Soil Health for Resilience to Climate Change

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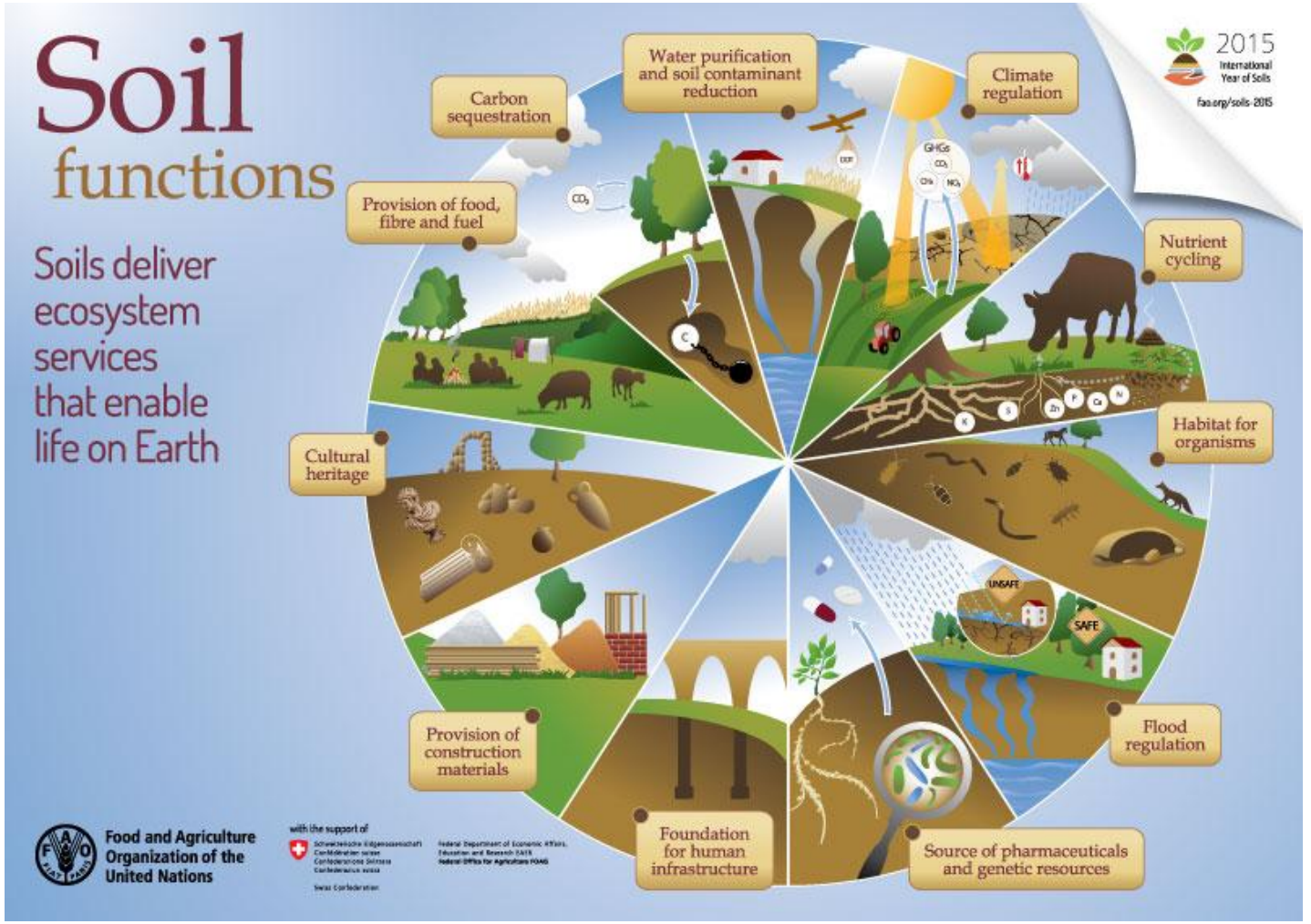
Soil Health

- The variety of soil types across the landscape vary in properties and therefore in suitability and limitations for specific functions
- Soil Health...the ability of the soil to sustain the productivity, diversity, and environmental services of terrestrial ecosystems (UN-FAO-ITPS, 2023)
- Key factor for evaluating sustainability of agricultural systems

Extreme weather and climate change challenge the functioning of soil

Soil: a natural resource

- Society's Reliance on Soil: Ecosystem Services
  - Provision of food, fiber, fuel
    - Supply of water, nutrients, physical support,
  - Habitat for organisms
  - Nutrient Cycling
  - Carbon sequestration
  - Water purification and soil contaminant reduction
  - Groundwater supply, flood regulation
  - Climate regulation



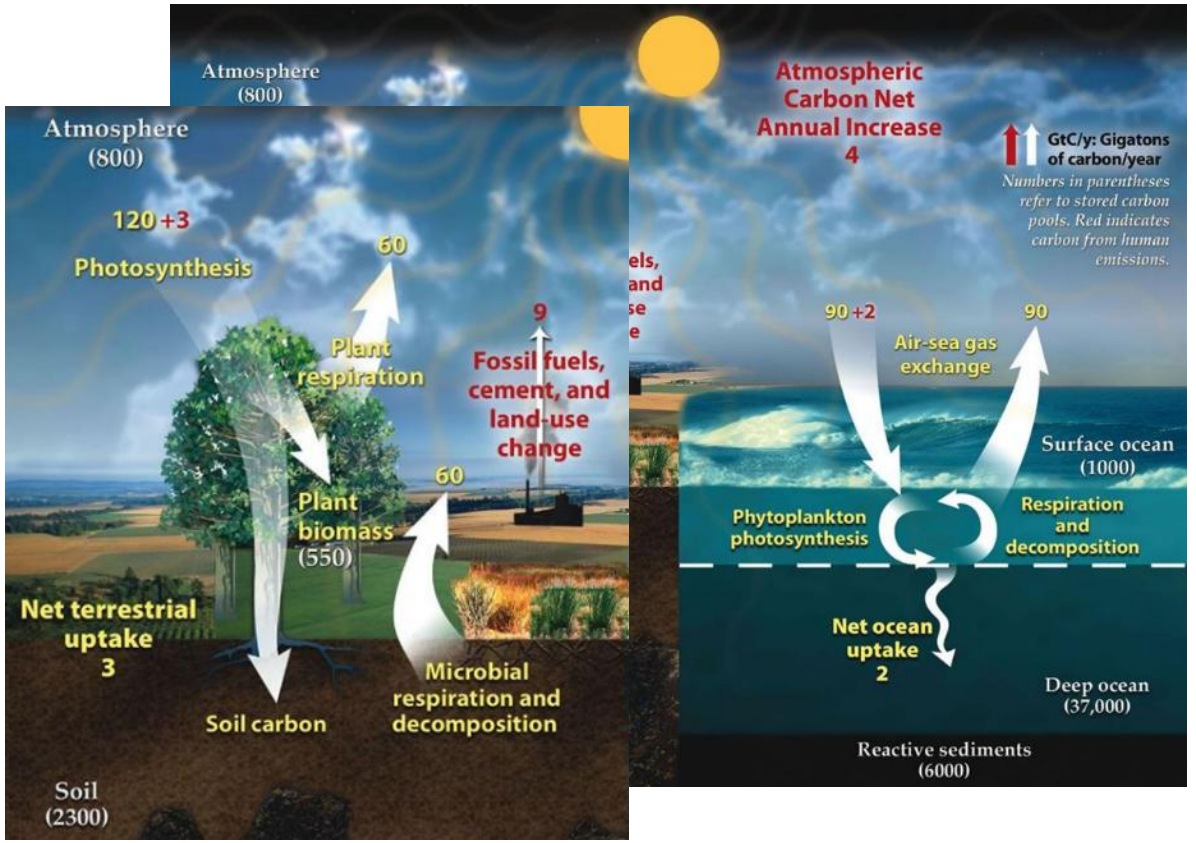
Key indices of Healthy (functioning) Soils

- Organic matter content
- Soil Structure:
  - aggregation, stability
  - pore-size distribution
  - bulk density
- Water processes:
  - infiltration rate
  - plant-available water
  - permeability rate
- Organism populations and diversity
- Fertility:
  - plant-available nutrients, pH

Interpretation of Organic Matter Levels in New Jersey Soils				
Organic Matter	Soil Texture			
%	*Loamy Sand*	*Sandy Loam*	*Loam*	*Silt Loam*
less than 0.5%	Very Low	Very Low	Very Low	Very Low
0.5 to 1.0 %	Low	Very Low	Very Low	Very Low
1.0 to 1.5 %	Medium	Low	Very Low	Very Low
1.5 to 2.0 %	High	Medium	Low	Low
2.0 to 2.5%	Very High	High	Medium	Low
2.5 to 3.0 %	Very High	Very High	Medium	Medium
3.0 to 3.5 %	Very High	Very High	High	Medium
3.5 to 4.0 %	Very High	Very High	High	Medium
4.0 to 5.0 %	Very High	Very High	Very High	High
more than 5 %	Very High	Very High	Very High	Very High

Bulk density (g/cc)	Ideal	Root-restrictive
Sand, loamy sand	< 1.60	> 1.80
Sandy loam, loam	< 1.40	> 1.80
Sandy clay loam, clay loam	< 1.40	> 175
Silt, silt loam	< 1.30	> 1.75
Silty clay loam	< 1.40	> 1.65
Sandy clay, silty clay	< 1.10	> 1.58
Clay	< 1.10	> 1.47

Soil Organic Matter



- Soil organic matter content
  - Nutrient supply (cycling) and nutrient-holding capacity
  - Sustenance for soil organisms
  - pH and nutrient buffering
  - Water-holding capacity
  - Soil structure, porosity
- Over- or mis-management leads to declining organic matter (C) content in soil (more CO2 in atmosphere)
- Practices that reduce soil disturbance and promote organic matter accumulation sequester carbon underground (C sequestration)

Soil Structure –

- Aggregation and/or porosity
  - Resistance to erosion
  - Water transmission by gravity in macropores
  - Aeration – gas exchange by diffusion
  - Root growth – minimize penetration resistance
- *Avoid* soil compaction (dense packing)
  - Limit equipment load and passes in field
  - Soil most susceptible when wet
  - Consequences of compaction:
    - Reduces macroporosity
      - Reduces water infiltration, drainage, and aeration
    - Impedes root growth

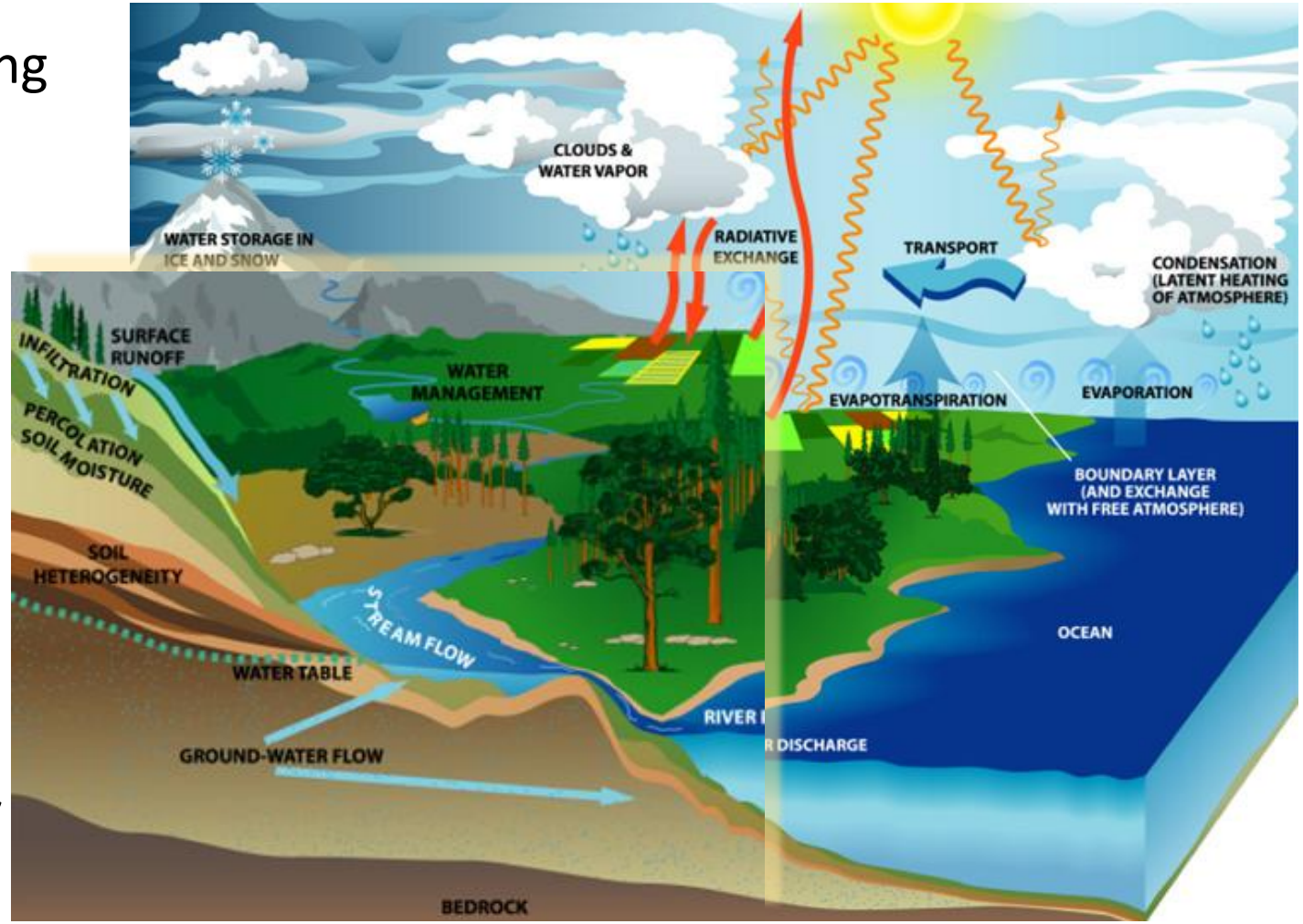
Credit: Iowa State Press. Soil Judging in Iowa

Credit: Penn State Extension. Effects of Soil Compaction.

Soil in the hydrologic cycle

- Infiltration, percolation: moderating extreme precipitation events
  - Reduce runoff & erosion & flooding
- Storage of plant-available water
  - Avoid/minimize drought risk
- Filtering, purifying
- Groundwater recharge
- Evaporation – temperature moderation
- Dissipates radiant/thermal energy

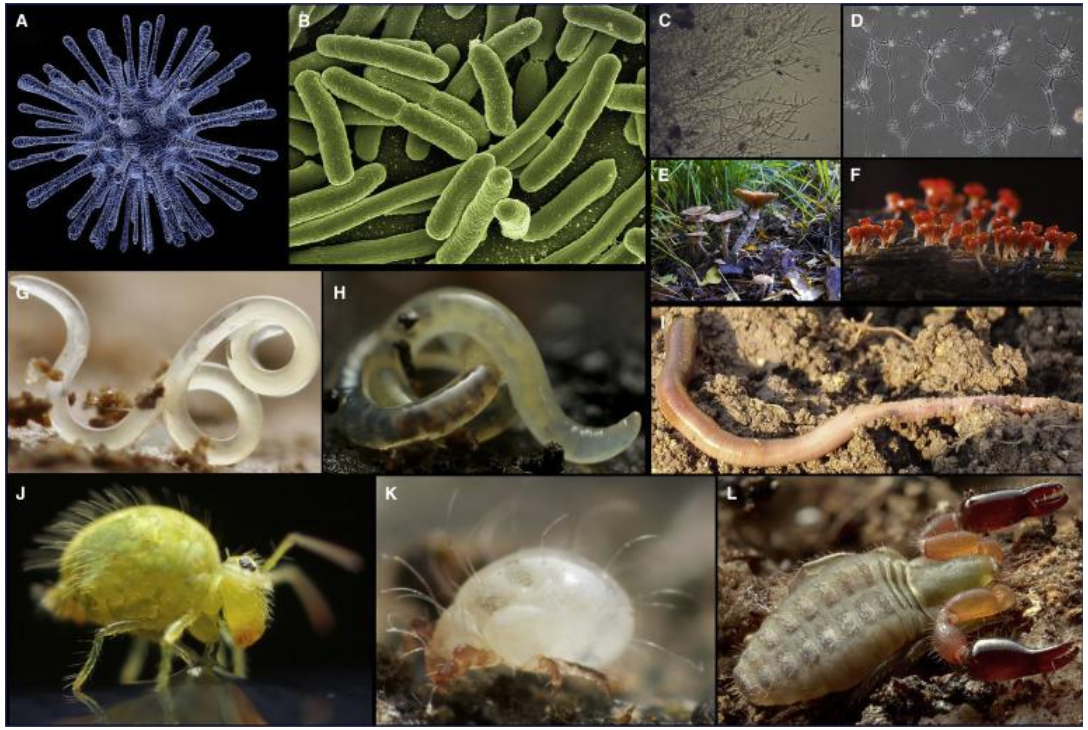
Porosity & organic matter factors



(U.S. Global Change Research Program 2003)

Biology: Organisms in the soil ecosystem

- Robust populations and diversity of organisms
  - Filling all nutrient/energy transfer roles
    - Autotrophs (photosynthetic and otherwise)
    - Grazers, Shredders
    - Detritovores
    - Mutualists
    - Pathogens, Parasites
    - Predators
    - Etc.
  - Replication of metabolic capabilities
  - Cycling of nutrients
  - Converting organic residues to humus
  - Balance – prevent overpopulation of pest organisms



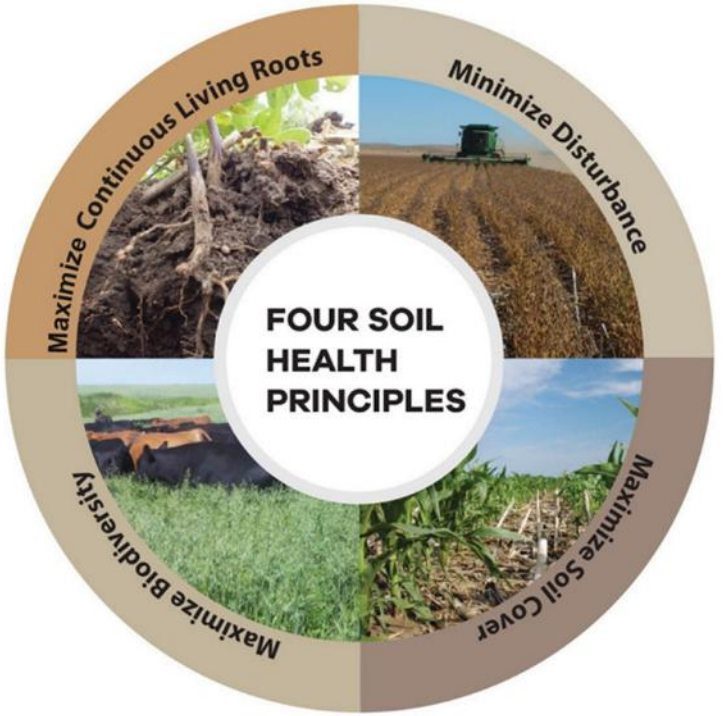
Geisen, et al. Current Biology, 2019. https://doi.org/10.1016/j.cub.2019.08.007

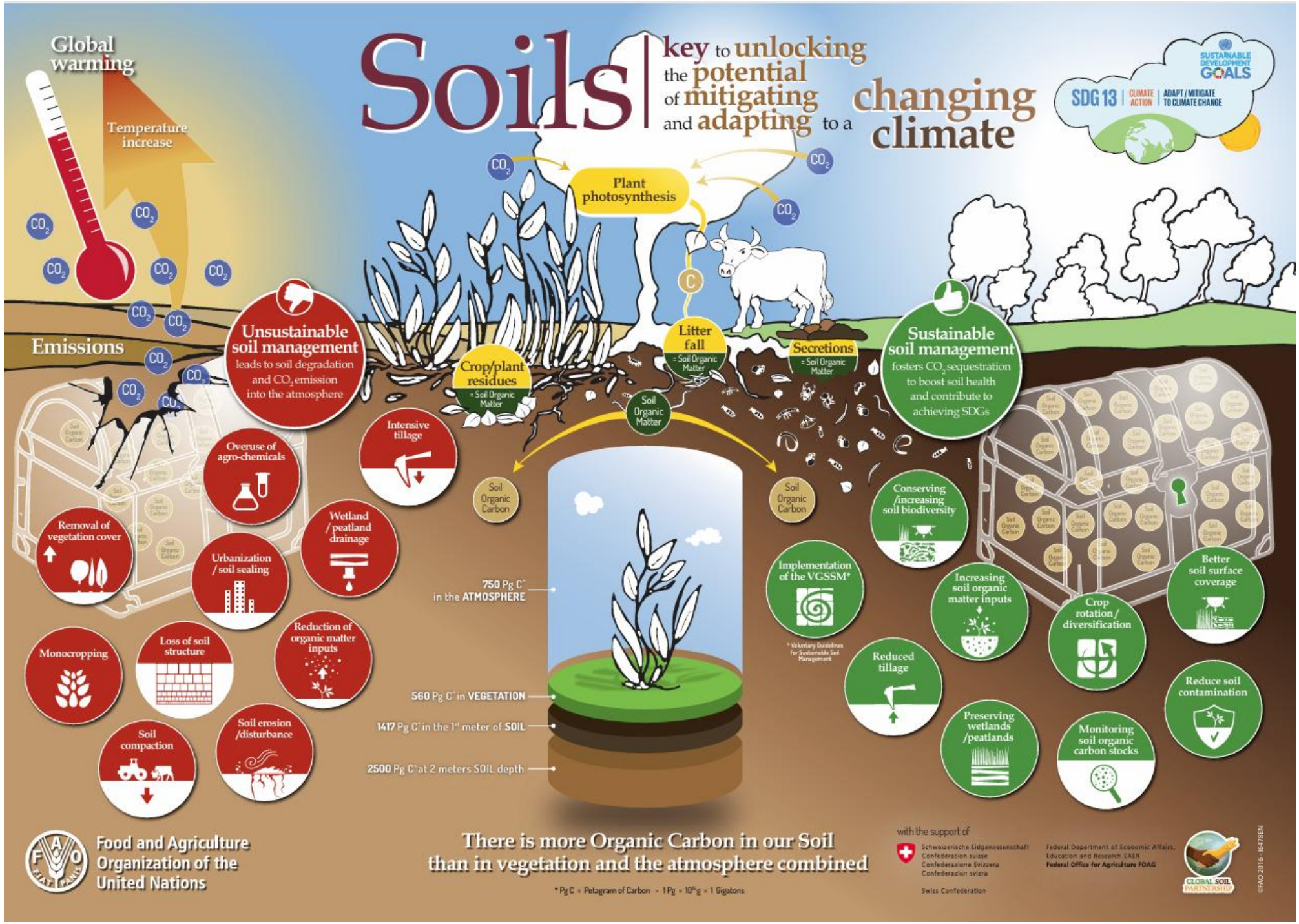
Soil Health contributions to resilience for production agriculture

- High soil organic matter content
  - Nutrient cycling
  - Sustenance for soil organisms
  - pH and nutrient buffering
  - Water-holding capacity
  - Soil structure, porosity
- Strong, stable soil structure, porosity
  - Water infiltration, redistribution, storage, drainage, & recharge of groundwater
  - Aeration: adequate diffusion of gases
  - Resistance to erosion
  - Root growth proliferation

Practices to maintain or enhance Soil Health

- Preserve and protect natural and working landscapes
- Manage for soil health
  - Prevent loss by erosion
  - Limit disturbance and : no- or reduced tillage
    - Maintain soil structure and porosity, biological communities
    - Retention of crop residue for protection of soil surface
    - Preservation of organic matter
  - Avoid compaction
  - Maximize vegetative input of carbon
    - Perennial vegetation (incl. agroforestry) or crop rotation and cover crops to maintain living roots year-round
    - Other practices that promote biological diversity
    - Amendments such as nutrients, manure, compost





Sustainable Soil Management:

- Conserve/ increase soil biodiversity
- Increase organic matter input
- Use crop rotation & diversification
- Reduce tillage
- Maintain better soil surface cover
- Reduce soil contamination
- Preserve wetlands & peatland