

Land and Water Use

AP Environmental Science ■ Unit 5

AP Environmental Science



What we will cover

- 1 The tragedy of the commons
- 2 Agriculture and food
- 3 Irrigation and water
- 4 Pest control and IPM
- 5 Harvesting resources
- 6 Urbanization and sustainability





The tragedy of the commons

A shared **common resource** open to all tends to be over-used:

- the gain goes to **one** user
- the cost is shared by **all**

Fix it with **regulation** (catch limits) or **private ownership** (owner protects it).



Open pit mine



Agriculture and food

The **Green Revolution** raised yields with high-yield crops, fertilizer, irrigation, mechanization, and monoculture.

Costs: eutrophication, desertification, lost biodiversity.



Intensive farmland: high yield, high impact

What intensive farming costs



*Tillage, fertilisers and monoculture raise yields – and erode
soil*

Tilling, **monoculture** and heavy fertiliser and pesticide use cause:

- **erosion** and **soil salinization** ;
- nutrient runoff, driving **eutrophication** ;
- loss of biodiversity.

Meat, grazing and desertification

CAFOs use large amounts of land, water, feed and energy, and generate waste and **methane** . Meat is far less energy-efficient than plant food: the **10% rule** means every trophic level wastes more energy.

Overgrazing – livestock eating vegetation faster than it regrows – strips the soil's protective cover. On dry land that drives **desertification** .

The answer is **rotational grazing** : move the livestock so no area is grazed bare.



Irrigation and water

Irrigation methods differ in waste:

- **flood** wastes most; **drip** wastes least

Over-watering causes **salinization** and **aquifer depletion**.



Rice terraces

Irrigation is the largest human use of fresh water

the figure

about **70%** of world freshwater use – the exam expects this number

aquifers

underground stores; pumped faster than they refill, the water table falls

saltwater intrusion

over-pumping near a coast lets sea water move into the aquifer, ruining it for drinking and crops

the hydrologic cycle

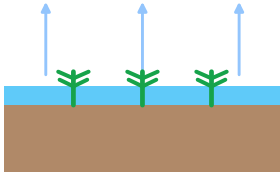
irrigation diverts water out of it; **waterlogging** and **salinization** follow poor drainage

Every irrigation question is the same trade: more crop now against a **falling water table** and a saltier soil later.

Irrigation methods, and what each costs

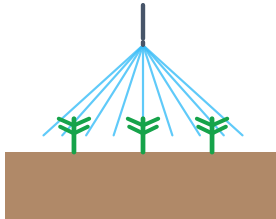
Flood / furrow

much evaporates
& runs off



water efficiency
~50%

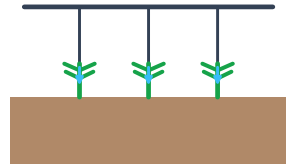
Spray / sprinkler



water efficiency
~70%

Drip

water to the roots



water efficiency
~90%

AP Environmental Science · U5 · three irrigation methods, from low to high water efficiency

Flood irrigation is cheap and wasteful; drip delivers water to the root and wastes least. The trade-off is always **cost against water lost**.



Pest control and IPM

Two approaches to pests:

- **chemical** : fast, but breeds **pesticide resistance**
- **biological** : natural predators, no poison

IPM : monitor first, spray last.



Chemical control: fast, but resistance rises

What pesticides cost, and what IPM does instead

pesticides

raise yields, but harm non-target species and pollute water

pesticide resistance

survivors breed, so stronger doses are needed – the **pesticide treadmill**

integrated pest management

IPM: biological controls (natural predators), crop rotation, **limited targeted** pesticide, and monitoring

why IPM wins

lower cost and lower environmental damage, and it does not breed resistance the way blanket spraying does

IPM is not 'no pesticides'. It is pesticide as the **last** tool rather than the first.



Harvesting resources

Take renewables no faster than they regrow – the **sustainable yield** .

- **clearcutting** erodes; selective cutting sustains
- mining: acid drainage + tailings; reclaim afterward



Clearcutting: short yield, long erosion

Overfishing and aquaculture

Overfishing removes fish faster than they reproduce, collapsing populations – cod is the standing example. **Bycatch** and bottom trawling damage the ecosystem as well as the target stock.

The open ocean is the classic **tragedy of the commons**: no one owns the fish.

Aquaculture eases pressure on wild stocks and is efficient, but it can:

- pollute water with waste and antibiotics;
- spread disease to wild fish;
- destroy habitat – mangroves cleared for shrimp farms.

Mining



Benches cut ever wider and deeper to reach the ore

Surface (strip) mining and mountaintop removal disturb the most land. Impacts:

- habitat destruction;
- **acid mine drainage** ;
- toxic tailings polluting water.

When easy deposits run out, mining goes **subsurface** – costlier and more dangerous. Coal follows the same path.

Conservation methods, and what happens when the easy ore runs out

contour plowing

ploughing across a slope, not down it, so furrows hold water instead of channelling it

terracing

cutting a hillside into level steps – steep land farmed without losing the soil

windbreaks

rows of trees that slow the wind before it lifts topsoil

subsurface mining

once easily reached deposits are gone, mining goes underground: far more expensive and dangerous

The same pattern runs through the whole unit: the cheap, easy resource is taken first, and every later unit costs more to get.



Urbanization and sustainability

Urbanization adds **impervious surfaces** :

- more runoff, less recharge; heat island; sprawl
- fix with permeable pavement, green roofs

An ecological footprint above biocapacity cannot last.



Sprawl: impervious surfaces and heat islands

What a city does to the land it covers

impervious surfaces

roads and buildings replace soil, so rain **runs off** instead of soaking in – more flooding, less recharge

urban heat islands

dark surfaces and waste heat leave a city several degrees warmer than the land around it

urban sprawl

low-density spread consumes farmland and locks in car dependence

synthetic fertilizers

from the surrounding farms, carried into the city's rivers by that same runoff

Runoff is the link: pave the ground and you change the flood risk, the groundwater, and what reaches the river, all at once.

Reducing urban runoff

- **permeable pavement**
- **rain gardens** and **green roofs**
- retention ponds, and preserved vegetation

Each one lets water **soak in** – filtering pollutants and recharging groundwater instead of flooding the stream all at once.

Ecological footprints

An **ecological footprint** is the land and water one person needs to supply their resources and absorb their wastes.

Wealthy, high-consumption nations have much larger footprints. Footprint **per person** is the yardstick.

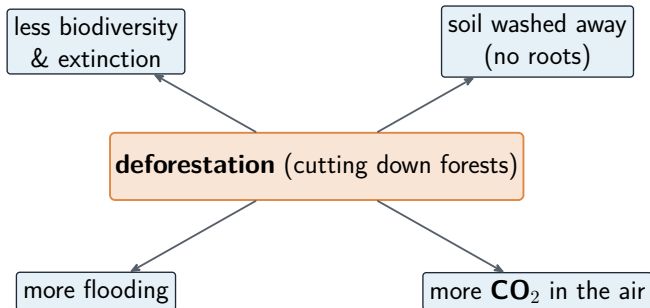
How many Earths?

Earth provides about 1.6 global hectares (gha) of **biocapacity** per person.

$$\frac{2.7}{1.6} \approx 1.7 \text{ Earths at the world average,}$$

$$\frac{8}{1.6} = 5 \text{ Earths if everyone lived at 8 gha.}$$

Sustainable forestry



Selective cutting instead of clearcutting, replanting, buffer strips along streams, long rotations. Forests store CO₂, so cutting and burning them releases it. Mitigate with **reforestation**, sustainably sourced wood, and reuse.

A **prescribed burn** is a separate tool: burn under control to clear fuel, so a later wildfire cannot grow catastrophic.

The Green Revolution

N**nitrogen**leaf and stem
growth**P****phosphorus**

strong roots

K**potassium**

flowers and fruit

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**).

Introduction to Sustainability



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

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 $\div$ biocapacity per person); it is measured **per person**.
- List the harms of **deforestation** (erosion, flooding, lost habitat, more CO₂).
- Define **sustainability** (meeting needs without harming future generations) and give sustainable methods (IPM, crop rotation, quotas).



Worked example – the tragedy of the commons

A shared pasture supports 100 cattle. Each of 10 herders adds one more animal. Explain the outcome.

- The **benefit** of an extra animal goes entirely to **one** herder.
- The **cost** – overgrazing – is shared by **all ten**.
- So it is rational for each to add one, though all lose: 110 cattle **exceed the carrying capacity**.
- The grass fails $\Rightarrow$ **the resource collapses and everyone is worse off**.

The tragedy needs an **open-access** resource with **private gain and shared cost**. Fixes: regulate, privatise, or agree limits – as with fisheries and the atmosphere.

Unit 5 – key takeaways

1

Commons

gain to one, cost to all; regulation or ownership

2

Food & water

Green Revolution trade-offs; drip beats flood

3

Pests & harvest

IPM over spraying; sustainable yield

4

Cities

impervious runoff, heat island; footprint vs biocapacity

Check yourself

- 1 In the commons, who gets the gain and who pays the cost?
- 2 Which irrigation method wastes the least water?
- 3 What does IPM do before spraying pesticide?
- 4 Name the three pillars of sustainability.



Answers 1. gain to one user, cost shared by all 2. drip 3. monitor pest numbers
4. economic, social, environmental