

# ALLAMA IQBAL OPEN UNIVERSITY, ISLAMABAD

(Department of Environmental Science)

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| Course Name:   | Introduction to Environmental Science |
| Course Code:   | 1421 / 5443                           |
| Level:         | BA / BS                               |
| Semester:      | Autumn 2026                           |
| Assignment No: | Assignment-2 (Units 5-9)              |
| Total Marks:   | 100                                   |
| Pass Marks:    | BS: 50 / BA: 40                       |

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**Question 1: Explain the hydrological cycle and its components (evaporation, condensation, precipitation, infiltration, runoff). How do human activities disrupt this cycle? (20)**

## Answer:

### 1. Overview of the Hydrological Cycle

The hydrological (water) cycle is a continuous global biogeochemical cycle driven by solar energy and gravity that circulates water among the atmosphere, hydrosphere, lithosphere, and biosphere.

### 2. Primary Components of the Hydrological Cycle

- **Evaporation & Transpiration:** Evaporation transforms surface liquid water from oceans and lakes into atmospheric vapor. Transpiration releases water vapor from plant stomata (combined as Evapotranspiration).
- **Condensation:** Water vapor cools as it rises, condensing around microscopic cloud condensation nuclei (CCN) to form clouds and fog.
- **Precipitation:** Water drops aggregate until atmospheric updrafts can no longer support them, falling as rain, snow, sleet, or hail.
- **Infiltration & Percolation:** Precipitation soaks into surface soil (Infiltration) and moves deeper through soil strata into underlying aquifers (Percolation).
- **Surface Runoff & Streamflow:** Excess precipitation unable to infiltrate flows across the ground surface into streams, rivers, and ultimately back into oceans.

### 3. Human Disruptions to the Hydrological Cycle

- **Deforestation & Land Clearing:** Reduces vegetative transpiration, lowers atmospheric humidity, and diminishes local rainfall while dramatically increasing flood runoff.
- **Urbanization & Impervious Surfaces:** Infrastructure prevents natural groundwater infiltration, lowering local water tables and intensifying flash urban flooding.
- **Groundwater Over-extraction:** Pumping aquifers faster than natural recharge rates causes severe water table depletion, land subsidence, and saltwater intrusion in coastal aquifers.
- **Climate Change & Glacier Melt:** Accelerated melting of Himalayan and Karakoram glaciers alters seasonal river

discharge patterns in the Indus River System, heightening drought and flood risks.

**Question 2: Describe the carbon cycle, distinguishing between geological and biological components. How has human activity (e.g., burning fossil fuels, deforestation) affected atmospheric CO<sub>2</sub> levels? (20)**

**Answer:**

### 1. The Carbon Cycle Framework

Carbon is the fundamental building block of life. The global carbon cycle tracks the exchange of carbon among four main reservoirs: Atmosphere, Terrestrial Biosphere, Oceans, and Geological Lithosphere.

### 2. Biological Carbon Cycle (Short-Term)

Operates on daily, seasonal, and annual timescales. Green plants and phytoplankton fix atmospheric CO<sub>2</sub> into glucose via Photosynthesis. Organisms release CO<sub>2</sub> back into the atmosphere via Cellular Respiration and Decomposition of organic detritus. Marine organisms utilize dissolved carbonate to form calcium carbonate shells.

### 3. Geological Carbon Cycle (Long-Term)

Operates over millions of years. Carbon dioxide dissolved in rainwater forms carbonic acid, weathering continental silicate rocks. Carbonate sediments settle on ocean floors, undergoing subduction into the mantle and eventually returning to the atmosphere via Volcanic Outgassing. Dead organic biomass trapped under anaerobic sediment converts into fossil fuel deposits (coal, petroleum, natural gas).

### 4. Anthropogenic Perturbations and Atmospheric CO<sub>2</sub> Elevation

- **Fossil Fuel Combustion:** Burning compressed geological carbon reserves releases vast quantities of ancient carbon into the active biological-atmospheric cycle at unprecedented rates.
- **Deforestation & Biomass Burning:** Destroys major terrestrial carbon sinks while combustion releases stored vegetative carbon into the atmosphere.
- **Impact on Atmospheric Concentrations:** Atmospheric CO<sub>2</sub> levels have surged from pre-industrial baseline of ~280 ppm to over 420 ppm today (as documented by the Keeling Curve), amplifying the greenhouse effect, global warming, ocean acidification, and climate destabilization.

**Question 3: Discuss the factors that influence the distribution of biodiversity across the globe. How do climate, geography, and human activities affect species richness? (20)**

**Answer:**

### 1. Factors Influencing Global Biodiversity Distribution

Biodiversity is not distributed uniformly across Earth. It exhibits a Latitudinal Diversity Gradient (LDG), where species richness peaks in equatorial tropical zones and declines toward polar regions.

### 2. Key Drivers of Species Richness

- **Climatic Drivers:** Solar energy availability, mean annual temperature, and precipitation levels. High energy and moisture in tropical rainforests support high net primary productivity (NPP) and complex multi-layered habitats.
- **Geographical & Topographical Drivers:** Environmental gradients create microclimates that foster high endemic biodiversity in mountain biodiversity hotspots. Island Biogeography principles demonstrate that larger and less isolated landmasses support greater species richness.
- **Evolutionary & Historical Factors:** Geological stability and absence of recent glaciations in the tropics provided millions of years for uninterrupted evolutionary speciation.

### 3. Impacts of Human Activities on Biodiversity (HIPPO Framework)

- **Habitat Destruction & Fragmentation:** Conversion of natural forests into agricultural fields and urban centers isolates populations and accelerates extinction risks.
- **Invasive Species:** Introduction of non-native invasive species (e.g., *Parthenium hysterophorus* and *Eucalyptus* in Pakistan) outcompetes indigenous flora and fauna.
- **Pollution & Overexploitation:** Industrial effluent, plastic waste, over-hunting, and over-fishing decimate native populations.
- **Climate Change:** Rapid thermal shifts force species to migrate poleward or upward, threatening specialized alpine and coral reef ecosystems.

**Question 4: Explain the concept of ecological footprint. How does human consumption of resources exceed Earth's carrying capacity? (20)**

**Answer:**

### 1. Definition and Scope of Ecological Footprint

Developed by Mathis Wackernagel and William Rees in the 1990s, the Ecological Footprint measures the biologically productive land and sea area required to provide the resources a population consumes and to absorb its corresponding waste products, expressed in global hectares (gha).

### 2. Core Components of Ecological Footprint

- **Carbon Footprint:** Land required to absorb anthropogenic carbon emissions.
- **Cropland & Grazing Land:** Area needed to grow food, fiber, feed crops, and livestock.
- **Forestry & Fishing Grounds:** Forest area for timber/fuelwood and marine/freshwater areas for fisheries.
- **Built-up Land:** Physical footprint covered by urban infrastructure, roads, and housing.

### 3. Earth's Carrying Capacity and Global Ecological Overshoot

Carrying capacity refers to the maximum population size an ecosystem can sustainably support without degrading its natural capital. Biocapacity represents Earth's total biologically productive supply. Humanity currently operates in severe Global Ecological Overshoot - consuming renewable resources at a rate equivalent to approximately 1.75 Earths. Earth Overshoot Day marks the calendar date when humanity's annual resource consumption exceeds Earth's yearly regenerative capacity.

### 4. Ecological Consequences and Mitigation Path

Overshoot results in severe natural resource capital depletion, groundwater collapse, biodiversity loss, and atmospheric carbon overload. Mitigating footprint requires transitioning to renewable energy grids, adopting circular economy frameworks, reducing food waste, and compact urban planning.

**Question 5: Discuss Pakistan's major environmental challenges, including water scarcity, deforestation, soil erosion, and pollution. What are their socio-economic impacts? (20)**

**Answer:**

### 1. Overview of Pakistan's Environmental Vulnerability

Pakistan consistently ranks among the top ten most climate-vulnerable nations globally on the Global Climate Risk Index, despite contributing less than 1% to global greenhouse gas emissions.

### 2. Major Environmental Challenges

- **Water Scarcity:** Per capita water availability has plummeted from 5,260 m<sup>3</sup> in 1951 to below 1,000 m<sup>3</sup>, pushing Pakistan into the water-scarce threshold due to inefficient flood irrigation, lack of storage reservoirs, and Indus Basin pollution.

- **Deforestation:** National forest cover stands at under 5% (far below the recommended 25%), driven by timber illegal harvesting, urban expansion, and rural fuelwood dependency.
- **Soil Erosion & Land Degradation:** Overlogging, salinization in agricultural plains, and severe wind/gully erosion affect over 75% of total land area.
- **Environmental Pollution:** Hazardous urban smog (Air Quality Index exceeding 400 in Lahore/Punjab), untreated municipal sewage dumped into natural waterways, and unmanaged plastic waste crises.

### 3. Socio-Economic Impacts on Pakistan

- **Agricultural & Economic Losses:** Decreasing crop yields, reduced hydropower capacity, and soil degradation cost Pakistan billions of dollars annually (~9% of GDP according to World Bank estimates).
- **Public Health Burden:** High incidence of waterborne diseases (cholera, typhoid) and respiratory illnesses caused by toxic air smog.
- **Displacement & Climate Migration:** Extreme weather events like the catastrophic 2022 floods displaced over 33 million people, creating severe climate refugee crises and urban slum expansion.