complex process that involves the degradation of **physical, chemical, and biological properties of land,** leading to a decline in its ability to support various ecosystem services and human activities.

Major Causes of Land Degradation and Desertification (by Region):

- **Arid and Semi-Arid Regions (Rajasthan, Gujarat, Parts of Maharashtra):**
  - **Overgrazing:** Excessive grazing by livestock removes vegetation cover, exposing soil to wind and water erosion (e.g **Thar Desert in Rajasthan** experiencing desertification due to overgrazing by goats).
  - **Deforestation:** Unsustainable tree felling for fuelwood and timber reduces soil moisture retention and increases wind erosion (e.g., deforestation in the **Aravalli Hills** leading to **declining soil fertility and dust storms** in surrounding areas).
  - **Climate Change:** Erratic rainfall patterns, rising temperatures, and increased frequency of droughts exacerbate desertification (e.g., **erratic monsoon rains in Maharashtr**a impacting crop yields and soil moisture).
- **Deccan Plateau (Parts of Maharashtra, Karnataka, Telangana):**
  - **Salinization:** Excessive use of canal irrigation without proper drainage salinizes the soil, rendering it unfit for cultivation (e.g., **salinization problems in parts of Andhra Pradesh**).
  - **Mining Activities:** Open-cast mining disturbs the natural soil profile and pollutes land with heavy metals (e.g., **Jharia coalfields of Jharkhand** have led to land subsidence).
- **The Himalayan Region:**
  - **Unsustainable Tourism Practices:** Uncontrolled tourist footfall and infrastructure development cause soil compaction and degradation (e.g., **Joshimath Land Subsidence**).
  - **Climate Change:** Glacial retreat due to rising temperatures disrupts the hydrological cycle**, impacting downstream water availability** (e.g. the melting of Himalayan glaciers **could turn the Ganga into a seasonal river**, jeopardizing agriculture in the Gangetic plain).

Consequences of Land Degradation and Desertification:

- **Reduced Agricultural Productivity:** Loss of soil fertility and moisture retention leads to lower crop yields, impacting food security.
- **Water Scarcity:** Degradation reduces groundwater recharge, leading to water scarcity for drinking and irrigation purposes (e.g., recent **water crisis in Bengaluru**).
- **Loss of Biodiversity:** Degradation disrupts ecosystems, leading to habitat loss and species extinction (e.g.,**pink-headed duck and sumatran rhino** have become extinct due to desertification in India).
- **Increased Migration:** Land degradation can force people to migrate to urban areas in search of a better livelihood (e.g.**, migration from villages in Odisha** due to soil erosion and water scarcity).

Note:

Strategies for Sustainable Land Management:

- **Permaculture and Regenerative Agriculture:** Encouraging the adoption of permaculture principles, which involve **designing sustainable and self-sufficient agricultural systems** that mimic natural ecosystems.
  - Promoting regenerative agriculture practices, such as **no-till farming, cover cropping, and crop rotation**, to improve soil health and fertility while reducing erosion and nutrient depletion.
- **Landscape Restoration through Ecological Corridors and Rewilding:** Establishing ecological corridors and habitat connectivity between protected areas and degraded lands to facilitate the movement of species and enhance biodiversity.
  - Implementing rewilding projects, where degraded lands are allowed to recover naturally through the **reintroduction of native plant and animal species**, promoting ecosystem restoration and resilience.
- **Integration of Traditional Ecological Knowledge:** Incorporating the traditional ecological knowledge of indigenous communities and their sustainable land management practices into modern conservation strategies.
  - Encouraging the revival and promotion of traditional agroforestry systems.
- **Promotion of Sustainable Urbanization:** Encouraging sustainable urban planning and design that incorporates **green spaces, urban forests, and green infrastructure** to mitigate the impacts of urbanization on land resources.
- **Bioremediation and Phytoremediation Techniques:** Exploring the use of microorganisms and plants for the bioremediation of contaminated and degraded lands, harnessing their natural ability to **absorb, metabolize, or immobilize pollutants.**
  - Encouraging the use of phytoremediation techniques, such as the cultivation of specific plant species that can **extract, sequester, or degrade contaminants** from soil, water, and air.

Conclusion:

Sustainable land management practices must be tailored to the specific ecological, socio-economic, and cultural contexts of each region and in this way India can achieve its ambitious goal of restoring **26 million hectares of degraded land by 2030.**

Q. Analyze the significance of inland waterways for transportation and economic development. Discuss the geographical challenges associated with navigating rivers in India. (250 words)

Approach:

- Introduce the answer by delving into inland waterways
- Highlight the significance of Inland Waterways
- Delve into geographical challenges associated with navigating rivers in India
- Conclude positively.

Introduction:

Inland waterways refer to navigable **rivers, canals, lakes, and other inland water bodies** that are used for transportation and movement of goods and passengers.

- These waterways serve as an **alternative mode of transport to roads and railways,** offering a cost-effective and environmentally friendly way of moving cargo and people.

Body:

Significance of Inland Waterways:

- **Cost-effective Mode of Transportation:** Inland waterways offer a **highly cost-effective** mode of transportation, particularly for **bulk commodities and heavy cargo.**
  - The operational costs are significantly lower compared to road and rail transport, leading to reduced transportation expenses and increased profitability for businesses.
  - **Example:** The **National Waterway 1 (Ganga-Bhagirathi-Hooghly River System)** provides a cost-effective transportation route for goods and raw materials.
- **Environmental Sustainability:** Inland waterways are considered to be a more environmentally friendly mode of transportation due to **lower carbon emissions** and **reduced air pollution** compared to other modes.
  - **Greenhouse gas emissions** for inland water transport are **approximately 40% lower than road transport,** supporting sustainable development goals.
- **Connectivity and Economic Development:** Inland waterways facilitate the movement of goods and

Note:

people, promoting **connectivity between remote regions and urban centers.**

- They **stimulate economic activities along the riverbanks**, fostering the growth of industries, agriculture, and trade.
- **Example**: The **Mississippi River in the United States** has played a crucial role in the economic development of the **Midwest region.**

Geographical Challenges Associated with Navigating Rivers in India:

- **Seasonal Variations in Water Flow:** Many Indian rivers experience **significant seasonal variations in water flow,** with high discharge during the monsoon season and low water levels during the dry season.
  - This fluctuation in water levels poses **challenges for maintaining navigable depths**, limiting the operational period for inland waterway transport.
  - **Example**: The **Ganga River** experiences significant variations in water levels, hindering year-round navigation in certain stretches.
- **Siltation and Shoal Formation:** Many Indian rivers carry a **high sediment load,** leading to siltation and the formation o**f shoals (shallow areas) along the riverbed.**
  - These obstructions can **impede the movement of vessels** and require regular dredging to maintain navigable depths.
  - **Example:** The **Brahmaputra River in Assam** is known for its high sediment load, leading to frequent shoal formation and navigation challenges.
- **Meandering Nature of Rivers:** Many Indian rivers have a meandering nature, with **sharp bends and curves that can make navigation difficult**, especially for larger vessels.
  - These bends may require **specialized maneuvering techniques** and pose risks of grounding or collisions.
- **Presence of Rapids and Waterfalls:** Some Indian rivers, particularly in **hilly and mountainous regions,** have sections with rapids and waterfalls, which can be hazardous for navigation.
  - These natural obstacles may require the construction of locks or other infrastructure to facilitate the passage of vessels.
  - **Example**: **Shivanasamudra Falls of Kaveri River.**

Conclusion:

Addressing geographical challenges through **sustainable infrastructure development, river training works, and effective water resource management** can unlock the full potential of India's inland waterway network for **sustainable economic development and regional integration.**

Q. What are the primary causes contributing to train accidents in India? Highlighting the expert committee's recommendations propose effective measures that can be implemented to address these causes and enhance the safety and reliability of India's railway network. (250 words)

Approach:

- **Introduction:** Briefly introduce the answer by giving recent incidents of train accidents in India
- **Body:** Mention the primary causes of accidents and way forward measures citing various committee's recommendations.
- **Conclusion:** Summarize the key points and conclude with a forward-looking approach

Introduction:

Train accidents are a major concern for India's railway network, which is one of the largest and busiest in the world. According to data from the Ministry of Railways, there were more than 1,000 train accidents in India between 2009 and 2019, resulting in 1,800 deaths. A recent accident in Odisha where three train collided claimed lives of more than 275 people.

Body:

Some of the primary causes contributing to train accidents in India are:

- **Human errors:** Failures on the part of the railway crew, such as negligence, shortcuts, and disregard for safety rules and procedures, are the primary cause of train accidents in India. For example, in 2016, a train derailment near Kanpur killed 150 people due to negligence by the loco-pilot (train operator) who overshot a signal.
- **Unmanned level crossings:** Unmanned level crossings (UMLCs) are places where railway tracks cross roads without any barriers or signals to regulate traffic.

Note:

UMLCs continue to be one of the leading causes of rail accident fatalities. In 2018-19, UMLCs accounted for 16% of all train accidents.

- **Signaling failures:** Signaling failures can lead to trains running on the wrong track, colliding with other trains or stationary objects, or overshooting stations. For instance, in 2021, a signal failure caused a train collision near Mathura that killed around 25 people.
- **Infrastructural defects:** Train accidents can also be caused by defects in the tracks, bridges, overhead wires, or rolling stock (coaches and wagons) that compromise the safety and reliability of the railway network. Infrastructure defects can result from poor maintenance, ageing, vandalism, sabotage, or natural disasters. For example, in 2017, a train derailment near Muzaffarnagar killed 23 people due to a crack in the track.

To address these causes and enhance the safety and reliability of India's railway network, some of the recommendations made by various committees are:

- **Kakodkar Committee (2012):**
  - Creating a statutory Railway Safety Authority
  - Setting up a non-lapsable **Rashtriya Rail Sanraksha Kosh (RRSK)** of Rs. 1 lakh crores over five years for safety works
  - Eliminating unmanned level crossings
  - Adopting advanced technologies for track maintenance and inspection
  - Improving rolling stock design and quality
  - Improving human resource development and management
  - Ensuring independent accident investigation
- **Bibek Debroy committee (2014):**
  - Delegating more powers to the zonal and divisional levels
  - Allowing private entry and competition in rail services
  - Rationalizing passenger fares and freight charges
  - Creating a holding company for all railway PSUs
  - Separating railway budget from general budget
  - Outsourcing non-core activities
  - Creating a **Railway Infrastructure Authority of India**
- **Vinod Rai Committee (2015):**
  - Establishing an independent Railway Safety Authority with statutory powers to oversee and regulate safety matters.
  - Setting up a Railway Accident Investigation Board to conduct independent and impartial inquiries into accidents.
  - Creating a separate Railway Infrastructure Company to own and maintain railway assets such as tracks, bridges, signaling systems, etc.
  - Introducing a performance-linked incentive scheme for railway employees based on key performance indicators.
  - Implementing zero-based budgeting and accrual accounting systems to improve financial management and transparency.
  - Leveraging information technology and data analytics to improve decision making and service delivery.

Conclusion:

Addressing train accidents in India requires a multi-faceted approach including improving human resources, upgrading infrastructure, investing in modern rolling stock, implementing advanced safety technologies, and establishing robust safety management systems. By doing so, India can enhance the safety and reliability of its railway network, reducing the occurrence of train accidents and ensuring the well-being of passengers and railway personnel.

Q. Discuss the factors contributing to the increasing frequency of landslides in the Himalayan region and their implications. Suggest sustainable mitigation strategies that can be implemented to address this growing concern. (250 Words)

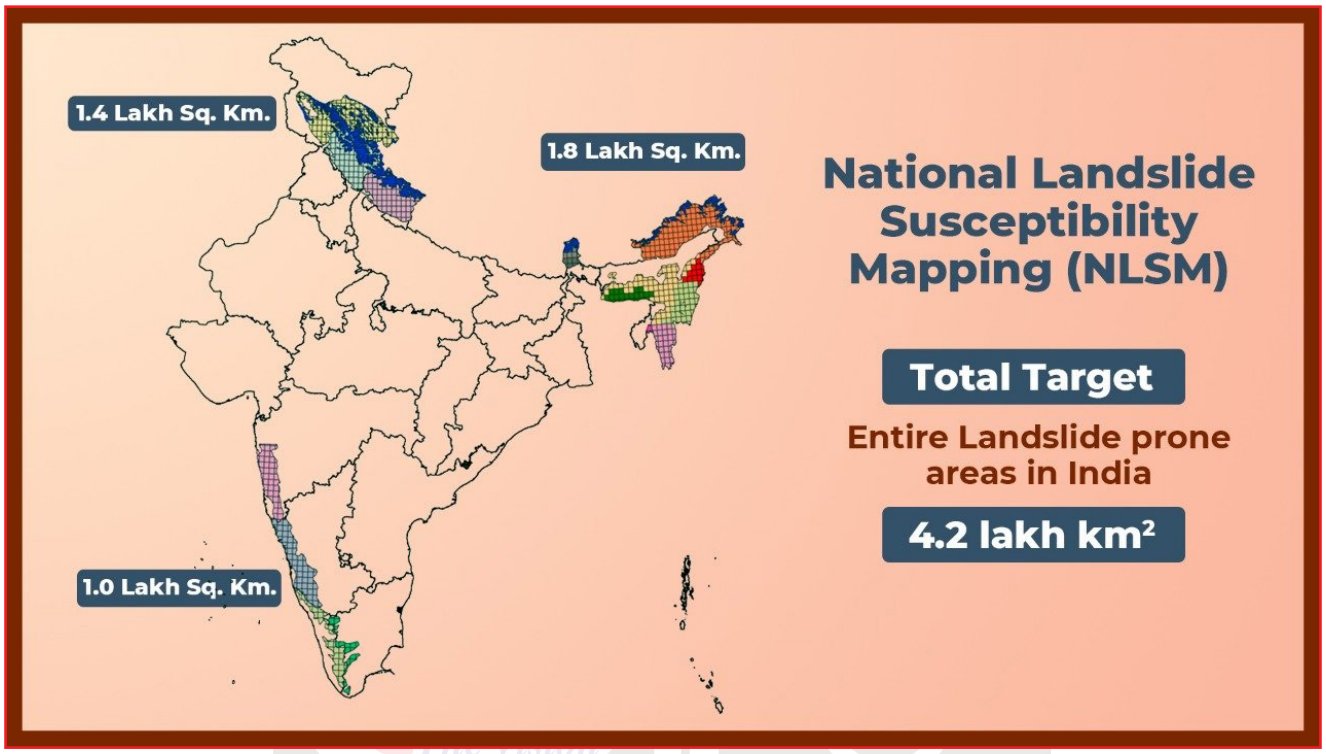
Approach:

- Start your answer with defining Landslide in the Himalayan Region.
- Discuss the reasons behind landslides in the Himalayan region and their implications.
- Suggest some sustainable mitigation strategies.
- Conclude with a forward looking approach.

Note:

Introduction

Landslides are the downward movement of masses of soil, rock, or debris under the influence of gravity. They are a common natural hazard in the Himalayan region, which is geologically young, tectonically active, and climatically diverse. The factors contributing to the increasing frequency of landslides in the Himalayas can be classified into two categories: natural and anthropogenic.



Body

Some of the reasons behind landslides in the Himalayan region:

- **Fragile Ecosystem:** Tectonic or neo-tectonic activities, associated with numerous subsurface processes like rock deformation, exhumation and reworking of rocks and surface processes such as erosion, weathering and rain/snow precipitation make the ecosystem inherently fragile.
  - **Earthquakes:** The convergence of the Indian plate with the Eurasian plate in the Himalayan region has created subterranean stresses that get released in the form of earthquakes which, in turn, cause fractures and loosen the litho-structures near the mountain surface. This increases the possibilities of rock movement along the slope.
    - Debris flow and underground water make a slope weak and landmass can slip down it.
- **Climate Induced Excessive Events:** Climate-induced excessive events like freezing/thawing and heavy rain/snow precipitation lead to avalanches, landslides, debris flow, glacial lakes outburst floods, landslide lakes outburst floods and flash floods. They add to the precariousness of the mountain system. The Himalaya is further stressed by anthropogenic activities.
  - Climate change has adverse impacts on glaciers, riverine systems, geomorphology and biodiversity, which, in turn, have increased the vulnerability of people in the mountainous states.
    - Land degradation aggravates the problem.
- **Geological Composition:** Some of the Himalayan rocks are made of limestone, which is more prone to water and landslides than other types of rocks because it can dissolve in weakly acidic rainwater or groundwater. This process creates caves, sinkholes, and other karst features that weaken the stability of the slopes.
- **Westerly Disturbance & Monsoon:** Confluence of Westerly Disturbance — a low-pressure system, originating from the Mediterranean Sea, moving eastward across central Asia and northern India

Note:

— and the South West Indian Summer Monsoon cause excessive and concentrated rainfall in parts of J&K, Himachal Pradesh and Uttarakhand leading to landslides and flash floods.

- **Anthropogenic Factors:** Human activities such as road construction, tunneling, mining, quarrying, deforestation, urbanization, agriculture, excessive tourism and hydroelectric projects can also cause or worsen landslides in the Himalayas. These activities can disturb the natural balance of the slopes by removing vegetation cover, altering drainage patterns, increasing soil erosion, creating artificial cuts and fills, blasting rocks, and generating vibrations.
  - These activities can also increase the exposure and risk of human settlements and infrastructure to landslides.
  - The 2013 Kedarnath Tragedy was also influenced by the unplanned development and construction activities in the area that had altered the natural drainage system and increased the soil erosion.

Some of the measures that can be taken as mitigation strategy:

- **Resilience Building:** To address these challenges, it's important to develop resilience against geo-hazards caused by natural processes, environmental degradation, and human activities. This involves implementing a network of sensors for real-time monitoring and data collection.
- **Leveraging Technology for Effective Monitoring:**
  - **Web-based sensors such as rain gauges, piezometers, inclinometers, extensometers, InSAR (Interferometric Synthetic Aperture Radar)**, and total stations can help monitor vulnerable areas. Monitoring should be prioritized in densely populated and built-up zones.
  - **Integrated Early Warning System (EWS):** The development of an integrated Early Warning System (EWS) using AI and Machine Learning (ML) algorithms is crucial. Such a system could help predict and alert communities about impending hazards, giving them valuable time to take preventive measures.
- **Formation of Himalayan States Council:** Establishing a collaborative platform that brings together the disaster management authorities from different states in the Himalayan region is a strategic move. This centralized council would enable the sharing of knowledge, experiences, and resources to effectively assess and manage the impacts of various stressors on the region.
- **Sustainable Socio Economic Development:** Recognizing the valuable natural resources present in the region, such as glaciers, springs, minerals, energy sources, and medicinal plants, offers the potential for sustainable socio economic development. However, it's crucial to strike a balance between resource exploitation and ecological preservation to ensure long-term viability.
- **Environmental Considerations:** Proper town planning that accounts for the unique characteristics of mountainous terrain is vital. Restricting heavy construction, implementing effective drainage systems, scientifically managing slope cutting, and using retaining walls are important aspects of environmentally conscious development.
  - Retaining walls are relatively rigid walls used for supporting soil laterally so that it can be retained at different levels on the two sides.
- **Sustainable Tourism:** Sustainable tourism can reduce landslides by promoting environmental awareness, conservation and protection of natural resources, and respect for biodiversity and ecosystems.
  - It can also provide economic incentives and social benefits for local communities, which can enhance their resilience and adaptive capacity to cope with natural hazards.
- **Building Sustainable Govt Projects:** To ensure responsible development in the Himalayan region, key measures include conducting environmental assessments, using eco-friendly technologies, involving local communities, increasing stakeholder awareness, and promoting coordination among governmental sectors.

Conclusion

The increasing frequency of landslides in the Himalayan region is a complex issue with multifaceted causes and significant implications. Sustainable mitigation strategies must encompass a holistic approach that combines geological understanding, climate adaptation, land-use planning, and community engagement to safeguard both the environment and the well-being of the people living in this vulnerable region.

Note:

Q. India faces increasingly frequent and severe heat waves. Suggest effective mitigation strategies for heatwave management in Indian cities. (250 words)

Approach:

- Introduce by defining heatwaves
- Highlight the factors responsible for intensified heatwaves in India
- Give mitigation strategies for heatwaves in Indian cities
- Conclude positively.

Introduction:

Heatwaves are prolonged periods of excessively hot weather, with temperatures significantly higher than the normal maximum for a particular region and time of year. As per IMD, the number of heatwave days in India has increased from 413 over 1981-1990 to **600 over 2011-2020.**

Body:

Factors Responsible for Intensified Heatwaves in India:

- **Urban Heat Island Effect:** Rapid urbanization and the expansion of cities have led to an increase in built-up areas, which absorb and retain more heat than natural landscapes. This creates urban heat islands, exacerbating the intensity of heatwaves in cities.
  - For example, **Delhi and Mumbai** have experienced higher temperatures compared to their surrounding rural areas due to this effect.
- **Deforestation and Loss of Green Cover:** Deforestation and the reduction of green spaces in urban areas have diminished the natural cooling effects provided by vegetation.
  - The loss of green cover in cities like **Bengaluru** has contributed to an increase in heat wave intensity.
- **Climate Change and Global Warming:** Rising global temperatures due to climate change have increased the frequency, duration, and intensity of heatwaves in India.
- **Lack of Preparedness and Adaptation Measures:** Many Indian cities lack adequate preparedness and adaptation measures to cope with heatwaves.
  - Limited access to **cooling infrastructure, inadequate early warning systems, and insufficient public awareness** about heatwave risks contribute to the severity of their impacts. The lack of comprehensive heat action plans in many cities has left populations vulnerable.
- **Anthropogenic Activities:** Human activities, such as **industrial processes, transportation, and energy consumption,** generate waste heat and greenhouse gas emissions, further contributing to the urban heat island effect and global warming.
  - The severe heat wave in **Delhi** in 2024, with temperatures reaching over **49°C in some areas.**

Mitigation Strategies for Heatwaves in Indian Cities:

- **Heat-resistant Infrastructure:** Promote the use of **reflective materials for pavements and rooftops** to reduce heat absorption.
- **Urban Greening Initiatives:** Developing **urban forests, parks, and rooftop gardens** to create natural cooling sinks.
  - Encourage **vertical gardens on building facades** to provide insulation and reduce ambient air temperature.
- **Heat Action Plans:** Develop and implement comprehensive heat action plans at the **city level**.
  - These plans should involve **heat forecasting, real-time alerts, and outreach programs** to educate citizens about heat-related illnesses and preventive measures.
- **Vulnerable Population Outreach:** Identify and target outreach programs towards vulnerable populations like the elderly, children, and those living in informal settlements who are more susceptible to **heatstroke.**
- **Smart Grid Management:** Implement **smart grid technologies to optimize power distribution** and reduce peak demand during heatwaves. This can help prevent power outages that exacerbate heat stress.

Conclusion:

By adopting a holistic approach that combines urban planning, early warning systems, technological interventions, and community engagement, cities can build resilience and mitigate the devastating effects of heatwaves moving towards achieving **Sustainable Development Goal (SDG) 11: Sustainable Cities and Communities**.

❖ ❖ ❖ ❖

Note: