Land and Water Use

AP Environmental Science

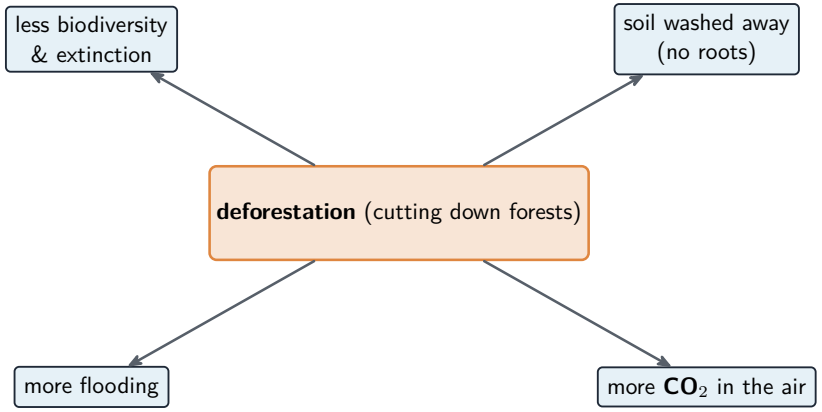
The Tragedy of the Commons

The **tragedy of the commons** : when a resource is shared and open to all (a fishery, the atmosphere, a pasture), each user takes as much as they can for private gain, and the shared resource is overused and degraded for everyone. Solutions require regulation, privatization, or cooperative management.

Clearcutting

Clearcutting removes all trees from an area at once. It is cheap and efficient but causes **erosion** , loss of habitat and biodiversity, flooding, and higher soil temperatures. Recovery is slow, and nearby streams suffer from sediment.

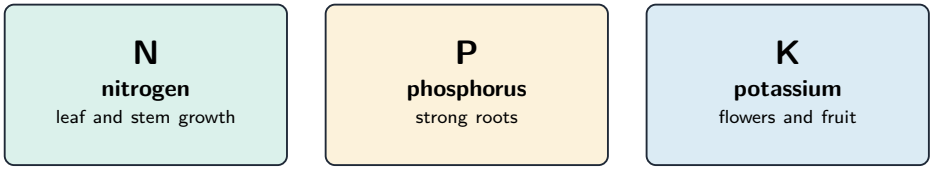
A fresh clearcut: every tree in the strip is taken at once, leaving bare soil that erodes and washes into streams



Deforestation lowers biodiversity and causes erosion, flooding, and higher CO2

The Green Revolution

The **Green Revolution** boosted crop yields with high-yield seeds, **synthetic fertilizers** , **pesticides** , irrigation, and mechanization. It fed billions but brought costs: soil degradation, water pollution, high energy and water use, and loss of crop diversity (**monoculture**).



NPK fertilisers contain all three - ammonium salts and nitrates supply the nitrogen

NPK fertilisers supply the three elements plants need most

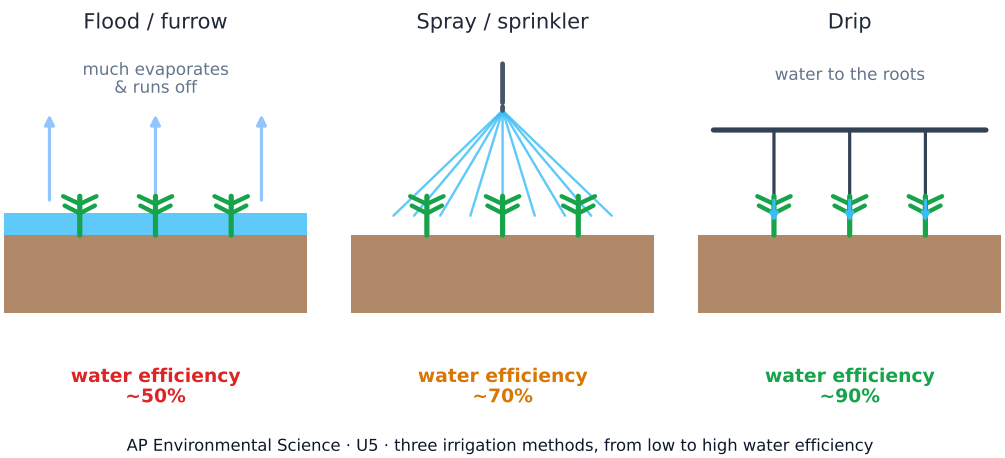
Impacts of Agricultural Practices

Practices such as tilling, monoculture, and heavy fertilizer/pesticide use cause **erosion**, **soil salinization** , nutrient runoff (causing **eutrophication**), and loss of biodiversity. Sustainable methods reduce these harms.

Intensive farmland: tillage, fertilisers and monocultures raise yields but can erode soil and pollute water

Irrigation Methods

Irrigation supplies water to crops, and it is by far the **largest human use of freshwater - about 70%** of it worldwide, a figure the exam expects you to know. **Drip** irrigation is the most efficient (least evaporation); **flood** and **spray** methods waste more water and can cause **waterlogging** and **salinization** as evaporation leaves salts behind. Over-irrigation depletes **aquifers** (underground stores of freshwater) faster than they refill.



Irrigation methods compared: drip wastes the least water, flooding the most

Pest Control Methods

Pesticides kill pests and raise yields, but cause problems: they harm non-target species, pollute water, and drive **pesticide resistance** (survivors breed, so stronger doses are needed – the "pesticide treadmill").

Aerial pesticide spraying: chemical pest control can protect yields but also harm non-target species and create resistant pests

Meat Production Methods

Producing meat, especially in **concentrated animal feeding operations** (CAFOs), uses large amounts of land, water, feed, and energy, and generates waste and **methane** (a greenhouse gas). Meat is far less energy-efficient than plant food because of the 10% rule – higher trophic levels waste more energy.

Overgrazing - letting livestock eat vegetation faster than it regrows - strips the soil of its protective cover. On dry land this can drive **desertification** : the degradation of low-precipitation regions until they become deserts. The sustainable answer is **rotational grazing** , moving livestock regularly between pastures so no single area is grazed bare.

Impacts of Overfishing

Overfishing removes fish faster than they reproduce, collapsing populations (like cod). **Bycatch** (unwanted catch) and destructive methods (bottom trawling) damage ecosystems. It is a classic tragedy of the commons in the open ocean.

Impacts of Mining

Mining extracts minerals and fuels but disturbs land, especially **surface (strip) mining** and **mountaintop removal**. Impacts include habitat destruction, **acid mine drainage**, and toxic tailings polluting water.

An open-pit mine: benches are cut ever wider and deeper to reach the ore, destroying habitat and exposing rock that pollutes water

When the easily reached deposits are gone, mining moves underground to **subsurface mining**, which is far more expensive and dangerous - the same pattern applies to coal as its accessible reserves shrink.

Impacts of Urbanization

Urbanization replaces natural land with **impervious surfaces** (roads, buildings), increasing runoff and flooding, creating **urban heat islands**, and generating pollution and waste. **Urban sprawl** consumes farmland and habitat. It also strains the **hydrologic cycle**: a dense city depletes local water, and heavy groundwater pumping near a coast draws seawater into the aquifer - **saltwater intrusion** - which can ruin a freshwater supply.

Urban sprawl: housing spreads over former farmland, sealing the soil so rain runs off instead of soaking in

Ecological Footprints

An **ecological footprint** measures the land and water a person or population needs to supply resources and absorb wastes. Wealthy, high-consumption nations have much larger footprints. If everyone's footprint exceeds Earth's capacity, resources are being used unsustainably.

> **Worked example.** Earth provides roughly 1.6 global hectares (gha) of **biocapacity** per person. If the average person's footprint is 2.7 gha, humanity is demanding about $\frac{2.7}{1.6} \approx 1.7$ Earths – living beyond what the planet can renew. Worse, if everyone consumed like a high-income nation at 8 gha per person, it would take $\frac{8}{1.6} = 5$ Earths – exactly why footprint-per-person is the key sustainability yardstick.

Introduction to Sustainability

Sustainability means meeting present needs without harming future generations' ability to meet theirs. It balances environmental health, economic viability, and social equity, using resources no faster than they can be replaced.

Wind turbines on farmland: sustainable resource use meets present needs without locking out future generations

Methods to Reduce Urban Runoff

Reduce runoff with **permeable pavement**, **rain gardens** and **green roofs**, retention ponds, and preserved vegetation. These let water soak in, filtering pollutants and recharging groundwater instead of flooding streams.

Integrated Pest Management

Integrated pest management (IPM) combines methods – biological controls (natural predators), crop rotation, limited targeted pesticides, and monitoring – to control pests with **less** chemical use, slowing resistance and protecting non-target species.

Sustainable Agriculture

Sustainable farming protects soil and water: **crop rotation**, **cover crops**, **contour plowing**, **terracing**, reduced tillage, and **agroforestry**. These cut erosion, maintain fertility, and reduce chemical inputs.

Rice terraces cut a steep slope into level steps, so water and soil stay in place instead of eroding downhill

Aquaculture

Aquaculture (fish farming) eases pressure on wild stocks and is efficient, but can pollute water with waste and antibiotics, spread disease to wild fish, and destroy habitat (like mangroves for shrimp farms).

Sustainable Forestry

Sustainable forestry keeps forests productive: **selective cutting** instead of clearcutting, replanting, leaving buffer strips along streams, and long rotation times. It maintains habitat, prevents erosion, and lets forests keep providing ecosystem services.

Forests also absorb pollutants and store carbon dioxide, so cutting and burning them releases CO_2 and worsens climate change. Ways to **mitigate deforestation** include **reforestation** (replanting), buying wood from ecologically sustainable forestry, and reusing wood. A separate tool is the **prescribed burn**: deliberately burning a forest under controlled conditions to clear fuel, so a later wildfire cannot grow catastrophic.

Exam tips

- Explain the **tragedy of the commons** – shared, unowned resources get overused – and how rules/ownership prevent it.
- Weigh the trade-offs of the green revolution, irrigation (salinisation, aquifer depletion), and mining/urbanisation.

- Compute an **ecological footprint** in "number of Earths" (footprint ÷ biocapacity per person); it is measured **per person**.
- List the harms of **deforestation** (erosion, flooding, lost habitat, more CO_2).
- Define **sustainability** (meeting needs without harming future generations) and give sustainable methods (IPM, crop rotation, quotas).