Land

Topic 5 · SL and HL

Restoring soil and livelihoods

Loess Plateau projects, 1994–2005

Terraces, vegetation and changed grazing in selected watersheds.

Water, **erosion** and livelihoods need integrated management.

Interpret the outcome

Surface cover can improve before lost profile depth returns.

A successful project site is not proof of equal recovery everywhere.

Why soil-carbon stores differ

Conditions and inputs

Cold tundra and oxygen-poor wetlands can slow decay.

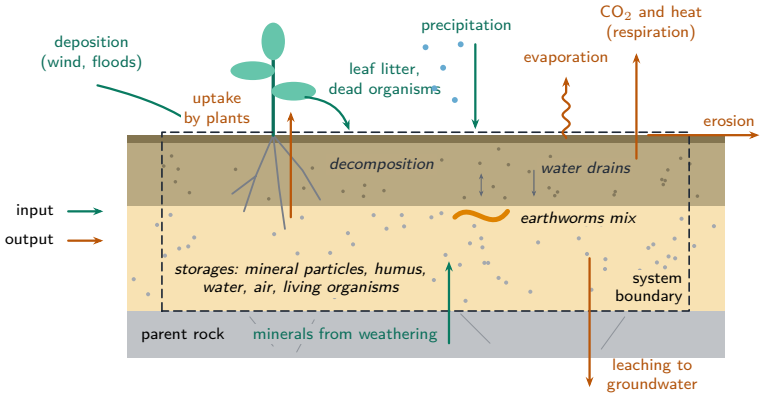
Grassland roots can add substantial carbon.

Important exceptions

Warm aerated tropical mineral soils can cycle carbon rapidly.

Tropical peatlands can store much carbon; compare depth and drainage.

Soil as an open system



Heat is an energy flow; water, minerals and carbon are matter flows.

Soil supports life

Components and functions

Minerals, **humus**, water, air and organisms.

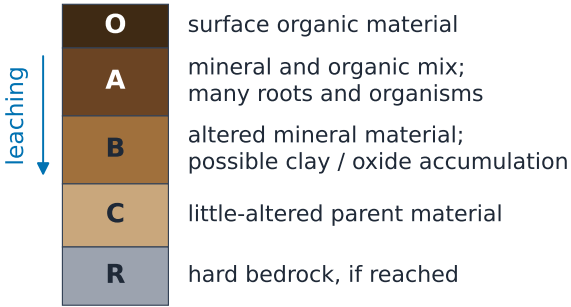
Roots obtain water and mineral nutrients; most plant carbon comes from atmospheric CO_2.

Transformations and transfers

Detritivores fragment litter; decomposers transform compounds.

Percolation, biological mixing and **leaching** move material.

A simplified soil profile



Real profiles vary: horizons may be absent, colours differ, and parent material may be transported sediment.

Texture and structure

Mineral texture

Sand 0.05–2 mm; silt 0.002–less-than-0.05 mm; clay below 0.002 mm.

Loam is a textural range, not a guarantee of suitability for every crop.

Structure and conditions

Aggregation, pore spaces, organic matter and compaction.

Water, aeration, nutrient retention, pH and climate affect productivity.

Formation and carbon balance

Formation versus loss

Formation rates vary; loss can exceed renewal.

Soil is often effectively non-renewable on human planning timescales.

Store versus sink

A store is an amount held; a net sink gains carbon over a stated period.

Large soil-carbon stocks can still be declining.

Distinct degradation pathways

Material and pores

Erosion removes material; nutrient depletion changes fertility.

Compaction alters pore space; pollutants have distinct effects.

Salt and dryland change

Salinisation can lower soil-water potential and add toxic ions.

Desertification is dryland degradation; dunes need not appear.

Match conservation to a process

Runoff and wind

Terracing and **contour ploughing** across slopes slow runoff.

Cover crops, mulching and windbreaks protect surfaces.

Nutrients and salts

Crop rotation with legumes uses nitrogen-fixing symbionts.

Manage salt inputs, leaching and drainage; drip irrigation alone is not enough.

Learn from two restoration contexts

Dust Bowl, 1930s USA

Drought interacted with exposed cultivated soils and wind.

Grass cover, windbreaks and contour practices target **erosion**.

Loess Plateau

Erodible slopes, cultivation and grazing pressure.

Measure soil loss, water, livelihoods and maintenance over time.

Mobility, fallows and recovery

Nomadic pastoralism

Movement can follow seasonal forage and water.

Access restrictions and concentrated stocking change pressure.

Shifting cultivation

Long fallows can permit recovery; shortened fallows may not.

Compare extraction, renewal, **erosion** and rights rather than age alone.

Independent farming classifications

Output and purpose

Arable, pastoral or mixed; **monoculture** or **polyculture**.

Subsistence or commercial; surplus sales can occur in household systems.

Input and area

Intensive/extensive: inputs per hectare.

Organic/conventional and irrigated/rain-fed are separate dimensions.

Honghe Hani terraces and Iowa row crops

Yunnan rice terraces

Forest–village–terrace water management; rice, fish and animals.

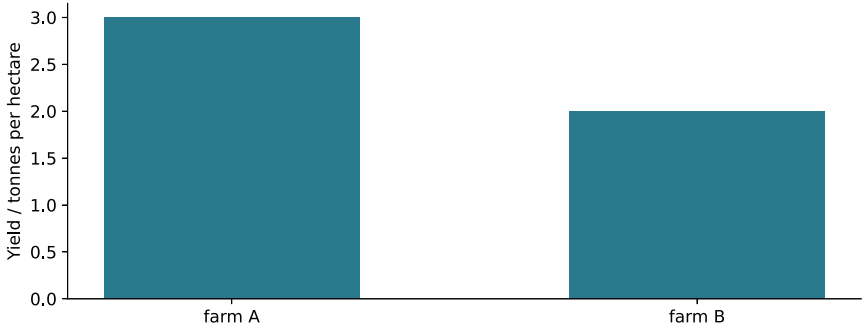
Labour, shared rules, terrain and maintenance matter.

Iowa maize–soybean

Mechanisation, nutrient inputs, drainage and market infrastructure.

Compare cover crops and tillage; farms within a region are not identical.

Total harvest is not area yield



18 t ÷ 6 ha = 3 t/ha; 20 t ÷ 10 ha = 2 t/ha. Name crop, period and edible-output basis.

Compare two invented farms

1. **Given.** X harvests 35 t from 7 ha; Y harvests 48 t from 16 ha.
2. **Area yield.** X: 35/7=5 t/ha. Y: 48/16=3 t/ha.
3. **Interpret.** Y has more total harvest; X has higher **yield** per hectare.

Decision

Use the functional unit needed for the decision; food mass, protein, energy and profit differ.

Energy output divided by counted input

1. **Invented givens.** A: food 45000 MJ, counted non-solar input 3000 MJ per ha. B: food 50000 MJ, input 20000 MJ per ha.
2. **Ratios.** A: 45000/3000=15. B: 50000/20000=2.5.
3. **Boundary.** Solar energy is excluded; count labour, fuel, fertiliser and machinery consistently.

Decision

A ratio above 1 does not violate conservation; this is not a complete thermodynamic efficiency.

Evaluate the Green Revolution

Possible benefits

High-yielding varieties with water, nutrients and pest control.

Improved availability, conditional on access and management.

Costs and distribution

Water, salinity, nutrient loss, pesticides and diversity.

Credit, irrigation, seed and markets influence who benefits.

Land rights and food security

Endorois, Lake Bogoria

Displacement affected pastoral access and cultural connections.

African Commission decision found violations and recommended remedies.

Evaluate implementation

A decision is not proof every remedy occurred immediately.

Consent, participation, compensation and land/water access matter.

Four dimensions of food security

Supply and access

Availability: food supply. Access: ability to obtain it.

A national surplus does not guarantee household affordability.

Use and continuity

Utilisation: nutrition, water and sanitation. Stability: continuity.

Conflict, drought and prices can disrupt several dimensions.

Interpret dated population estimates

FAO 2025 report

About 673 million people experienced hunger in 2024.

Not the same measure as all forms of food insecurity.

WHO 2022 adult estimates

2.5 billion with overweight, including about 890 million with obesity.

Do not add a subgroup to its whole; malnutrition includes deficiencies and excesses.

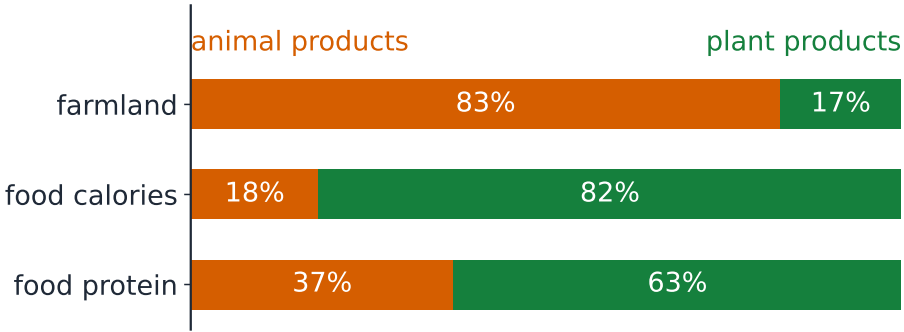
Sequential losses use changing denominators

1. **Invented harvest.** 100 tonnes; 10% lost before retail leaves 90 tonnes.
2. **Later waste.** 20% of 90 is 18 tonnes; 72 tonnes remain.
3. **Overall loss/waste.** 100−72=28 tonnes, or 28%, not 30%.

Decision

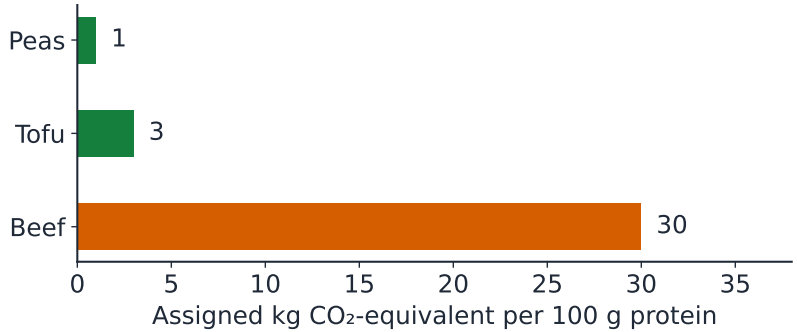
SDG 12.3: halve per-capita retail/consumer waste by 2030 and reduce supply-chain losses.

Dated land and nutritional shares



Oxford's 2018 research summary: attributed farmland, calorie and protein shares have distinct denominators.

Compare the same nutritional unit



Assigned data, not global medians: production methods and lifecycle boundaries affect real comparisons.

A matched-unit emissions model

1. **Assigned values.** Per 100 g protein: peas 1, tofu 3, beef 30 kg CO_2-equivalent.
2. **Substitute within the model.** Replacing 30 with 3 changes emissions by 27 per matched unit.
3. **Relative reduction.** $27/30 \times 100 = 90\%$.

Decision

Do not compare per-kg-food data with per-protein data without conversion and nutritional context.

Organic and conventional are broad categories

Organic systems

Follow the relevant input standards; can still lose nutrients.

Permitted pest-control products can have environmental effects.

Other systems

Can use manure, rotations, conservation and IPM too.

Compare actual output, biodiversity, pollution, energy and land demand.

Lower yield and land demand

1. **Invented fixed output.** 100 tonnes; original **yield** 5 t/ha gives 20 ha.
2. **Changed yield.** 4 t/ha requires 25 ha.
3. **Area increase.** $(25-20)/20 \times 100 = 25\%$, although yield fell 20%.

Decision

Extra land demand is not proof that a particular habitat was actually converted; trace the source.

Choose complementary strategies

Production and protection

Integrated pest management, **agroforestry** and suitable crop diversity.

Precision inputs and **sustainable intensification** need outcome evidence.

Demand and distribution

Avoidable waste, storage and suitable dietary shifts.

Compare livelihoods, access, nutrition and environmental effects over time.

Two farming systems

Honghe Hani terraces (Yunnan)

forest → villages → irrigated terraces
rice, fish and animals recycle nutrients
needs: terrace upkeep, shared water rules,
skilled labour
risks: erosion, changing livelihoods

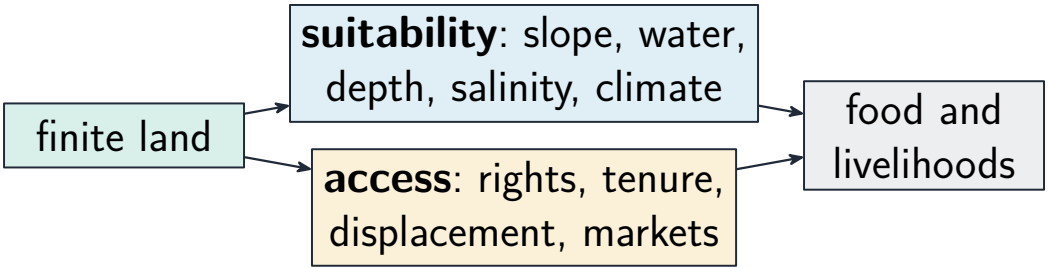
Iowa maize–soybean (USA)

large mechanised fields
high yield per worker
inputs: fertiliser, fuel, machinery, purchased seed
risks: nutrient runoff, soil loss

compare inputs, outputs and impacts; “traditional” does not mean impact-free

Each trades off differently

Two filters on land for food



> Land must pass both to feed people

AHL: Soil gases and methane clathrates

Soil processes

Aerobic decay releases CO_2; methanogenic archaea can produce CH_4.

Thaw, drainage, oxidation and transport affect feedbacks.

Distinct geological reservoir

Hydrate stability depends on temperature and pressure.

IPCC AR6: detectable trajectory effect this century from deeper/subsea clathrates very unlikely.

AHL: Explain soil formation

Interacting factors

Climate, organisms, landscape, parent material and time.

Slope, aspect, drainage and calcareous/volcanic materials.

Classification evidence

Brown earths, strongly weathered oxisols and contrasting exceptions.

Intensive cultivation does not automatically remove all surface horizons.

AHL: Cation exchange and pH

Charged sites

Clay and organic surfaces can retain K^+, Ca^{2+}, Mg^{2+} and $NH_4{}^+$.

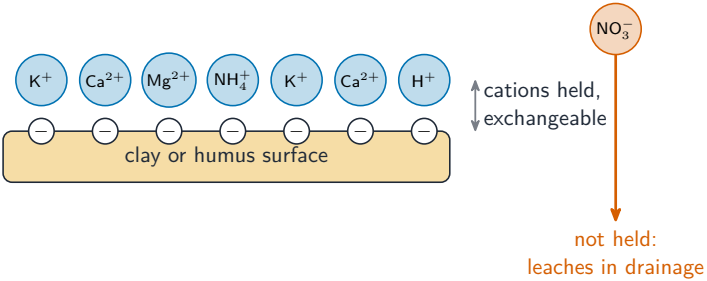
$NO_3{}^-$ is not retained in the same way by ordinary cation-exchange sites.

Limits and management

Mineralogy and pH alter availability; size alone is insufficient.

Lime is not a complete fertiliser; retained water is not all plant-available.

Cation exchange in soil



Nitrate, an anion, is not held and leaches

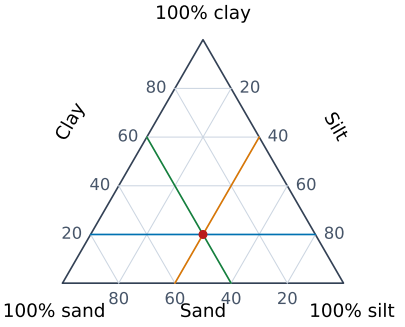
AHL: Derive the mineral fractions

1. **Invented dry mineral sample.** Total 20 g: sand 8 g, silt 8 g, clay 4 g.
2. **Calculate.** Sand: $8/20\times100=40\%$. Silt: $8/20\times100=40\%$. Clay: $4/20\times100=20\%$.
3. **Read the classification.** Plot the three fractions and use the specified USDA key: this sample is **loam**.

Decision

Gravel and organic matter do not silently enter the denominator for these mineral-size fractions.

AHL: Read a three-component composition



Assigned dot: 40% sand, 40% silt, 20% clay

Assigned fractions: 40% sand, 40% silt, 20% clay.

AHL: Mass loss and denominators

1. **Invented masses.** Fresh 12 g; oven-dry 10 g; post-ignition residue 9 g.
2. **Water content.** Dry basis: $(12-10)/10\times100=20\%$. Fresh basis: $2/12\times100=16.7\%$.
3. **Loss on ignition.** $(10-9)/10\times100=10\%$ of dry mass; not automatically 10% elemental carbon.

Decision

Use approved methods and a justified calibration; bound water and carbonates may affect mass loss.

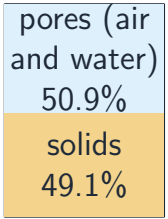
AHL: Physical-property calculations

1. **Invented core.** Dry mass 130 g in 100 cm^3: bulk density=1.30 g/cm^3.
2. **Assigned particle density 2.65 g/cm^3. Porosity**=$(1-1.30/2.65)\times100$=50.9%; not the same as air-filled pore volume.
3. **Invented infiltration.** 50 cm^3 across 100 cm^2 in 5 min gives 0.5 cm/5 min=1 mm/min.

Decision

Match moisture, depth, disturbance and head; repeated readings from one core are not independent sites.

Bulk density and porosity



core 100 cm^3

bulk density $= 130/100 = 1.30$ g cm^{-3}
(volume includes the pores)
porosity $= (1 - 1.30/2.65) \times 100 = 50.9\%$
assumes particle density 2.65 g cm^{-3}
and an undisturbed core (invented values)

Compaction raises bulk density and cuts **porosity**

AHL: Biome, capability and regeneration

Within temperate grassland

Deep workable soils may support cereals; shallow/drier sites may favour pasture.

Compare **erosion**, nutrient exports, nutrition and income.

Regenerative and permaculture approaches

Diverse interacting components and suitable nutrient cycling.

Harvest still exports nutrients; a practice name does not establish the outcome.

AHL: Animals and recovery periods

Potential roles and costs

Pigs/chickens disturb vegetation and recycle nutrients.

Excess disturbance can expose soil and concentrate wastes.

Pressure and recovery

Dense rotational grazing depends on stocking, rainfall and rest.

Mob grazing does not guarantee carbon gains or eliminate methane.

AHL: Soil-carbon budget

1. **Invented annual flows.** Inputs 4, respiration 3, **erosion**/export 0.5, all tonnes C/ha/year.
2. **Net change.** $4-3-0.5=+0.5$ tonnes C/ha/year.
3. **Carbon-mass equivalence.** $0.5\times44/12=1.83$ tonnes CO_2 per ha per year.

Decision

Whole-farm benefit also needs methane, nitrous oxide, off-farm inputs, permanence and leakage.

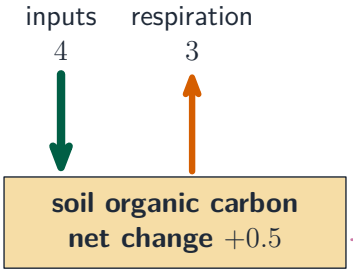
AHL: Electricity can dominate a comparison

1. **Invented vertical-farm use.** 8 kWh/kg edible crop.
2. **Two electricity factors.** At 0.4 kg CO_2e/kWh: 3.2 kg/kg. At 0.05: 0.4 kg/kg.
3. **Boundary.** Other inputs and infrastructure remain uncounted; match the edible crop.

Decision

Hydroponics and small land area do not prove a lower complete lifecycle footprint.

A soil carbon budget



$4 - 3 - 0.5 = +0.5$ t C ha^{-1} yr^{-1}
$= 0.5 \times 44/12 \approx 1.83$ t CO_2

Multiply carbon by 44/12 for carbon dioxide

AHL: Diets, chains and traditional harvest

Supply-chain choices

Production, heating, storage, mode, distance and waste.

The planetary health diet is a framework, not one menu for every community.

Wild harvest and wider needs

Brazil nuts, bamboo shoots, fungi and honey can retain habitat.

Assess regeneration, wildlife, rights, markets and capacity to meet wider demand.

AHL: Survey preferences without leading

Good evidence

Voluntary informed participation, privacy and neutral questions.

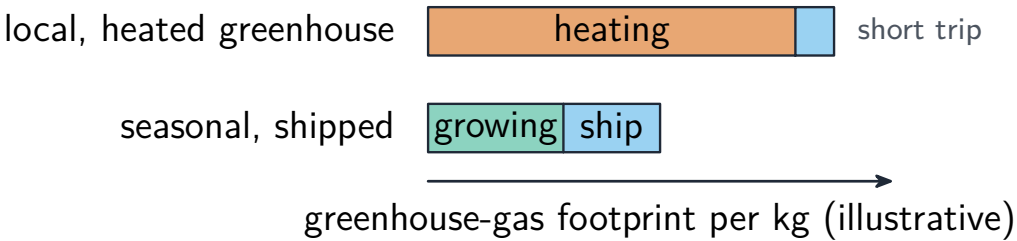
Transparent sampling, non-response and uncertainty.

Limits

Preference differs from affordability, intention and actual behaviour.

A convenience sample does not represent everyone or prove causation.

Local is not always lower



Heating outweighs the short trip

Balancing harvest and regeneration

sustainable only if harvest $\leq$ regeneration



Brazil nuts, bamboo shoots, fungi, honey

also depends on:

- habitat and dependent wildlife
- access rights and market incentives
- evidence, not the age of a practice

A sustainable harvest needs evidence

Exam tips

Quantities and boundaries

Stock/sink; texture/structure; total harvest/area **yield**.

Counted energy ratio differs from complete thermodynamic efficiency.

Evaluation

Give a mechanism, context, measurable outcome and limitation.

Compare nutrition, livelihoods, rights and ecological effects.

Apply a land-use comparison

1. **Invented yields.** Farm A: 18 t/6 ha=3 t/ha. Farm B: 20 t/10 ha=2 t/ha.
2. **Interpret.** B harvests more in total; A produces more per hectare.
3. **Evaluate.** Compare soil losses, energy, water and livelihoods; high area **yield** is one criterion.

Decision

A resource can regenerate while use exceeds renewal; soil timescales need particular care.

Check yourself

Your turn

An invented 100-tonne harvest loses 10% before retail, then 20% of the remainder. How much remains?

A. 72 tonnes.

B. 70 tonnes.

C. 90 tonnes.