How cities reshape land and carbon

Urbanization is the growth of urban populations and built environments. Buildings, roads and services support human activity, while changing land cover, resource demand and natural cycles.

1. URBAN GROWTH IS NOT ALWAYS URBAN SPRAWL

COMPACT DEVELOPMENT

Homes, jobs and services are closer together. More people can share infrastructure, and walking or public transport may become practical. This can reduce land conversion and travel demand per person.

LOW-DENSITY SPRAWL

Development spreads outward into rural land. Widely separated homes, workplaces and shops often require longer car trips and more roads. Farmland and natural habitats may be replaced or fragmented.

2. GROWING RESOURCE DEMAND

Construction requires materials; homes and businesses need energy and freshwater. Rising withdrawals can deplete accessible water supplies, especially when demand exceeds replenishment. Clearing land removes vegetation and fragments habitat into smaller patches. Impacts depend on consumption, energy sources and planning, not population density alone. Dense cities can still have large total demands even when demand per resident is lower.

3. THREE LINKS TO THE CARBON CYCLE

Combustion

Fossil fuels used for transport, buildings and electricity release stored carbon as CO_2.

Land conversion

Vegetation loss reduces carbon storage and can release carbon from biomass and soils.

Landfills

Decomposing organic waste produces landfill gas containing both CH_4 and CO_2. Methane is also a greenhouse gas.

Development patterns and emissions: EPA, About Smart Growth.
Urban water and land-use effects: USGS, Urbanization and Water Quality.
Carbon dioxide and methane: EPA, Landfills and GHGRP.

Scope: College Board AP Environmental Science CED, Topic 5.10, p. 106.

Too much runoff, less water stored

Urban development can increase flooding during storms while also stressing freshwater supplies. These are different effects of changing how water moves and how much people withdraw.

1. IMPERVIOUS SURFACES CHANGE THE WATER PATH

Pavement + roofs
Water cannot soak through

→

Less infiltration
Less local recharge

→

More runoff
Faster flow to drains

Infiltration is water entering the soil; recharge is water reaching an aquifer. Rain that cannot enter paved ground is redirected across the surface. Loss of vegetation also reduces interception and evapotranspiration. This is a general comparison with vegetated land, not a claim that every urban site has identical water flows.

2. FLOOD RISK AND WATER QUALITY

Drains route runoff to streams quickly, often producing an earlier, higher peak flow during the same storm. If channels or drainage systems cannot carry the flow, flooding can occur. Fast runoff can erode streambanks and wash oil, sediment, road salt, nutrients and litter into water. A storm drain does not necessarily lead to treatment. Flood risk also depends on rainfall, soils, topography and drainage design.

3. COASTAL PUMPING CAN DRAW IN SALTWATER

More pumping
Freshwater levels fall

→

Flow changes
Less seaward freshwater flow

→

Saltwater intrusion
Saline water enters fresh zones

In coastal aquifers, excessive pumping can pull saline water toward wells or upward from deeper zones. Water may become too salty for its intended use. This is groundwater contamination, not simply seawater flooding streets. Reduced recharge can add pressure to an already stressed supply.

Runoff timing and flood risk: USGS, Effects of Urban Development on Floods.
Pumping and coastal aquifers: USGS, Saltwater Intrusion.

Scope: College Board AP Environmental Science CED, Topic 5.10, p. 106.

Plan for water, heat and access

Extension: urban design can reduce some impacts while meeting housing and service needs. Evaluate a strategy by its mechanism, maintenance requirements and local conditions.

1. URBAN HEAT ISLANDS: A LOCAL TEMPERATURE EFFECT

Pavement and buildings store and release heat, while reduced vegetation means less shade and cooling by evapotranspiration. Vehicles and buildings add waste heat. Urban areas can therefore be warmer than nearby less-developed areas, increasing cooling demand. A heat island is not the same process as global greenhouse warming, although both can increase heat exposure.

2. MATCH THE DESIGN TO THE PROBLEM

Rain gardens / green roofs	Capture and store rainfall; plants and soil reduce or delay runoff. Green roofs do not directly recharge aquifers.
Permeable pavement	Let water pass into a storage layer, then into suitable soil or an underdrain. Reduce rapid surface runoff.
Compact, mixed-use areas	Bring destinations closer and support transit, walking and cycling; reduce car dependence and land use per resident.
Water-efficient use	Reduce unnecessary demand and leaks to ease withdrawals. Groundwater protection also needs appropriate pumping management.

3. BENEFITS COME WITH LIMITS

Green infrastructure needs space, suitable design and maintenance; clogged paving loses effectiveness and large storms can exceed storage capacity. Trees offer shade but need appropriate species and water. Compact development still needs drainage, open space and affordable access to services. Moving runoff downstream faster can shift flood risk rather than solve it. Combine measures and assess outcomes at both neighborhood and watershed scales.

Local heat mechanisms: EPA, What Are Heat Islands?
Rain gardens, green roofs and paving: EPA, Types of Green Infrastructure.
Compact development and travel choices: EPA, About Smart Growth.

Scope: College Board AP Environmental Science CED, Topic 5.10, p. 106.