

Unit 5: Land and Water Use

Unit 5 covers how humans use land and water. It covers the tragedy of the commons, the Green Revolution and its agricultural tradeoffs, irrigation and its problems, pest control, meat production, overfishing, mining, urbanization, and the sustainable alternatives for each.

AP Environmental Science

Land and Water Use

About 12 minutes to read

How to use this guide

Read it in order the first time because the topics follow a pattern. Each section introduces a human use of land or water, names its environmental costs, then introduces the more sustainable alternative. The tragedy of the commons in 5.1 explains why the problems in the rest of the unit happen. Clearcutting and mining show the same tradeoff in forests and mineral extraction, and agriculture gets the longest treatment because it uses the most land and water of any human activity.

After the first read, use the trap boxes and the tables to review the comparisons the exam tests most often. The exam likes to ask which irrigation method wastes the least water, which meat system has which tradeoff, and which soil method does what. Finish with the practice questions, then complete the recall check on the last page out loud and note any items you cannot explain yet.

What this unit is worth. Land and Water Use is about 10 to 15 percent of the AP Environmental Science exam, one of the largest units. It is also the unit most connected to everything else. The nitrogen and phosphorus cycles from Unit 1 show up in fertilizer runoff here, the water cycle from Unit 1 shows up in irrigation and aquifer depletion, and population growth from Unit 3 is the reason food demand keeps rising.

5.1 The Tragedy of the Commons

The **tragedy of the commons** describes what happens to a shared resource when individuals act in their own self-interest. Each person gains the full benefit of using the resource but bears only a fraction of the cost of depleting it, so everyone uses it heavily and the resource is destroyed. No single user intends to ruin it. The ruin comes from everyone making the same rational individual choice at the same time.

Fisheries are the classic example, and this unit returns to that idea in 5.8. Groundwater works the same way. Each farmer who pumps from a shared aquifer gets the full crop benefit of the water while the dropping water table is shared by everyone, which is why the Ogallala Aquifer has been severely depleted. When a question asks you to explain overuse of an unowned or shared resource, the tragedy of the commons is the concept it is testing.

Trap. The tragedy of the commons applies to *shared* resources, not to pollution of private property. A factory dumping waste onto its own land is not the tragedy of the commons. Fishermen overharvesting an open-access ocean fishery is.

5.2 Clearcutting

Clearcutting removes every tree from a tract of land at once. It is economically efficient because loggers can take all the timber in one pass, but the exposed soil erodes, soil and stream temperatures rise without shade, and flooding increases because nothing is left to slow or absorb runoff.

Forests are not just timber. They absorb air pollutants and store carbon dioxide, so cutting and burning them releases that carbon and contributes to climate change. The **sustainable forestry** methods in 5.17 are the direct alternatives: replant what you cut, burn undergrowth in controlled conditions, and stop cutting when insects or disease hit.

Trap. Do not confuse clearcutting with deforestation as a whole. Clearcutting is one harvesting method. Deforestation is the net loss of forest cover, which clearcutting causes only when the cleared land is not replanted.

5.3 The Green Revolution

The **Green Revolution** was a mid-20th-century shift to new agricultural strategies that raised global food production. The package included **mechanization**, fertilizers, irrigation, pesticides, and genetically modified organisms. The positive result was far more food per acre. The negative results were the environmental costs that fill the rest of this unit: fossil fuel dependence, fertilizer runoff, pesticide resistance, and groundwater depletion.

Mechanization itself is a tradeoff card. Machines raise profits and efficiency, but they run on fossil fuels and replace the human and animal labor that traditional systems relied on. Any question that asks about a Green Revolution downside is usually pointing at one of the practices named above, so learn the package as a list.

5.4 Impact of Agricultural Practices

Agriculture damages the environment in several ways before a single pesticide is sprayed. **Tilling** breaks up soil structure and speeds erosion. **Slash-and-burn farming** clears forest by burning it, releasing stored carbon and losing the soil's cover. **Fertilizers** add nitrogen and phosphorus that wash into waterways and feed algal blooms. These three practices are the core environmental costs of farming in general, before you get to any specific method.

Trap. Tilling, slash-and-burn, and fertilizer use are distinct problems, not interchangeable answers. Tilling degrades soil structure. Slash-and-burn destroys forest cover. Fertilizers cause nutrient pollution downstream. Match the cause to the right effect on the exam.

5.5 Irrigation Methods

Agriculture uses about **70 percent of human freshwater consumption** worldwide, and most of that goes through irrigation. That single number is why irrigation methods and their problems get so much exam attention. There are four methods, ranked by efficiency:

METHOD	HOW IT WORKS	EFFICIENCY AND TRADEOFFS
Drip irrigation	Perforated hoses release small amounts of water directly to plant roots.	Most efficient. About 5% lost to evaporation and runoff. Expensive and rarely used.
Spray irrigation	Groundwater is pumped into overhead nozzles across the field.	More efficient than flood or furrow. One quarter or less lost. Expensive and energy-dependent.
Flood irrigation	The whole field is flooded with water.	About 20% lost to evaporation and runoff. Can waterlog the soil.
Furrow irrigation	Water fills furrows cut between crop rows.	Inexpensive, but about one third lost to evaporation and runoff.

Trap. The most efficient method is not the most common one. Drip irrigation wastes the least water by far, but its cost keeps it from being widely used. Exam questions love asking which method is most efficient, then testing whether you picked furrow or flood because those are the common ones.

Irrigation causes two soil problems and one water problem. **Waterlogging** happens when too much water sits in the soil, raising the groundwater table so roots cannot absorb oxygen. **Salinization** happens when irrigation water evaporates and leaves its dissolved salts behind, building up until the soil is toxic to plants. **Aquifer depletion** happens when pumping for irrigation draws down underground reserves faster than they recharge. The Ogallala Aquifer under the central United States is the standard example of a severely depleted aquifer.

Trap. Waterlogging and salinization are different soil problems with different causes. Waterlogging is too much water drowning the roots. Salinization is salt left behind after the water is gone. A question about white crusts or toxic salt buildup is asking about salinization, not waterlogging.

5.6 Pest Control Methods

Pesticides, herbicides, fungicides, rodenticides, and insecticides all decrease crop damage and raise yields, but their overuse selects for **pesticide resistance**. Resistance develops through artificial selection: the chemical kills the susceptible pests and leaves the resistant ones to reproduce, so each generation is harder to kill. **Genetically engineered crops** that resist pests and disease are one way to use fewer chemicals, though they can reduce the genetic diversity of the crop.

Trap. Pests do not become resistant by learning or adapting during their lifetimes. Resistance is evolution by natural selection acting on the pest population, driven by the farmer's pesticide use. The resistant individuals were already different; the chemical just let them win.

5.7 Meat Production Methods

Producing meat costs more land, water, and energy per gram of protein than producing plant-based foods, and it increases nutrient pollution and greenhouse gas emissions, especially methane. The two systems on the exam are **CAFOs** and **pasture-based grazing**:

SYSTEM	CHARACTERISTICS	TRADEOFFS
CAFOs (concentrated animal feeding operations)	Animals confined and crowded, fed grain and soy diets.	Economically efficient, cheaper for consumers. Concentrated manure can contaminate waterways, and routine antibiotic use raises resistance risks.
Free-range and pasture-based grazing	Animals feed on grass or forage. Rotational grazing moves herds between pastures.	Manure fertilizes pasture soils. Needs more land, costs more, and manure runoff and erosion still happen if animal density is high.

Overgrazing happens when livestock numbers exceed what the land can regenerate. Plant cover drops, soil erodes and compacts, and fertility, biodiversity, and carbon storage all fall. In arid and semi-arid regions overgrazing can push the land all the way into **desertification**, though conservation and better grazing practices can slow or reverse it. **Reducing meat consumption**, especially meat from ruminants like cattle and sheep, cuts CO₂, CH₄, and N₂O emissions while conserving freshwater and reducing antibiotic use.

Trap. Free-range is not a free pass. Pasture systems still produce manure runoff and erosion when animals are crowded, and they require more land than CAFOs. When a question asks for the drawback of free-range grazing, the answer is usually land use or cost, not water contamination disappearing.

5.8 Impacts of Overfishing

Overfishing means catching fish faster than populations can reproduce. Some species have become extremely scarce, aquatic biodiversity has fallen, and the people who depend on fishing for food and income have lost their livelihoods. This is the tragedy of the commons from 5.1 playing out in the oceans: the fishery belongs to no one, so everyone harvests as much as they can.

5.16 Aquaculture

Aquaculture, farming fish in controlled waters, has expanded because it is efficient, needs only small areas of water, and burns little fuel. But the drawbacks are real. Wastewater from fish farms can contaminate surrounding water, escaped fish can compete or breed with wild fish, and the high density of farmed fish encourages disease outbreaks that spread to wild populations.

Trap. Aquaculture reduces pressure on wild fish stocks, but it does not eliminate fishing impacts. Farmed carnivorous fish are often fed fishmeal made from wild-caught fish, and disease and escape problems are the exam's favorite drawbacks to ask about.

5.9 Impacts of Mining

Mining provides the energy and materials modern products depend on, but it gets harder and dirtier over time. As the richest deposits are used up, operations move to **lower-grade ores**, which takes more energy and creates more waste and pollution per unit of mineral recovered.

MINING TYPE	HOW IT WORKS	IMPACTS
Surface mining (strip mining)	Large portions of soil and rock, called overburden, are removed to reach the ore below. Stripped vegetation leaves the area exposed.	Habitat destruction, erosion, and groundwater contamination. Coal surface mining also releases dust and methane.
Subsurface mining	Underground shafts and tunnels reach deep coal seams after surface reserves are exhausted.	Expensive, with serious miner-safety hazards.

Mining waste comes in two forms. **Overburden** is the soil and rock moved aside to get at the ore. **Slag and tailings** are what remains after the minerals are removed from the ore. Both have to go somewhere, and both can leach contaminants into soil and water.

Trap. Surface mining and subsurface mining have different cost profiles. Surface mining is cheaper and destroys the surface; subsurface mining is expensive and dangerous to miners. A question about which is more expensive or which threatens miner safety is asking about subsurface mining.

5.10 Impacts of Urbanization

Urban sprawl is the spread of low-density suburbs into rural land. As cities grow outward, **impervious surfaces** like roads, buildings, sidewalks, and parking lots replace soil. Water cannot infiltrate, so flooding increases and runoff carries oil, metals, and other pollutants into waterways instead of filtering through soil. Pumping groundwater for growing cities can deplete aquifers and let saltwater intrude into coastal aquifers, and burning fossil fuels plus landfill waste raises atmospheric CO₂.

5.13 Methods to Reduce Urban Runoff

The fix for urban runoff is letting water back into the ground. Replace traditional pavement with **permeable pavement**, plant trees, and reduce car dependence with public transportation. **Building up instead of out** fights sprawl directly by housing more people on less land, which means fewer new impervious surfaces.

Trap. Impervious surfaces cause flooding *and* pollution. Students remember the flooding and forget that the same runoff carries contaminants straight into streams without any soil filtration. If a question mentions urban water quality, impervious surfaces are usually in the answer.

5.11 Ecological Footprints

An **ecological footprint** compares the resource demands and waste production of an individual or a society against what the planet can support. It is the accounting behind the sustainability ideas that follow: if every person lived like a high-consumption society, the math does not work.

5.12 Introduction to Sustainability

Sustainability means using resources without depleting them for future generations. The guiding indicators include biodiversity, food production, average global surface temperatures and CO₂ concentrations, human population, and resource depletion. **Sustainable yield** is the practical version for any one resource: the amount you can take without reducing the available supply.

Trap. Sustainable yield is about the harvest rate, not the size of the stock. A forest can be huge and still be overharvested if logging exceeds regrowth. A fishery can be small and sustainable if the catch stays below the reproduction rate.

5.14 Integrated Pest Management

Integrated pest management (IPM) controls pests with a combination of methods that minimize environmental disruption: biological control, intercropping, crop rotation, physical methods, natural predators, and only limited chemical use. The **benefits** are less risk to wildlife, water supplies, and human health. The **drawback** is that IPM is complex and expensive compared to simply spraying.

5.15 Sustainable Agriculture

Soil conservation is about preventing erosion, and the methods are a list worth memorizing. **Contour plowing** follows the land's curves. **Windbreaks** block wind erosion. **Terracing** cuts flat steps into slopes. **No-till agriculture** leaves soil undisturbed. **Strip cropping** alternates crop rows with ground cover. **Perennial crops** keep roots in the ground year after year.

Soil fertility improves with **crop rotation**, which cycles nutrients and breaks pest patterns, plus **green manure** (plowing cover crops back into the soil) and **limestone** to correct acidity. **Rotational grazing**, moving livestock between pastures so no area is overused, prevents the overgrazing described in 5.7.

Trap. Know what each soil method *does*, not just its name. Terracing and contour plowing fight water erosion on slopes. Windbreaks fight wind erosion on flat land. No-till fights erosion everywhere by never exposing the soil. The exam will describe a slope and ask which method fits.

5.17 Sustainable Forestry

The forest alternatives to clearcutting start with **reforestation**, replanting what was cut, plus buying wood from certified sustainable forestry and reusing wood products. Forests are protected from pathogens and insects with IPM and by **removing affected trees** before problems spread. **Prescribed burns** set controlled fires to clear undergrowth, which reduces the fuel available for uncontrolled wildfires.

Trap. Prescribed burns reduce the *severity* of natural fires; they do not prevent fires. Burning off the underbrush removes fuel, so when lightning strikes, the fire stays low instead of crowning through the canopy.

Confusions That Cost Points

PAIR	HOW TO KEEP THEM STRAIGHT
Drip vs furrow irrigation	Drip is the most efficient (about 5% lost) but expensive. Furrow is the cheapest but loses about a third of its water. Efficiency and cost run in opposite directions.
Waterlogging vs salinization	Waterlogging is too much water drowning roots. Salinization is salt left behind after water evaporates. Different causes, different damage.
CAFOs vs pasture grazing	CAFOs are cheap but concentrate manure and antibiotic risks. Pasture systems cost more, need more land, and still erode when crowded.
Surface vs subsurface mining	Surface mining is cheap and scars the land. Subsurface mining is expensive and dangerous for miners.
Terracing vs windbreaks	Terracing stops water erosion on slopes. Windbreaks stop wind erosion on flat land. Match the method to the terrain.
IPM vs pesticides alone	IPM combines biological, physical, and limited chemical methods to protect wildlife and water. It costs more and is harder to manage than spraying.

Practice Questions

Original questions written for this guide in the style of the AP exam. Answers and explanations are on the next page, so complete the questions before checking them.

- 1.** A farmer switches from furrow irrigation to drip irrigation. The most likely environmental benefit is
 - A. reduced soil salinization over time
 - B. a large reduction in water lost to evaporation and runoff
 - C. lower energy costs for pumping water
 - D. elimination of the need for fertilizer

- 2.** A concentrated animal feeding operation (CAFO) is proposed near a stream. Which environmental concern is most directly associated with CAFOs?
 - A. Methane emissions from enteric fermentation only
 - B. Concentrated manure contaminating nearby waterways
 - C. Desertification of the surrounding region
 - D. Reduced genetic diversity of the livestock

- 3.** A city wants to reduce flooding and improve stream water quality after heavy development. Which combination of actions best addresses both problems?
 - A. Building more highways and widening storm drains
 - B. Replacing pavement with permeable surfaces and planting trees
 - C. Channelizing streams and lining them with concrete
 - D. Restricting all new construction within the city limits

- 4.** A farmer has used the same pesticide for ten years, and it no longer controls the target pest. The best explanation is that
 - A. the pests learned to avoid the pesticide during their lifetimes
 - B. the pesticide has chemically broken down in the soil
 - C. repeated use selected for resistant individuals through artificial selection
 - D. the pesticide was applied at the wrong time of day

Answer Key

- 1. B.** Furrow irrigation loses about a third of its water to evaporation and runoff, while drip loses about 5 percent. A is tempting because less water can mean less salt buildup, but the direct, certain benefit of the switch is water savings. C is wrong because drip systems are expensive and not widely used, not cheaper to run. D is wrong because irrigation method has nothing to do with fertilizer needs.
- 2. B.** Concentrated manure from crowded animals is the signature CAFO water-pollution problem. A is too narrow; methane matters, but enteric fermentation is not the CAFO-specific concern the question asks for. C describes overgrazing in arid regions, not confined feeding. D confuses CAFOs with genetically engineered crops, where reduced genetic diversity is the tradeoff.
- 3. B.** Permeable pavement and trees let water infiltrate instead of running off, which reduces flooding and lets soil filter pollutants. A makes the problem worse by adding impervious surfaces. C moves water faster but does nothing for quality and increases downstream flooding. D is unrealistic and does not address the existing impervious surfaces.
- 4. C.** Pesticide resistance develops through artificial selection: the chemical kills susceptible pests and the resistant survivors reproduce. A describes individual learning, which does not happen; resistance is a population-level change. B might occur but does not explain why the pest population survives. D is irrelevant to a population-wide loss of effectiveness.

One-Page Recall Check

- Explain the tragedy of the commons and give two examples from this unit.
- List the environmental costs of clearcutting beyond the lost timber.
- Name the five Green Revolution strategies and one environmental cost of each.
- Rank the four irrigation methods by efficiency and give the water loss for each.
- Explain the difference between waterlogging and salinization.
- Explain how pesticide resistance develops, and name the process that drives it.
- Compare CAFOs and pasture-based grazing: cost, land use, and environmental tradeoffs.
- Explain how overgrazing can lead to desertification.
- Describe the environmental impacts of surface mining versus subsurface mining.
- Explain how impervious surfaces affect both flooding and water quality.
- Define sustainable yield and explain why it depends on harvest rate, not stock size.
- List three soil conservation methods and the erosion type each addresses.
- Explain what a prescribed burn does and what it does not do.

Where to go next. Turn every missed item above into flashcards and drill them spaced out over several days rather than in one sitting. In Rycal, open the AP Environmental Science deck and work the Unit 5 cards. The deck covers the terms in this guide, and its practice questions target the same traps named here. If you have a test date, add it in the Test Planner. You can also start your next review with a Brain Dump, then check what you missed against this guide.

Key terms for this unit

Tragedy of the commons, Clearcutting effects, Forests and carbon storage, Green Revolution, Mechanization of farming, Environmentally damaging agricultural practices, Agricultural water use, Irrigation methods, Waterlogging, Furrow irrigation, Flood irrigation, Spray irrigation, Drip irrigation, Salinization, Aquifer depletion (Ogallala), Pesticide resistance, Genetically engineered crops, Meat production methods, Meat vs. plant-based environmental impacts, CAFOs, Free-range and pasture-based grazing, Overgrazing, Desertification, Reducing meat consumption, Overfishing, Lower-grade ores, Surface mining (strip mining), Mining wastes and impacts, Subsurface mining, Urbanization and resource depletion, Urbanization and the carbon cycle, Impervious surfaces, Urban sprawl, Ecological footprint, Sustainability, Sustainable yield, Methods to reduce urban runoff, Integrated pest management (IPM), Benefits of IPM, Drawbacks of IPM, Soil conservation methods, Improving soil fertility, Rotational grazing, Benefits of aquaculture, Drawbacks of aquaculture, Mitigating deforestation, Protecting forests from pests, Prescribed burn.

About this guide. Written for Rycal and aligned to the College Board AP Environmental Science course framework, Unit 5. All questions and explanations are original Rycal writing. Rycal is independent and is not affiliated with or endorsed by the College Board.