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ALLAMA IQBAL OPEN UNIVERSITY, ISLAMABAD

Course: Introduction to Environmental Science (1421) • Level: BA/BS

Semester: Autumn 2026

Assignment No. 1 (Units 1–4)

Total Marks: 100 • Pass Marks: BA 40 / BS 50

SOLVED ASSIGNMENT GUIDE

(For Study & Reference)

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Note: This guide is prepared for study and reference purposes. Students are advised to read the relevant units of the course book and write the answers in their own words in the actual assignment.

Question 1: Historical Development of Environmental Awareness in Pakistan (20 Marks)

Discuss the historical development of environmental awareness in Pakistan. (20)

Introduction

Environmental awareness means the public understanding that human life, health and prosperity depend upon the condition of air, water, soil, forests and wildlife, and that these natural systems can be damaged by careless human activity. In Pakistan this awareness did not appear suddenly; it developed slowly over many centuries, passing through traditional, colonial, developmental and modern phases. In the earliest periods people protected nature mainly

through custom, religion and practical necessity. After independence in 1947 the new state concentrated on dams, industry and agricultural production, and the environment was largely ignored. From the 1970s onwards, influenced by world events such as the Stockholm Conference of 1972, Pakistan gradually built environmental institutions, laws, policies and movements. Today climate change, smog, floods and water scarcity have made the environment a daily public concern. This answer traces that historical development phase by phase and shows how awareness grew from scattered traditional practices into a national policy question.

Traditional and Pre-Partition Roots

Long before the modern word 'environment' existed, the people of the Indus Valley lived close to nature and depended directly upon rivers, forests and seasonal rains. The Indus Valley Civilization built planned cities with covered drains, wells and public baths, which shows an early practical concern for clean water and sanitation. In later centuries, Islamic teachings, which deeply shaped the culture of the region, encouraged cleanliness, forbade wastefulness (israf), and treated the planting of trees as an act of charity (sadaqah). Village communities protected grazing lands, sacred groves and water sources through customary rules, and farmers practised rotations and fallowing that preserved soil fertility.

During the British colonial period (1849–1947 in Punjab and Sindh), the state began managing nature mainly for revenue and timber. The Forest Department was established in 1864, and Forest Acts were passed in 1878 and 1927 to reserve forests for railway sleepers, fuel and commercial timber. Canal colonies transformed the Indus plains, and large irrigation works

raised production but also began the long-term problems of waterlogging and salinity. Colonial rule therefore created the first environmental institutions, but their purpose was extraction and control, not public awareness or conservation for its own sake.

The Early Post-Independence Period, 1947–1971

After 1947, Pakistan's overwhelming priorities were food, industry, defence and settlement of refugees. Development was understood simply as more dams, more factories and more cultivated land. The Indus Waters Treaty of 1960, the construction of Mangla and Tarbela dams, and the spread of tube wells, fertilizers and pesticides during the Green Revolution of the 1960s dramatically increased output. However, these achievements carried hidden costs: rising water tables, soil salinity, pesticide poisoning of farm workers and wildlife, and the shrinking of the Indus Delta mangroves as river flows below Kotri declined.

Public and official awareness in this period remained weak. There was no environment ministry, no environmental law of general application and almost no press coverage of pollution. A few specialist bodies, such as the Pakistan Forest Institute at Peshawar and university departments of botany and zoology, studied natural resources scientifically, and conservationists raised isolated concerns, for example about the decline of game birds and the cutting of mountain forests. Hunting restrictions and the creation of a few game reserves existed, but environmental protection was treated as a minor technical matter, not a national development issue.

The Awakening of the 1970s

The turning point came from outside Pakistan. The United Nations Conference on the Human Environment held at Stockholm in 1972 placed the environment on the world agenda, and Pakistan, as a participating state, accepted that development and environment must be planned together. In the same decade, voluntary conservation began to organize: WWF-Pakistan was founded in 1970 and worked on wildlife surveys, protected areas and public education. Kirthar National Park was established in 1974, and other national parks and wildlife sanctuaries followed, giving practical shape to the idea that nature had value beyond timber and game.

At home, visible problems forced attention. Rapid industrial growth around Karachi, Lahore and Faisalabad discharged untreated waste into rivers and drains; the Ravi and Chenab began receiving heavy loads of industrial effluent and city sewage. The health effects of pesticides used on cotton became widely reported. These experiences taught an important lesson: pollution was not a rich country's luxury problem, as was sometimes claimed, but a direct threat to the health and livelihoods of poor Pakistanis.

Institution Building in the 1980s

In the 1980s awareness began to be converted into institutions. The Pakistan Environmental Protection Council was created in 1984 as the highest policy body, chaired by the head of government, and the Environmental Protection Ordinance of 1983 had already provided the first general legal framework. A small Environment and Urban Affairs Division was set up at the federal level, and environmental protection agencies were gradually organized in the provinces.

Though these bodies were weak and under-funded, their existence showed that the state now formally accepted environmental protection as its responsibility.

Equally important, the National Conservation Strategy (NCS) process was launched in the late 1980s with the support of IUCN. The NCS involved wide consultation with government departments, experts, businesses and citizens, and it spread environmental discussion far beyond a small circle of specialists. Environmental journalism also grew in this period: newspapers began carrying regular reports on deforestation, the threatened Indus dolphin, and the state of Karachi's coast. Schools of thought within planning changed, and the Planning Commission began asking how projects affected natural resources, even if enforcement remained poor.

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The 1990s: Policy, Law and Civil Society

The National Conservation Strategy was approved in 1992, the same year as the Rio Earth Summit, and it set out fourteen core programme areas from soil conservation to pollution control. It remains a landmark because it linked environment with population, health, agriculture and industry in one national document. In 1997 the Pakistan Environmental Protection Act replaced the 1983 Ordinance; it created the legal basis for National Environmental Quality Standards, Environmental Impact Assessment (EIA) of projects, environmental tribunals and penalties for polluters. For the first time, citizens and industries operated under a comprehensive environmental law.

Civil society expanded rapidly in the same decade. Organizations such as IUCN Pakistan, WWF, Shirkat Gah, the Sustainable Development Policy Institute (founded 1992) and numerous local

NGOs ran awareness campaigns, community forestry, clean-up drives and environmental education. Television and radio carried discussions on population, water and forests, and environmental reporting became a recognized beat in journalism. At the same time, court decisions, including the famous Shehla Zia case of 1994 in which the Supreme Court read the right to a clean environment into the constitutional rights to life and dignity, gave environmental awareness a strong legal and moral foundation.

Mainstreaming in the 2000s and the Climate Era

In the 2000s environmental questions entered mainstream planning. The National Environmental Policy was approved in 2005, a full Ministry of Environment functioned at the federal level, and EIA became a routine, if imperfectly enforced, step for large projects. Pakistan signed and ratified the major global conventions on climate change, biodiversity, desertification and wetlands, and sites such as the Indus Delta and high mountain wetlands gained international recognition. The devastating floods of 2010, which affected about twenty million people, together with the earlier 2005 earthquake, made disaster risk and environmental fragility matters of daily public debate.

After the Eighteenth Amendment (2010), environment was devolved to the provinces, which passed their own environmental protection acts and had to build their own institutions. In 2012 Pakistan adopted its first National Climate Change Policy, and the federal ministry was renamed to focus on climate change. Mass tree plantation drives, especially the Billion Tree Tsunami in Khyber Pakhtunkhwa (2014 onwards) and the later Ten Billion Tree Tsunami programme, took environmental awareness into popular politics: trees, clean air and the slogan of a 'Clean Green

Pakistan' became election and media themes. Pakistan's active diplomacy, its hosting of World Environment Day 2021, and the catastrophic floods of 2022, which submerged one-third of the country, placed Pakistan at the centre of the global debate on climate justice and loss and damage.

Awareness Today: Strengths and Remaining Gaps

Today environmental awareness in Pakistan operates at many levels: school and university curricula include environmental science as a subject (Allama Iqbal Open University itself teaches this course to distance learners across the country); electronic and social media report smog emergencies in Lahore, heatwaves in Sindh and water shortages in Karachi in real time; youth climate marches and citizen litigation keep pressure on governments; and businesses increasingly discuss cleaner production and waste treatment. Problems such as plastic waste, hospital waste, untreated sewage and vehicle emissions are publicly recognized rather than hidden.

Yet awareness has not fully become behaviour or enforcement. Implementation of the 1997 Act and provincial laws remains uneven; environmental agencies lack staff, laboratories and political backing; brick kilns, tanneries and factories still pollute openly; and the environment rarely decides election results. Awareness is also urban-centred, while rural communities, who are most dependent on natural resources and most exposed to their degradation, often receive the least environmental information. The historical task that remains is to convert growing awareness into consistent enforcement, investment and everyday habits.

Conclusion

The historical development of environmental awareness in Pakistan has moved through four broad stages: traditional and customary care for nature; a colonial and early post-independence phase in which nature was managed or exploited for production with little public awareness; an awakening in the 1970s and 1980s driven by Stockholm, visible pollution and new institutions; and a phase of policy, law and popular climate awareness from the 1990s to the present, marked by the NCS of 1992, the Act of 1997, devolution, plantation campaigns and the flood disasters. Awareness has clearly grown in depth and reach, but the history also shows a repeated gap between words, law and action. Closing that gap is the challenge for the present generation of students, officials and citizens.

Question 2: Environmental Education and Sustainable Development in Pakistan (20 Marks)

Evaluate the role of environmental education in achieving sustainable development in Pakistan. (20)

Introduction

Sustainable development is development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs, as defined by the Brundtland Commission in 1987. It stands on three pillars — economic growth, social well-being and environmental protection — which must advance together. Environmental education is the process by which people acquire knowledge, values, skills and motivation to understand

environmental problems and act to solve them. Its importance was recognized at the Tbilisi Conference of 1977, which set its goals as awareness, knowledge, attitudes, skills and participation. For Pakistan, a country facing water scarcity, deforestation, pollution and climate vulnerability while still struggling with poverty and literacy, environmental education is not an optional extra: it is the instrument that converts policy and law into the everyday behaviour of millions of citizens. This answer evaluates what environmental education has contributed, where it works, and where it falls short.

Why Pakistan Needs Environmental Education

Pakistan's development problem is deeply environmental. Per-capita water availability has fallen from about 5,650 cubic metres in 1951 to around the absolute scarcity threshold of 1,000 cubic metres; forest cover is only about five per cent of the land area; cities like Lahore suffer hazardous smog every winter; and the floods of 2022 caused damage and economic losses estimated above thirty billion US dollars. Most of these problems are aggravated by human behaviour at every level — the farmer who over-pumps groundwater or burns crop residue, the factory owner who discharges untreated effluent, the household that wastes water and throws plastic into drains, and the official who approves projects without assessment. Laws and technology alone cannot change millions of daily decisions; only education can. Environmental education therefore addresses the root cause of unsustainable development: ignorance and careless habits.

Role in Building Awareness and Knowledge

The first contribution of environmental education is cognitive: it teaches people how natural systems work and how human actions affect them. A student who understands the hydrological cycle, soil formation and food chains can understand why cutting a hillside forest causes floods and erosion downstream, or why a wetland is not 'wasteland' but a water-purifying, flood-controlling asset. In Pakistan, environmental topics have gradually entered school textbooks, college courses and university programmes; environmental science is now taught as a full subject at BA/BS and postgraduate levels, and distance education through Allama Iqbal Open University carries these ideas to working people, teachers and housewives in remote districts who cannot attend regular institutions. Knowledge also corrects harmful misconceptions — for example that groundwater is unlimited, that smoke from fields is harmless, or that population growth has no resource limit.

Role in Shaping Attitudes, Values and Skills

Information alone rarely changes behaviour; environmental education aims deeper, at values. Programmes that include field visits, tree planting, school gardening and nature clubs create emotional attachment to the local environment and a sense of stewardship, which in Pakistan also connects with religious and cultural values of cleanliness and avoiding waste. International frameworks for Education for Sustainable Development, and Sustainable Development Goal 4.7 in particular, emphasize exactly this combination of knowledge, values and action skills.

The skills dimension is equally practical. Environmental education trains people to observe, measure and solve problems: students learn to test water quality, conduct simple waste audits,

prepare compost, practise water-saving irrigation, and evaluate the environmental effects of a proposed project. At higher levels it produces the environmental managers, EIA specialists, foresters, teachers and journalists a sustainable economy requires. Without this human capital, policies such as the National Climate Change Policy or provincial pollution laws cannot be staffed or implemented.

Role in Participation and the Three Pillars of Sustainability

Sustainable development requires public participation, and environmental education creates citizens able to participate meaningfully: to attend public hearings on EIAs, to demand enforcement from environmental protection agencies, to organize community forestry and watershed committees, and to hold governments accountable through the courts, as happened in the Shehla Zia case. It supports each pillar of sustainability directly. Economically, it promotes resource efficiency, recycling industries and green jobs, and reduces the huge health and disaster costs of pollution. Socially, it improves public health, supports equity — because the poor suffer most from polluted water and air — and empowers women, who manage household water, fuel and food and are therefore central to resource decisions. Environmentally, it directly reduces pressure on forests, water, soil and biodiversity by changing consumption and production habits.

Channels: Formal, Non-Formal and Informal Education

In Pakistan environmental education flows through three channels. Formal education includes schools, colleges, universities and teacher-training institutions; its strength is reach and structure, and initiatives such as the Single National Curriculum have included environmental

themes, while cleanliness and plantation drives in schools create habits early. Non-formal education includes NGO campaigns, mosque and community programmes, farmers' field schools and extension services, which reach adults outside classrooms — crucial in a country with a large out-of-school population. Informal education comes through television, radio, newspapers and social media; coverage of Lahore's smog, Karachi's water tanker crisis and the 2022 floods has probably done more to raise mass awareness than any textbook. Distance learning occupies a special place among these channels, because printed and broadcast lessons reach learners in every district at low cost and also train the school teachers who multiply the message.

Critical Evaluation: Achievements and Shortcomings

An honest evaluation must record real achievements. Environmental studies have been institutionalized as a discipline; thousands of graduates now staff agencies, NGOs and consultancies; public awareness of climate change is far higher than a generation ago; and plantation and cleanliness campaigns mobilize millions of volunteers. Pakistan's negotiating position at international climate conferences is supported by a growing domestic constituency that understands the issues.

The shortcomings, however, are serious. First, environmental content in schools is often a small, examination-oriented portion of other subjects (general science, Pakistan studies, geography) rather than a coherent, activity-based programme; students memorize definitions of pollution rather than investigate their own mohalla's water quality. Second, teacher training is weak: most teachers have never received environmental education training and lack teaching

aids, laboratories or field opportunities. Third, the system is urban-biased and English-biased, while environmental realities are local and best taught in local languages with local examples. Fourth, there is little evaluation of outcomes: enrolment and syllabus coverage are counted, but changes in actual behaviour — water use, waste disposal, tree survival — are rarely measured. Fifth, poverty constrains choices; a family that cannot afford clean fuel will burn wood or plastic however well educated it is, which shows that education must accompany economic alternatives and enforcement, not replace them. Finally, coordination among federal and provincial governments, curriculum bodies and NGOs remains fragmented after devolution.

Recommendations

Several steps would strengthen the role of environmental education. Environmental content should be integrated across all subjects and grades with activity-based methods, local fieldwork and project assessment instead of rote questions alone. A compulsory, well-designed environmental course at undergraduate level for all disciplines would reach future officials and professionals. Teacher education, both pre-service and in-service, must include environmental pedagogy. Non-formal programmes for farmers, industry workers, municipal staff and religious and community leaders deserve funding equal to their importance. Media partnerships, mobile applications and open distance-learning materials in Urdu and regional languages can widen reach. Most importantly, schools and communities should practise what is taught — segregation of waste, water conservation, kitchen gardens and tree care on the premises — because the hidden curriculum of daily practice teaches more powerfully than any chapter.

Conclusion

Environmental education is a necessary, though not sufficient, condition for sustainable development in Pakistan. It builds the knowledge, values, skills and participatory capacity without which laws remain unenforced, technologies unused and policies unsupported. Its record in Pakistan shows genuine institutional growth and rising public awareness, but also rote learning, untrained teachers, weak evaluation and a gap between awareness and behaviour. If reformed along the lines suggested — practical, local, lifelong and linked with enforcement and economic alternatives — environmental education can become the engine that moves Pakistan from unsustainable habits towards genuinely sustainable development.

Question 3: Structure and Function of an Ecosystem: The Freshwater Pond (20 Marks)

Explain the structure and function of an ecosystem, using a freshwater pond as an example. (20)

Introduction

An ecosystem is a self-contained unit of nature in which living organisms interact with each other and with their non-living environment, exchanging energy and materials. The term was introduced by A. G. Tansley in 1935. Ecosystems range in size from a drop of water to the whole biosphere, but a freshwater pond is the classic teaching example because it is small, complete and self-sufficient: within its banks it contains producers, consumers, decomposers, sunlight, water, gases and minerals, and it carries on all essential life processes — production, consumption, decomposition and nutrient recycling — largely within itself. Studying the pond

therefore reveals the structure and function of every larger ecosystem, including lakes, forests and the Indus river system.

Structure of an Ecosystem: Abiotic Components

The structure of an ecosystem consists of its abiotic (non-living) and biotic (living) components and the way they are organized in space. The abiotic components of a pond include: (i) inorganic substances — water itself, dissolved carbon dioxide, oxygen, nitrogen, phosphorus, calcium and other mineral salts, which are the raw materials of life; (ii) organic compounds — proteins, carbohydrates and humic substances produced by organisms or washed in from outside, which link the living and non-living parts; and (iii) the climatic and physical regime — sunlight reaching different depths, temperature, the acidity (pH) of water and the pond's depth and bottom sediments. These factors set the limits within which pond life operates: light determines how deep photosynthesis can occur, while temperature and dissolved oxygen vary with season and depth and govern which animals can survive.

Structure: Biotic Components

The biotic components are organized by how organisms obtain food. Producers (autotrophs) are green plants and algae that make food by photosynthesis: in a pond they include phytoplankton (microscopic floating algae such as diatoms and Chlamydomonas), submerged plants (Hydrilla, Vallisneria), floating plants (duckweed, water hyacinth, lotus) and rooted plants at the margins (Typha, grasses). Consumers (heterotrophs) feed on other organisms: primary consumers or herbivores include zooplankton (Cyclops, Daphnia), insect larvae, snails, tadpoles and small herbivorous fish; secondary consumers include larger insects, frogs and small

carnivorous fish; tertiary consumers are the top carnivores such as large fish, snakes, kingfishers and herons. Decomposers (saprotrophs) — bacteria and fungi living mainly in the bottom mud — break down dead bodies and wastes and release minerals back into the water. Humans, birds and mammals visiting the pond form a further, occasional consumer level.

Spatial Organization: The Zones of a Pond

Pond life is arranged in horizontal and vertical zones according to light and depth. The littoral zone is the shallow margin where rooted plants grow and where most animals live; it is the richest zone. The limnetic zone is the open, well-lit water out to the depth where light still supports photosynthesis; phytoplankton and zooplankton dominate it. Below it lies the profundal zone, the deep, dark region where photosynthesis cannot occur and animals depend on food sinking from above. The benthic zone is the bottom itself, inhabited by decomposers, worms, molluscs and insect larvae in the mud. This zonation shows a general principle of ecosystem structure: organisms are distributed according to the availability of energy and resources, and each zone has its characteristic community.

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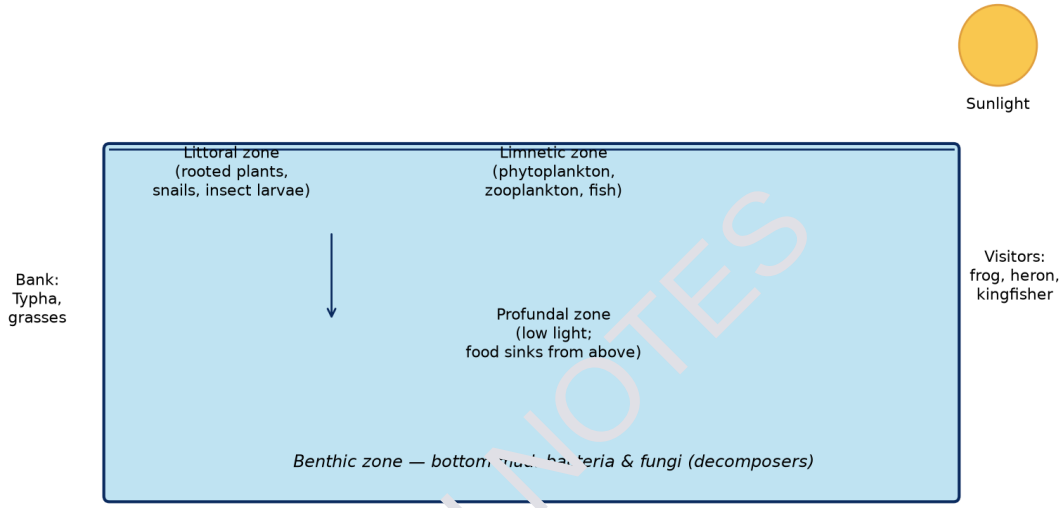


Figure 1: Zones and main organisms of a freshwater pond ecosystem.

Table 1. Main components of a pond ecosystem and their roles

Component	Examples in a pond	Role
Phytoplankton	Diatoms, Chlamydomonas, blue-green algae	Main producers of the open water
Submerged/floating plants	Hydrilla, duckweed, lotus, water hyacinth	Producers; provide oxygen and shelter
Zooplankton	Daphnia, Cyclops	Primary consumers; food for fish
Insects and larvae	Mayfly and dragonfly nymphs, mosquito larvae	Consumers at several levels
Bottom animals	Snails, worms, molluscs	Feed on detritus; recycle matter
Fish, frogs, birds	Rohu, catfish, frogs, kingfisher,	Higher consumers; control

	heron	populations
Bacteria and fungi	Decomposers in bottom mud	Decompose dead matter; release minerals

Function I: Production and the Flow of Energy

The functioning of an ecosystem means the processes by which it captures energy and circulates materials. The basic functional process is production: producers convert solar energy into chemical energy through photosynthesis, forming gross primary production; after meeting their own respiration needs, the remainder is net primary production, the food base of the whole ecosystem. Energy then flows in one direction through food chains: a typical pond chain runs phytoplankton → zooplankton → small fish → large fish → heron. Interconnected chains form a food web, which is more realistic and more stable, because a consumer with several foods survives the failure of one.

At each transfer, most energy is lost as heat, respiration and waste; on average only about ten per cent passes to the next trophic level (the 'ten per cent law'). This explains the pyramid of energy and numbers: the pond must contain a huge mass of phytoplankton to support a few top carnivores, and it explains why food chains rarely exceed four or five links. Energy flow is thus one-way — the pond needs a continuous supply of sunlight — while matter behaves differently, as the next section shows.

Function II: Decomposition and Nutrient Cycling

Unlike energy, materials circulate. When plants and animals die, decomposers in the pond mud break their bodies down and release nitrogen, phosphorus, carbon and other elements as

simple inorganic compounds, which producers absorb again. The pond therefore recycles its scarce nutrients continuously, and its fertility depends on this loop. Carbon cycles between dissolved carbon dioxide, plant tissue, animal bodies and back; oxygen released in photosynthesis supports respiration and decomposition; and sediments store nutrients that are returned to the water when the pond is stirred by wind or temperature turnover. If decomposers were removed, the pond would choke on its own dead matter and starve for nutrients within a short time, which demonstrates that even the smallest organisms perform an indispensable ecosystem function.

Function III: Regulation, Balance and Succession

A pond ecosystem also regulates itself. Predator–prey relationships, competition and feedback loops keep populations within limits: if herbivorous zooplankton multiply, fish predation and food shortage reduce them again. This self-regulation, called homeostasis, keeps the system stable within a range, though it can be broken by external shocks such as pesticide inflow or excessive nutrient loading (eutrophication), which causes algal blooms, oxygen depletion and fish kills.

Over long periods the pond changes through ecological succession. Sediments and dead matter accumulate, the pond becomes shallower, marsh plants invade the margins, and the pond gradually turns into a marsh, then a meadow and eventually dry land. Succession shows that ecosystems are dynamic, not static: structure and function change together as conditions change. It also warns managers that village ponds and small wetlands need periodic desilting and catchment protection if they are to survive as aquatic ecosystems.

Human Dependence and Disturbance

Pond ecosystems supply direct services: fish production, irrigation and livestock water, groundwater recharge, flood moderation, and habitat for birds and pollinators. In Pakistan, village ponds, dhands of Sindh and the shallow lakes such as Manchar and Haleji support fisheries and wildlife of national importance. Yet these systems are among the most threatened: sewage and industrial effluent, agricultural fertilizer and pesticide runoff, encroachment and water diversion have severely degraded many of them — Lake Manchar's collapse as a fishery is a well-known example. Protecting pond structure (its zones, species and water regime) is therefore the only way to protect pond functions and the services people draw from them.

Conclusion

The freshwater pond demonstrates the complete anatomy and physiology of an ecosystem. Its structure combines abiotic factors — light, water, gases and minerals — with producers, consumers and decomposers arranged in littoral, limnetic, profundal and benthic zones. Its functions are the capture of solar energy, one-way energy flow through food chains and webs with large losses at each level, the cyclic recycling of nutrients through decomposition, self-regulation, and long-term succession. Because everything in the pond is connected, any disturbance — pollution, overfishing or diversion — affects the whole system. These same structural and functional principles govern forests, grasslands, rivers and the sea, which is why the humble pond remains the finest introduction to ecology.

Question 4: Factors Influencing World Climates and the Köppen Classification (20 Marks)

Discuss the factors influencing world climates and explain the Köppen climate classification system. (20)

Introduction

Climate is the average condition of the atmosphere of a place over a long period, conventionally thirty years or more, as distinct from weather, which describes day-to-day conditions. The climates of the world range from the steaming rainforests of the Congo to the frozen wastes of Antarctica, and this variety is not accidental: it is produced by a set of geographical and atmospheric factors acting together. Understanding these factors explains why Karachi is hot and dry, Murree cold and wet, and London mild and rainy. On this understanding, scientists have built systems of climate classification, of which the most widely used is that of the German climatologist Wladimir Köppen, who based his scheme (first published in 1900 and refined in 1918 and 1936, later with Rudolf Geiger) on temperature and precipitation values linked to natural vegetation. This answer first discusses the factors influencing world climates and then explains the structure, merits and limitations of the Köppen system.

Latitude and the Sun's Energy

Latitude is the single most important control of climate. Because the Earth is spherical, the sun's rays strike the equator nearly vertically and are concentrated over a small area, while

near the poles they arrive slanting and spread over a larger area, and also pass through more atmosphere. The result is a general decrease of temperature from equator to poles, producing the broad thermal belts — tropical, temperate and frigid. Latitude also governs the length of day and the strength of seasons: at the equator day and night are nearly equal all year and seasons are weak, while higher latitudes have long summer days, short winter days and strongly contrasting seasons. The migration of the overhead sun between the tropics shifts pressure and wind belts seasonally, bringing monsoons to South Asia and Mediterranean climates their winter rains.

Atmospheric Circulation: Pressure Belts, Winds and Air Masses

Unequal heating sets the atmosphere in motion. Warm air rises at the equator (the equatorial low, with heavy convectional rain), descends around latitudes 30° (the subtropical highs, under which the great deserts — Sahara, Arabian, Thar — lie beneath clear, dry skies), rises again near 60° (subpolar lows) and descends over the poles. The resulting planetary winds — trade winds, westerlies and polar easterlies — transport heat and moisture around the globe. Places under the westerlies (western Europe) receive frequent moist oceanic air and rain; places under offshore trade winds are dry. Seasonal shifts of these belts, and regional systems like the South Asian monsoon (driven by the heating of the Tibetan Plateau and the land–sea contrast), determine the rhythm of wet and dry seasons for billions of people.

Altitude, Relief and Aspect

Temperature falls with height at an average rate of about 6.5 °C per thousand metres (the environmental lapse rate), so highlands are cooler than neighbouring lowlands at the same

latitude — which is why Pakistan's northern mountains have alpine climates while the adjacent plains are subtropical, and why Quito in Ecuador is mild though it stands on the equator. Mountains also force rising air to cool and shed rain on windward slopes (orographic precipitation), leaving dry rain-shadow areas on the leeward side as in the case of the dry interior of Balochistan behind coastal ranges. The direction a slope faces (aspect) matters too: south-facing slopes in the northern hemisphere receive more sun and are warmer and drier than north-facing ones.

Distance from the Sea and Ocean Currents

Water heats and cools more slowly than land, so the sea moderates climate. Coastal places have maritime climates — small annual temperature range, higher humidity and more evenly distributed rainfall — while interiors have continental climates with hot summers, cold winters and scanty rain; compare Karachi with Jacobabad, or London with Moscow at similar latitude. Ocean currents extend this influence: warm currents such as the Gulf Stream and North Atlantic Drift keep north-western Europe far warmer than its latitude warrants, while cold currents such as the Humboldt (Peru) and Benguela currents cool and dry the adjacent coasts, helping to form the Atacama and Namib deserts. Ocean–atmosphere oscillations such as El Niño and La Niña periodically disturb rainfall patterns across whole continents, including Pakistan's monsoon and winter rains.

Other Factors: Surface Cover and Human Activity

The nature of the surface adds local variety. Forests increase humidity and moderate temperature through evapotranspiration; bare rock, sand and snow reflect more solar radiation

(albedo) and intensify heating or cooling; lakes and irrigated tracts moisten nearby air. Human activity has now become a climatic factor in its own right: cities form 'heat islands' several degrees warmer than their surroundings; deforestation reduces rainfall recycling in regions such as the Amazon; and the accumulation of greenhouse gases from fossil fuels, industry and agriculture is raising global temperatures, shifting rainfall patterns and intensifying extremes — the background to Pakistan's recent heatwaves and the super-flood of 2022. These local and human factors modify, but do not abolish, the great latitudinal and circulatory controls.

The Köppen Classification: Basis and Main Groups

Köppen sought a classification that could be applied anywhere from ordinary weather-station records yet would correspond to the world's vegetation regions, since vegetation is the best visible expression of climate. He therefore used monthly and annual means of temperature and precipitation, with critical threshold values chosen to match vegetation boundaries — for example the 18 °C coldest-month limit for tropical climates corresponds roughly to the poleward limit of certain tropical plants, and the boundary of the dry (B) climates is calculated from a formula relating rainfall to temperature and its seasonal distribution. Climates are denoted by a code of two or three capital and small letters: the first letter gives the main group, the second the precipitation pattern, and the third the temperature pattern.

Table 1: The main groups of the Köppen climate classification

Group	Name	Defining feature	Example regions
A	Tropical (megathermal)	Coldest month 18 °C or above	Amazon, Congo Basin, Indonesia

B	Dry (arid and semi-arid)	Evaporation exceeds precipitation (formula-based)	Sahara (BWh), Thar, central Sindh
C	Temperate (mesothermal)	Coldest month between -3 °C and 18 °C; warm summers	Mediterranean (Csa), China coast (Cwa), western Europe (Cfb)
D	Continental / snow (microthermal)	Coldest month below -3 °C; warmest month above 10 °C	Siberia, Canada, northern USA (Dfa, Dfb)
E	Polar	Warmest month below 10 °C	Arctic tundra (ET), ice caps (EF)
H	Highland	Climate governed by altitude	Himalaya, Karakoram, Andes

Within the groups, second and third letters add precision. In group A, f means rain in all seasons (Af, equatorial rainforest, e.g. Singapore), m means monsoon (Am), and w means a dry winter (Aw, savanna). In the dry group B, W denotes true desert (Wüste) and S steppe or semi-arid; h (heiss) means hot (mean annual temperature 18 °C or above) and k (kalt) cold — hence BWh is the hot desert of Sindh and the Thar, while BSk is the cold semi-arid steppe of parts of Central Asia. In groups C and D, s means dry summer (the Mediterranean Csa of California and southern Europe), w dry winter (Cwa, found in Pakistan's northern plains and foothills, where monsoon rain falls in summer), and f rain at all seasons (Cfb, the marine west-coast climate of Britain); third letters a, b and c grade the warmth of the summer. Polar E divides into ET (tundra, warmest month 0–10 °C) and EF (permanent frost). Pakistan alone displays several types within

a small area — BWh and BSh over most of Sindh and southern Punjab, Cwa in the northern plains and Pothohar, and highland and ET-type conditions in the Karakoram — which makes the scheme useful for teaching and for agricultural and water planning.

Merits of the Köppen System

The system's strengths explain its survival for over a century. It is quantitative and objective: any station's climate can be classified from its records without subjective judgement. It is vegetation-linked, so its map resembles the map of natural vegetation and agriculture, making it meaningful to geographers, ecologists and planners. Its letter code is compact and universally understood, appearing in atlases and textbooks worldwide, and it covers the whole globe on a comparable basis, which permits world-scale comparison. Finally, because it rests on monthly data, it captures seasonality — distinguishing, for example, Csa (winter rain) from Cwa (summer rain), a difference of great practical importance.

Limitations of the Köppen System

The classification also has weaknesses. Its thresholds are somewhat arbitrary, and a station near a boundary can change class because of a tiny difference, while two places in the same class can feel quite different. It considers only temperature and precipitation, ignoring wind, humidity, cloudiness and evaporation measurements directly (the last enters only indirectly through the dryness formula). It was designed for lowlands: mountain areas compress many climates into short distances and are lumped under H in later versions. Agricultural and human perceptions of climate — frost frequency, growing-season length, extreme events — are poorly represented, and in an era of rapid climate change the fixed boundaries are shifting, so maps

based on older data increasingly misdescribe the present. Alternative schemes (such as Thornthwaite's, which uses water balance) answer some of these objections, but none has displaced Köppen in general use.

Conclusion

World climates are produced by the interplay of latitude and solar energy, the planetary circulation of pressure belts and winds, altitude and relief, distance from the sea and ocean currents, surface cover, and increasingly human activity. The Köppen classification translates the two most measurable results of these controls — temperature and precipitation — into a simple letter code tied to vegetation regions. Despite arbitrary boundaries and the omission of winds and extremes, its objectivity, compactness and vegetation basis have made it the standard world scheme, and it remains an effective framework for comparing regions as different as the Thar desert, the Mediterranean and Siberia — and for tracking how those climatic regions are now beginning to shift.

Question 5: Soil Erosion in Pakistan: Causes, Types, Impacts and Control (20 Marks)

Analyze the causes, types, and impacts of soil erosion in Pakistan. What measures can be taken to control erosion and conserve soil? (20)

Introduction

Soil is the thin living skin of the land from which almost all food, fodder and fibre comes, yet it forms at the rate of only a few centimetres in a human lifetime. Soil erosion — the removal of

topsoil by water, wind or gravity faster than it can form — is therefore among the most serious environmental problems of Pakistan. National studies commonly estimate that around three-quarters of the country's land area is affected by erosion in some degree, that roughly forty million hectares suffer water or wind erosion, and that the Indus river system carries one of the world's heaviest sediment loads — hundreds of millions of tonnes a year — drawn largely from the northern mountains and the eroded Pothohar plateau. With a rapidly growing population to feed from a limited cultivated area, every tonne of lost topsoil is a direct loss of national food security. This answer analyzes the causes and types of erosion in Pakistan, examines its impacts, and evaluates the measures available to control it and conserve the soil.

Types of Erosion

Water erosion is the dominant type. It begins as sheet erosion, the fairly uniform removal of a thin layer of topsoil by raindrop impact and surface flow, often unnoticed until yields fall. Where flow concentrates, rill erosion cuts small channels that ploughing can still remove; when rills deepen into gullies, the land is dissected into badlands that machinery cannot cross — the ravined lands of the Pothohar plateau and parts of Dera Ghazi Khan are examples. Riverbank erosion along the Indus and its tributaries consumes fertile farms and villages during floods, while in the northern mountains landslides and mass movements deliver whole slopes of soil and rock into valleys.

Wind erosion rules the dry regions. In the Thar, Cholistan and Thal deserts and the dry plateaux of Balochistan, strong winds lift fine particles from bare, loose soil, producing dust storms, burying fields, roads and canals under drifting sand, and forming moving dunes that engulf

settlements. Wind strips the most fertile fraction first, leaving coarse, infertile material behind. Gravity-driven erosion — landslides, slips and debris flows on steep, deforested or road-cut slopes in Murree, Hazara, Gilgit-Baltistan and Azad Kashmir — is a third type, frequently triggered by monsoon rain and earthquakes. In the irrigated plains a further soil degradation process, waterlogging and salinity, often accompanies erosion problems and compounds the loss of productive land.

Natural Causes

Part of Pakistan's erosion is natural in origin. The climate is aggressive: most rain falls in the short, intense monsoon season, when high-energy downpours strike slopes that are baked hard or thinly vegetated, so a large share runs off, carrying soil with it. In the dry west and south, long rainless periods leave soil loose and exposed to seasonal winds. The topography is equally unfavourable: the country includes some of the steepest terrain on earth in the Karakoram, Hindu Kush and Himalaya, where gravity, freeze–thaw action and young, unstable geology shed material rapidly. Many soils themselves are erodible — the loess-like silts of Pothohar and the sandy soils of the deserts detach and move easily — and natural vegetation cover is sparse everywhere except the northern forests because of the arid climate. Erosion would therefore occur even without people; human action has greatly accelerated it beyond geological rates.

Human Causes

The human causes are decisive and controllable. Deforestation is foremost: Pakistan's forest cover of about five per cent is far below the level needed for protection, and fuelwood cutting, timber extraction and forest fires in the northern hills and Balochistan juniper tracts strip the

cover that binds slopes and breaks raindrop force. Overgrazing by large livestock herds removes grass cover and compacts the soil around villages and water points across the rangelands, which form more than half the country. Faulty cultivation — ploughing up and down slopes instead of along contours, cultivating steep marginal lands, leaving fields bare between crops and removing crop residues and dung as fuel — exposes soil precisely when the monsoon arrives. Construction adds to the load: unplanned road-cutting in the mountains, mining and urban expansion onto agricultural land all generate sediment. Finally, poor irrigation management waterlogs and salinizes plains soils, destroying their structure and productivity, while abandonment of degraded land leads to further neglect and gully spread.

Impacts: On Land, Water and People

The impacts begin on-site. Loss of topsoil removes the most fertile, organic-rich layer, reducing yields progressively; Pakistan's gullied and sheet-eroded lands show declines in productivity that farmers compensate for with ever more fertilizer, raising costs. Gullies fragment holdings and take land out of cultivation entirely, and sand encroachment buries fields and homes in desert districts. Off-site, the eroded sediment enters rivers and settles where water slows: it has already consumed a substantial share of the live storage of Tarbela and Mangla reservoirs, shortening the life of the nation's most valuable irrigation and hydropower assets, and it raises river beds, increasing flood risk. Sediment and the nutrients and pesticides attached to it pollute water supplies and fisheries.

The socio-economic impacts follow directly. Falling farm productivity deepens rural poverty and food insecurity and pushes families to migrate. Floods fed by degraded catchments — where

deforested slopes shed rain within hours — impose huge relief and reconstruction costs, as in 2010 and 2022. Dust storms damage health, transport and machinery in desert-fringe cities. Nationally, erosion quietly taxes every sector: more fertilizer imports, more dredging, shorter dam life and less reliable water storage. It is a slow disaster less visible than a flood but, year after year, comparably expensive.

Control Measures: Agronomic and Vegetative

The cheapest and most sustainable controls work through vegetation and farm practice. Contour cultivation — ploughing and sowing along level lines across the slope — slows runoff and is basic practice for the sloping lands of Pothohar and the northern foothills; strip cropping alternates close-growing and row crops in contour bands, and cover crops, mulching and leaving crop residues protect the surface from raindrop impact. Crop rotation with legumes and the addition of farmyard manure rebuild soil organic matter and structure, increasing infiltration so that more rain enters the soil and less runs off. Minimum or zero tillage, now spreading in the rice–wheat belt, keeps the surface protected year-round. On rangelands, controlled and rotational grazing, reseeding of grasses and protection of regeneration areas restore the grass shield that prevents both wind and water erosion.

Control Measures: Mechanical, Biological and Institutional

Where slopes are steep or erosion advanced, engineering measures are needed: bench terracing of hillsides (long practised in parts of the north), contour bunds and trenches, check dams and gabion structures in gullies to trap sediment and raise the channel bed, and spurs and embankments against riverbank erosion. Biological engineering combines these with planting:

afforestation and reforestation of catchments, shelterbelts and windbreaks around desert farms and canals, sand-dune stabilization by planting hardy shrubs and grasses such as Saccharum and Prosopis in Thar and Cholistan, and stabilization of road cuts with vegetation. Programmes such as watershed management projects in the Tarbela and Mangla catchments and the national tree-plantation campaigns show these methods at work.

Institutions and policy complete the picture. Soil conservation departments and agriculture extension services must carry techniques to farmers with demonstrations, subsidized machinery for terracing and check dams, and secure land tenure that rewards long-term care. Land-use planning should keep cultivation off the steepest slopes and protect forests and rangelands under law and community management. Combating salinity through drainage, gypsum application and salt-tolerant crops conserves the irrigated soil resource alongside erosion control. Public awareness — the subject of this whole course — underlies everything, because erosion control succeeds only when thousands of individual landholders each protect their own fields.

Conclusion

Soil erosion in Pakistan is the product of an aggressive natural setting — intense monsoon rain, steep young mountains, erodible soils and arid winds — multiplied by human pressures: deforestation, overgrazing, faulty cultivation and careless construction. Its types range from silent sheet erosion to spectacular gullies, landslides and marching dunes, and its impacts run from falling farm yields to the silting of Tarbela and Mangla, worsened floods and deepening rural poverty. The encouraging fact is that erosion is the most preventable of Pakistan's

environmental problems: contour farming, cover and residue management, terracing, check dams, afforestation, shelterbelts and controlled grazing are all proven and affordable. Conserving the soil is, quite literally, conserving the foundation of the nation's food security and development.

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