Q.1) River interlinking projects in India promise water security but pose ecological and social risks. Examine the key challenges in implementing such projects and suggest a balanced approach. (150 words, 10 marks)

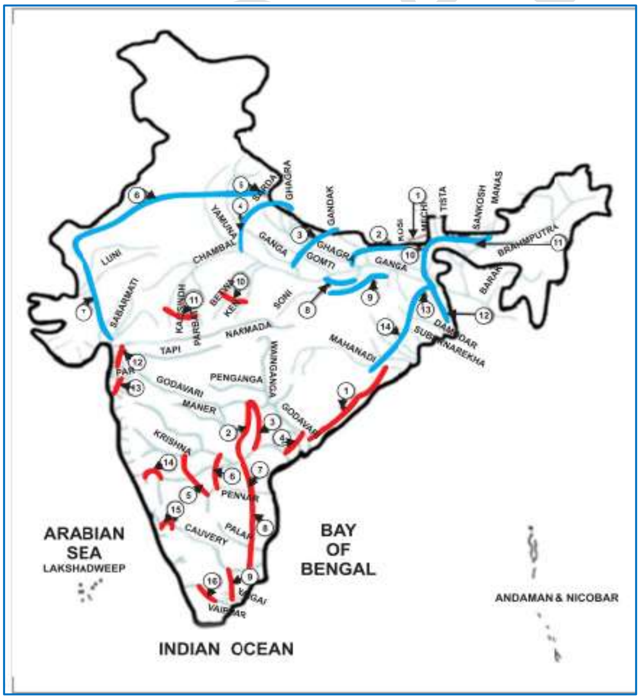
Introduction

India's **National River Linking Project (NRLP)** aims to ensure equitable water distribution by connecting **30 rivers** through **16 Himalayan and 14 peninsular links**. While promising water security, it raises serious ecological and social concerns.

Body

Ensuring Water Security

1. **Addressing regional imbalances:** NRLP proposes transferring water from surplus to deficit basins, e.g., **Ken-Betwa link** aims to benefit drought-prone Bundelkhand.
2. **Flood and drought mitigation:** Himalayan links aim to reduce annual flood damages **(₹6,000 crore/year)**, while Peninsular links tackle recurring droughts in Tamil Nadu, Karnataka.
3. **Enhancing irrigation potential:** The project targets adding **35 million hectares** of irrigation capacity, vital for doubling farmer incomes.
4. **Drinking water supply and hydropower:** Links are expected to provide drinking water to **62 million people** and generate **34,000 MW** of hydropower.



Major River Inter-Linking projects

Key Challenges

1. **Ecological disruption:** Submergence of forests and alteration of river flows threaten biodiversity and aquatic ecosystems.
   Example: **Ken-Betwa link** may impact **Panna Tiger Reserve**.
2. **Displacement and rehabilitation:** Large-scale relocation of communities with inadequate resettlement remains a major humanitarian concern.
   Example: **Polavaram project** displacing over **44,000 families**.
3. **Inter-state disputes:** Conflicts between states like Karnataka-Tamil Nadu (Cauvery) and Uttar Pradesh-Madhya Pradesh (Ken-Betwa) hinder consensus.

4. **Financial viability and delays:** The NRLP demands over **₹5.6 lakh crore** in funding, while several links face delays due to bureaucratic and environmental clearance hurdles.

Balanced Approach

1. **Decentralised water management:** Emphasise **watershed development**, rainwater harvesting, and aquifer recharge at the micro level.
2. **Environmental safeguards:** Comprehensive Environmental Impact Assessments **(EIAs)** and inclusion of ecological flow provisions in all link plans.
3. **Technological integration:** Use of **remote sensing, GIS, and AI** to evaluate river basin dynamics before implementing interlinking.
4. **Stakeholder engagement:** Transparent consultation with affected communities, experts, and state governments to build consensus and address grievances.
5. **International best practice – Australia's Murray-Darling Basin Plan:** It integrates basin-level management with ecological sustainability, water trading, and stakeholder participation—offering a model for India's inter-basin projects.

Conclusion

While river interlinking can enhance water security and agricultural productivity, it must be pursued with **environmental prudence, public participation, and integrated planning** to ensure long-term sustainability and equitable benefits for all regions.

Q.2) Mangrove forests play a crucial role in enhancing climate resilience and safeguarding coastal ecosystems in India. Elaborate on their ecological importance in this context. What are the major anthropogenic threats contributing to their decline? (150 words, 10 marks)

Introduction

Mangrove forests are dense, salt-tolerant vegetations that occur along tropical and subtropical coastlines. India hosts the world's **fourth-largest mangrove cover,** playing a pivotal role in climate adaptation and coastal protection.

Body

Ecological Importance of Mangroves in Climate Resilience

1. **Coastal Protection:** Mangroves act as natural barriers against storm surges, cyclones, and coastal erosion by stabilising shorelines with their intricate root systems.

Example: During the **1999 Odisha super cyclone**, mangrove belts near Kendrapara significantly reduced destruction.

2. **Carbon Sequestration:** Mangrove ecosystems are carbon-rich sinks, storing up to four times more carbon than tropical rainforests, thus mitigating greenhouse gas emissions. Example: **Sundarbans** store approximately **33 million tonnes** of carbon.
3. **Biodiversity Support:** They provide critical breeding and nursery grounds for marine species, supporting coastal fisheries and food security. Example: **Bhitarkanika and Sundarbans mangroves** support diverse species like the **saltwater crocodile** and **Bengal tiger**.
4. **Water Quality Regulation:** Mangroves filter sediments, heavy metals, and pollutants, improving the quality of coastal waters and reducing eutrophication.
5. **Livelihood Support:** Local communities depend on mangroves for firewood, honey, fish, and sustainable eco-tourism, making them essential for socio-economic resilience.

Major Anthropogenic Threats to Mangroves

1. **Urbanisation and Land Reclamation:** Coastal cities expand into mangrove areas, leading to large-scale deforestation and habitat loss.
   Example: **Mumbai and Navi Mumbai** have lost substantial mangrove tracts to infrastructure projects.
2. **Aquaculture Expansion:** Conversion of mangroves to shrimp farms alters salinity and depletes biodiversity.
   Example: **Andhra Pradesh** witnessed major mangrove decline due to brackish water aquaculture.
3. **Industrial Pollution and Oil Spills:** Effluents from thermal plants, refineries, and ports affect mangrove soil and water quality, stunting growth.
4. **Unsustainable Tourism:** Unregulated tourism damages root systems, increases litter, and alters hydrology in sensitive zones.
5. **Climate Change:** Sea level rise and increasing salinity affect mangrove regeneration and zonation, particularly in low-lying delta regions.

Government Initiatives for Mangrove Conservation

1. **MISHTI (Mangrove Initiative for Shoreline Habitats & Tangible Incomes):** Launched in Union Budget 2023–24, it aims at intensive afforestation of mangroves along India's coastline through community participation.
2. **National Coastal Mission under NAPCC:** Focuses on conserving coastal ecosystems, including mangroves, through vulnerability mapping and ecosystem-based adaptation.
3. **Integrated Coastal Zone Management Programme (ICZMP):** Implements scientific mangrove management in states like Gujarat, Odisha, and West Bengal, promoting sustainable coastal development.
4. **CAMPA (Compensatory Afforestation Fund Management and Planning Authority):** Utilises compensatory afforestation funds for mangrove regeneration and coastal afforestation projects.

Conclusion

Mangroves are **frontline climate defenders and biodiversity hotspots**. Their conservation requires integrated coastal zone management, community participation, and strict regulation of human activities to ensure long-term sustainability and ecological balance

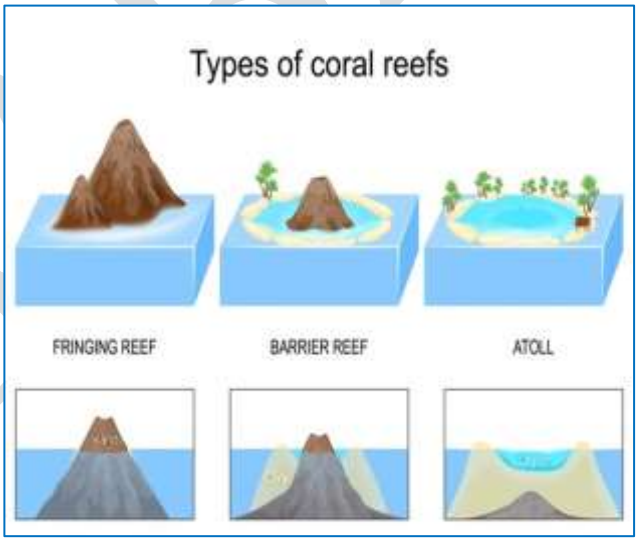
Q.3) Explain the ecological significance of coral reefs. How do phenomena like ocean acidification and coral bleaching threaten marine biodiversity and coastal economies? (150 words, 10 marks)

Introduction

Coral reefs, often called the **"rainforests of the sea,"** cover less than **1%** of the ocean floor yet support nearly **25% of all marine life.** Their ecological significance and vulnerability have drawn global conservation focus.

Body

Ecological Significance of Coral Reefs



1. **Biodiversity Hotspots:** Coral reefs provide critical habitat to over **4,000 species** of fish and countless invertebrates, playing a vital role in sustaining global marine biodiversity.
   Example: **Great Barrier Reef** hosts more than **1,500 fish species**.
2. **Coastal Protection:** Reefs act as natural barriers against wave action, storms, and erosion, safeguarding shorelines and coastal populations.
   Example: Coral systems around **Lakshadweep** reduce **wave energy by over 70%**.
3. **Breeding and Nursery Grounds:** Many marine organisms use coral reefs as breeding, spawning, and nursery grounds, ensuring continuity of fish populations.
   Example: Groupers, snappers, and l**obsters spawn** in reef ecosystems.
4. **Livelihood and Food Security:** Coral reefs support fisheries, tourism, and associated livelihoods, particularly in tropical coastal regions.
   Example: Over **500 million people** globally depend on reefs for food and income.

Threats from Ocean Acidification and Coral Bleaching

1. **Ocean Acidification:** Increased CO_2 absorption reduces carbonate ion concentration, hampering coral calcification and weakening reef structures.
   Example: **Indian Ocean reefs** are experiencing reduced growth rates due to acidification.
2. **Coral Bleaching Events:** Rising sea temperatures lead corals to expel symbiotic algae (zooxanthellae), turning them white and leading to mortality.

Example: The **2016 bleaching event** affected nearly **90% of corals** in the **Great Barrier Reef.**

3. **Ecosystem Collapse:** Loss of coral reefs destabilizes food chains, leading to decline in fish stocks and impacting predator-prey dynamics.
   Example: **Maldives** reported loss of reef fish post-bleaching events.
4. **Economic Losses:** Decline in **reef tourism**, fisheries, and protection services result in direct economic setbacks for coastal economies.
   Example: Coral degradation could cost Southeast Asia over **$38 billion annually by 2050**.

Government and Global Initiatives

1. **MISHTI (Mangrove Initiative for Shoreline Habitats and Tangible Incomes):** Though focused on mangroves, it indirectly supports coral ecosystems through integrated coastal zone management.
2. **Use of Biorock Technology:** Adopted in the Gulf of Mannar and Andaman Islands to restore damaged reefs using low-voltage electrical currents to enhance coral growth.
3. **ENVIS Reef Monitoring:** Under the Environment Ministry, regular monitoring of coral health is conducted in states like Gujarat and Tamil Nadu.
4. **UNDP-GEF Project:** Promotes coral reef conservation through protected area management in marine zones such as Gulf of Mannar and Malvan.

Conclusion

Coral reefs are crucial to biodiversity, economy, and coastal security. Combating their degradation through direct interventions and global cooperation is vital to achieving **SDG 13** (Climate Action) and **SDG 14** (Life Below Water).

Q.4) Rapid glacier retreat in the Himalayas is altering hydrological patterns and increasing disaster risks. Analyze the implications for agriculture, river systems, and human settlements in India. (250 words, 15 marks)

Introduction

The Himalayas, known as the **"Water Tower of Asia,"** are experiencing accelerated glacier melt (**more than 40% lost**) due to climate change in the last few decades. This retreat significantly impacts India's water systems, agriculture, and population living in vulnerable mountain and downstream areas.

Body

Altering Hydrological Patterns and Disaster Risks

1. **Unpredictable River Discharge:** Glacial retreat is disturbing the seasonal flow regimes of rivers, increasing variability and affecting water availability in both lean and flood seasons.
   Example: The Ganga and Indus basins now show altered peak flow timings.

2. **Glacial Lake Outburst Floods (GLOFs):** Melting glaciers form unstable moraine-dammed lakes that pose high flood risks when breached.
   *Example: **South Lhonak lake in Sikkim** was recently identified as a GLOF threat zone.*
3. **Increased Landslide and Flash Flood Frequency:** Glacier retreat destabilizes slopes, making hilly terrains prone to landslides and sudden floods.
   *Example: **Uttarakhand** has seen a sharp rise in disaster events post-2013.*
4. **Water Scarcity in Dry Seasons:** Though glacial melt may temporarily raise water flow, long-term retreat reduces base flow in dry months.
   *Example: **Springs and streams** in Himachal and Uttarakhand are drying up faster.*

Implications for Agriculture

1. **Changing Irrigation Availability:** Initial rise in meltwater may increase irrigation temporarily, but long-term water scarcity is likely as glaciers recede.
   *Example: The **Indus basin,** heavily dependent on glacier melt, may face reduced flow in peak agricultural seasons.*
2. **Altered Cropping Patterns:** Unpredictable water availability and erratic precipitation affect sowing and harvesting cycles.
   Example: Farmers in Himachal Pradesh and Uttarakhand report shifting from paddy to less water-intensive crops.
3. **Reduced Food Security:** Water stress affects productivity in the Indo-Gangetic plains, India's agricultural heartland.
   *Example: Decline in **wheat and sugarcane yields** projected under changing glacial-fed river flows.*

Implications for River Systems

1. **Disturbed Seasonal Flows:** Glacial retreat alters timing and volume of river discharge, affecting perennial nature of rivers.
   *Example: **Ganga and Brahmaputra** may become increasingly seasonal with flow reduction during dry months.*
2. **Increased Risk of Glacial Lake Outburst Floods (GLOFs):** Melting glaciers create unstable glacial lakes that may breach catastrophically.
   *Example: The **2021 Chamoli disaster** in Uttarakhand was triggered by a glacier-related event.*
3. **Sedimentation and River Morphology Changes:** Increased melt accelerates erosion and sediment load, altering river paths and increasing flood risks.
   *Example: **Brahmaputra's braided channels** in Assam are becoming more unstable.*

Implications for Human Settlements

1. **Increased Disaster Vulnerability:** Settlements in mountain regions face greater risks from landslides, flash floods, and GLOFs.
   *Example: Towns like **Joshimath and Gangotri** are showing subsidence and vulnerability signs.*

2. **Water Stress in Hill Communities:** Reduced glacier-fed springs and streams threaten domestic water supply.
   *Example: Several villages in **Sikkim and Uttarakhand** report drying of natural springs.*
3. **Forced Migration and Livelihood Loss:** Recurrent disasters and water scarcity are pushing populations to migrate from hills to plains.
   *Example: Studies show increased out-migration from **Kinnaur and Pithoragarh** districts.*

Government Initiatives

1. **National Mission on Sustaining the Himalayan Ecosystem (NMSHE):** Monitors glaciers and promotes ecosystem resilience in the Himalayan region.
2. **GLOF Risk Mitigation Projects:** Installation of early warning systems and controlled lake drainage at glacial lakes such as South Lhonak in Sikkim.
3. **National Adaptation Fund for Climate Change (NAFCC):** Funds local projects to strengthen climate-resilient agriculture and water management.
4. **Secure Himalaya Project:** Launched with **UNDP** support to promote sustainable livelihoods and climate resilience in ecologically sensitive Himalayan zones.

Conclusion

As the **UNDP** notes, **"Melting glaciers are not just environmental concerns—they are development challenges."** Proactive climate adaptation in the Himalayas is crucial to safeguard India's water security, agriculture, and the lives of millions dependent on them.

Q.5) Identify and discuss the factors responsible for diversity of natural vegetation in India. Evaluate the role of National Parks in conserving forest ecosystems and biodiversity, especially in rain-fed regions. (250 words, 15 marks)

Introduction

India hosts nearly **8% of the world's biodiversity**, encompassing **over 47,000 plant species** and **90,000 animal species**. This ecological richness stems from the country's diverse geography, climate, and soil—leading to a wide array of natural vegetation types.

Body

Factors Responsible for Natural Vegetation Diversity in India

1. **Climatic Variation:** Regional differences in rainfall, temperature, and humidity significantly influence vegetation patterns.
   Example**: Tropical evergreen forests** in high rainfall areas of the Western Ghats versus thorn forests in Rajasthan.
2. **Physiography and Altitude:** Mountains, plateaus, and plains support varied plant species due to changes in elevation and slope.
   Example: **Alpine vegetation** in Himalayas versus deciduous forests in the Deccan plateau.

3. **Soil Types:** Fertile alluvial soils, black cotton soils, laterites, and red soils support distinct vegetative growth.
   Example: **Sal forests in alluvial tracts** of Uttar Pradesh; teak in black soil regions of Madhya Pradesh.
4. **Latitude and Sunlight:** Variation in solar radiation due to latitudinal spread affects photosynthesis and growing seasons.
   Example: Dense tropical forests near the equator taper into temperate flora in northern hill states.
5. **Biotic Interference and Human Activities:** Agriculture, grazing, deforestation, and urbanization influence vegetative cover.
   Example: **Shivalik forests** degraded due to encroachment and overgrazing.
6. **Natural Hazards and Climatic Extremes:** Floods, droughts, and forest fires alter vegetation growth and composition.
   Example: Forest fires in **Uttarakhand** affecting chir pine forests.

Role of National Parks in Conserving Forest Ecosystems and Biodiversity

India has **over 100 National Parks** covering around **1.35%** of its geographical area, playing a critical role in preserving diverse vegetation across climatic zones.

1. **Habitat Protection:** National parks provide legal protection to flora and fauna by restricting human activity.
   Example: **Jim Corbett National Park** conserves sal forests and the Bengal tiger habitat.
2. **Rain-fed Region Conservation:** Many parks are located in rain-fed zones where forests are climate-sensitive and biodiversity-rich.
   Example: **Bandipur and Nagarhole parks** in Karnataka conserve deciduous forests dependent on monsoon rains.
3. **Biodiversity Hotspot Safeguarding:** Parks in biodiversity-rich zones help conserve endemic and endangered species.
   Example: **Silent Valley National Park** protects endangered lion-tailed macaque in the Western Ghats.
4. **Ecological Services and Climate Resilience:** National parks help in carbon sequestration, soil moisture retention, and maintaining the hydrological cycle in monsoon-dependent areas.
   Example: **Kaziranga National Park** aids in Brahmaputra floodplain regulation and ecosystem balance.
5. **Research, Education, and Ecotourism Promotion:** National parks support ecological research, awareness generation, and sustainable tourism.
   Example: **Sundarbans National Park** provides insights into mangrove ecosystems and climate adaptation.
6. **Corridor Creation and Landscape Connectivity:** Parks contribute to landscape-level conservation by facilitating species migration across protected areas.
   Example: **Kanha-Pench corridor** supports tiger movement and genetic diversity.

Conclusion

With growing pressures from population and climate change, National Parks are vital for ecological balance. As per **India's State of Forest Report 2021**, they help maintain forest cover and biodiversity. Strengthening them ensures long-term sustainability.