Soils and the Critical Zone

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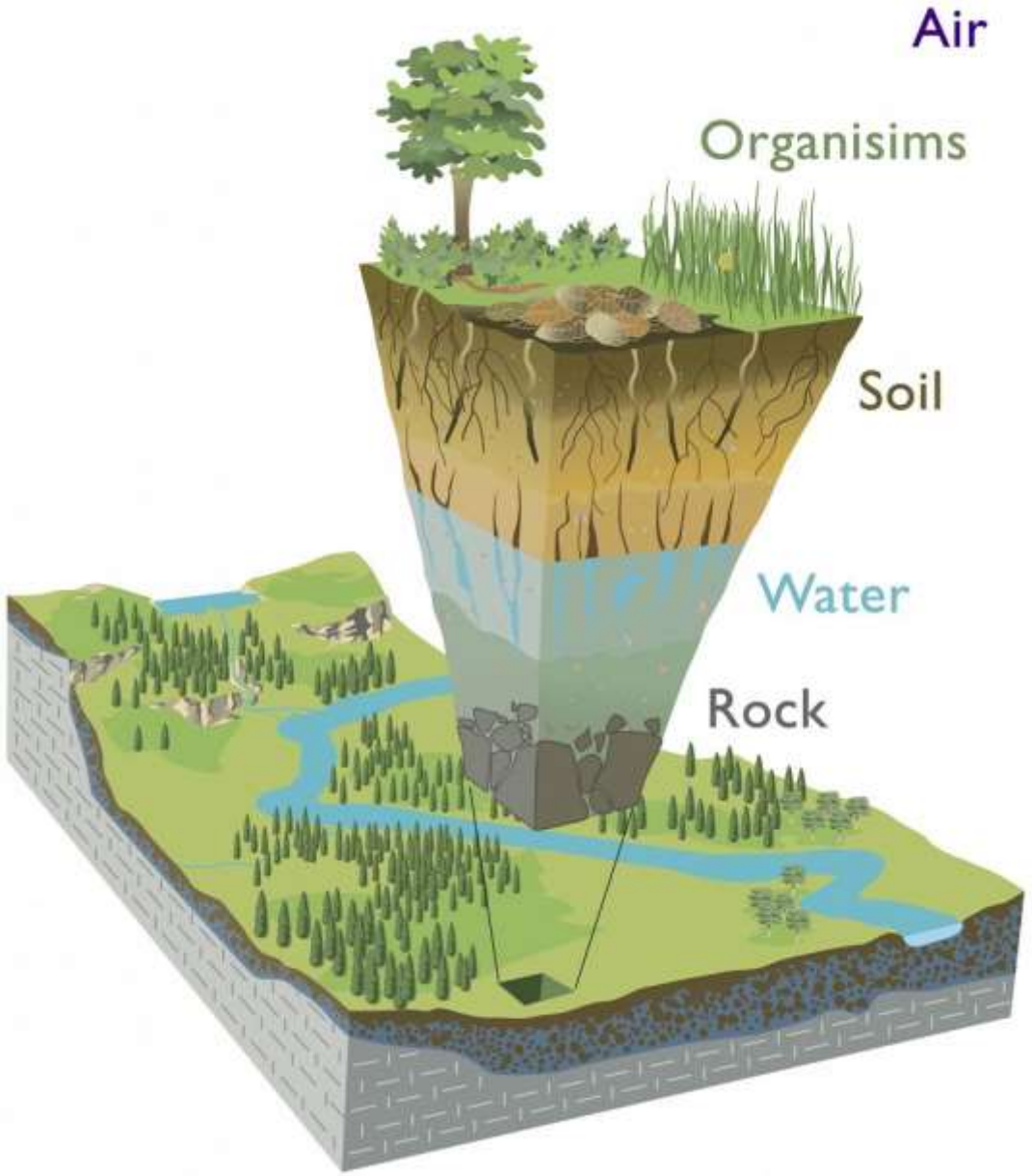
Outline:

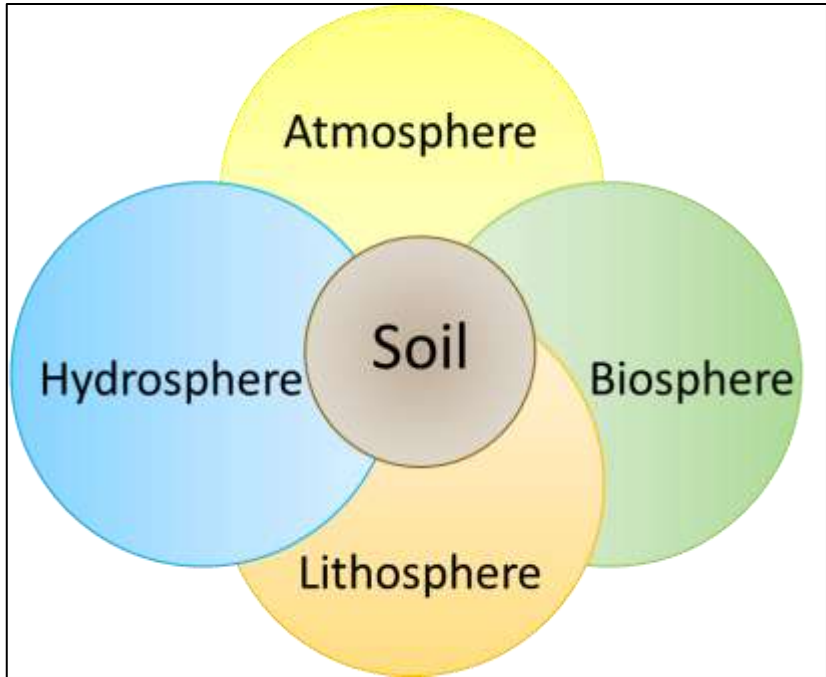
- Introduction to the Critical Zone
- What is soil?
- Soil functions
- Environmental gradients
- Soil forming factors
- Soil measurements



Critical Zone: Where rock meets life

The Critical Zone (CZ) extends from the top of the vegetation canopy to the groundwater beneath the Earth's surface and includes interactions within the four main spheres of Earth:

Atmosphere
Hydrosphere
Geosphere
Biosphere



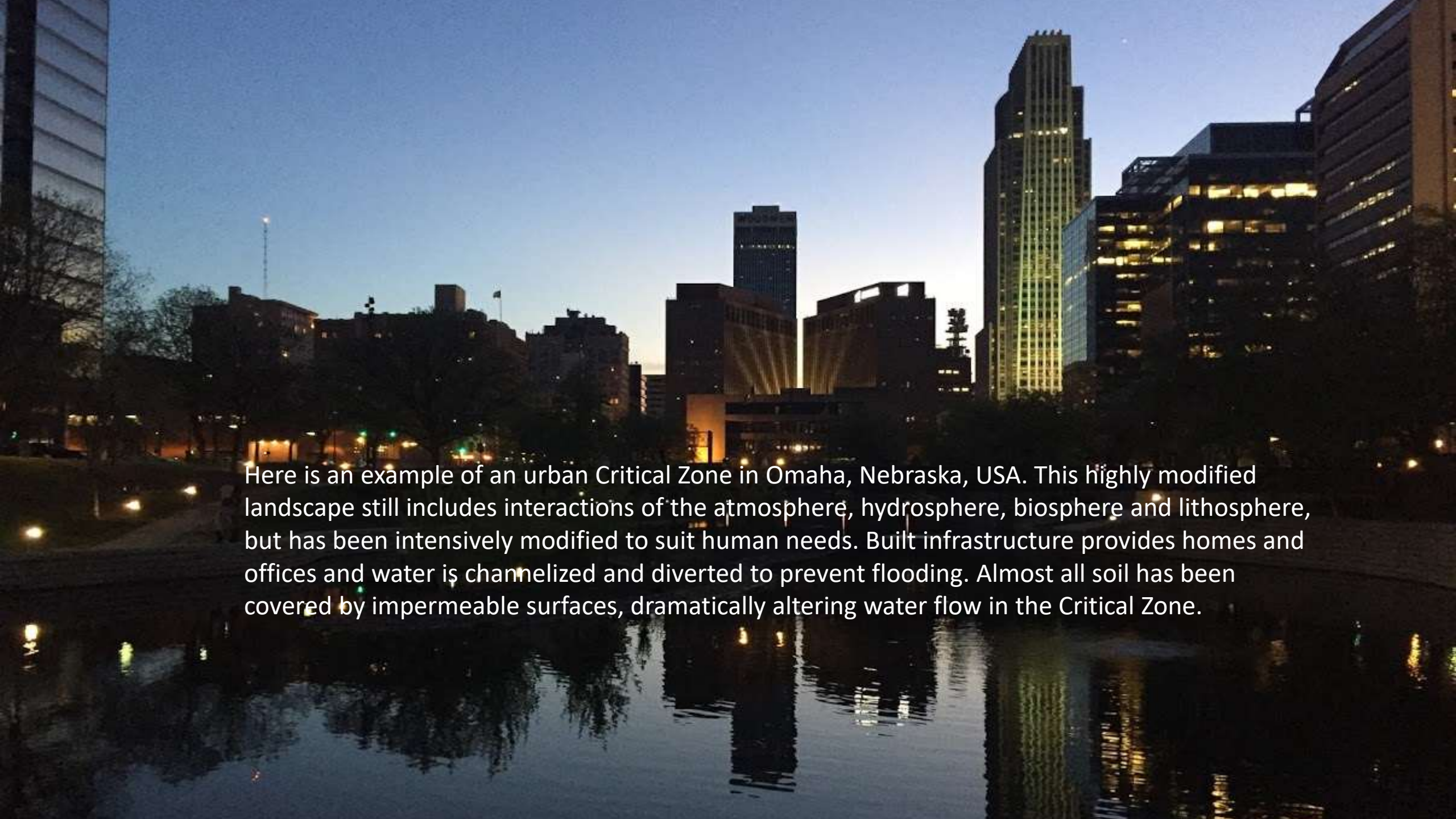
The Critical Zone is found everywhere on Earth, forming the thin layer that supports humans and ecosystems alike.

Here is an example of the Critical Zone in central Wales, United Kingdom, extending from the top of the forest canopy to the groundwater in the rock. At this site humans harvest the forest for wood products and excavate the rock for building local roads.


Critical Zone
Here is an example of a very deep Critical Zone from a quarry in central Brazil. Note the human use of the rock from this Critical Zone for building material. Humans extract many resources from the Critical Zone.

Here is an example of the surface of the Critical Zone in the Italian Alps. In the past humans used the timber from the forest, but more recently the land is used for cattle grazing during the summer and human recreation year-round. In addition, water from snowmelt produces energy. Note very small glaciers visible in the distance that have been retreating due to climate change, which will impact water availability, energy production, livestock and the local economy.

Here is an examples of the surface of the Critical Zone in central Pennsylvania, USA. At this site, the land surface has been modified to grow potatoes, which includes tilling the surface soils, adding fertilizer, and irrigating with water to produce crops. This intensive land management is concentrated at the surface but will ultimately impact much deeper by altering water, biology and leaving soil susceptible to erosion.



Here is an example of an urban Critical Zone in Omaha, Nebraska, USA. This highly modified landscape still includes interactions of the atmosphere, hydrosphere, biosphere and lithosphere, but has been intensively modified to suit human needs. Built infrastructure provides homes and offices and water is channelized and diverted to prevent flooding. Almost all soil has been covered by impermeable surfaces, dramatically altering water flow in the Critical Zone.

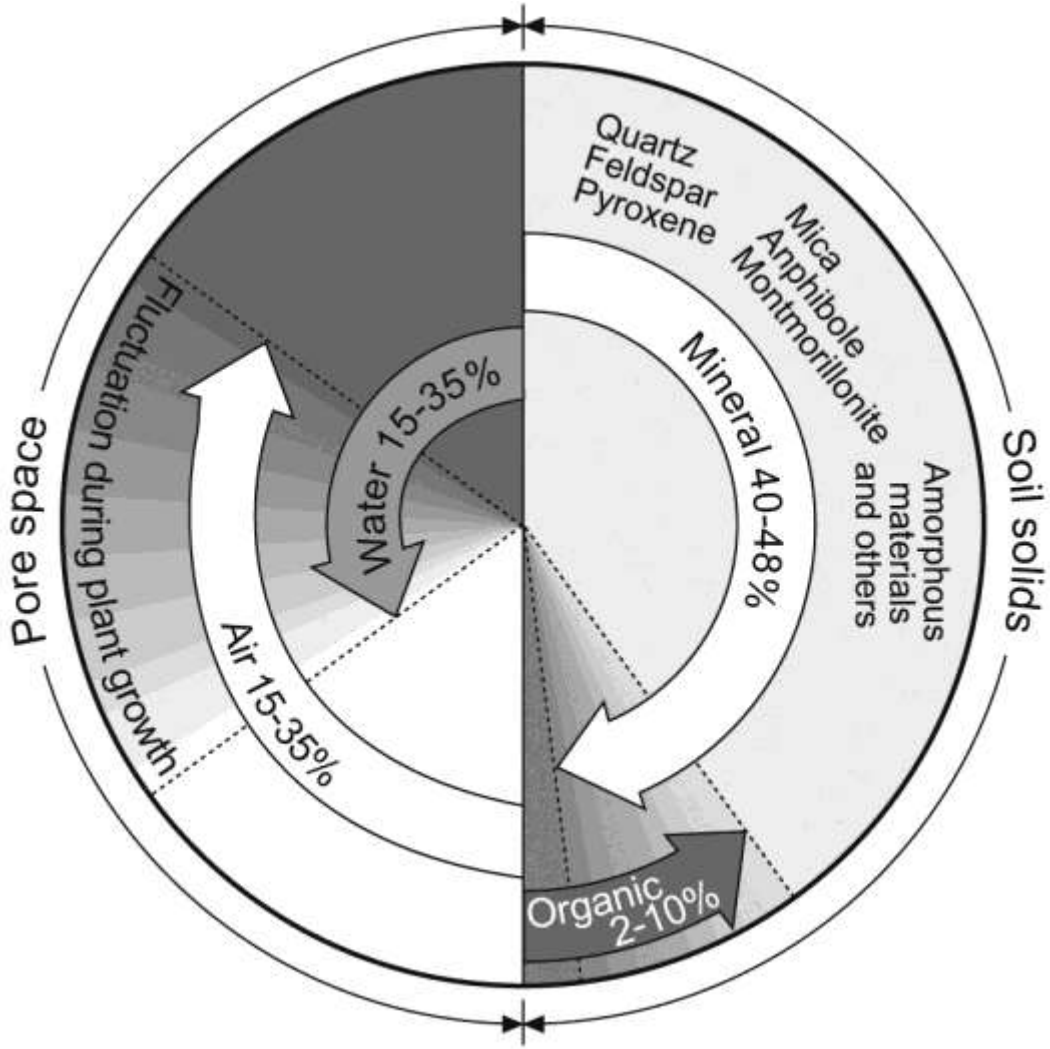

Within the Critical Zone system, soil is an important interface, regulating gas and water exchange and supporting terrestrial life above and within the soil.
Critical Zone

What is soil?

Soils are made of:

- Minerals
- Organic matter
- Air
- Water
- Organisms

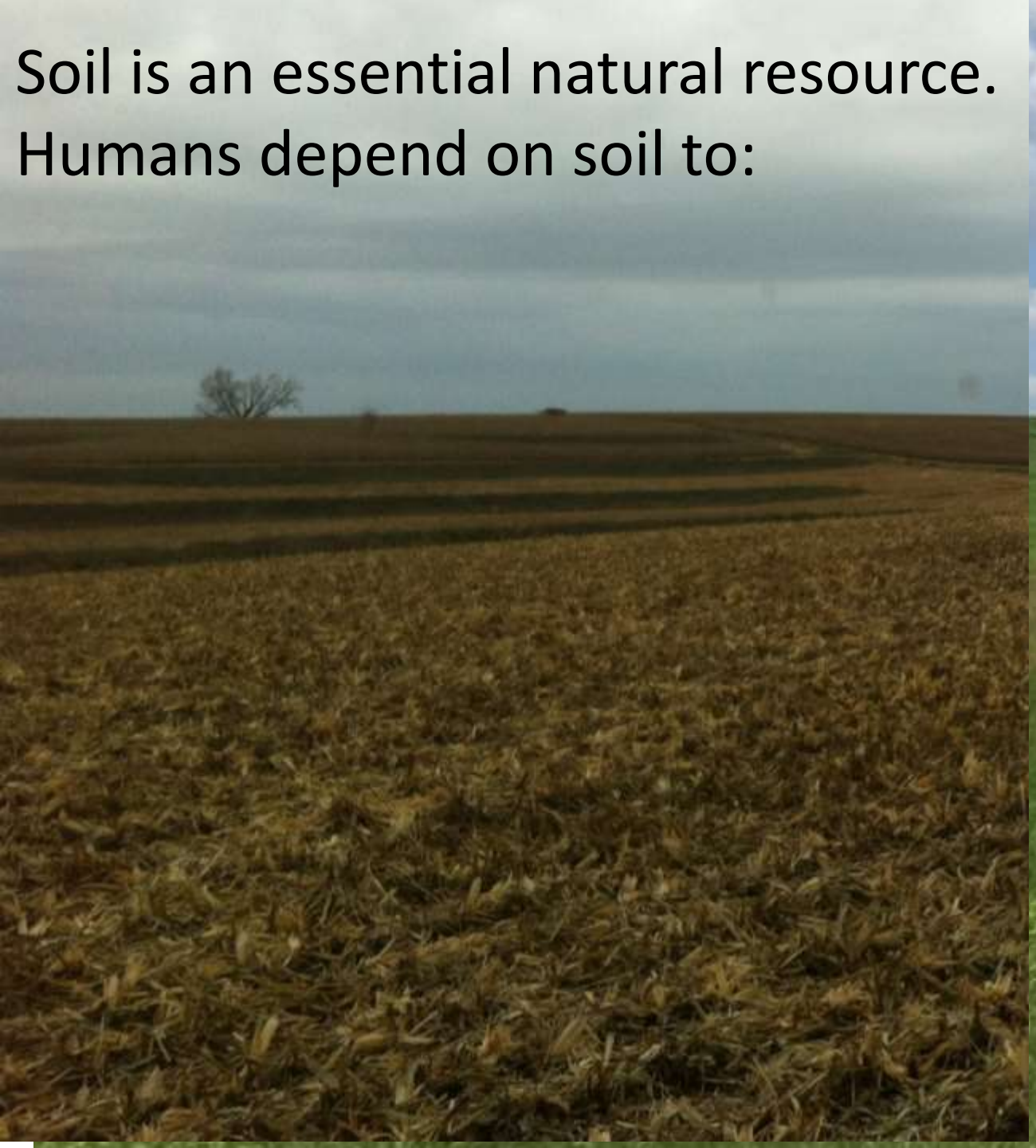
Soils serve as living systems that provide fundamental functions for life.



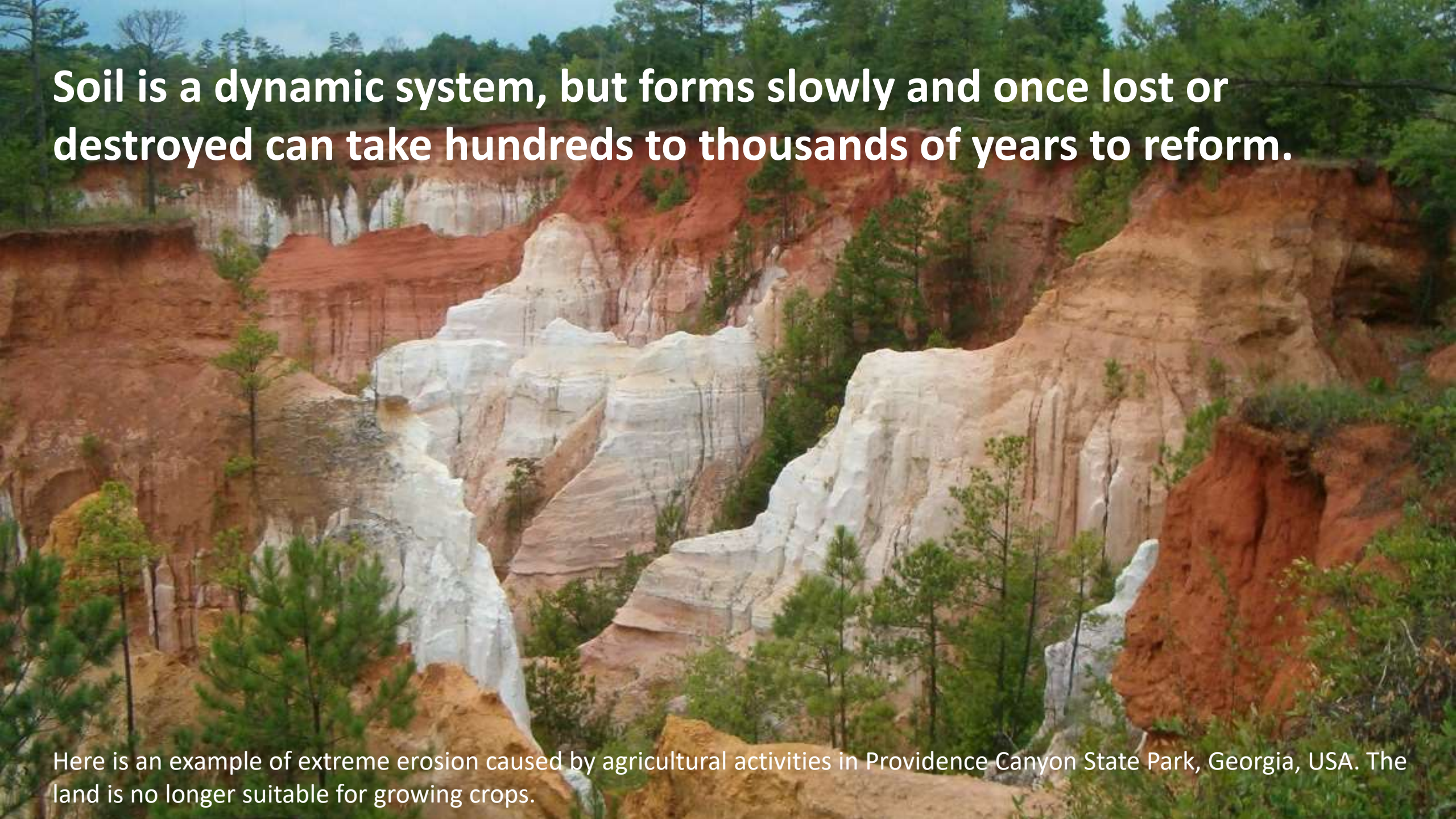
Note that the air and water components of soil can change substantially depending on environmental conditions, while the mineral and organic components of soil are slower to change.

Schaetzl and Thompson, 2015

Soil is an essential natural resource. Humans depend on soil to:



- filter water
- decompose and recycle chemical and organic material
- provide plant nutrients
- provide habitat for organisms
- grow food, fuel and fiber

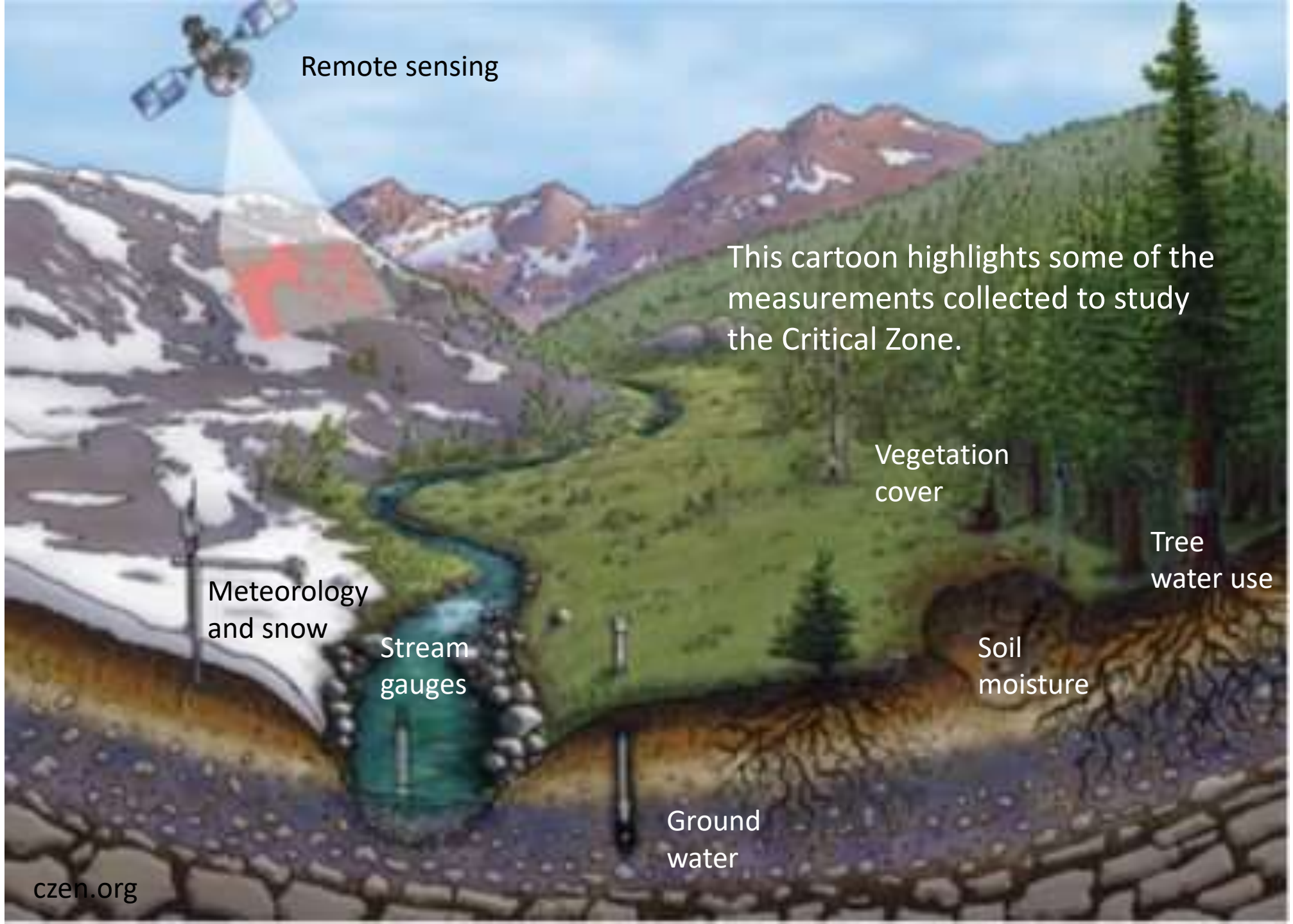


Soil is a dynamic system, but forms slowly and once lost or destroyed can take hundreds to thousands of years to reform.

Here is an example of extreme erosion caused by agricultural activities in Providence Canyon State Park, Georgia, USA. The land is no longer suitable for growing crops.

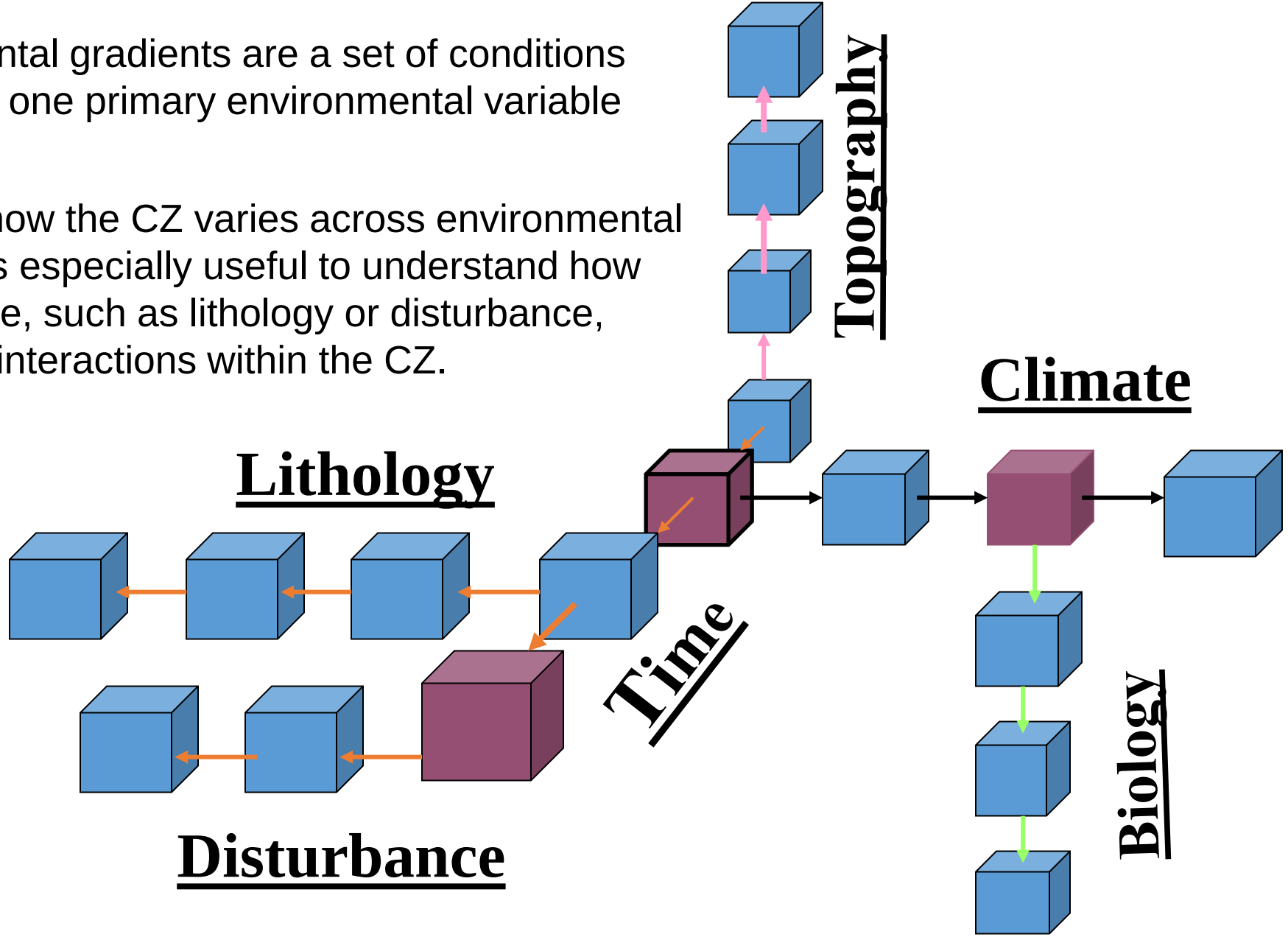
Critical Zone Observatories exist throughout the world and serve as sites to study interactions within the CZ across a range of environmental conditions.

czen.org


Remote sensing
This cartoon highlights some of the measurements collected to study the Critical Zone.
Vegetation cover
Tree water use
Meteorology and snow
Stream gauges
Soil moisture
Ground water
czen.org

Environmental gradients are a set of conditions where only one primary environmental variable varies.

Exploring how the CZ varies across environmental gradients is especially useful to understand how one variable, such as lithology or disturbance, influences interactions within the CZ.



The five soil forming factors include climate, organisms, relief, parent material, and time. These factors vary across the Earth and interact to form a particular soil (S) in any given location. Changing any of the variables will influence how the soil develops and functions.

S = soil

$$S = f(Cl, O, R, P, T, \ldots)$$

Cl = climate

O = organisms

R = relief

P = parent material

T = time

Soil quality and characteristics determine how land is used and the type of biodiversity it will support.

Measurements of soil that can help determine soil health include:

- Soil chemistry: pH, electrical conductivity, nutrients, organic matter
- Soil physical properties: particle size, bulk density, porosity, mineralogy
- Soil biology: organisms, root distribution, microbial composition