BUILDINGENERGY BOSTON

Carbon in the Landscape: A New Frontier in the Whole-Carbon Approach

Sebastian Gutwein, Regenerative Design Group
Jim Newman, Linnean Solutions

Curated by Clay Tilton

Northeast Sustainable Energy Association (NESEA) | March 20, 2025

Guidance for Implementing Healthy Soils in Landscape and Construction

SEBASTIAN GUTWEIN *Regenerative Design Group*

JIM NEWMAN *Linnean Solutions*

Ecological Landscape Design

Educational Landscapes + Trainings

Regenerative DesignGroup COOPERATIVE

Research , Analysis, + Planning

Regenerative Agriculture


Collective Climate Action
Buildings with Positive Impact
LINNEAN
SOLUTIONS
Evolving Relationships with Land
Circularity and Whole System Health

1. **Soil Function + Health**

2. **MA Healthy Soils Action Plan: What We Learned**

3. **Landscape Impacts: Best Management Practices**

4. **Case Studies + Lessons Learned**

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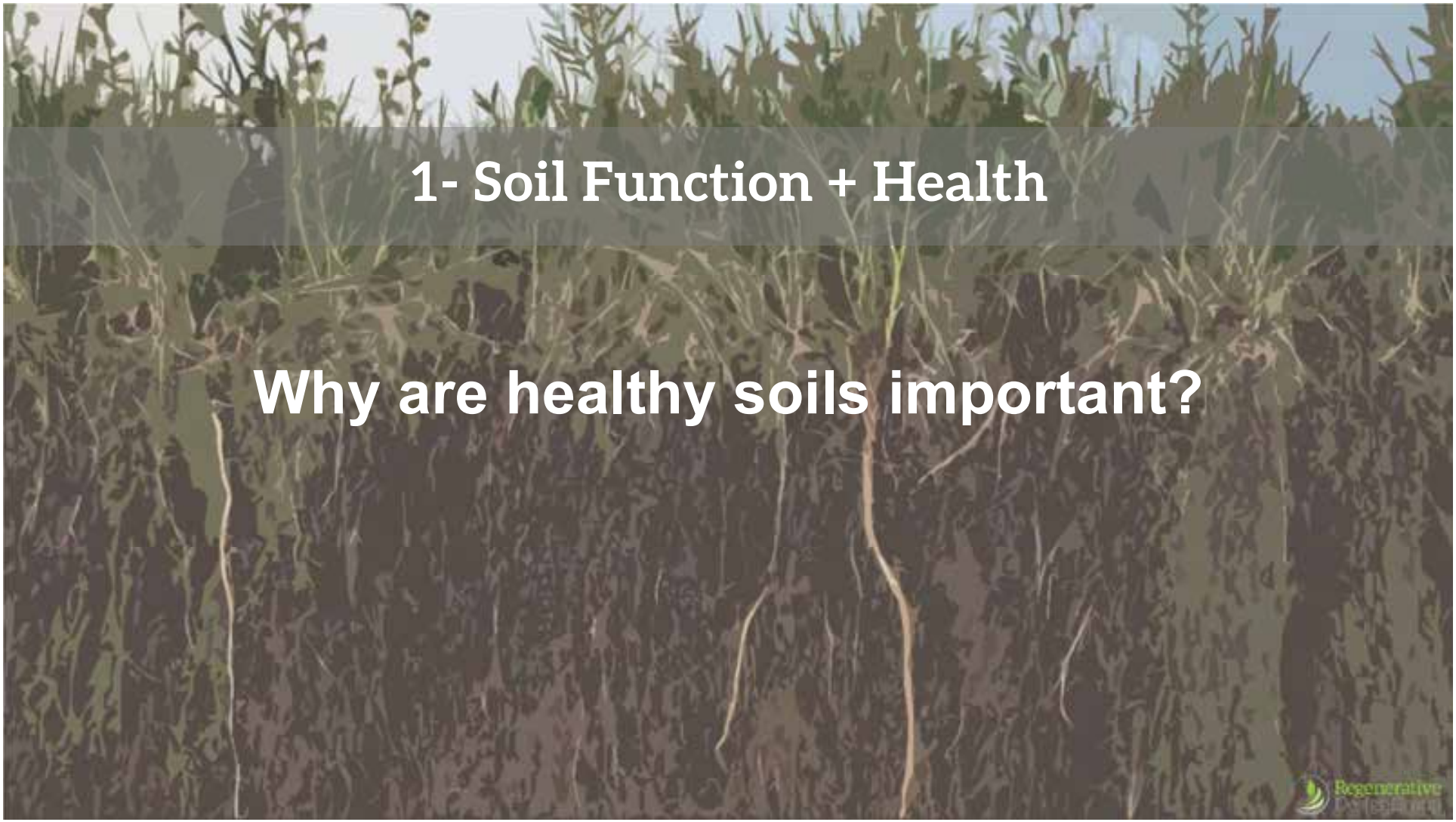
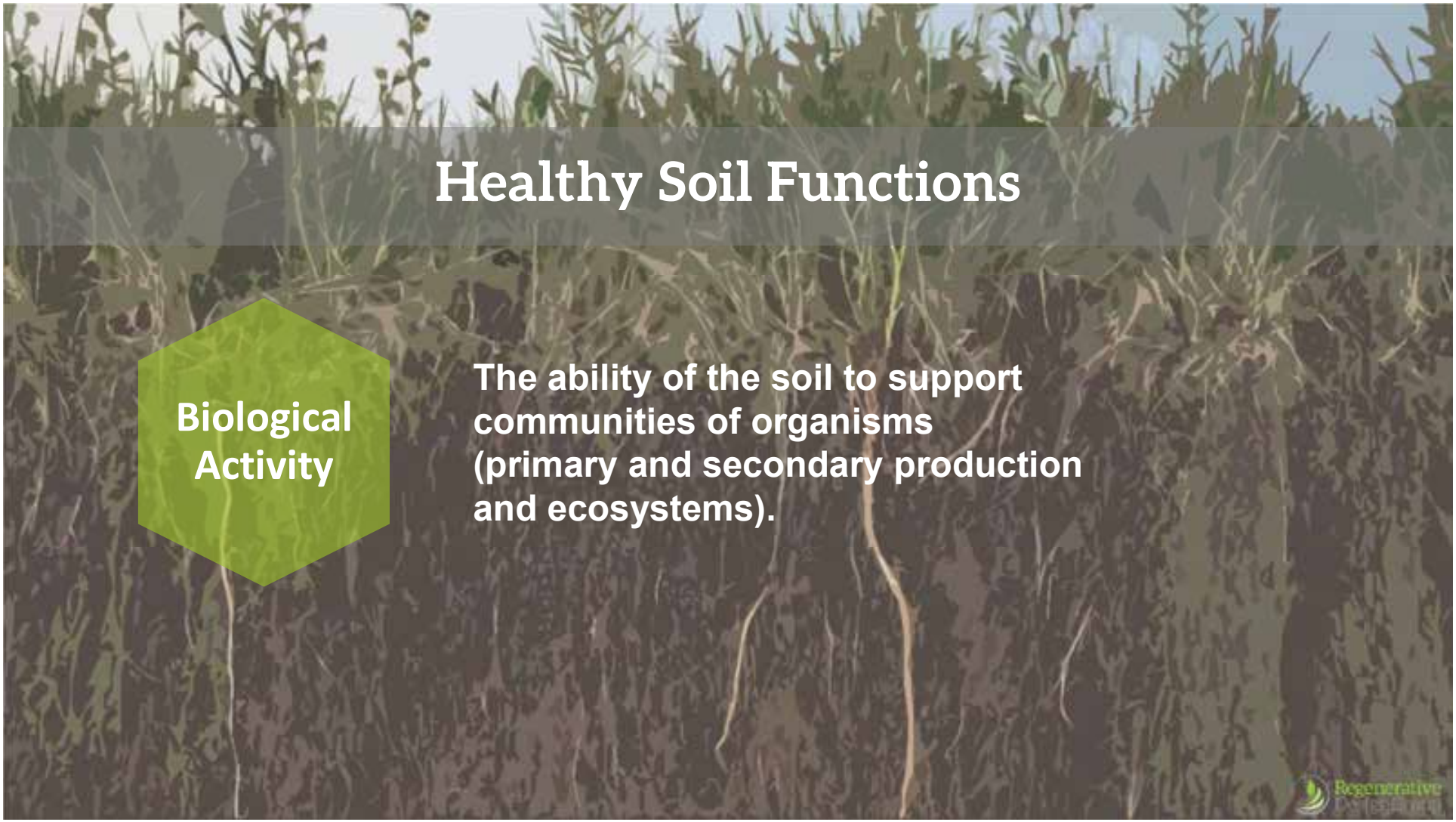
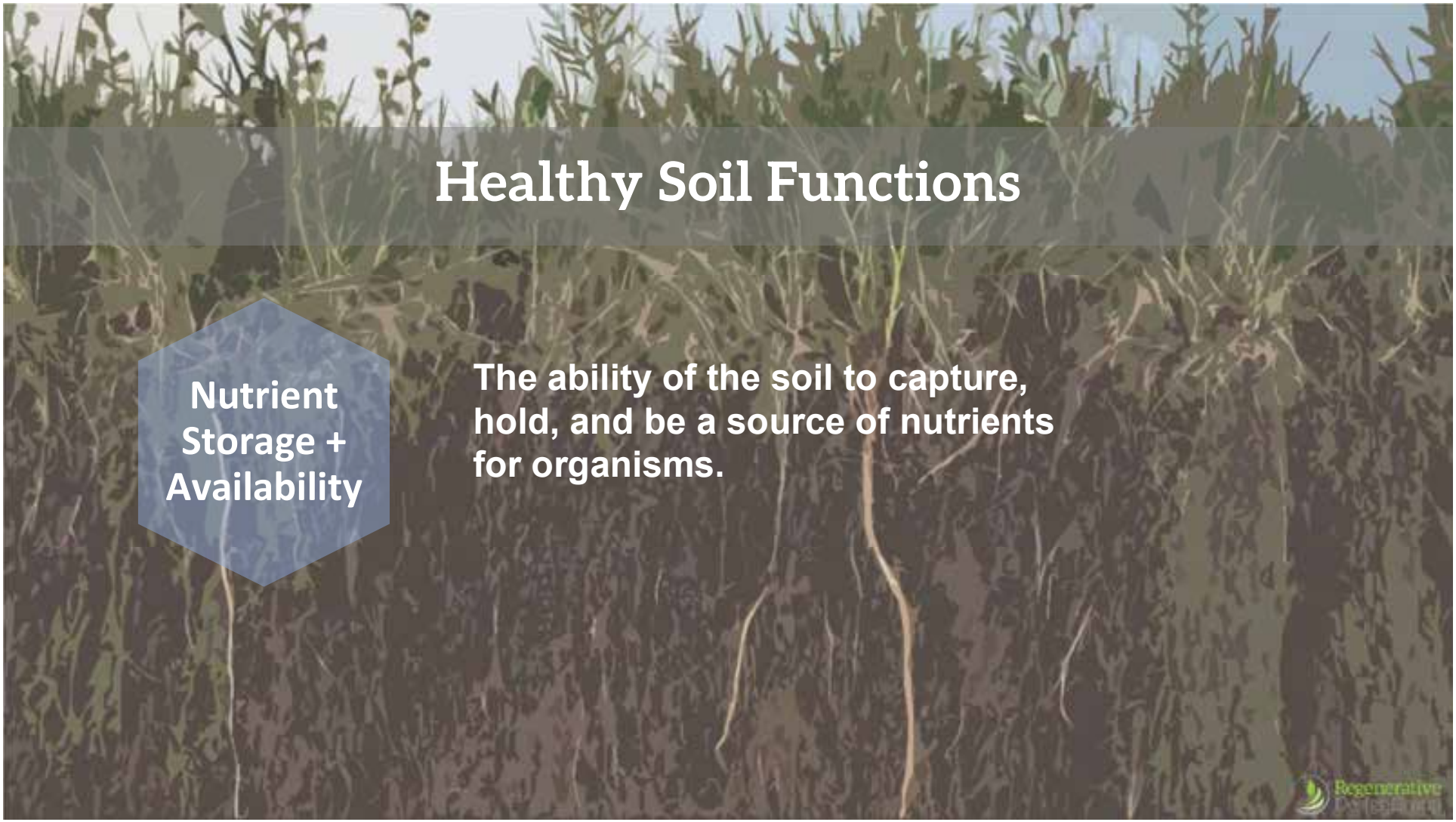

1- Soil Function + Health
Why are healthy soils important?

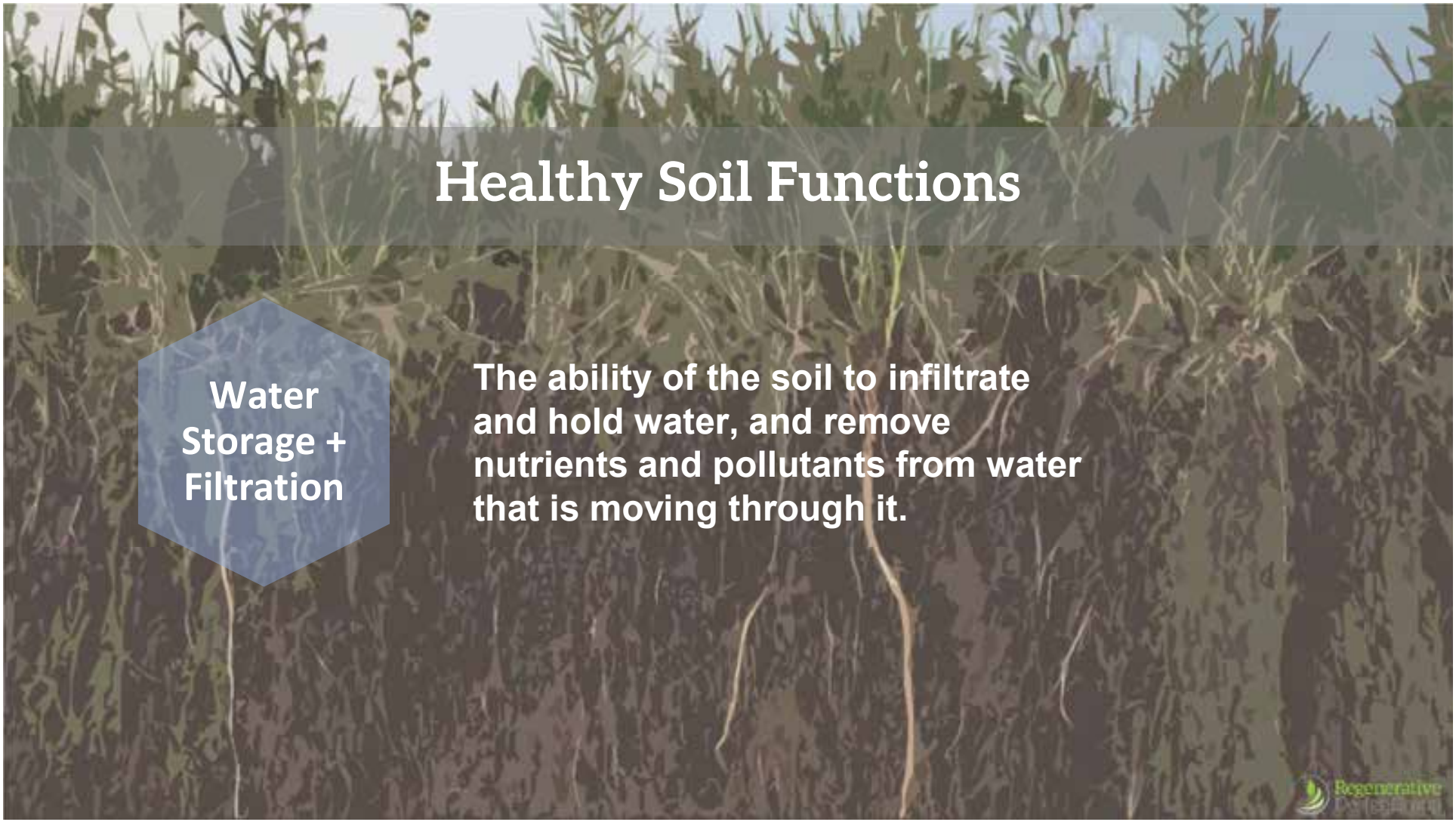
Healthy Soil Functions

Productive Capacity

The capacity of the soil to support plants and plant growth (primary production).


Healthy Soil Functions
Biological Activity
The ability of the soil to support communities of organisms (primary and secondary production and ecosystems).

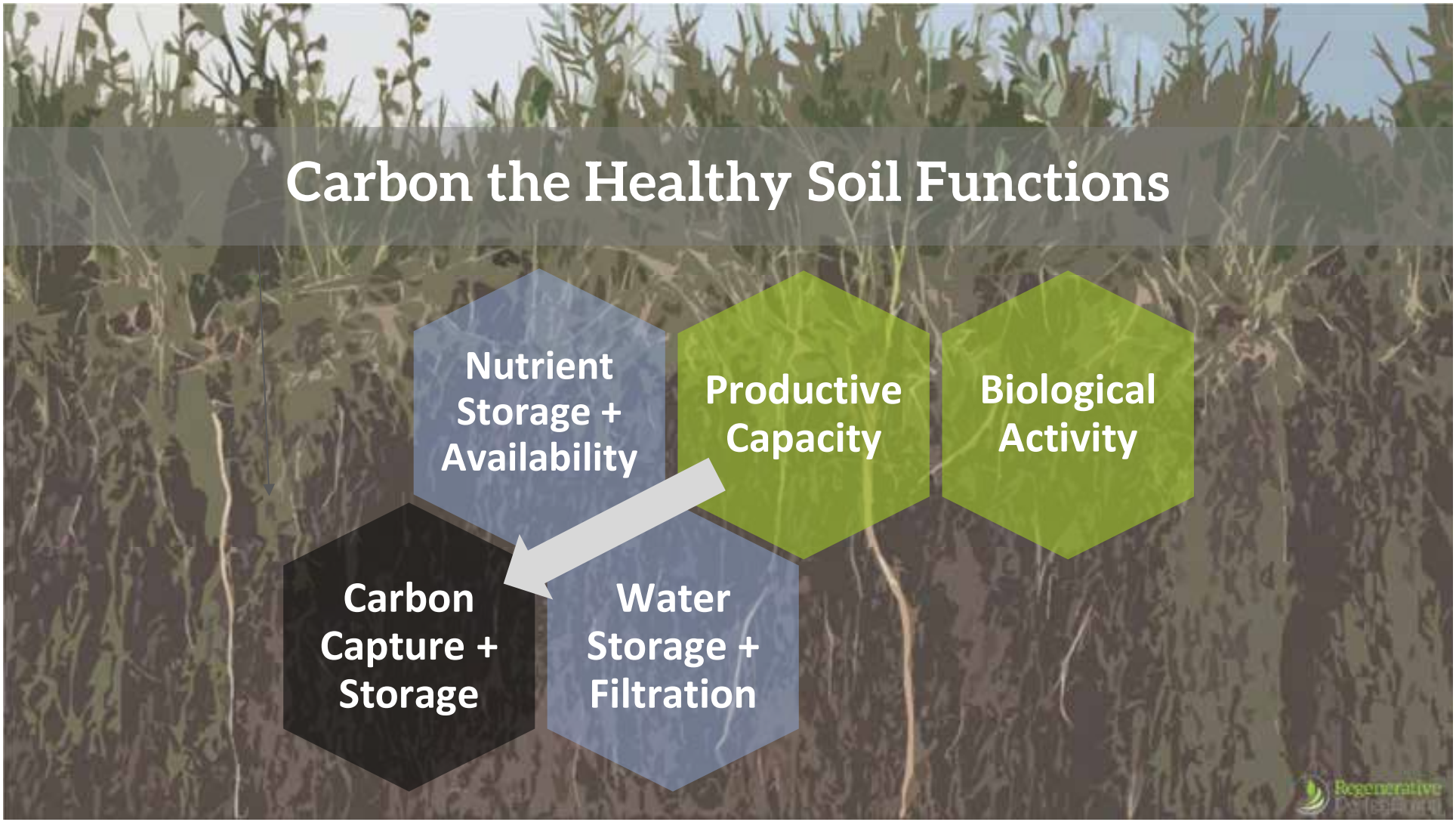

Healthy Soil Functions
Nutrient Storage + Availability
The ability of the soil to capture, hold, and be a source of nutrients for organisms.


Healthy Soil Functions
Water Storage + Filtration
The ability of the soil to infiltrate and hold water, and remove nutrients and pollutants from water that is moving through it.

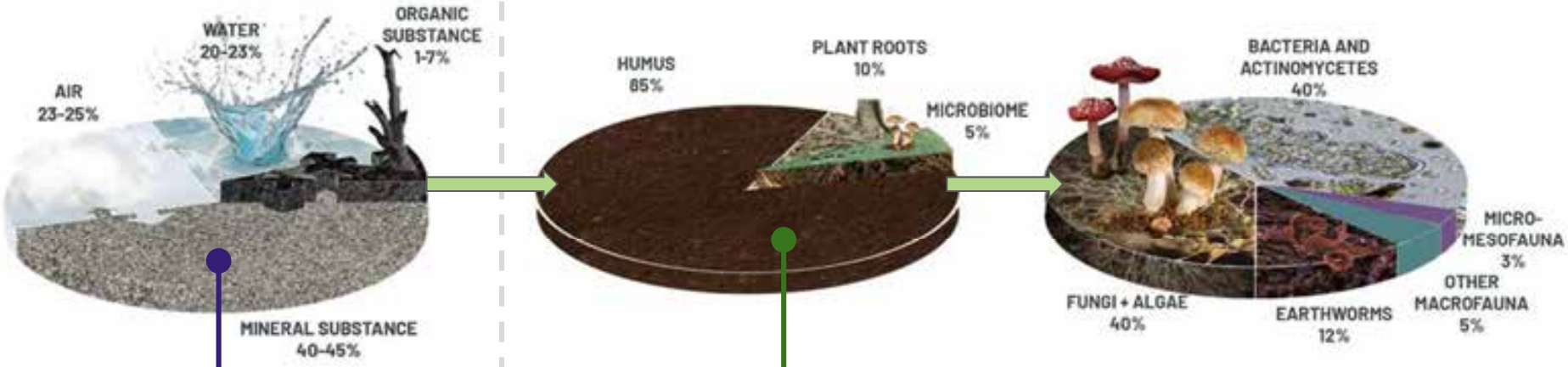
Healthy Soil Functions

Carbon Capture + Storage

The ability of the soil to hold on to carbon that plants have removed from the atmosphere and store it for extended periods of time as soil organic carbon and below ground biomass.


Carbon the Healthy Soil Functions
Nutrient Storage + Availability
Productive Capacity
Biological Activity
Carbon Capture + Storage
Water Storage + Filtration

Soil Components



Inherent Soil Property: Soil Texture

ABIOTIC SOIL COMPONENTS

- Fairly stable
- Difficult + slow to change

% Carbon = Soil Organic Carbon (SOC) → **80% of GLOBAL terrestrial carbon stock** (~) 2500 GT_1

BIOTIC SOIL COMPONENTS

- Fragile, dynamic cycles
- Influenced by land cover, climatic conditions, + human disturbance

Image: RDG

1Le Quéré et al., Global Carbon Budget 2016. Earth System Science Data. 2016;8:605–649. DOI: 10.5194/essd-8-605-2016

Abiotic: Mineral Soil Texture

- Unique composition of sand, silt, and clay.
- Very stable over human time (without disturbance)
- Largely determined by parent material (bedrock)

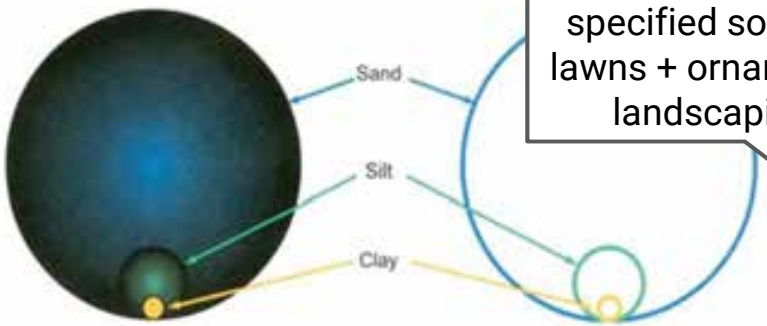
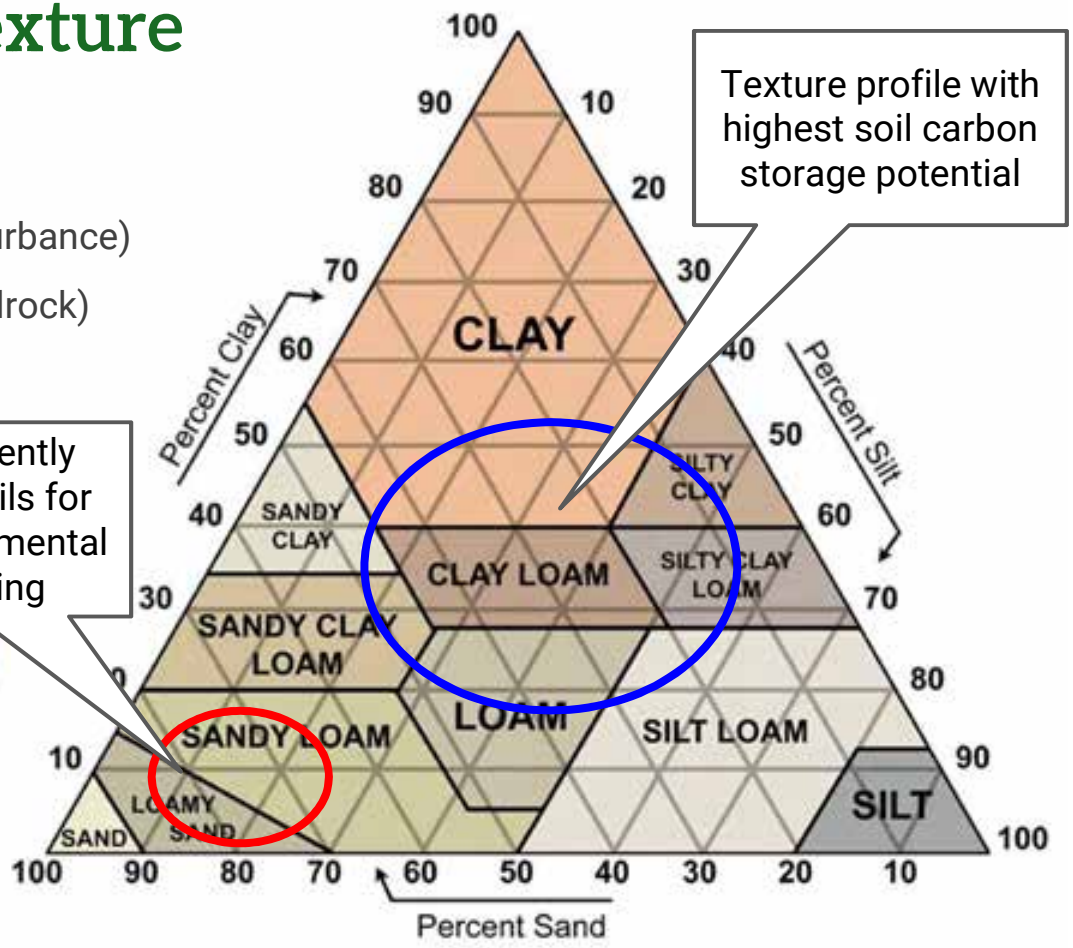


Figure 2.9: Relative sizes of sand, silt, and clay particles.

Most frequently specified soils for lawns + ornamental landscaping

Texture profile with highest soil carbon storage potential



Left: USDA NRCS “Urban Soil Primer” 2005. Right: NRCS Soil Texture Triangle. https://www.chegg.com/.

Geodiversity

Biodiversity requires diversity of habitats. Therefore, a diversity of soil types not only high functioning soils.

Soil Formation (Pedogenesis)

5 SOIL FORMING FACTORS

INVISIBLE

- Time: Short to geologic

VISIBLE

- Parent Material
- Climate and Climate Change
- Organisms/ Biota
- Landscape Position/ Topography

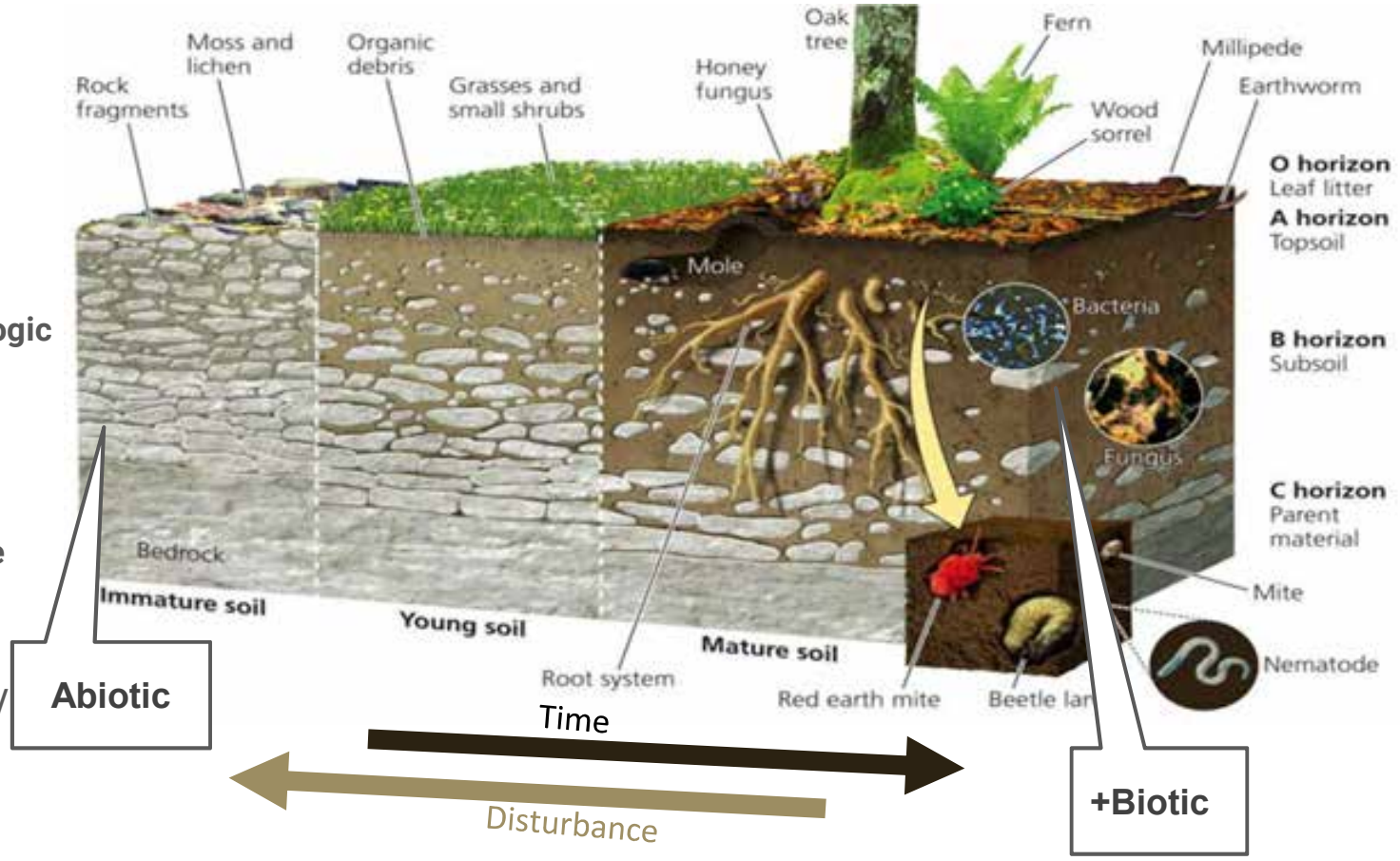
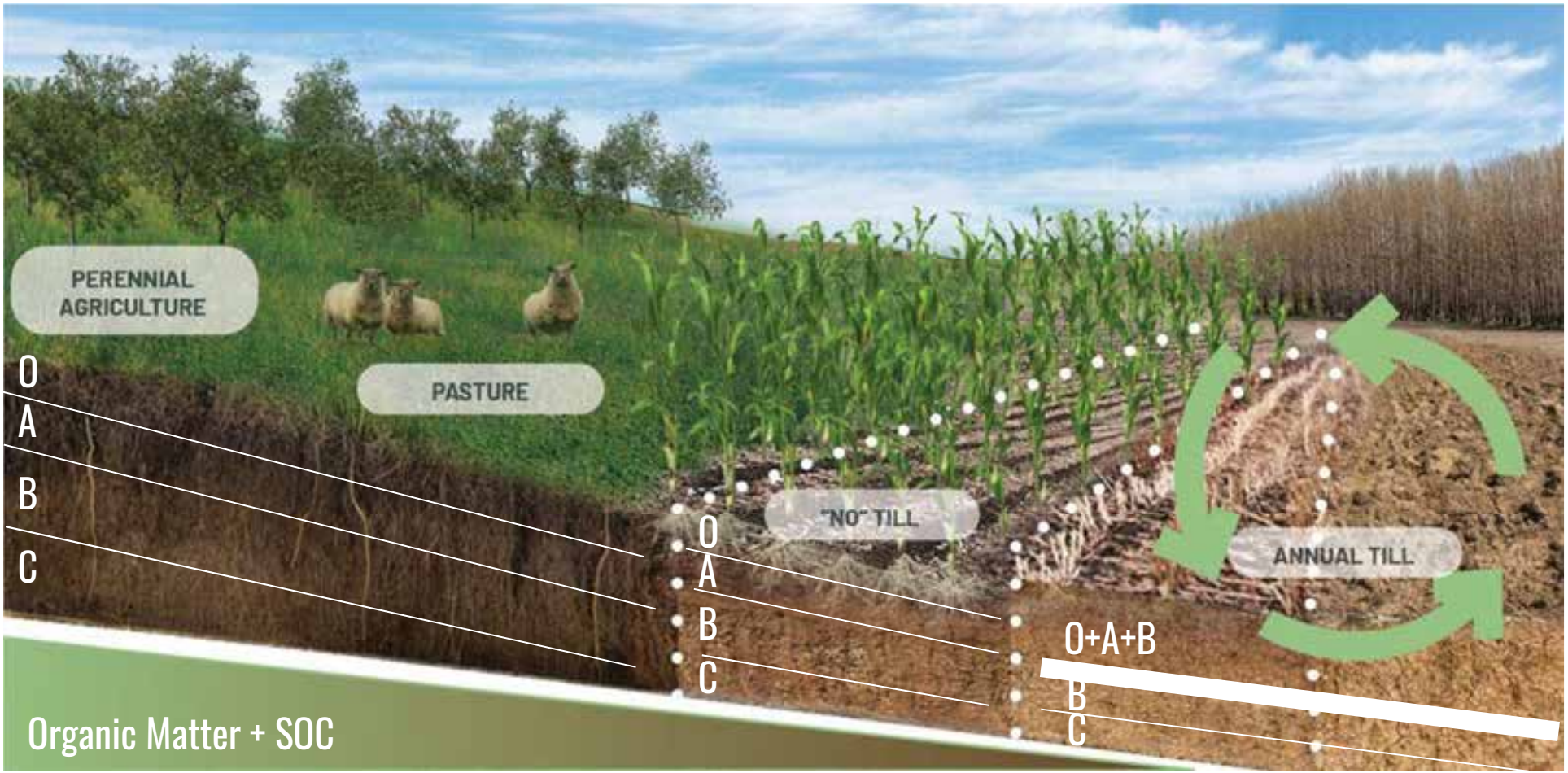


Image: University of Minnesota Extension

Agricultural Soils: Patterns of Disturbance



Construction Soils: Patterns of Disturbance

Understanding SOC Risks from Demolition & Site Preparation

Risks of soils emissions during site construction

- When developed, soils typically lose 25-60% of their total soil organic carbon and the soil horizon structure.
- Engineered stormwater solutions and external fertilization sources and irrigation become necessary.
- **Excavation and improper stockpiling can lose as much as 60-90% of SOC** - both fast and slow carbon pools, especially if horizons are mixed.
- Emissions increase each time soil is moved + SOC is exposed to oxygen

1. **Soil Function + Health**

2. **MA Healthy Soils Action Plan: What We Learned**

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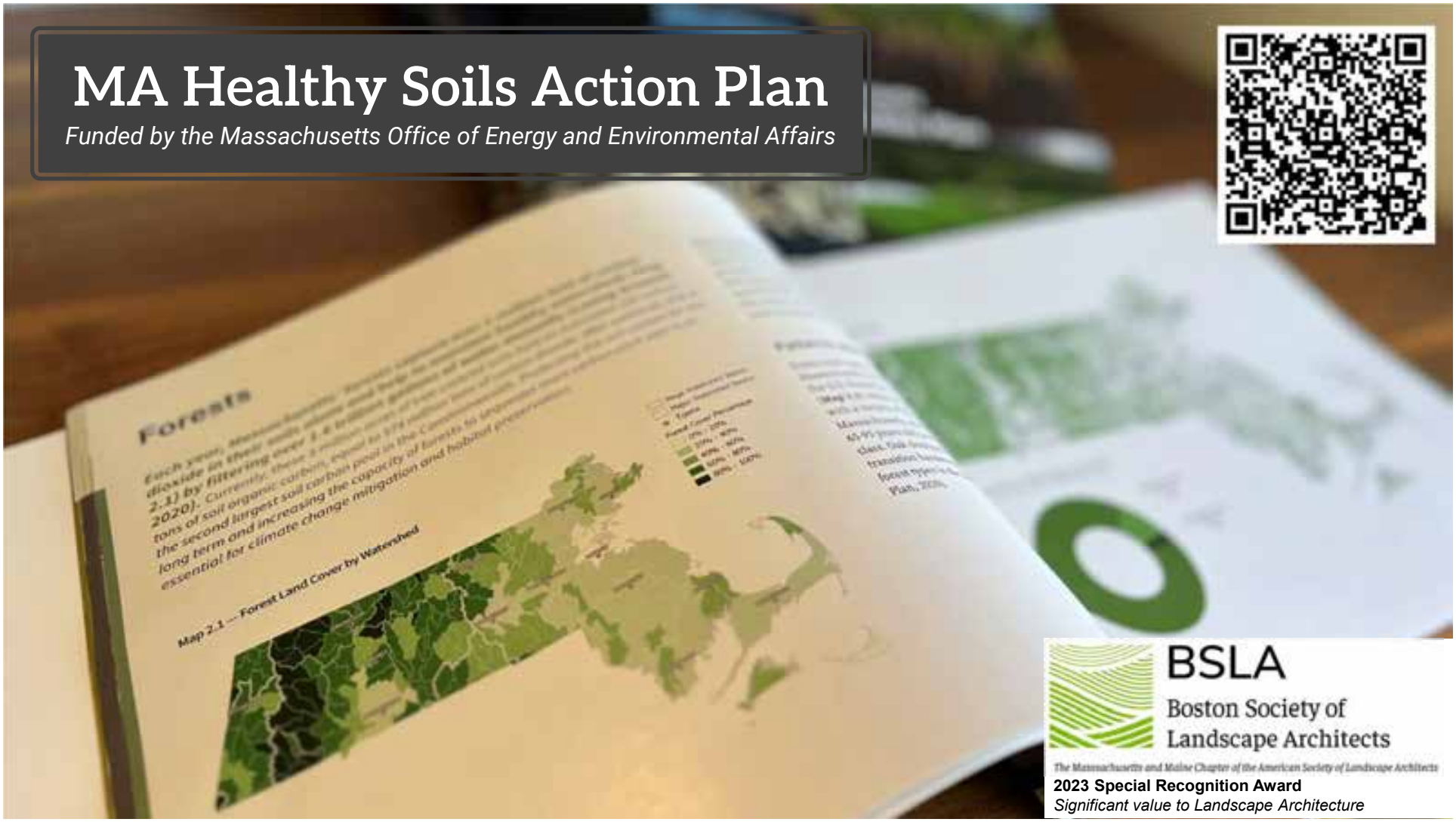
MA Healthy Soils Action Plan

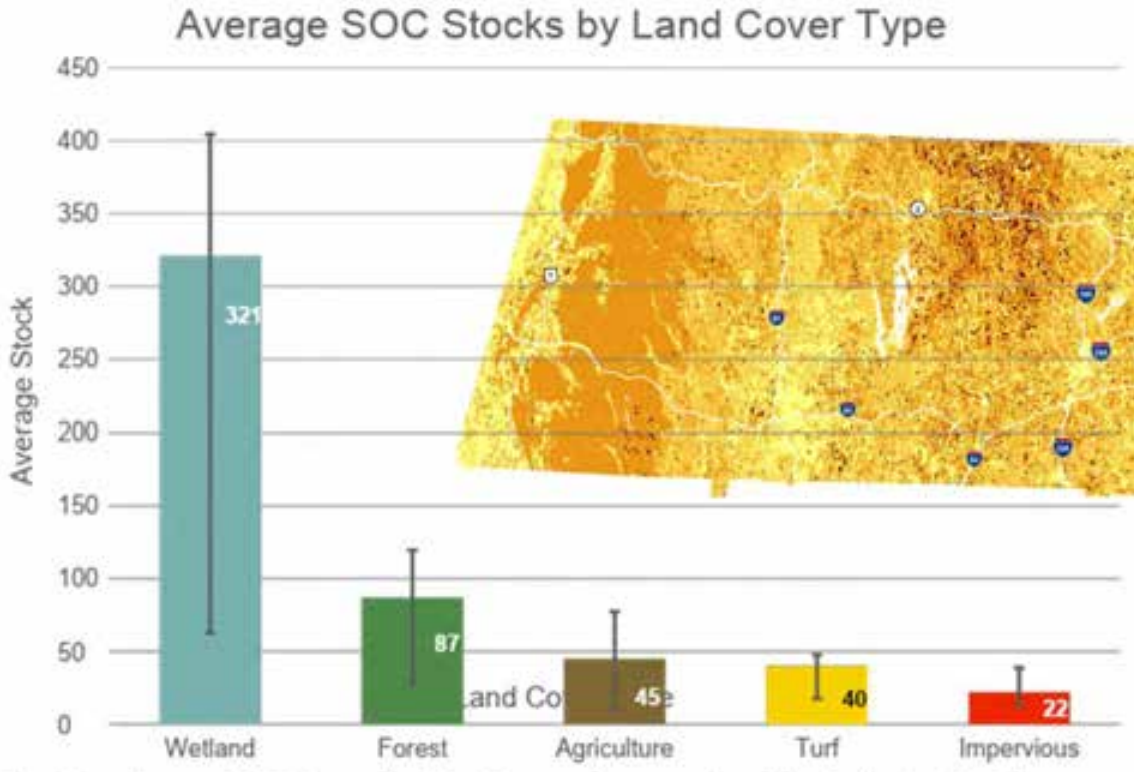
Funded by the Massachusetts Office of Energy and Environmental Affairs

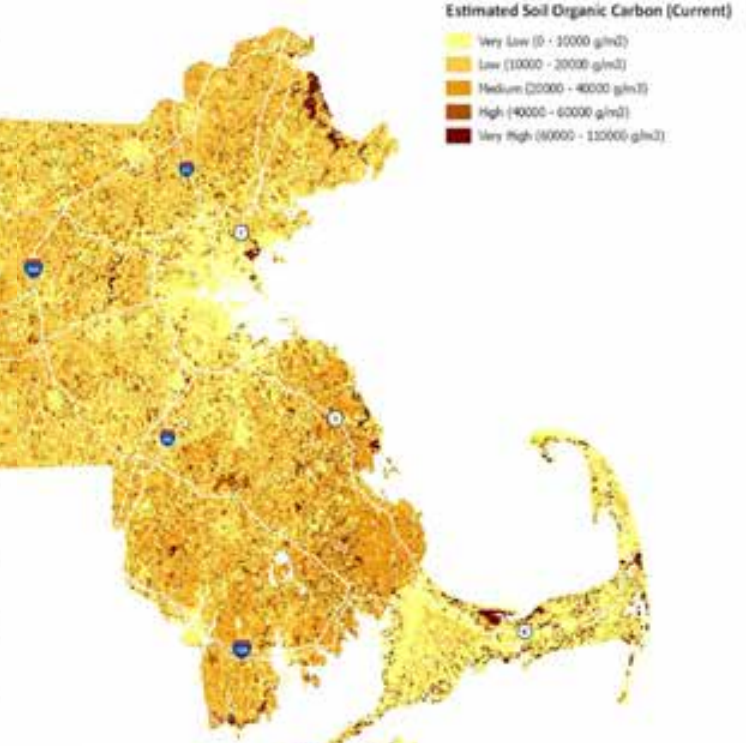


BSLA
Boston Society of Landscape Architects
The Massachusetts and Maine Chapter of the American Society of Landscape Architects

2023 Special Recognition Award
Significant value to Landscape Architecture

Land Cover Adjusted Soil Carbon Concentration





Final estimate of SOC stocks for Massachusetts Healthy Soils Action Plan

Average land cover tons of SOC values per acre from the NRCS Rapid Carbon Assessment & meta-analysis, adjusted for forest variability, were assigned to acreage of each land cover from simplified 2016 High Resolution Land Use Land Cover layer from MassGIS.

396 Million Metric Tons

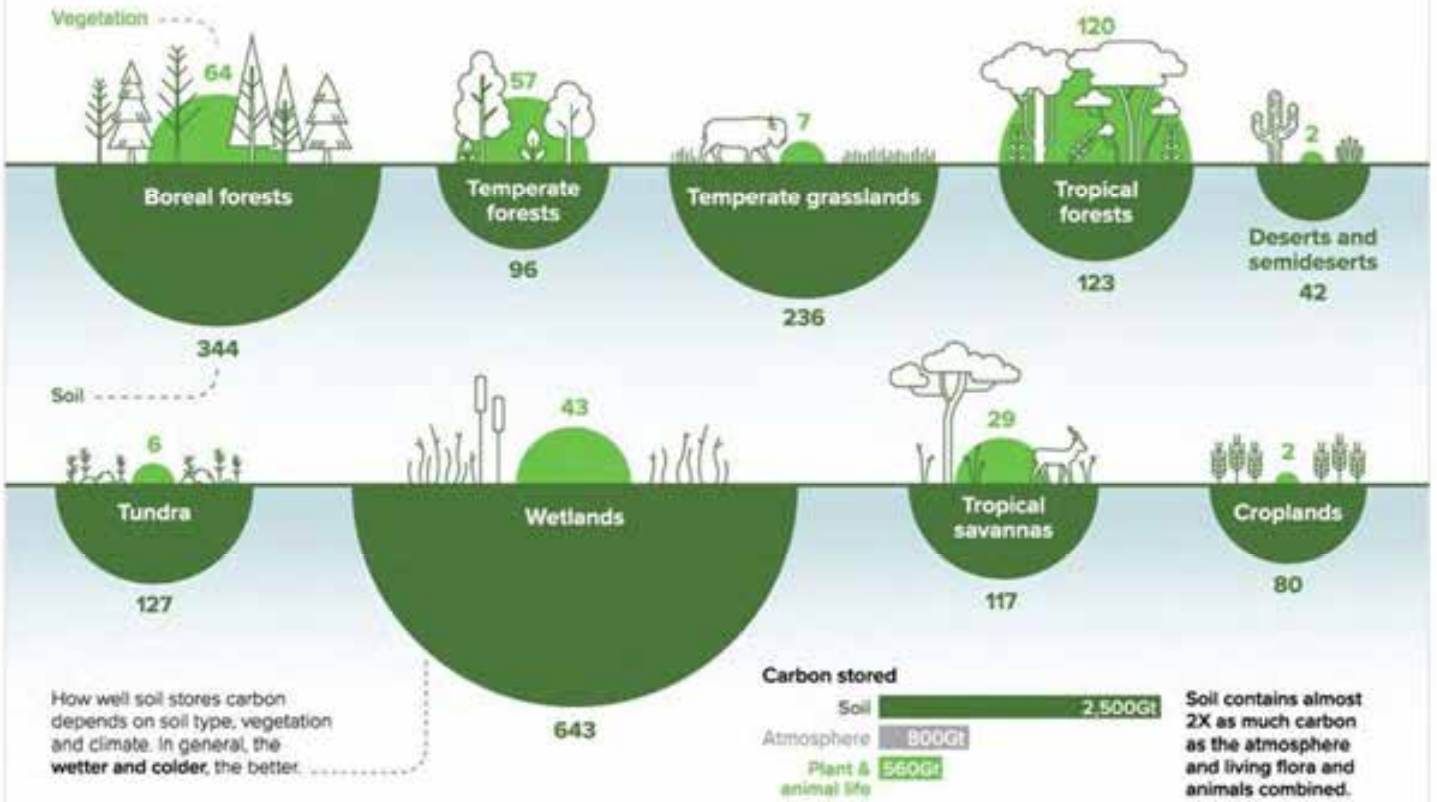
Estimated Soil Organic Carbon

Carbon Storage

Tonnes of Carbon

The world's forests absorb around **15.6 gigatonnes** of CO_2 each year. That's around 3X the annual CO_2 emissions of the United States.

However, around **8.1 gigatonnes of CO_2 leaks back into the atmosphere** due to deforestation, fires and other disturbances.



How well soil stores carbon depends on soil type, vegetation and climate. In general, the **wetter and colder**, the better.

Carbon stored

Soil contains almost 2X as much carbon as the atmosphere and living flora and animals combined.

Average stored carbon in tonnes per hectare at a ground depth of one meter

Sources: IPCC, NASA

Existing SOC Stocks by Land Cover Type

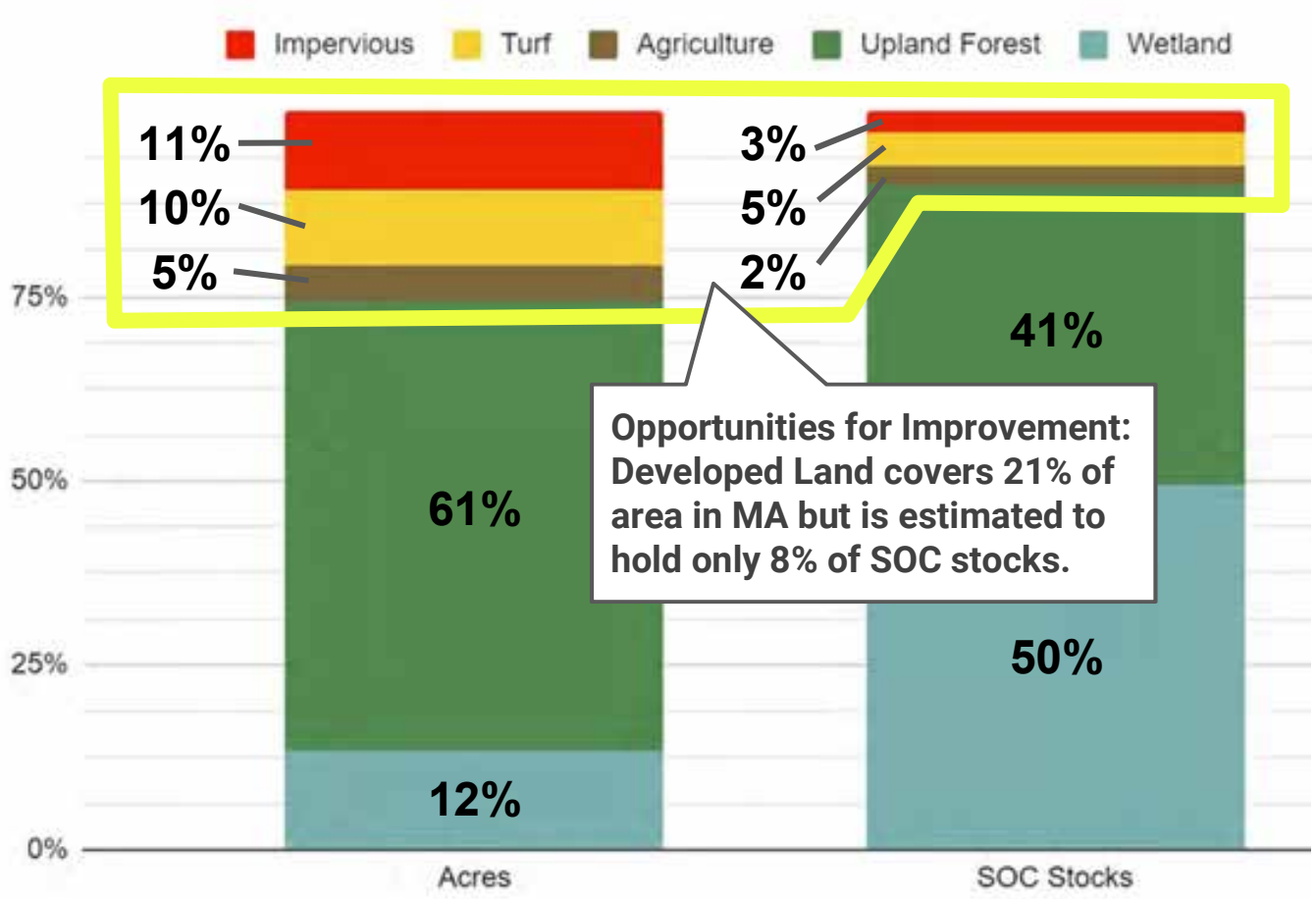
Soil Organic Carbon (SOC) in Massachusetts

396 million metric tons,

equal to 1.5 billion tons CO_2

Regionally specific ratios + conditions:

- Most wetlands in MA are forested wetlands
- Combined with land use change patterns to inform strategic soil conservation planning



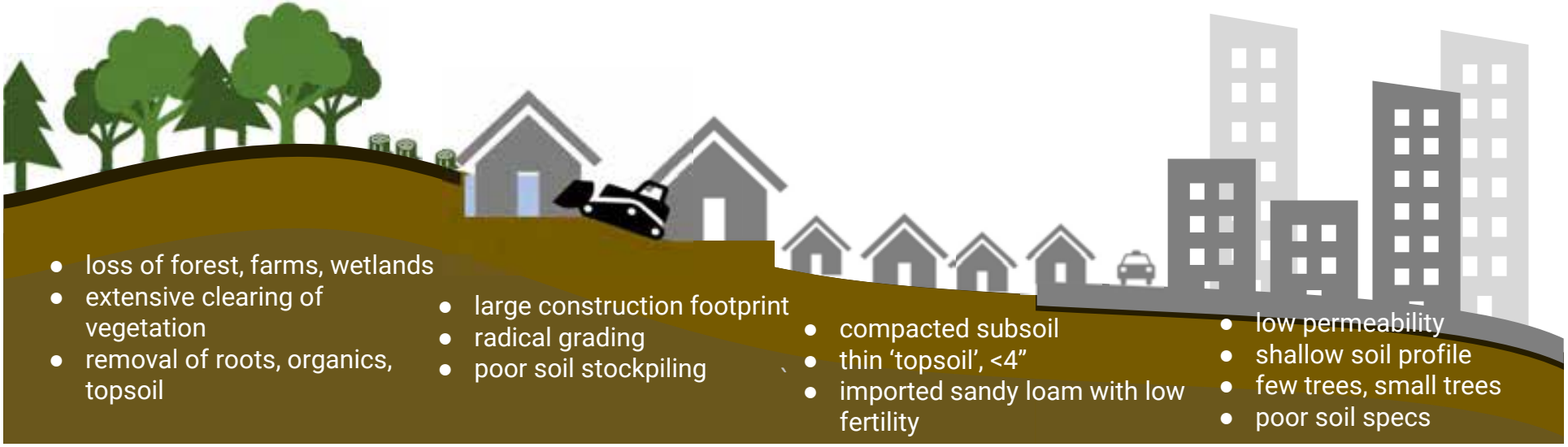
Business-as-usual Development

from Massachusetts Healthy Soils Action Plan 2050 projections for land cover change and carbon flux

Total Area Impacted = >360,000 ac
Forest, Farms, Wetland = - **146,000 ac**
Re-Developed Land = 214,000 ac

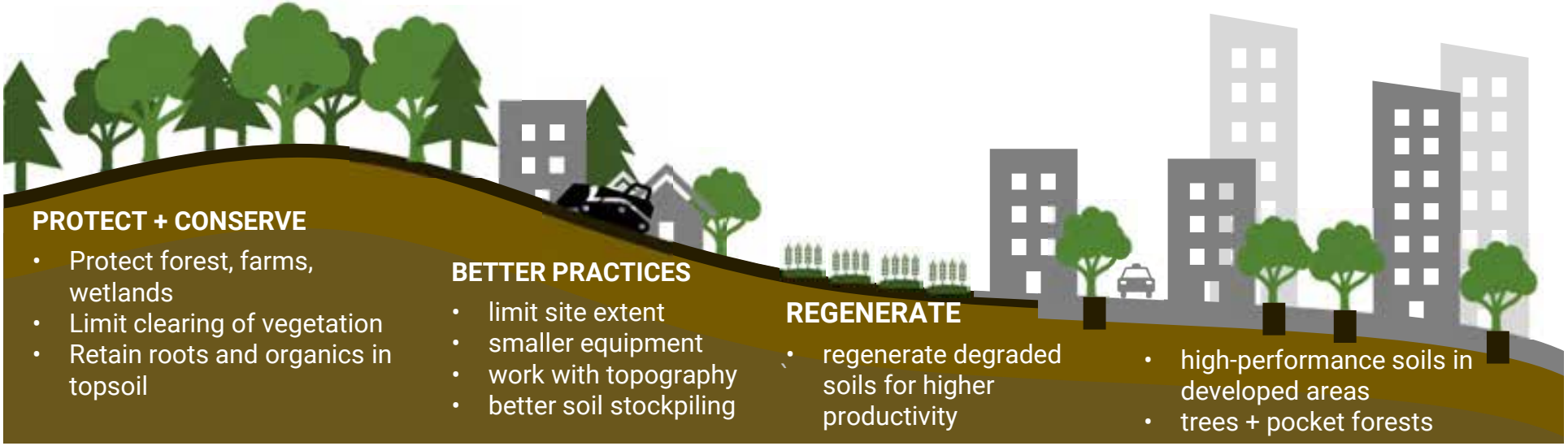
Total SOC Losses by 2050 = 25 million metric tons CO2

(Soil disturbance alone, not including biomass + carbon footprint of construction)



Priority Actions + Takeaways

- ➔ Minimize Site Disturbance
- ➔ Protect Existing Soils, Especially Wetland Soils
- ➔ Minimize Imported Soils
- ➔ Design for High SOC Soils through locally sourced amendments
- ➔ Manage landscapes to keep and accumulate SOC
- ➔ Reduce emissions



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Landscape Impacts: Best Management Practices

Landscape Impacts: Best Management Practices

- Soil Protection Zone
- Soil Preservation and Management Plan
- Soil Diagnostics and Testing
- Soil Profile Design for Function
- Stockpiling for Carbon
- Compaction Sensitive Soil Reinstallation
- Reducing Compaction through Equipment Selection
- Amending Soils On-Site
- Regenerative Site Restoration

Vegetation and Soils Protection Zones

Protect as much existing areas of healthy vegetation as possible, prioritizing:

- Existing and potential habitats for threatened or endangered species
- Forests and mature trees
- Wetlands & other plant communities with stable hydric soils & aquatic ecosystem buffers
- Farmland

Wherever possible, selectively remove mature vegetation rather than scrape + replace

Image: Sasaki

Slide 31

1 replace with dwight johnson protection zone map.
Sebastian Gutwein, 3/7/2025

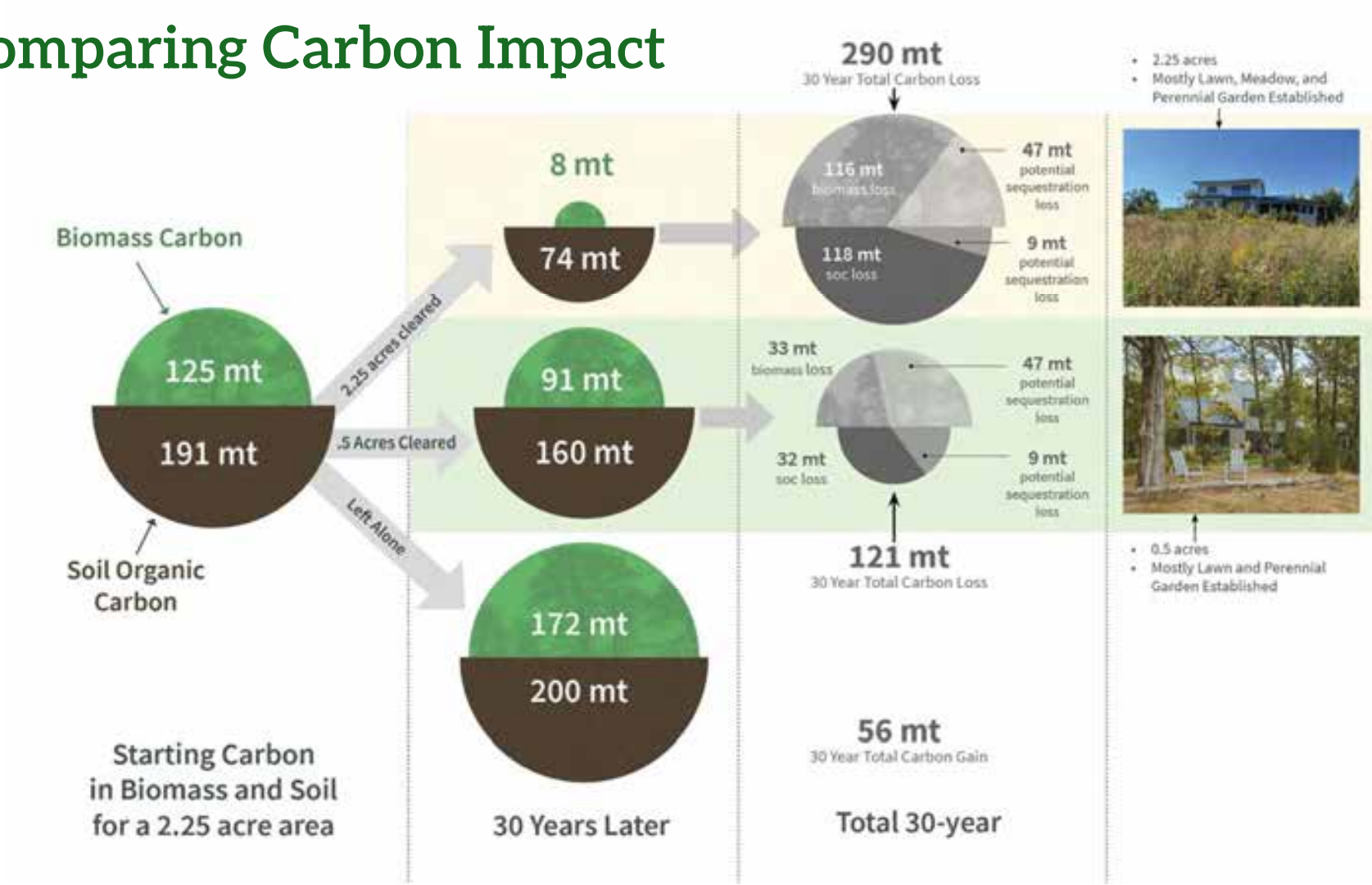

Site A


2.25 Acres Cleared


Site B


0.5 Acres Cleared

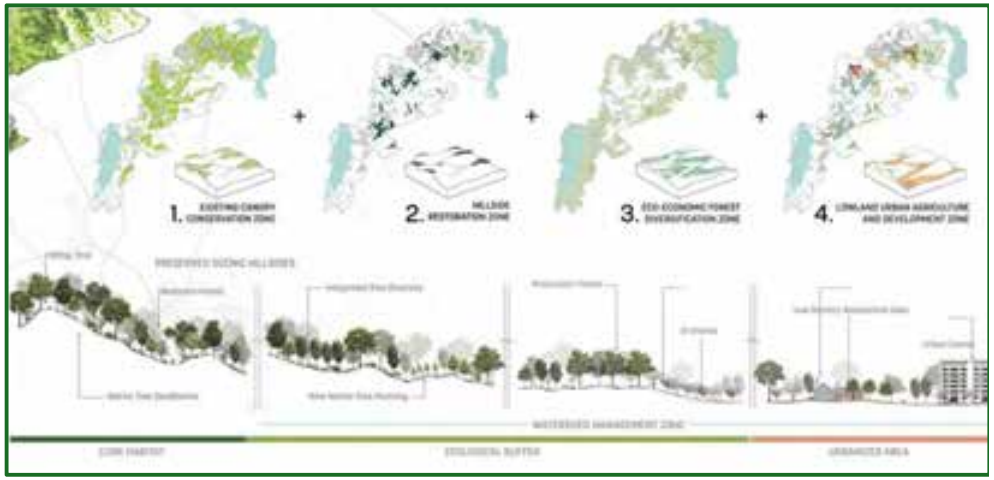
Comparing Carbon Impact



Test early to know what you have

Testing

- Determine locations based on existing conditions/future improvements
- **Soil Horizon Depth, Texture, and Bulk Density**
- **Organic Matter (by horizon)**
  - SOC and SOM
- **Field Compaction (Bulk Density)**
  - Penetrometer
- **Extractable nutrients (fertility)**
  - (N, P, K, Ca, Mg, Fe, Mn, Zn, Cu, B)
  - Cation Exchange Capacity (CAC)
- **Soluble Salts (EC 1:2 test)**
- **Cation Exchange Capacity (CEC)**
- **Soil Microbiology: biomass & pathogens**



Images: Sasaki

Develop a soil preservation & management plan

Set minimal site work limits + communicate them to installers

- Map existing healthy soils & Vegetation and Soils Protection Zones (VSPZs)
- Specify how construction activities will minimize adverse impacts
- Identify disturbed soils & Soil Restoration Treatment Zones (SRTZs)
- Include excavation, stockpiling, and amendment strategies
- Include import specifications

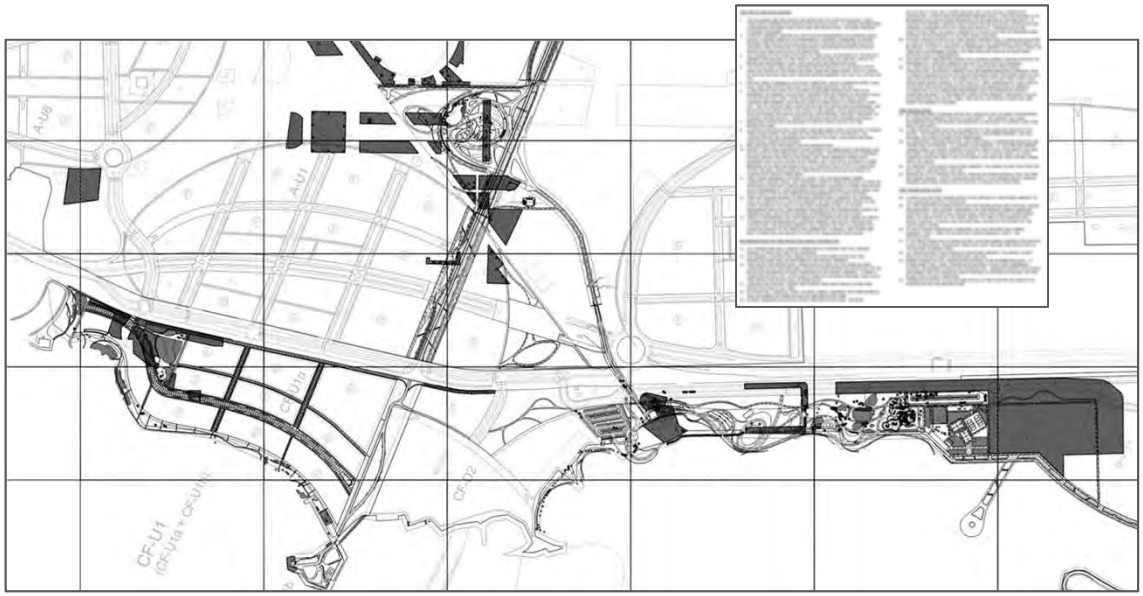


Image: Sasaki

Design soil profiles for the desired soil function

Soil Horizons

- Restore soil horizons with different blends to reflect natural soil types of reference ecosystems
- Include blending layers to avoid perched water tables

Design Amendments for Intended Use

- Lab recommendations will often make amendment recommendations to modify soils to support high productivity agricultural uses

Images: Sasaki

Functional Soil Profile Design

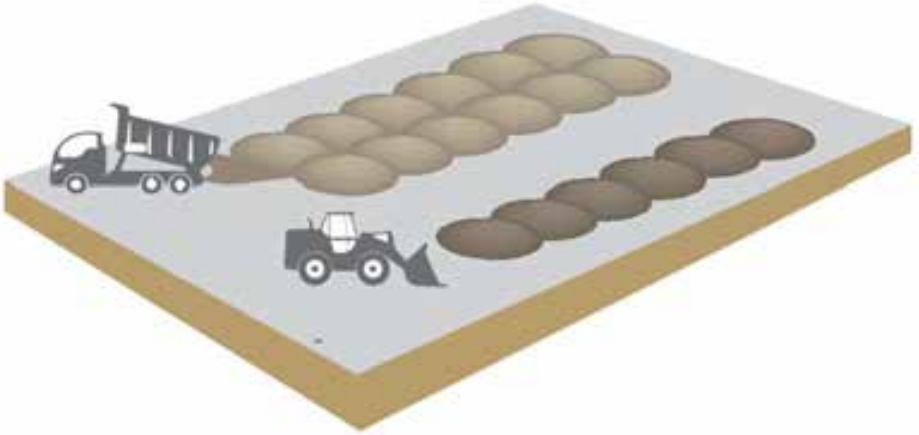
Design soil profiles for the desired soil function:

Images: Sasaki

How you stockpile matters

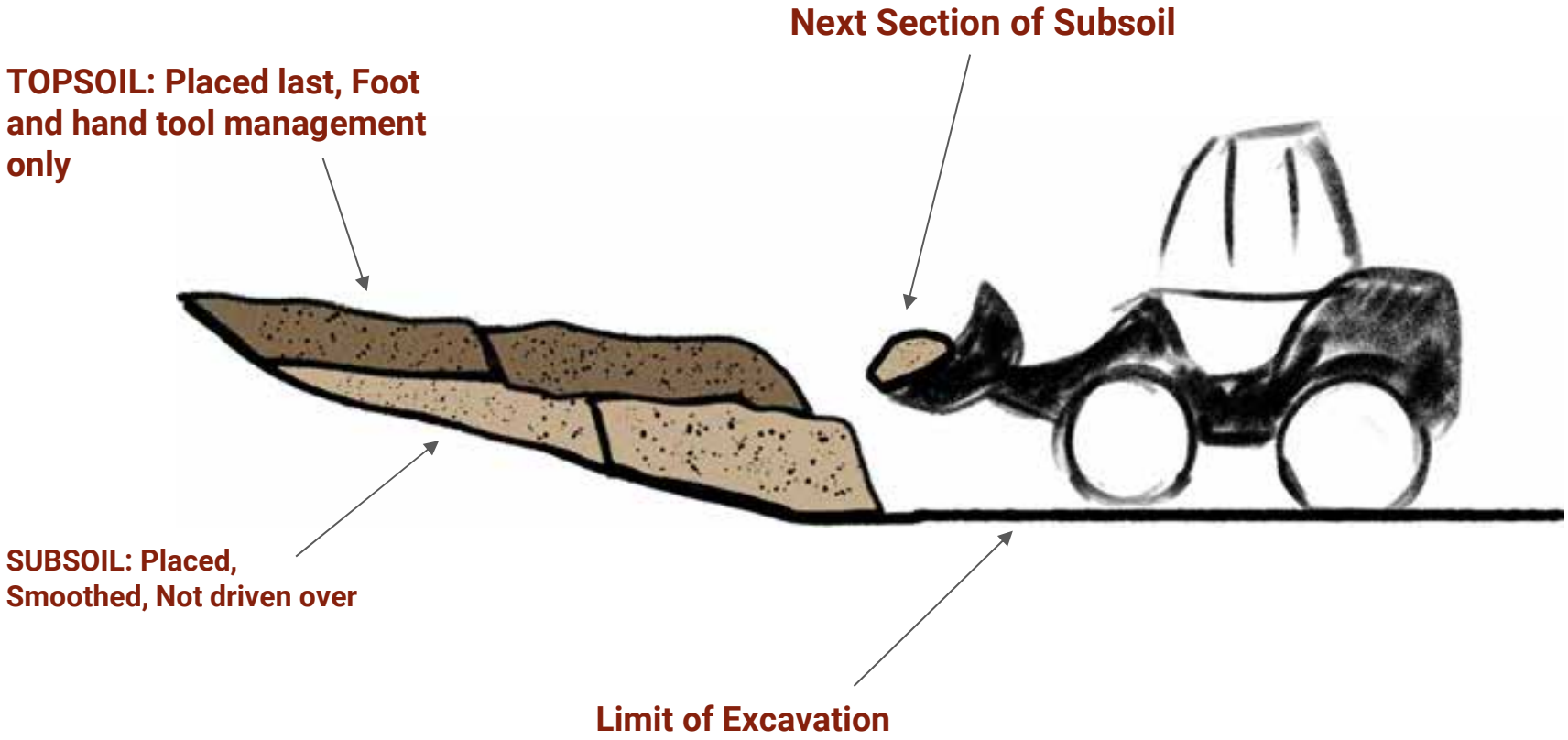
Stockpiling

- Excavation & deep plowing that mixes horizons causes SOC to destabilize and accelerate decomposition
- Compaction of soils leads to long term depletion of SOC by limiting additions of fresh organic matter.
- Deep Stockpiles can compact and lose soil structure and life due to anoxic conditions
- When sieved and placed, anoxic soils from deep stock piles can be a source of methane emissions.

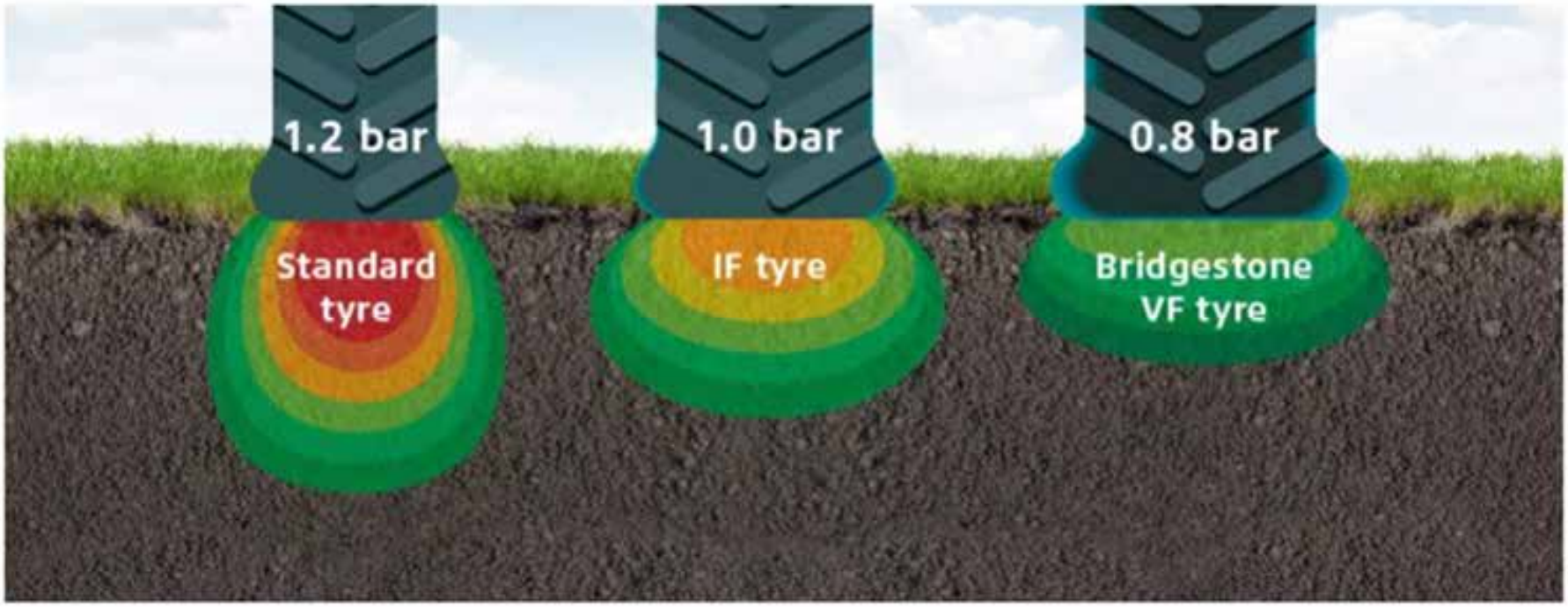


Brevik, E., Fenton, T., & Moran, L. (2002). Effect of soil compaction on organic carbon amounts and distribution, South-Central Iowa. *Environmental Pollution*, *116*, S137–S141. https://doi.org/10.1016/S0269-7491(01)00266-4

Compaction Sensitive Soil Reinstallation



Equipment Selection



Slide 40

3 Add tracks?
Sebastian Gutwein, 3/7/2025

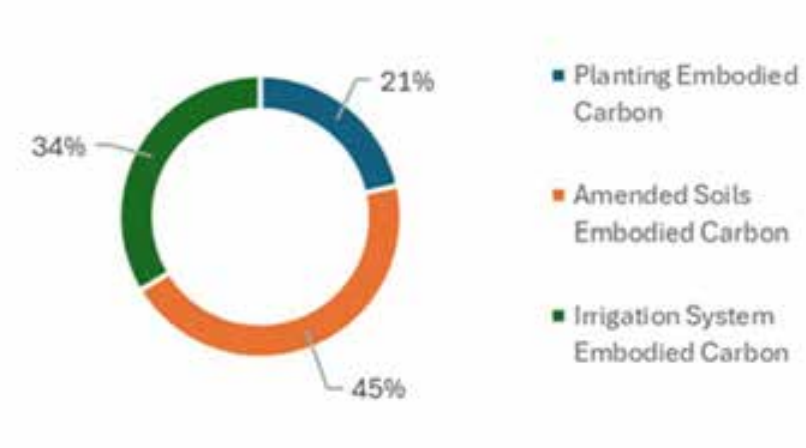
2 other compaction BMP's such as woodchips and CRZ exclusion.
Sebastian Gutwein, 3/7/2025

Soil Amendments

Amending On-Site vs. Importing Soil

Garden Soil Amended On Site

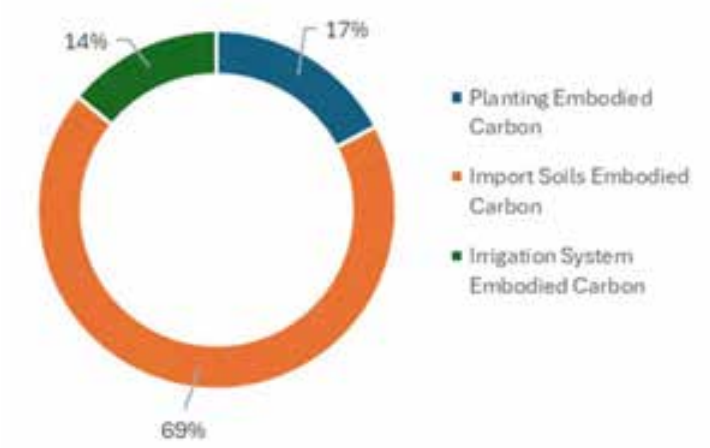
- Earthworks (0.5M depth)
- Blended Amended Soil
- Local sourcing (16 km)



Total Embodied Carbon:
~25 kgCO2e/SM

Imported Garden Soil

- Earthworks (0.5M depth)
- Blended Import Soil
- Local sourcing (16 km)

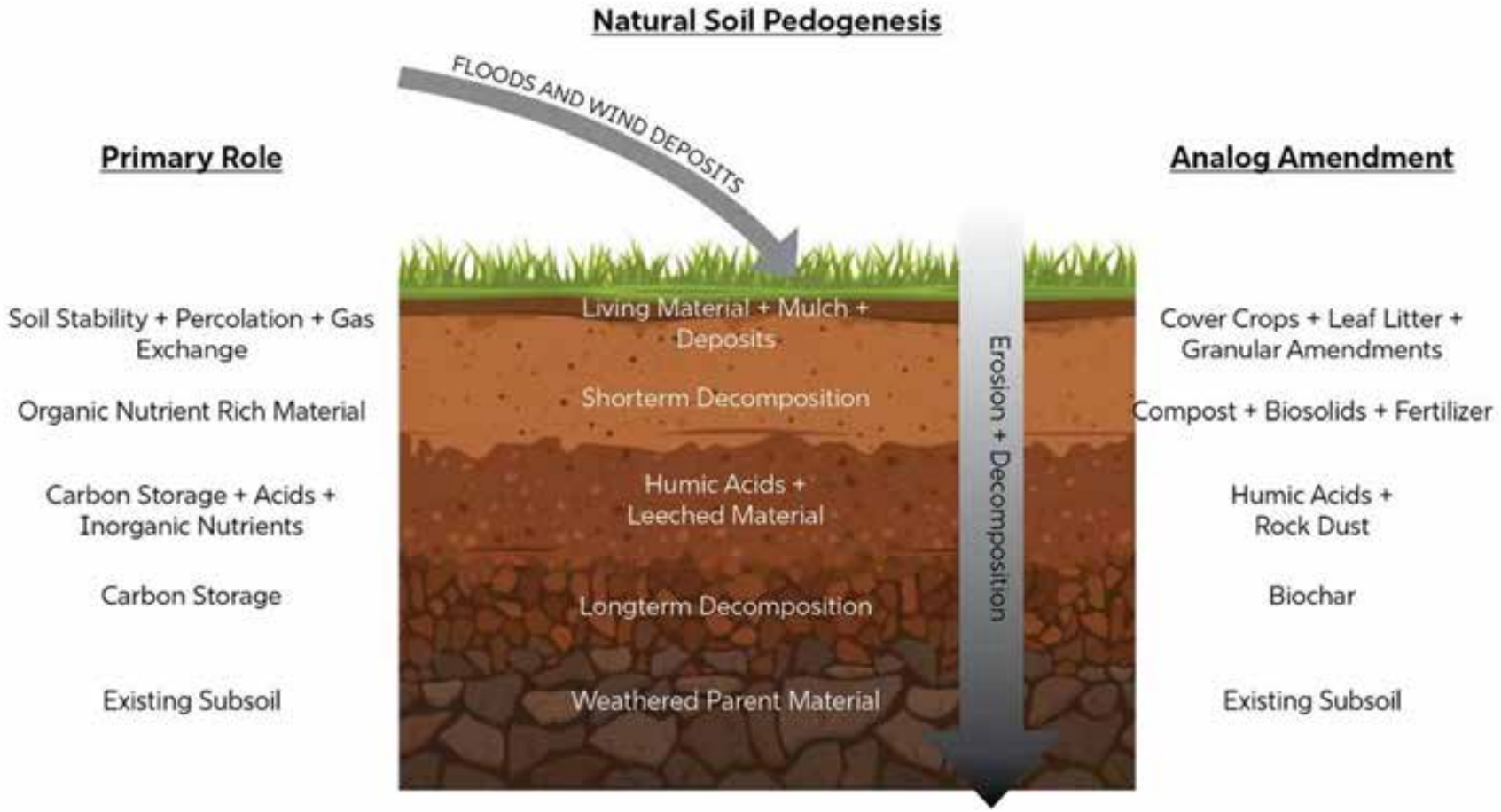


Total Embodied Carbon:
~64 kgCO2e/SM

Soil Amendments

Soil Component	Primary Purpose/Function	Soil Health Considerations
Loam	Bulk and Texture	Unknown; see sourcing and quality notes.
Sand	Drainage	Lowers
Aggregate/Fines	Stability / Erosion Prevention	
Compost	Fertility, Organic Matter, Lower Bulk Density	High carbon ratio Generally low fertility (~1-2%N) Encourages biological soil activity
Biochar	Increased Water Holding Capacity, Nutrient/Pollutant Filtration, Lower Bulk Density, Increased Cation Exchange Capacity	
Rock Dust	Carbon Sequestration, Re-Mineralization	Increased Long-term fertility Encourages biological soil activity
Biosolids	Fertility, Organic Matter	Low carbon ratio means a slower fast-to-slow carbon pool transition ratio Generally high fertility (~2-8%N)
Clay	Increased Water Holding Capacity, Increased Cation Exchange Capacity	
Polymer	Increased Water Holding Capacity	
Expanded Shale	Lower Bulk Density, Drainage, Nutrient/Pollutant Filtration.	

Soil Amendments



Regenerative Site Restoration

Regeneration / Selective Removal

Source: Regenerative Design Group

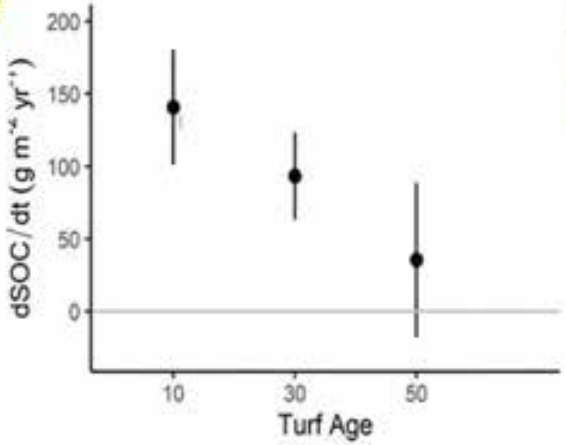
Reuse Slash On-Site / Hugelkultur

Source: Regenerative Design Group

Turf Management

How much soil carbon does turfgrass sequester?

Across 63 studies, sequestration rates were initially very high but declined to zero by 50 yrs.



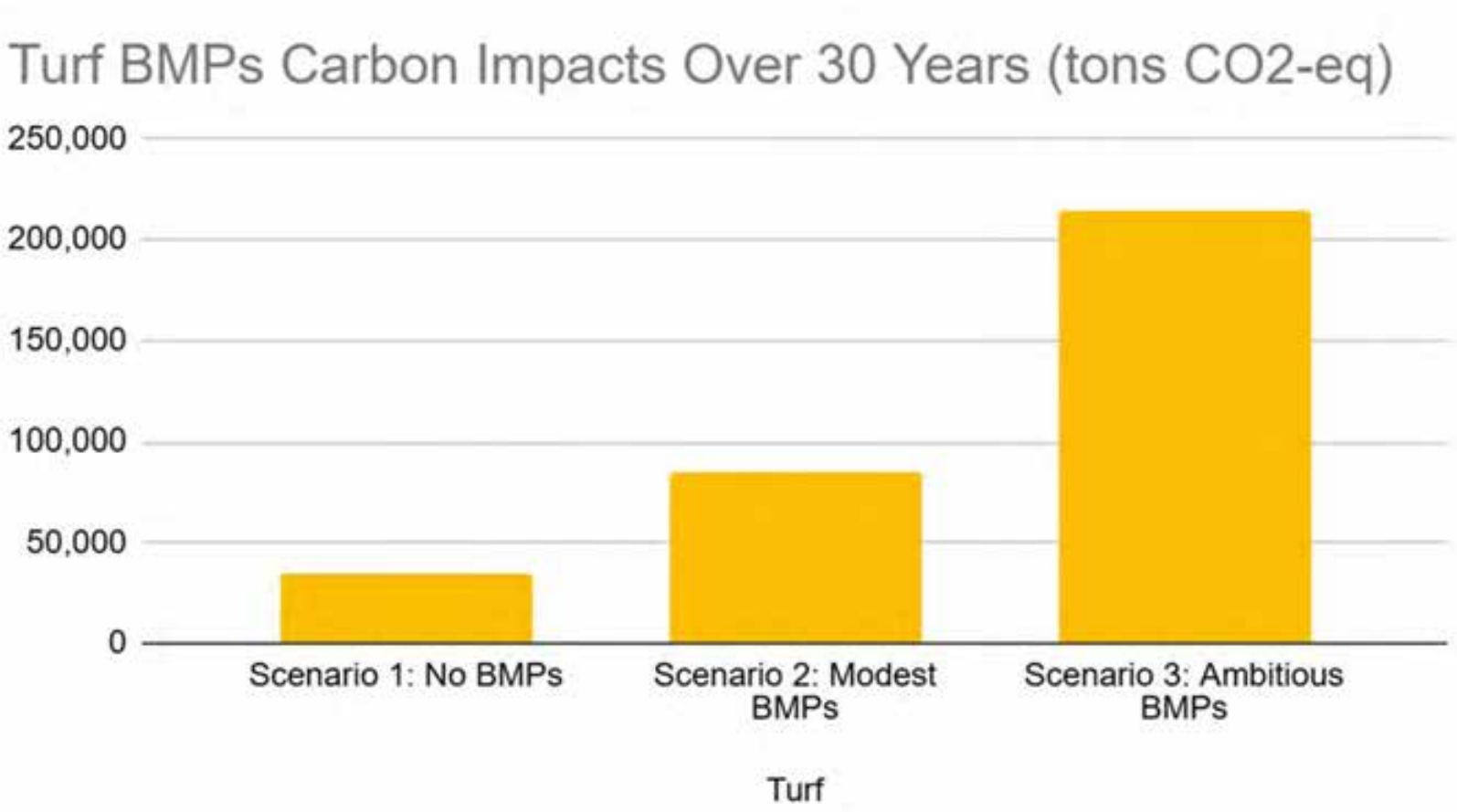
Claire L. Phillips, Ruying Wang, Clint Mattox, Tara L.E. Trammell, Joseph Young, Alec Kowalewski, "High soil carbon sequestration rates persist several decades in turfgrass systems: A meta-analysis", Science of The Total Environment, Volume 858, Part 3, 2023

Turf Management

25% of open lawn planted with trees + minimum of 3% organic matter in the top 8” of lawns could sequester an additional ~180,000 tons of carbon dioxide equivalent per year in Massachusetts.

- Raise your mower height
- Test your soil + fertilize wisely
- Leave your grass clippings
- Diversify with trees + shrubs
- Aerate
- Electrify all maintenance
- Leave topsoil onsite + amend

Turf Management



Reduce lawn

No-till, Organic Gardening

Add trees + shrubs to lawns

Plant regionally appropriate, beneficial perennials

Limit Disturbance + New Development


How we specify and manage our soils during site construction and ongoing landscape maintenance can be the difference between a net carbon positive and a net carbon emitting landscape.
Image: Sasaki

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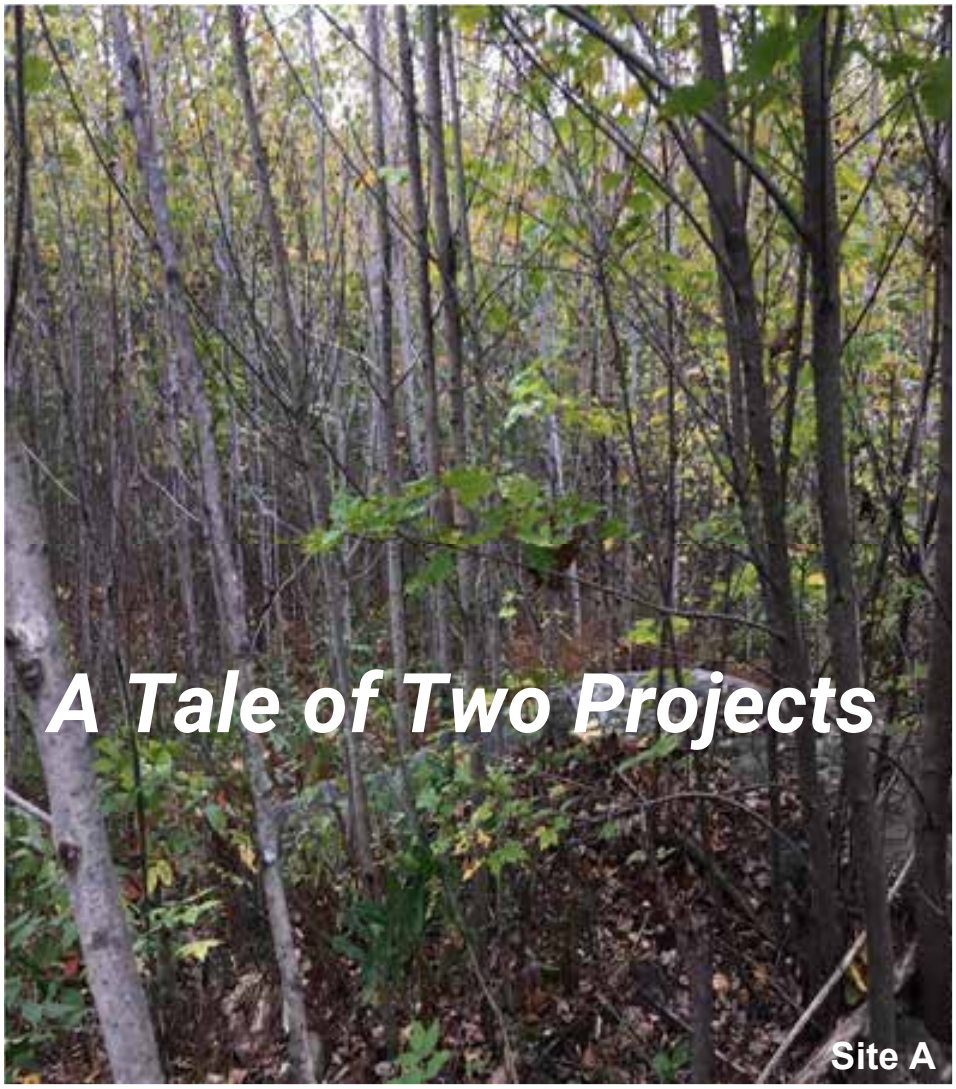
Case Studies + Lessons Learned


A Tale of Two Projects
Site A


Site B


A Tale of Two Projects
Site A


Site B


Site A


Site A

Site B


Site B


A Tale of Lawn That Wouldn’t Grow
September 2015

Soil Remediation, *not replacement*

May 2016


August 2021

Lessons Learned:

- Amend soil to repair damage from compaction
- It pays to plant seeds – self select, low carbon footprint
- Embracing the change as ecosystems develop
- Goal to mulch less every year + let the vegetation cover take over
- Time + Patience

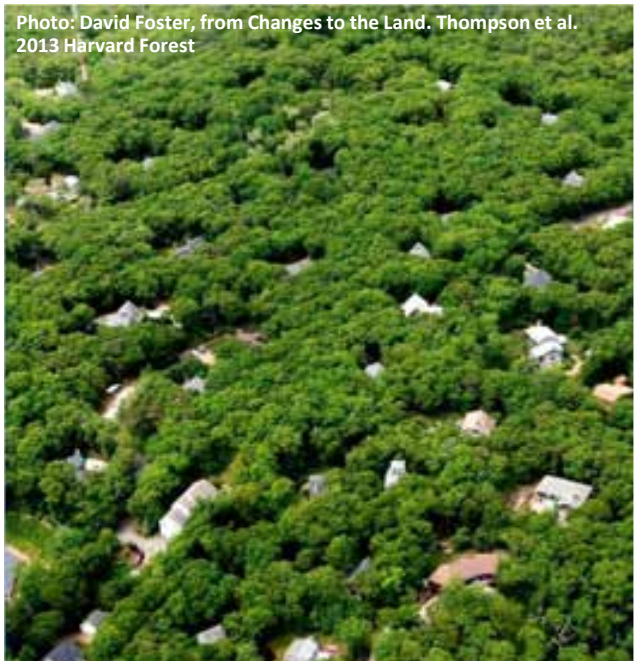


Photo: David Foster, from Changes to the Land. Thompson et al. 2013 Harvard Forest

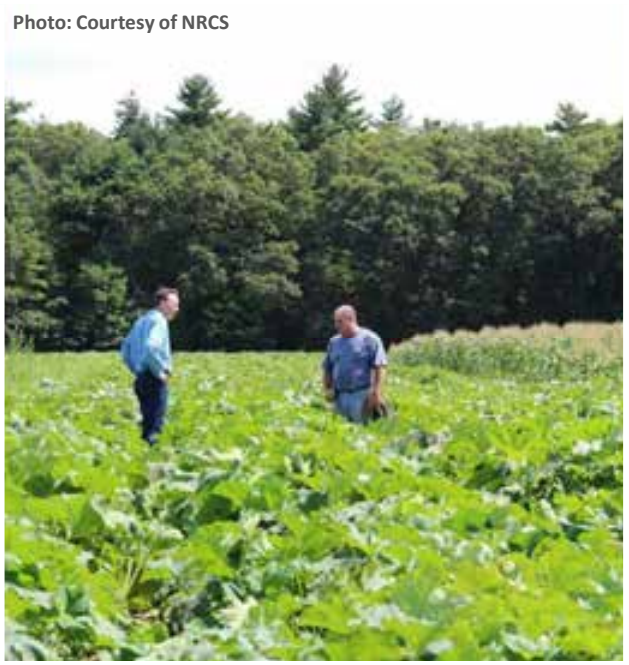


Photo: Courtesy of NRCS

Photo: NASA Earth Observatory image by Robert Simmon, using Landsat

Soil Health Vulnerabilities

Land conversion | Management Change | Climate

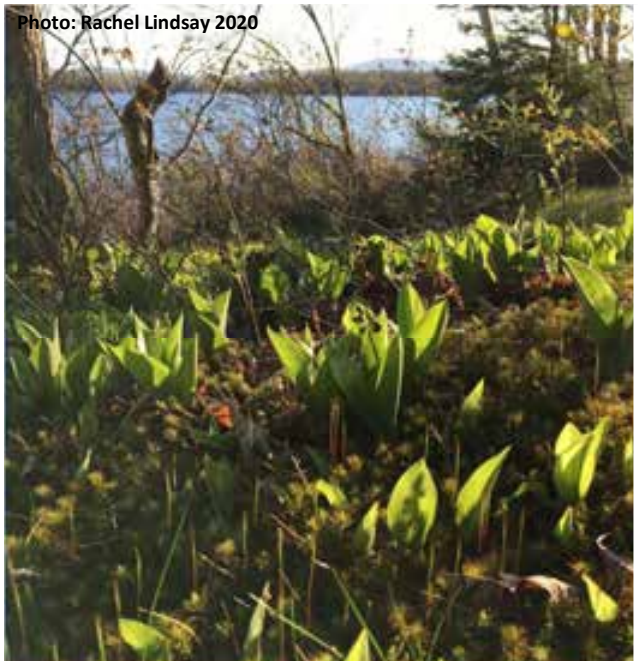
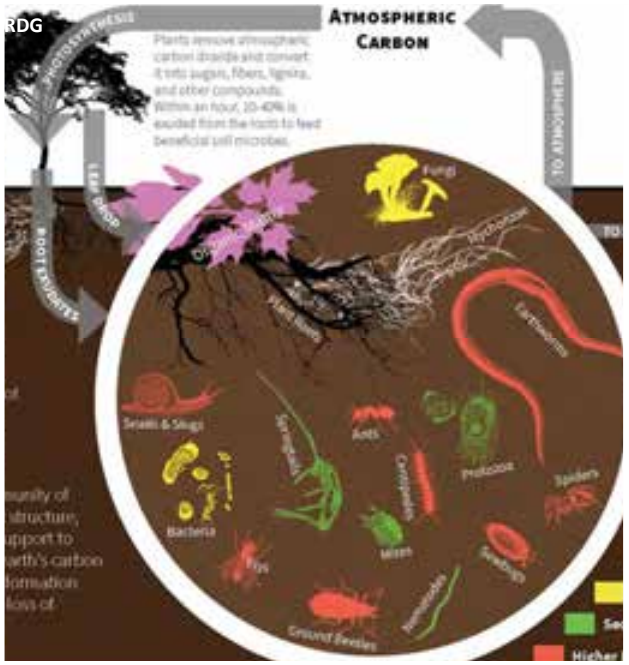


Photo: Rachel Lindsay 2020



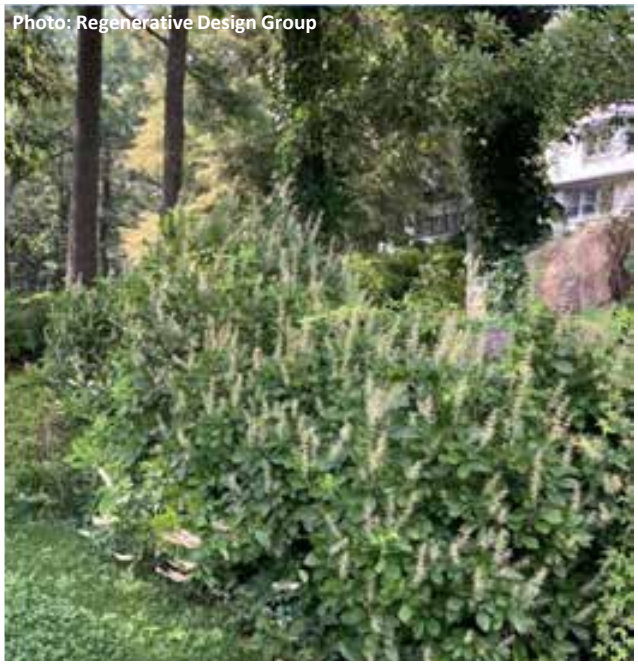


Photo: Regenerative Design Group

Soil Health Indicators

Low Disturbance | High SOC* | Vegetation


What Builds Soil Health?
Limited Disturbance
Permanent Vegetative Cover
Diverse Soil Food Web
Remineralization + Nutrient Management
Protection from Compaction,
Contamination, + Conversion

www.masshealthysoils.org

Next Steps: Individual Guides

- What aspects of these recommendations present challenges for your business or services?
- What soil health practices could you prioritize most easily?
- What information is missing for you to implement healthy soil practices?

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SASAKI Better design, together.
READ
A.D. MAKEPEACE

Industry Partners


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Guidance for
Implementing Healthy Soils in
Landscape and Construction
A multi-firm collaborative project funded by the MA Office of Energy and Environmental Affairs Healthy Soils Challenge Grant program
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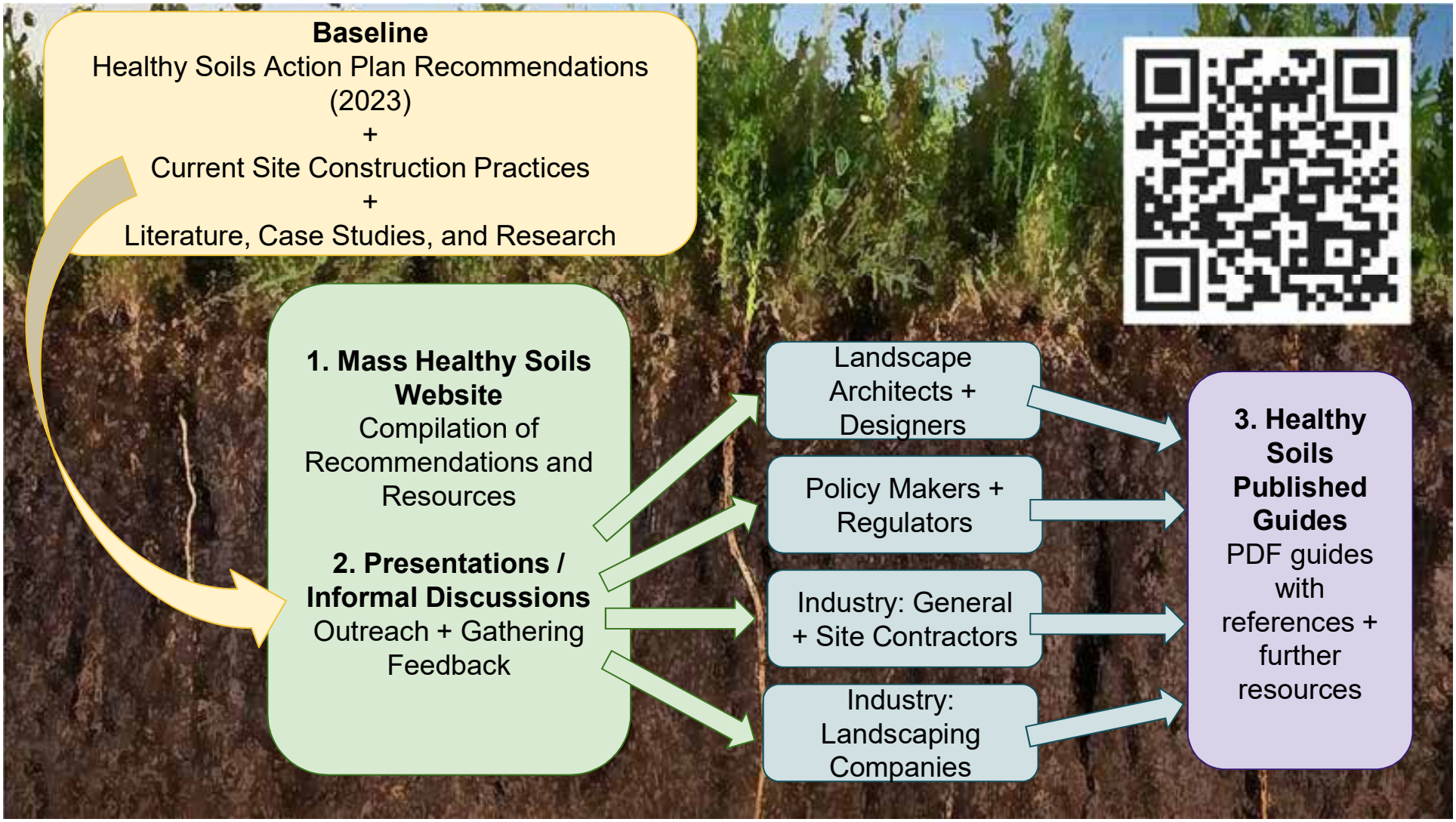
Baseline
Healthy Soils Action Plan Recommendations (2023)
+
Current Site Construction Practices
+
Literature, Case Studies, and Research
1. Mass Healthy Soils Website
Compilation of Recommendations and Resources
2. Presentations / Informal Discussions
Outreach + Gathering Feedback
Landscape Architects + Designers
Policy Makers + Regulators
Industry: General + Site Contractors
Industry: Landscaping Companies
3. Healthy Soils Published Guides
PDF guides with references + further resources

Slide 69

1 @bas@regenerativedesigngroup.com Think it makes sense to put this project specific material at the end with the other slide I've moved there? Thinking this might allow a segue from the presentation materials to the larger effort of the project rather than interjecting it.
Patrick Black, 3/13/2025