Welcome to the CLU-IN Internet Seminar

Terrestrial Carbon Sequestration: An Ecosystem Service Provided by Using Soil Amendments for Site Remediation and Reuse

Sponsored by: U.S. EPA Office of Superfund Remediation and Technology Innovation

Delivered: October 27, 2011, 2:00 PM - 4:00 PM, EDT (18:00-20:00 GMT)

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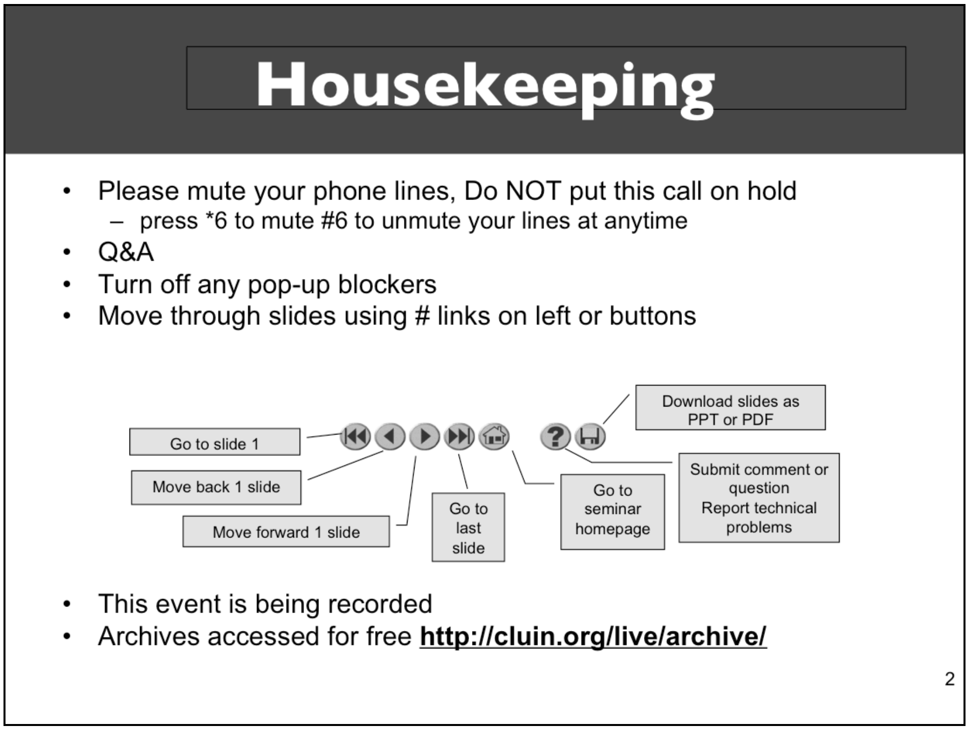

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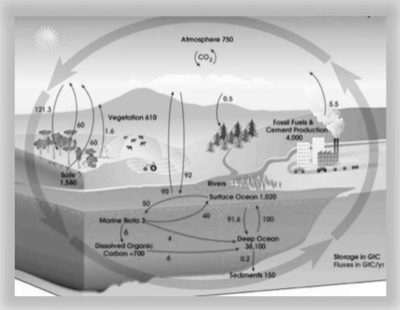
With that, please move to slide 3.

Terrestrial Carbon Sequestration: An Ecosystem Service Provided by Using Soil Amendments for Site Remediation and Reuse



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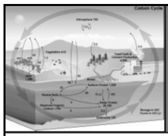
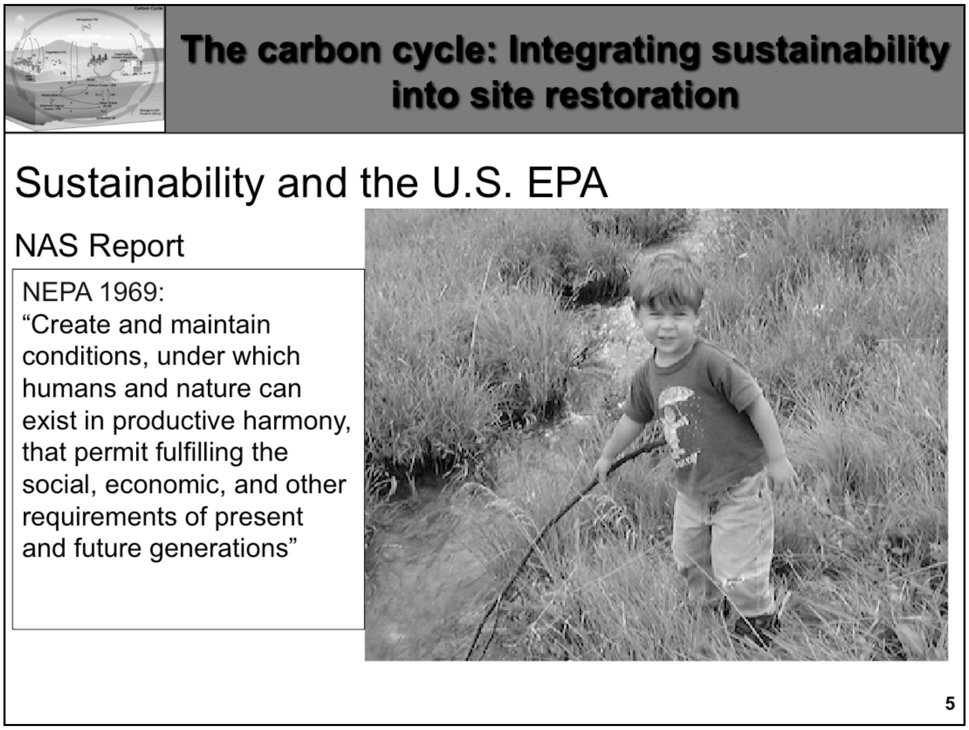
October 27, 2011



Part 1: The Carbon Cycle

Sally Brown, University of Washington

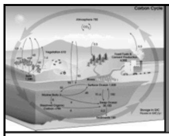


The carbon cycle: Integrating sustainability into site restoration

Sustainability and the U.S. EPA

NAS Report

NEPA 1969:
“Create and maintain conditions, under which humans and nature can exist in productive harmony, that permit fulfilling the social, economic, and other requirements of present and future generations”

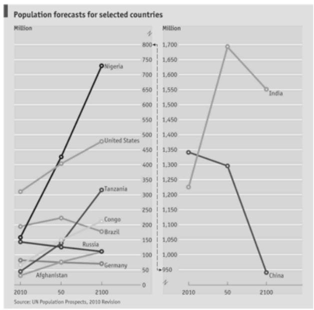


NAS Report continues:

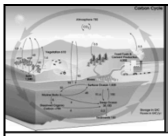
The recognition that **current approaches aimed at decreasing existing risks**, however successful, **are not capable of avoiding the complex problems in the US and globally that threaten the plant's critical natural resources and that put current and future human generations at risk**:

These problems include (ones that we can't solve):

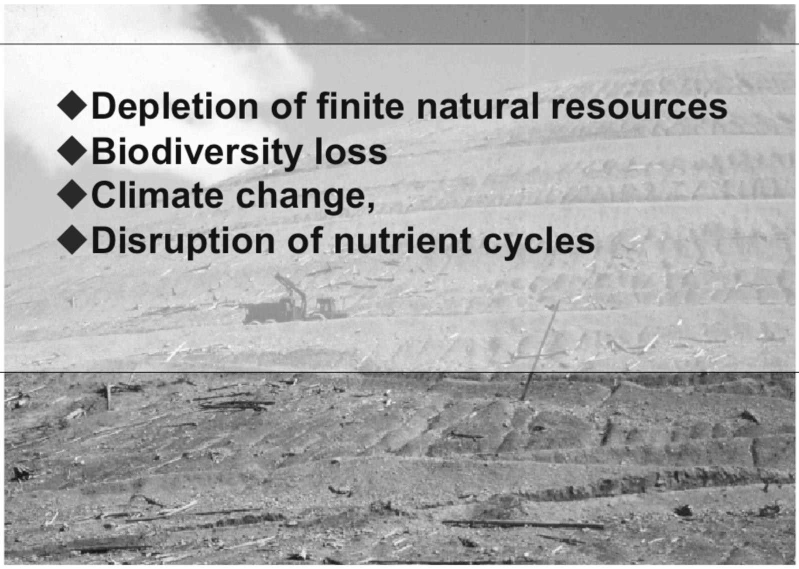
- Population growth
- Widening gaps between rich and poor


Population forecasts for selected countries

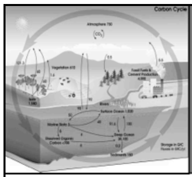
Source: UN Population Prospects, 2010 Revision



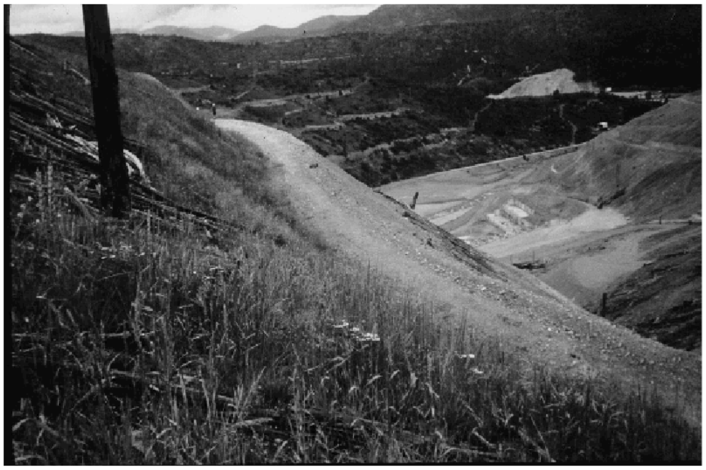
And some problems that you can have an impact on

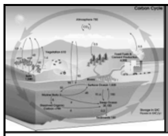


- Depletion of finite natural resources
- Biodiversity loss
- Climate change,
- Disruption of nutrient cycles



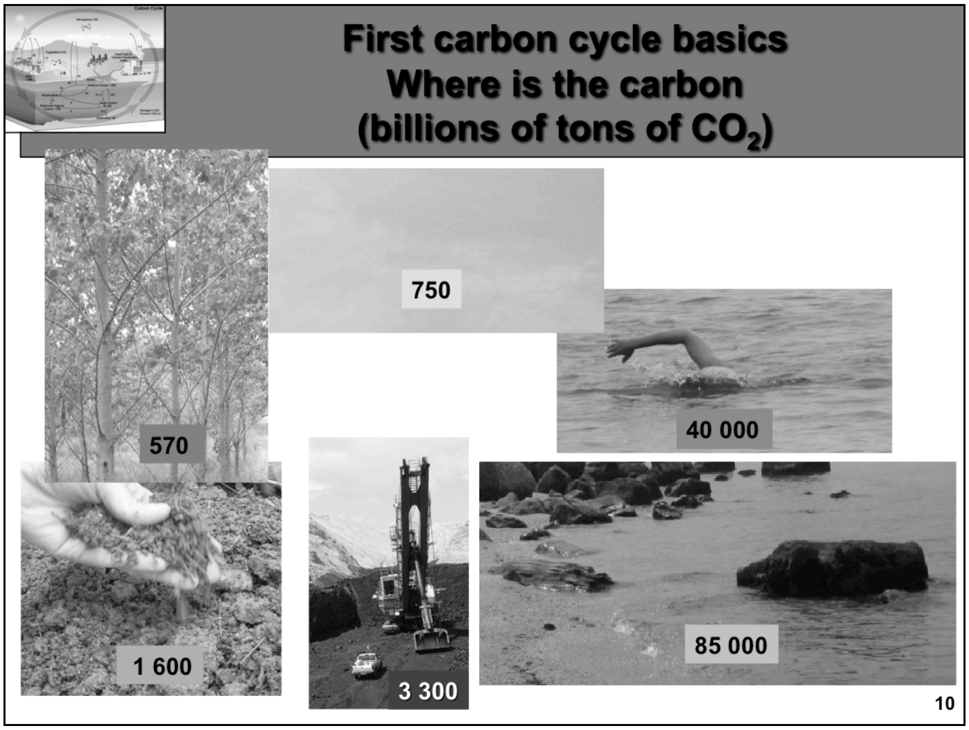
NAS report argues that consideration of risk is no longer sufficient, sustainability considerations must also be taken into account





Site restoration to maximize sustainability:

- ◆Carbon cycle basics
- ◆Amendments and:
  - •Depletion of finite natural resources
  - •Biodiversity loss
  - •Climate change,
  - •Disruption of nutrient cycles



First carbon cycle basics
Where is the carbon
(billions of tons of CO_2)

570

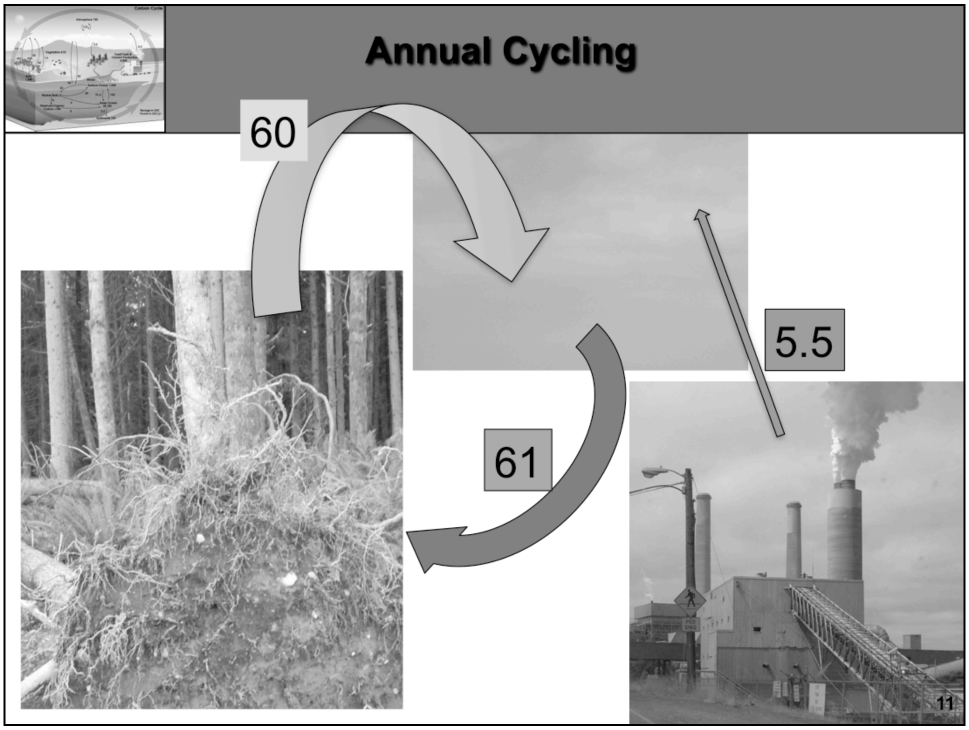
750

40 000

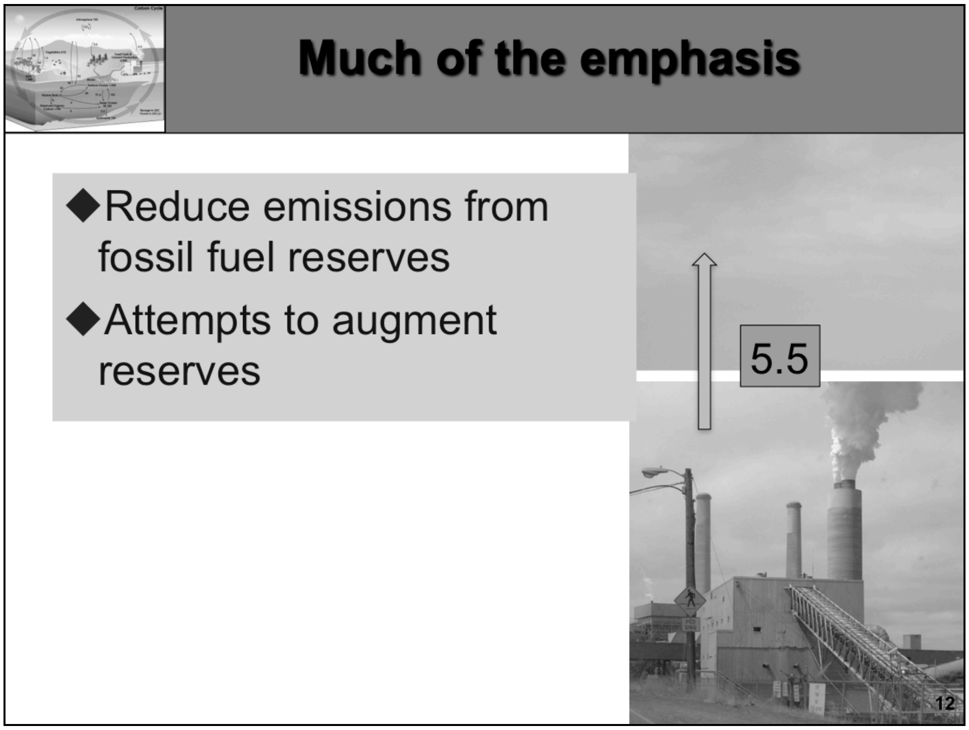
1 600

3 300

85 000

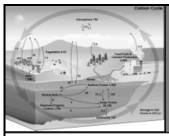


Annual Cycling



Much of the emphasis

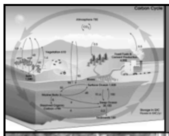
- ◆Reduce emissions from fossil fuel reserves
- ◆Attempts to augment reserves



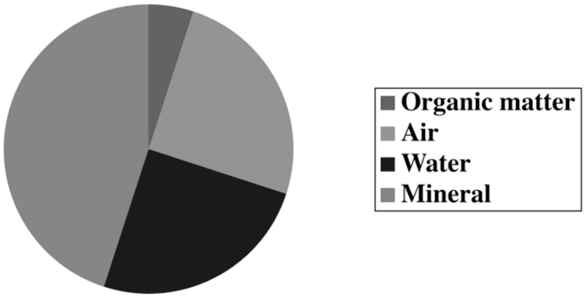
Soils and plants:

Are an alternative sink

- 158x10^6 Mg released from 1850-1998 through conventional agriculture, deforestation, and soil disturbance

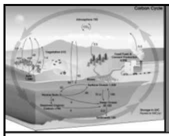


Soil Carbon:

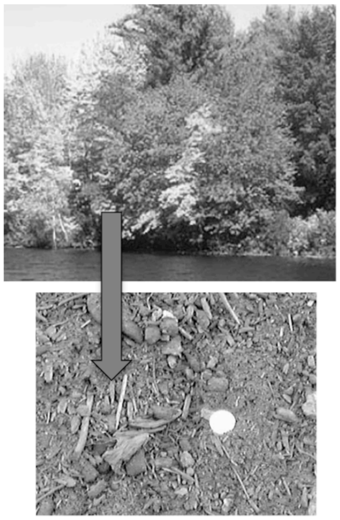


Carbon content of soil ranges from 0.5-8%.
It is derived from plant carbon (as is oil and gas)

Photosynthesis ($6CO_2+6H_2O+$ energy$=C_6H_{12}O_6+6O_2$)



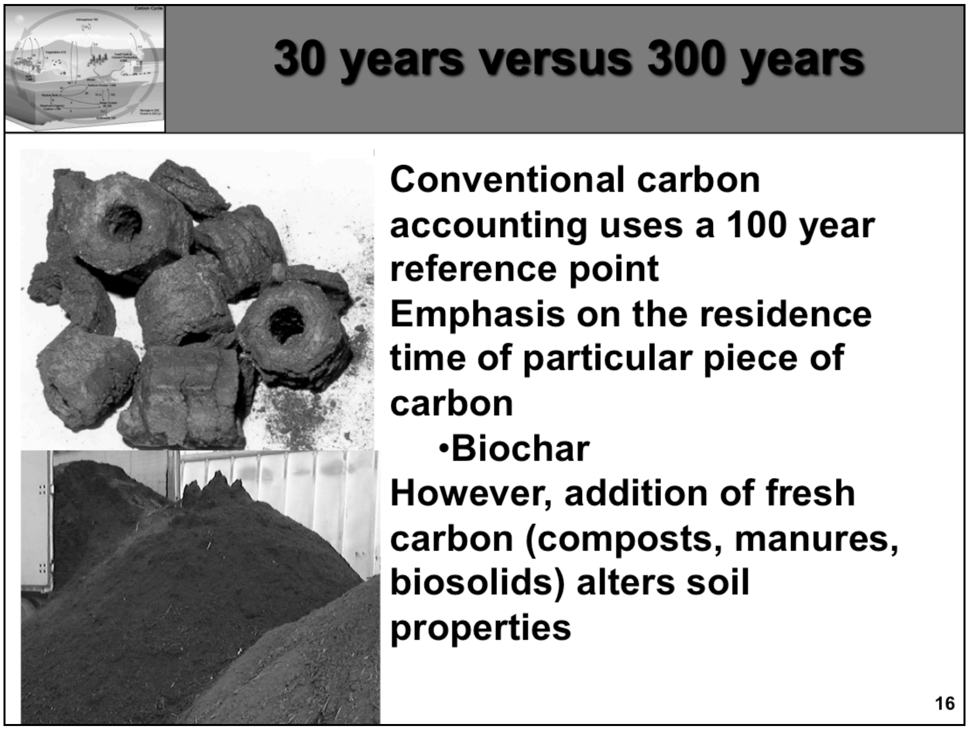
Soil Carbon:



Plants release C into soil via above and below ground deposition

- **This is used by soil organisms for energy (respired as CO_2)**
- **Or turned into biomass**
- **Or transformed into soil organic matter**

Average residence time for SOM is 20-30 years



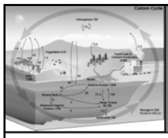
30 years versus 300 years

Conventional carbon accounting uses a 100 year reference point

Emphasis on the residence time of particular piece of carbon

- Biochar

However, addition of fresh carbon (composts, manures, biosolids) alters soil properties



Composts, manures, biosolids

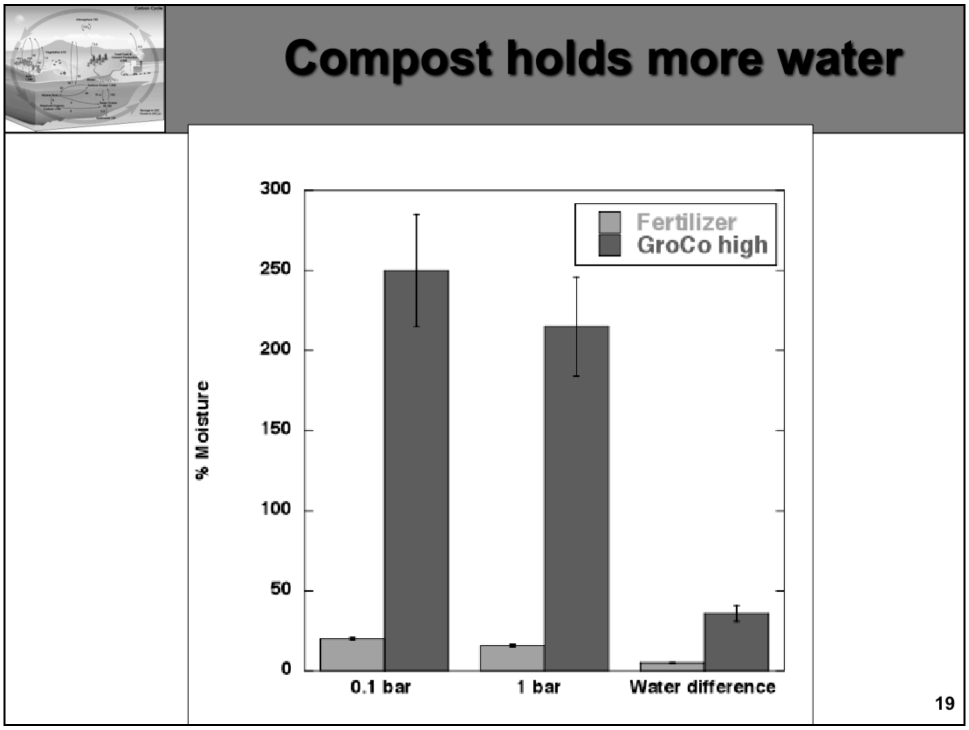
Every year each person produces/ is responsible for
- 30 kg biosolids
- >50 kg food and yard waste
- 1 ton animal manure

Using these materials is sustainable both for soils and as an alternative to landfill disposal

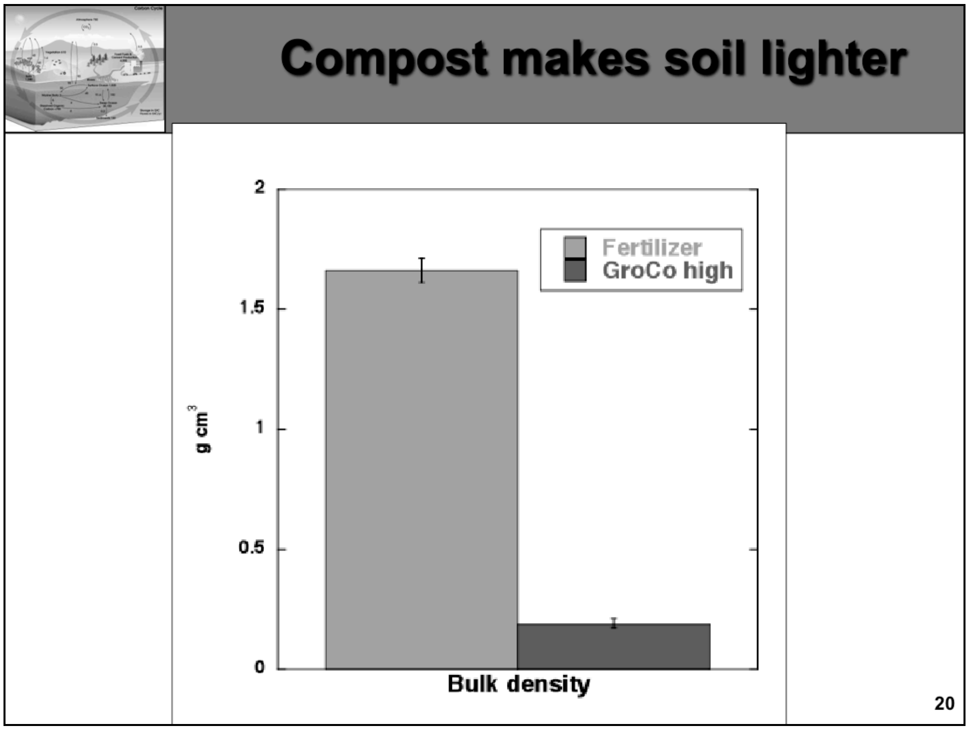
Vashon Island Borrow Pit

Fertilizer

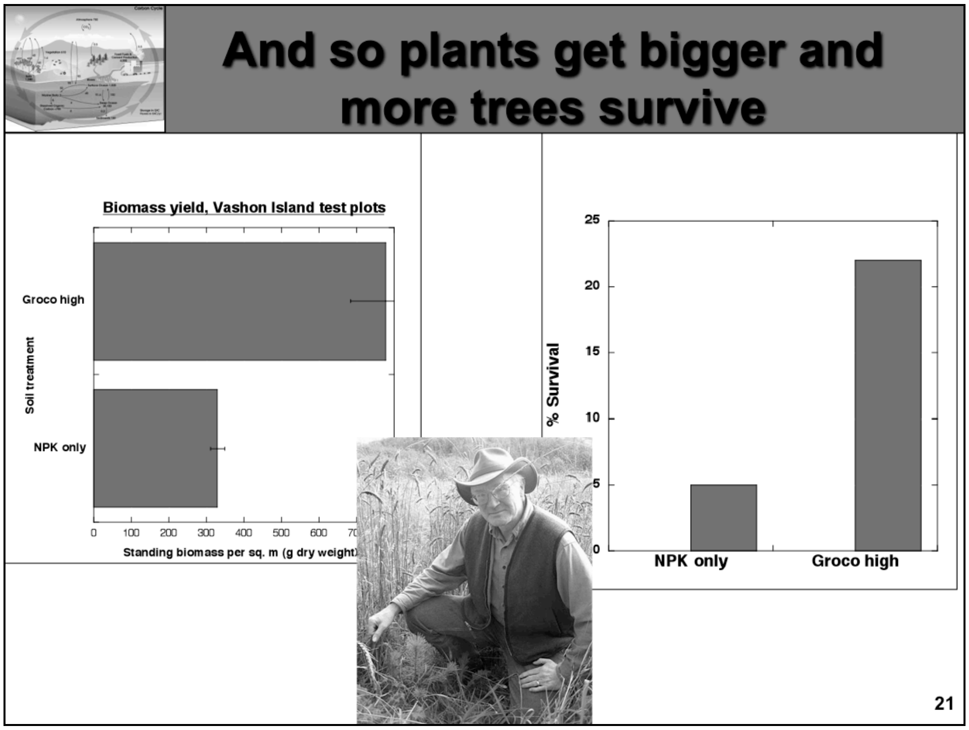
GroCo Compost



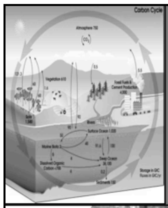
Compost holds more water



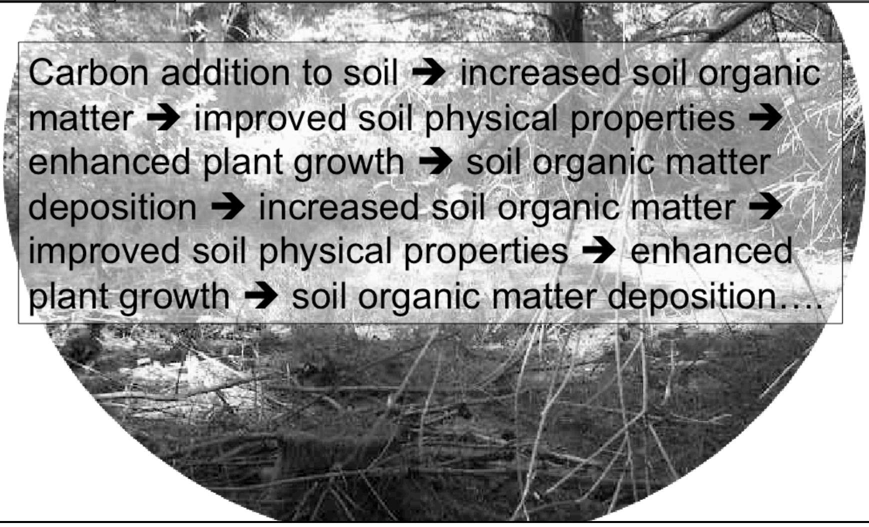
Compost makes soil lighter



And so plants get bigger and more trees survive



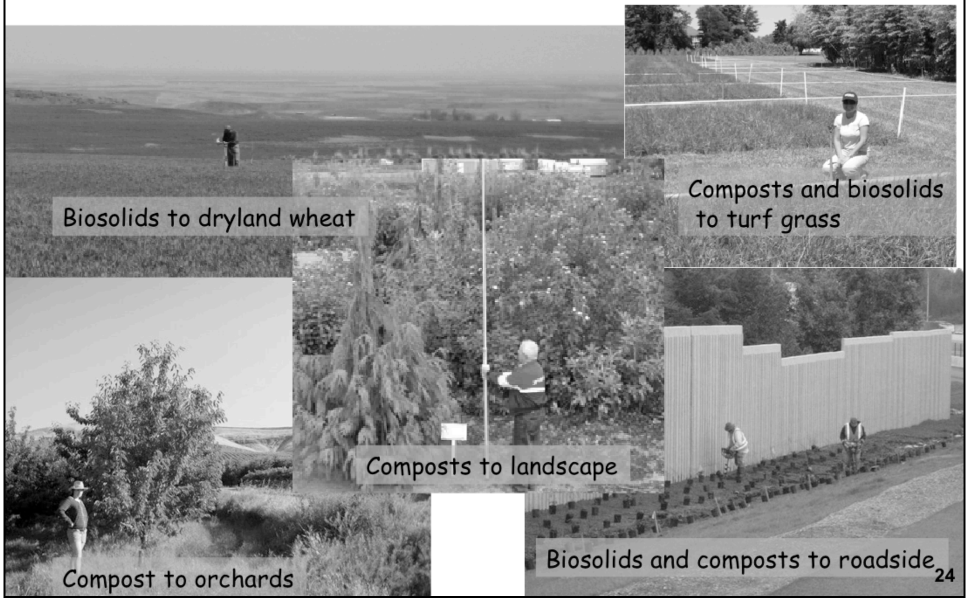
Annual carbon cycle renews and increases soil carbon over time

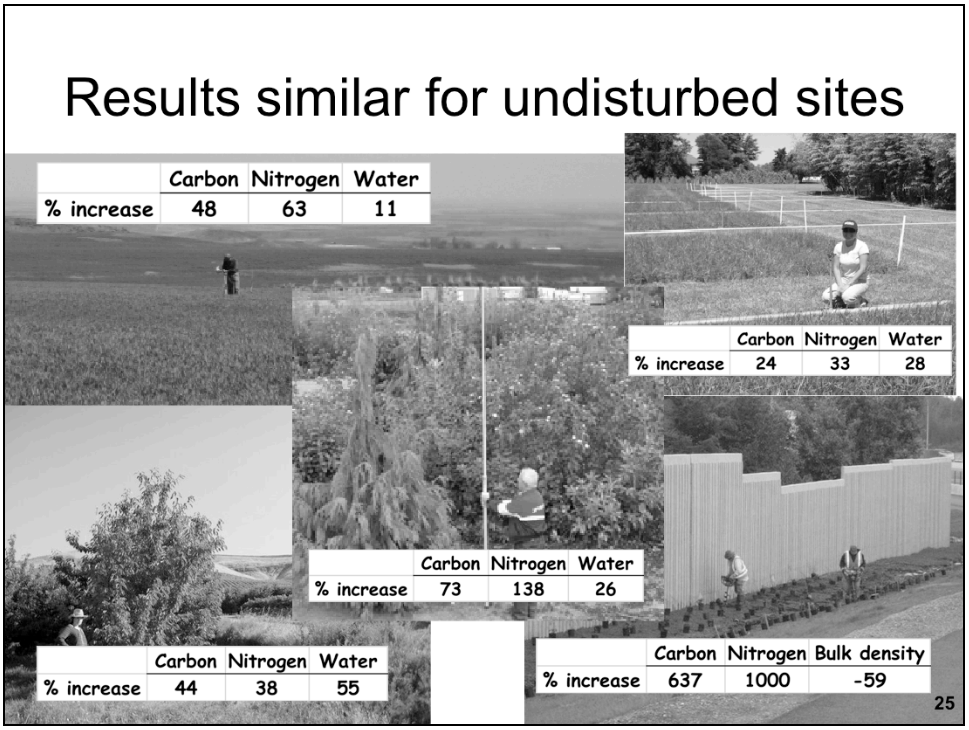


Carbon addition to soil ➔ increased soil organic matter ➔ improved soil physical properties ➔ enhanced plant growth ➔ soil organic matter deposition ➔ increased soil organic matter ➔ improved soil physical properties ➔ enhanced plant growth ➔ soil organic matter deposition….

Kate Kurtz, MS 2010
Sampled wide range of sites in WA State

Results similar for undisturbed sites





Results similar for undisturbed sites

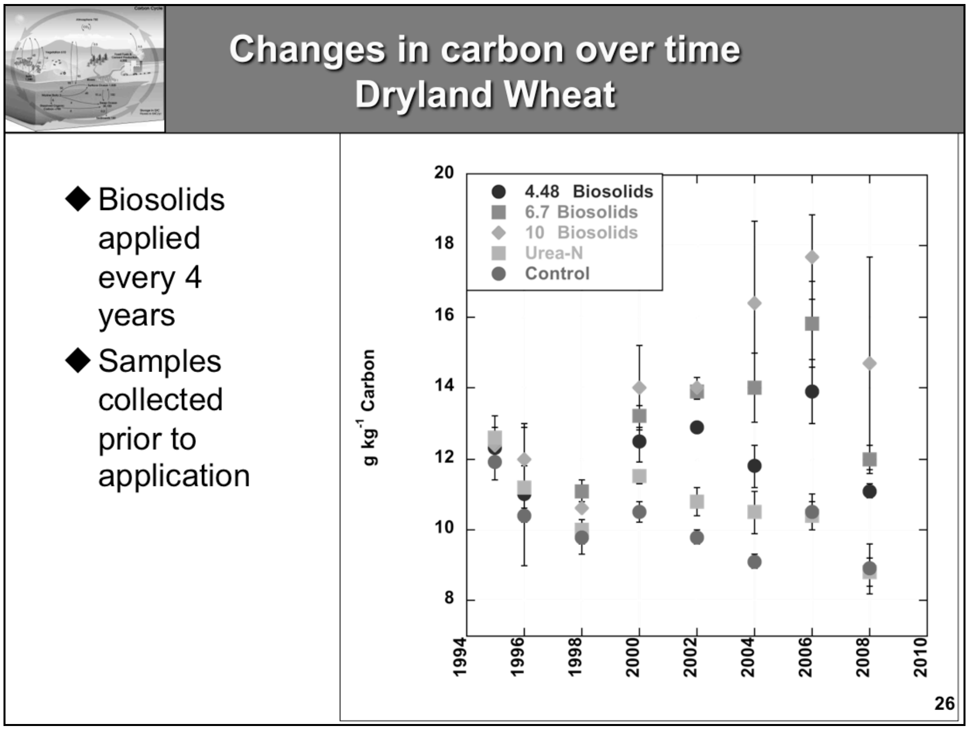
	Carbon	Nitrogen	Water
% increase	48	63	11

	Carbon	Nitrogen	Water
% increase	24	33	28

	Carbon	Nitrogen	Water
% increase	73	138	26

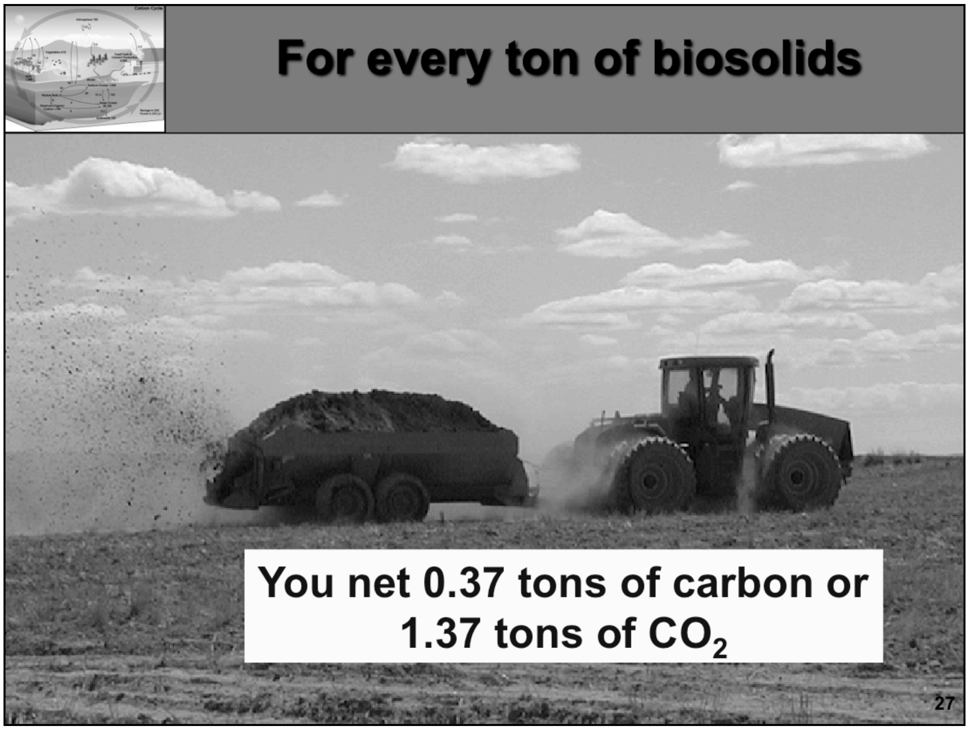
	Carbon	Nitrogen	Water
% increase	44	38	55

	Carbon	Nitrogen	Bulk density
% increase	637	1000	-59



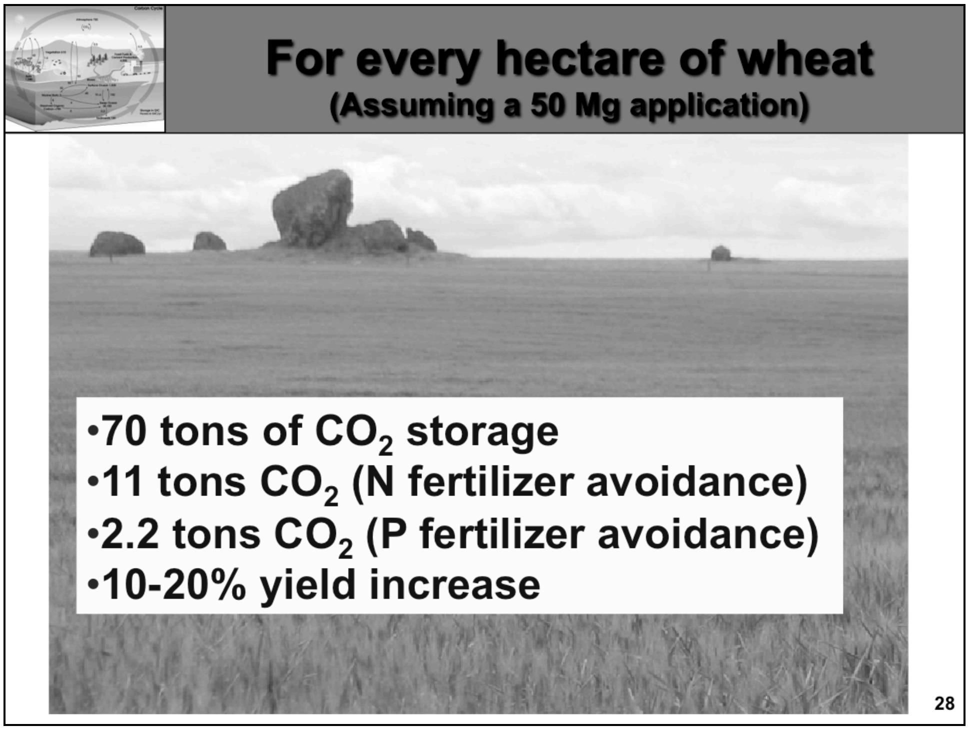
Changes in carbon over time Dryland Wheat

- Biosolids applied every 4 years
- Samples collected prior to application



For every ton of biosolids

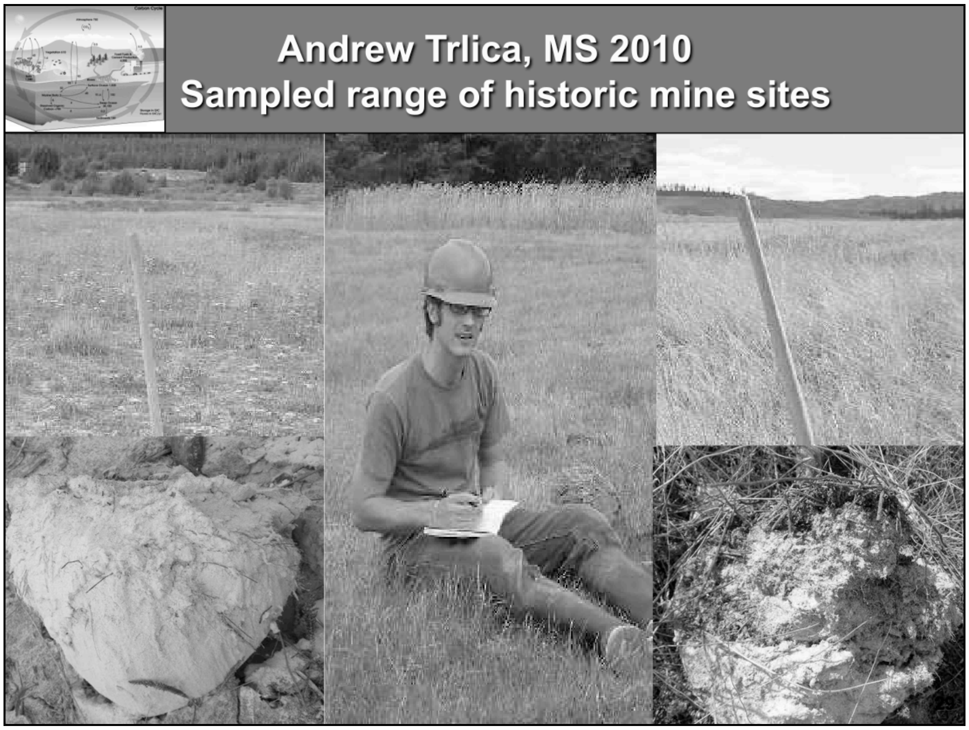
You net 0.37 tons of carbon or 1.37 tons of CO_2



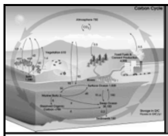
For every hectare of wheat

(Assuming a 50 Mg application)

- 70 tons of CO_2 storage
- 11 tons CO_2 (N fertilizer avoidance)
- 2.2 tons CO_2 (P fertilizer avoidance)
- 10-20% yield increase



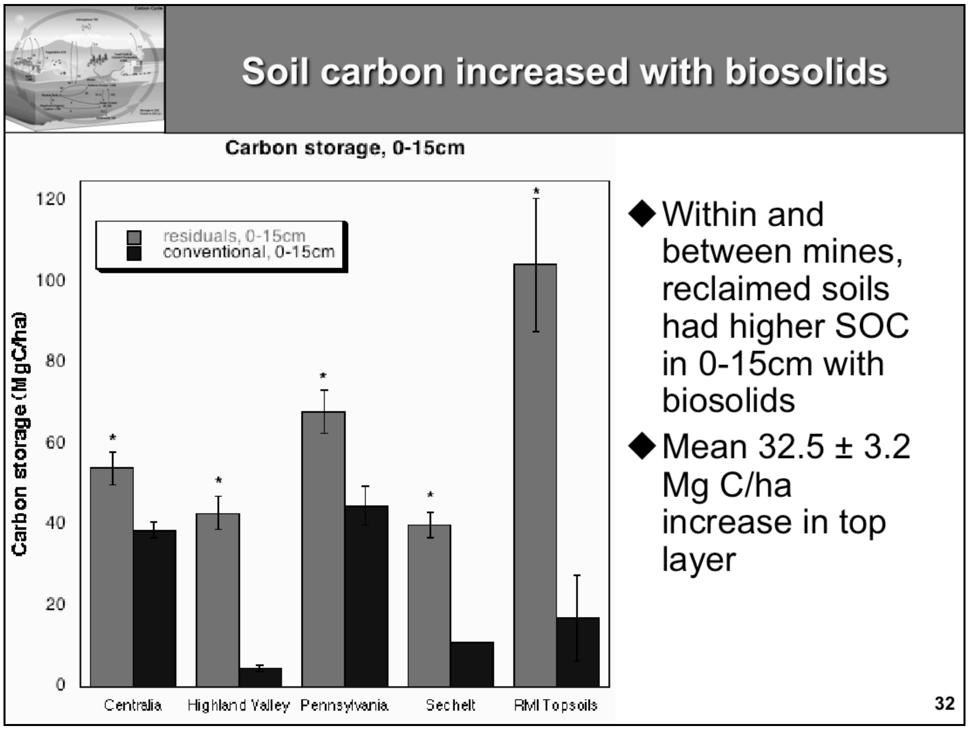
Andrew Trlica, MS 2010
Sampled range of historic mine sites



Field study locations

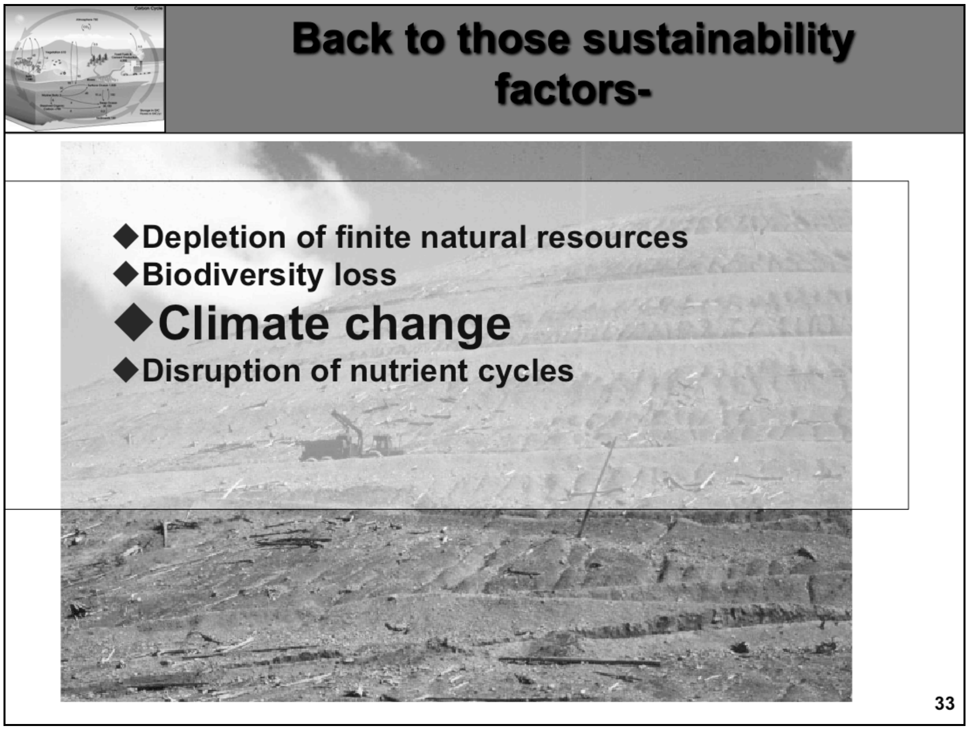
Courtesy Google Maps, 2010

Location	Mine type	Sample N	Max Age
Centralia, WA	Coal	35	17
Sechelt, BC	Sand & Gravel	25	9
Highland Valley, BC	Copper/Moly	20	8
RMI, Mass. & NH	Sand & Gravel	9	7
Pennsylvania	Coal	28	27



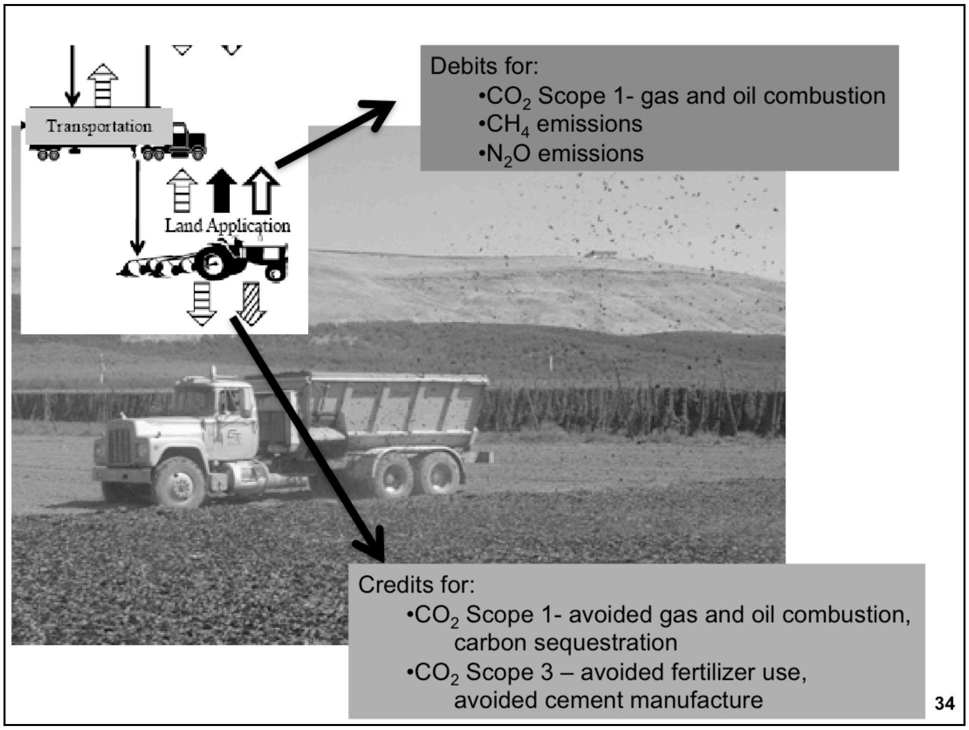
Soil carbon increased with biosolids

- Within and between mines, reclaimed soils had higher SOC in 0-15cm with biosolids
- Mean 32.5 ± 3.2 Mg C/ha increase in top layer



Back to those sustainability factors-

- ◆Depletion of finite natural resources
- ◆Biodiversity loss
- ◆**Climate change**
- ◆Disruption of nutrient cycles

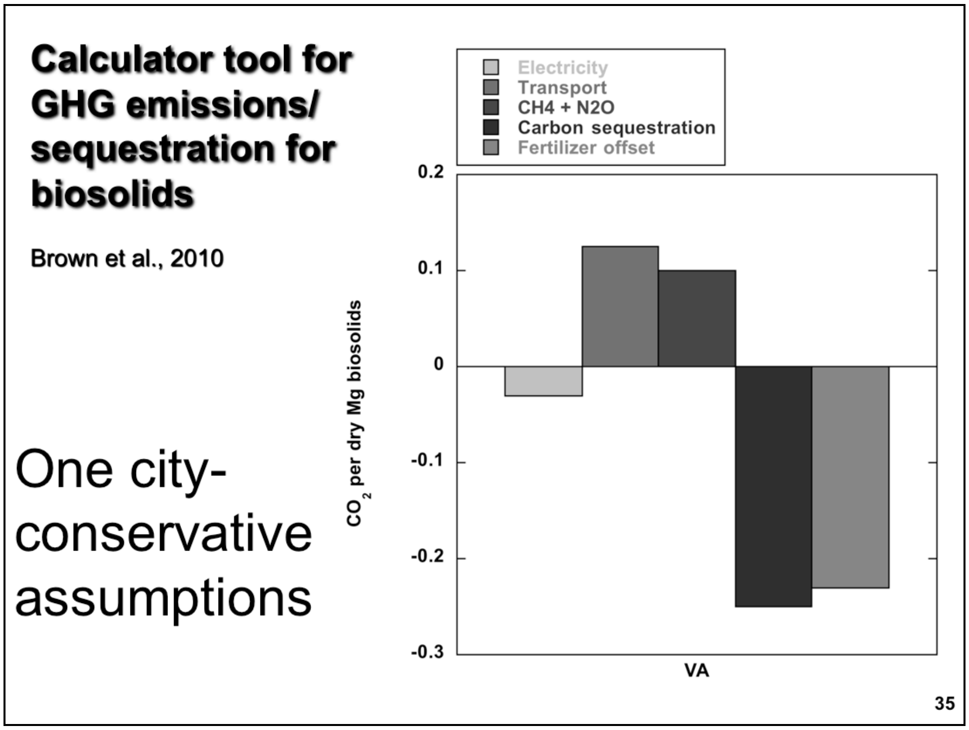


Debits for:

- CO_2 Scope 1- gas and oil combustion
- CH_4 emissions
- N_2O emissions

Credits for:

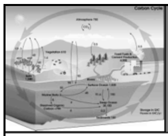
- CO_2 Scope 1- avoided gas and oil combustion, carbon sequestration
- CO_2 Scope 3 – avoided fertilizer use, avoided cement manufacture



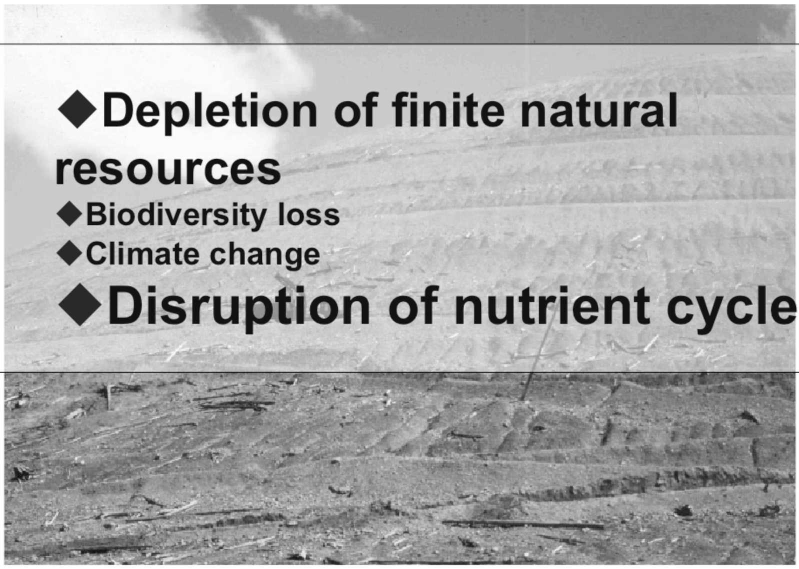
Calculator tool for GHG emissions/ sequestration for biosolids

Brown et al., 2010

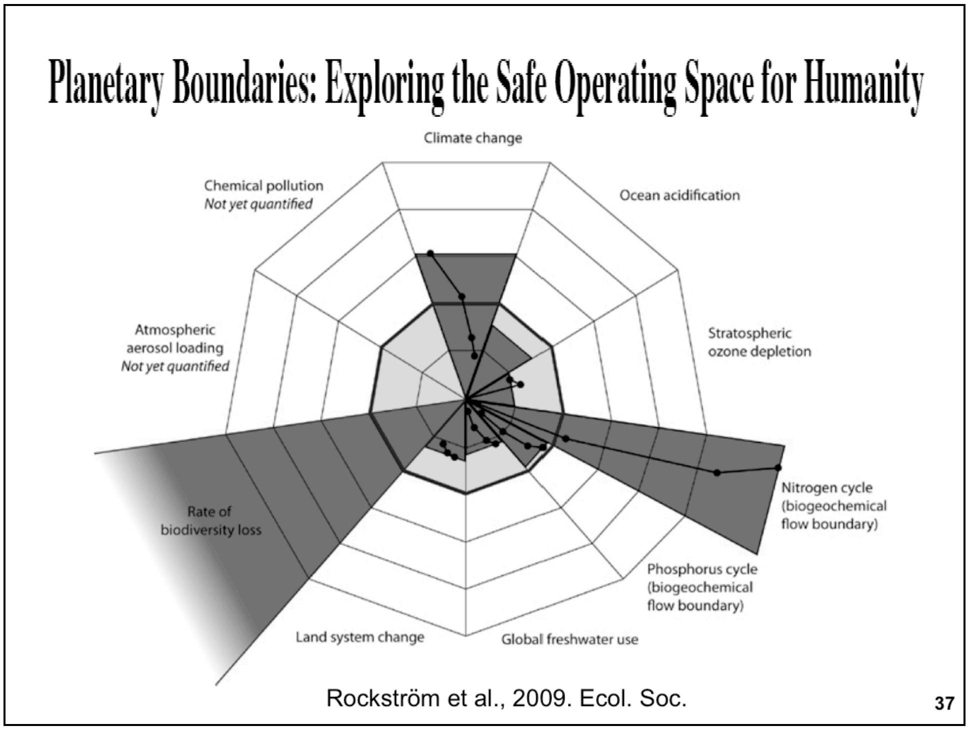
One city- conservative assumptions



Back to those sustainability factors-

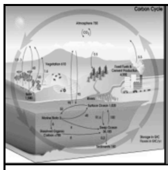


- ◆Depletion of finite natural resources
    - ◆Biodiversity loss
    - ◆Climate change
- ◆Disruption of nutrient cycles

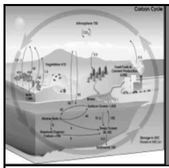


Planetary Boundaries: Exploring the Safe Operating Space for Humanity

Rockström et al., 2009. Ecol. Soc.



Nutrient cycling – residuals contain complete plant nutrients

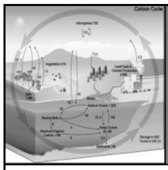


Finally, biodiversity

Ecosystem Restoration Quiz:

Name that Scat

Restoring the land to open space will provide habitat

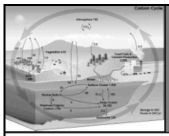


Conclusions

When you restore a site to open space using organic amendments:

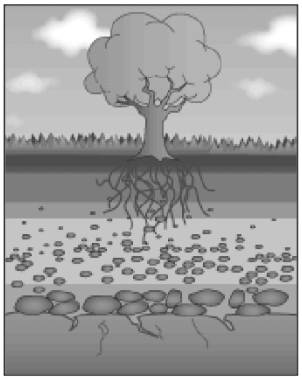
Realize a wide range of benefits critical to restoring ecological functions like the carbon cycle, nutrient cycle, biodiversity, all enhancing sustainability

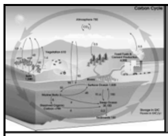
And it looks good too…



Part 2: Terrestrial Carbon Sequestration Field Study

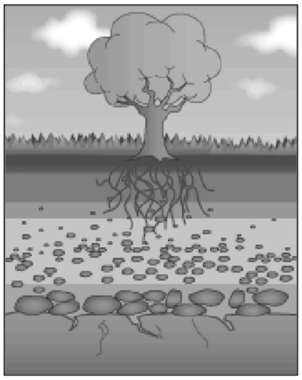
Michele Mahoney, OSRTI
Mark Colsman, Tetra Tech



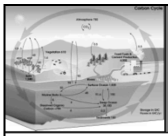


Terrestrial Carbon Sequestration Field Study

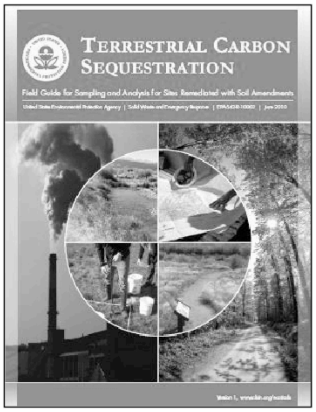
Introduction



- ♦ Purpose of Field Study
- ♦ Three sites
  - Stafford Airport Site, Virginia
  - Sharon Steel Site, Pennsylvania
  - Leadville Site, Colorado



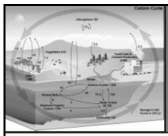
Field Guide for Sampling & Analysis



TERRESTRIAL CARBON SEQUESTRATION

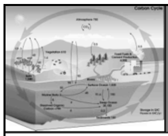
Field Guide for Sampling and Analysis for Sites Remediated with Soil Amendments

- Consistent sampling approach
- Drafted and tested at three sites
- Living document
- http://www.clu-in.org/download/issues/ecotools/Terrestrial_Carbon_Seq_Field_Guide.pdf



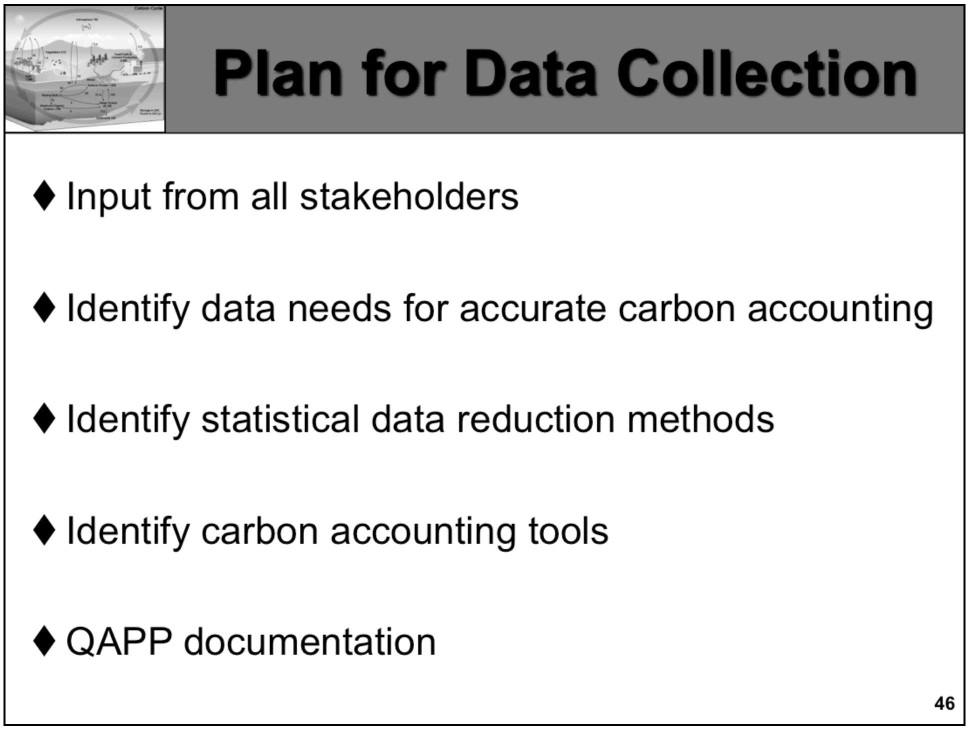
Data Collection Approach

- Document Site-Specific Information
- Plan for Data Collection
- Collect and Analyze Data
- Manage and Interpret Data



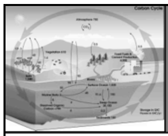
Document Site Specifics

- Required for carbon sequestration calculations
- Used for calculating other aspects of carbon sequestration potential and results
- Provides useful background information and data to compare results across sites over time
- Suggested format in Appendix 1 of Field Guide



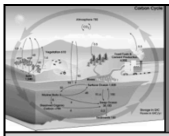
Plan for Data Collection

- ♦ Input from all stakeholders
- ♦ Identify data needs for accurate carbon accounting
- ♦ Identify statistical data reduction methods
- ♦ Identify carbon accounting tools
- ♦ QAPP documentation



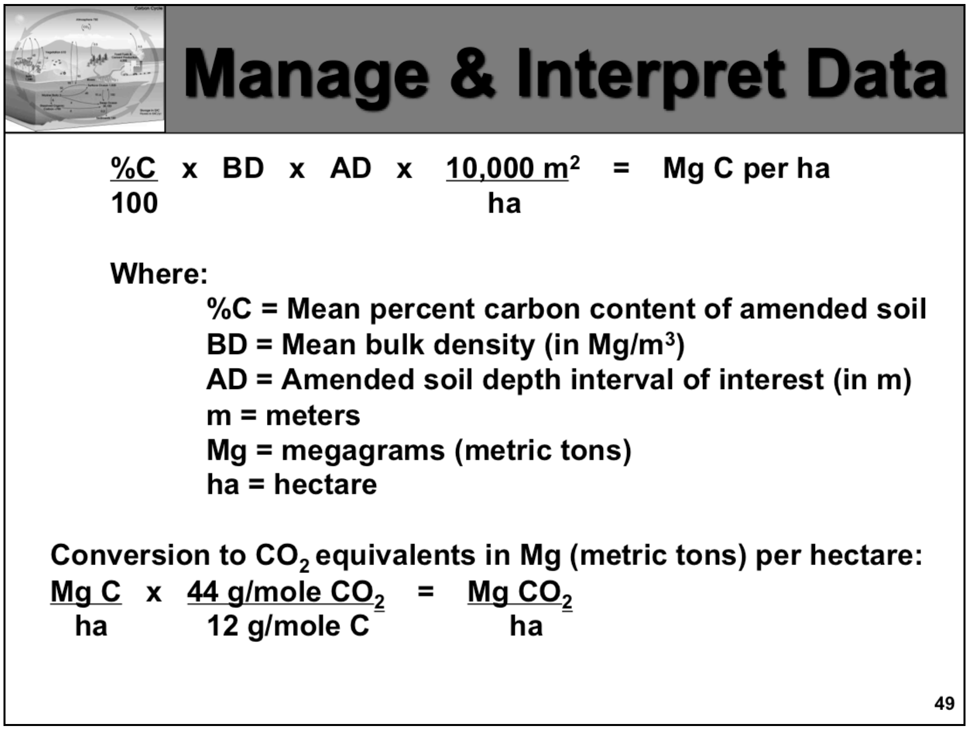
Analytical Measurements for Soil Amendments, Cores, Gases and Plants

Matrix	Analyses	Method(s)
Amendments	Total Carbon Inorganic/Organic Carbon Fractionation Total Nitrogen Organic Matter Content Moisture Content pH Electrical Conductivity (EC)	Dry flash combustion Acid vapor exposure Dry flash combustion Loss on ignition Thermal-gravimetry Paste-electrode Paste-electrode
Soil	Total Carbon Inorganic/Organic Carbon Fractionation Total Nitrogen Organic Matter Content Moisture Content Particle Size Analysis (sand, silt, clay) Bulk Density pH EC	Dry flash combustion Acid vapor exposure Dry flash combustion Loss on ignition Thermal-gravimetry Sieving-gravimetry Gravimetry Paste-electrode Paste-electrode
Biomass/ Plants	Above and below ground biomass sampling and estimation (dry weight)	Thermal-gravimetry
Gases	Nitrous oxide Carbon dioxide Methane	Static flux chamber: headspace gas chromatography (GC)



Sampling Events

Sampling Event	Matrices	Purpose
Time 0 or before (pretreatment)	Soil amendment; soil	Establish baseline carbon assessment for site
Time 0 or before (pretreatment)	Plant biomass (if present)	Establish baseline
Time 0	Amended soil, reference soil	Initial carbon measurement
Time 0	Plant biomass (if present)	Initial biomass measurement
Time 0	Gases in air	Determine nitrous oxide, carbon dioxide, and methane emissions from amendment for a minimum of one month.
Year 1	Amended soil, reference soil	Assess one-year changes in terrestrial carbon
Year 1	Plant biomass (if present)	Assess one-year plant growth
Year 3	Amended soil, reference soil	Assess changes in terrestrial carbon
Year 3	Plant biomass (if present)	Assess changes in biomass
Year 5	Amended soil, reference soil	Assess longer-term changes in terrestrial carbon; determine need for further sampling times
Year 5	Plant biomass (if present)	Assess longer-term changes in biomass
Year 10	Amended soil, reference soil	Assess longer-term changes in terrestrial carbon; determine need for further sampling times
Year 10	Plant biomass (if present)	Assess longer-term changes in biomass



Manage & Interpret Data

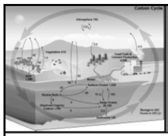
$$\frac{\%C}{100} \times BD \times AD \times \frac{10{,}000\ m^2}{ha} = \text{Mg C per ha}$$

Where:

%C = Mean percent carbon content of amended soil
BD = Mean bulk density (in Mg/m^3)
AD = Amended soil depth interval of interest (in m)
m = meters
Mg = megagrams (metric tons)
ha = hectare

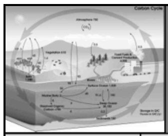
Conversion to CO_2 equivalents in Mg (metric tons) per hectare:

$$\frac{\text{Mg C}}{\text{ha}} \times \frac{44\ \text{g/mole}\ CO_2}{12\ \text{g/mole C}} = \frac{\text{Mg}\ CO_2}{\text{ha}}$$



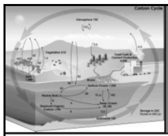
Field Guide Appendices

1. Suggested Format for Site Information
2. Example Sampling Approach
3. Standard Operating Procedure for Carbon/Nitrogen Elemental Analysis
4. Methods for Inorganic/Organic Carbon Fractionation
5. Method for Bulk Density Measurement
6. Standard Operating Procedures for Above and Below Grade Biomass Characterization
7. Protocol for Gas Flux Measurement



Overview of Sites for Terrestrial Carbon Sequestration Study – Fall 2008

Site Type and Contaminants	Amendment Type	Period & Rate of Application	Weather – Mean Annual Temperature and Precipitation (www.usclimate.com)	Elevation	Soil Type	Area
Leadville Superfund Site – Leadville, Lake County, CO						
Former mine tailings site (Trace metals, acid mine drainage)	Biosolids, compost, pellets, limestone, wood chips, manure	1998-2001; 100 dry tons of biosolids per acre, 100 dry tons of lime per acre	Temperature: 35°F Precipitation: 12 inches	9,928 feet	Sandy Loam	80 acres amended (Superfund site is 11,500 acres)
Stafford Airport Site –Stafford, VA						
New development/ construction (airport) (Acid drainage)	Biosolids, straw mulch, salt tolerant grasses	2002; 120 dry tons per acre	Temperature: 56°F Precipitation: 43 inches	106 feet	Sandy Loam	257.5 acres amended (Sampling area was 1.2 acres)
Sharon Steel Farrel Works Disposal Area Superfund Site – Mercer County, PA						
Redeveloped steel mill (Metals, organics)	Biosolids, compost, and pine bark	2008; field demonstration – application to 6 inches depth over pilot plots	Temperature: 49°F Precipitation: 43 inches	1,194 feet	Silty loam	400 acres (Area of Superfund site, area to be amended has not been determined)

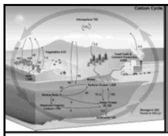


Site Description

Leadville

Leadville Site (Before and After)

- Located 100 miles southwest of Denver, CO
- Site History:
  - 120 years – Mined and milled for silver, gold, lead and zinc
  - 1983 – Leadville site listed on the NPL
- Sandy loam soil
- Elevation at site is 8,200 – 10,000 feet
- Sulfide mine tailings washed down the Arkansas River impacting an 11-mile stretch of the river causing acidic conditions and metal contamination.

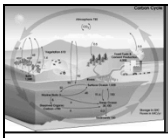


Site Description

Stafford

Photograph of Stafford Regional Airport provided by Lee Daniels, Virginia Tech

- Located 35 miles from Washington D.C.
- Site history:
  - 1997 – Construction began for an airport
  - 2001 – Airport completed
- 550-acre facility with paved aircraft parking and a runway
- Sandy loam soil; construction exposed sulfidic rock
- Rolling hills geography

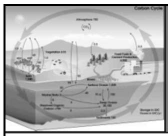


Site Description

Sharon Steel

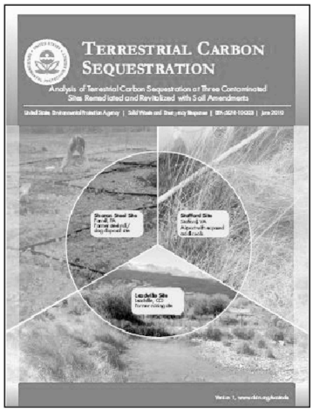
Photograph courtesy of
Libby Dayton, Ohio State
University

- Located Mercer County, Pennsylvania
- Site history:
  - **1900 – Steel product manufacturing facility**
  - **1992 – Sharon Steel declared bankruptcy**
  - **Waste byproducts were disposed of on site**
  - **1998 – Sharon Steel was listed on the NPL**
- Topography consists of hilly uplands and broad deep valleys
- Silty loam soil
- Contamination in soil consists of metals, PAHs, PCBs, and pesticides



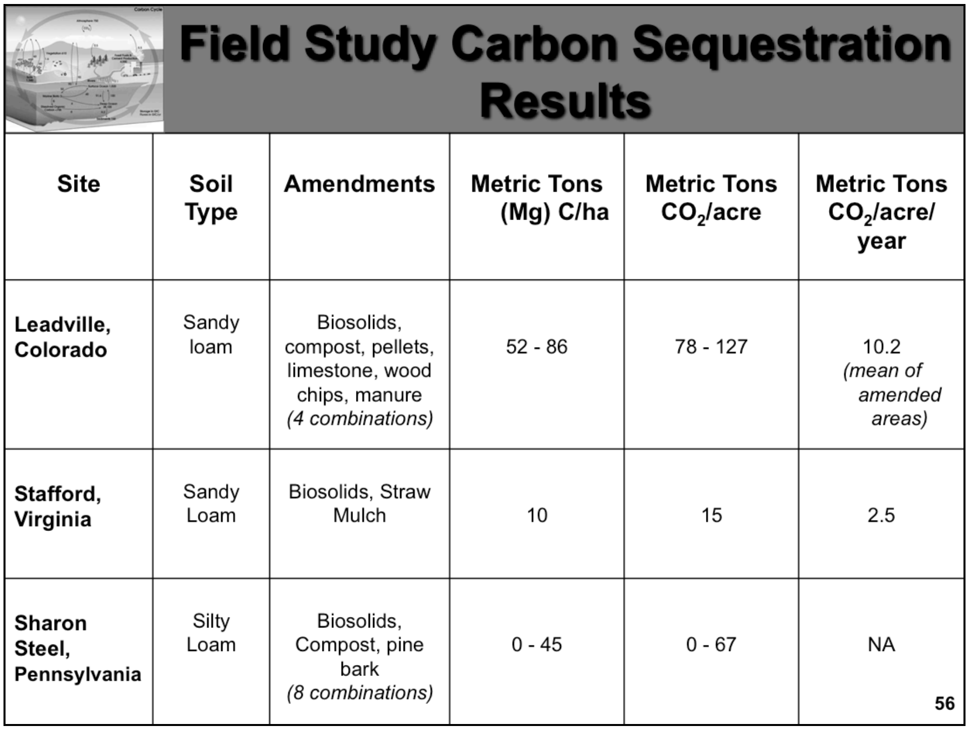
Analyses of Data Collected During the Field Study

- ♦ Sampling and analysis based on methodology described in the field guide
- ♦ Results published in a report dated February 2011
- ♦ Report includes sampling and analytical results for all three sites, including statistical analyses of field data
- ♦ http://www.clu-in.org/download/issues/ecotools/Terrestrial-Carbon-Sequestration-Report.pdf



TERRESTRIAL CARBON SEQUESTRATION

Analysis of Terrestrial Carbon Sequestration at Three Contaminated Sites Remediated and Revitalized with Soil Amendments



Field Study Carbon Sequestration Results

Site	Soil Type	Amendments	Metric Tons (Mg) C/ha	Metric Tons CO_2/acre	Metric Tons CO_2/acre/ year
Leadville, Colorado	Sandy loam	Biosolids, compost, pellets, limestone, wood chips, manure *(4 combinations)*	52 - 86	78 - 127	10.2 *(mean of amended areas)*
Stafford, Virginia	Sandy Loam	Biosolids, Straw Mulch	10	15	2.5
Sharon Steel, Pennsylvania	Silty Loam	Biosolids, Compost, pine bark *(8 combinations)*	0 - 45	0 - 67	NA

Sampling Summary

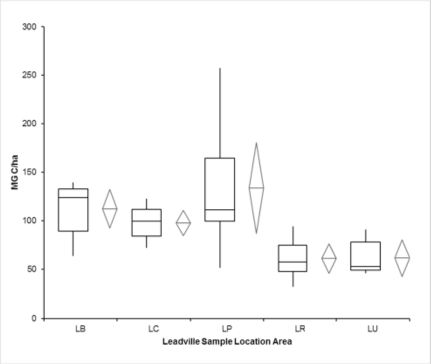
Leadville

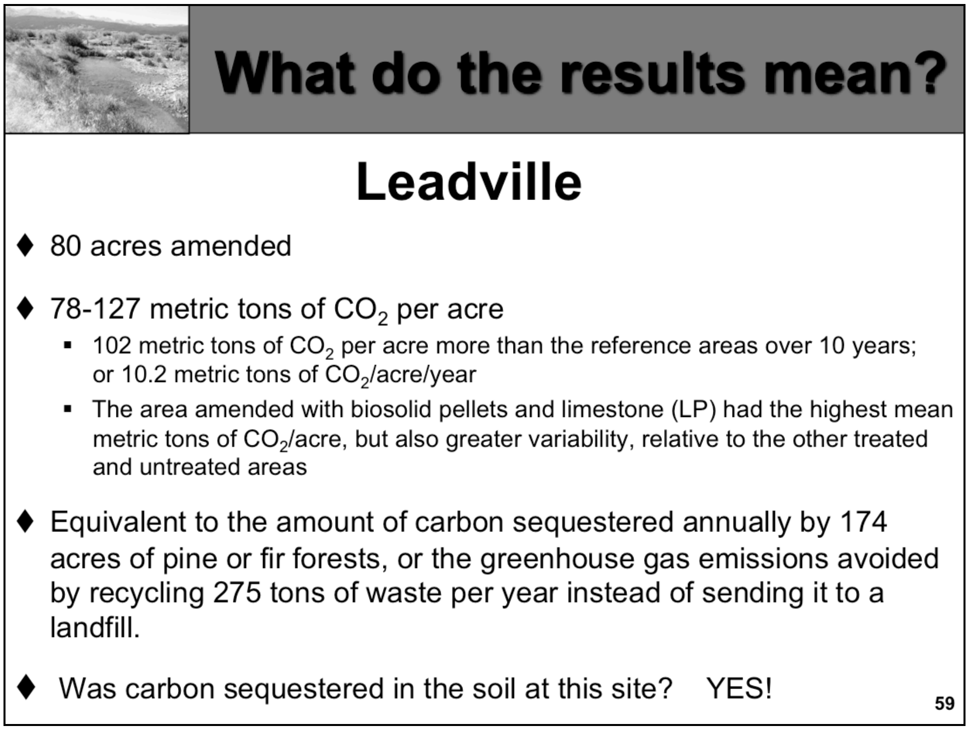
- Three amended areas were sampled, plus reference areas
  - LP – pellet biosolids, limestone
  - LB – cake biosolids, limestone
  - LC – cake biosolids
  - LU – untreated impacted
  - LR – untreated unimpacted
- Three 40X40’ sampling grids in each area; 3 composite samples from each grid
- Samples were collected at two depths from each location:
  0-15 cm and 15-30 cm
- For the 0-15 cm interval, carbon sequestration rates (Mg C/ha) were compared statistically for the treated and untreated areas

Statistical Evaluation of Results

Leadville

- 1-way Analysis of Variance (ANOVA) found the mean Mg C/ha values to be significantly different at the different areas (at 95% confidence)
- Subsequent post-hoc statistical tests (Dunnett's test) found that all three treated areas (LB, LC, and LP) were significantly higher in carbon relative to the combined untreated areas (LU/LR)





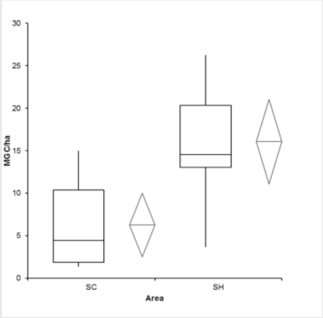
What do the results mean?

Leadville

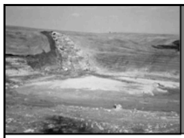
- 80 acres amended
- 78-127 metric tons of CO_2 per acre
  - 102 metric tons of CO_2 per acre more than the reference areas over 10 years; or 10.2 metric tons of CO_2/acre/year
  - The area amended with biosolid pellets and limestone (LP) had the highest mean metric tons of CO_2/acre, but also greater variability, relative to the other treated and untreated areas
- Equivalent to the amount of carbon sequestered annually by 174 acres of pine or fir forests, or the greenhouse gas emissions avoided by recycling 275 tons of waste per year instead of sending it to a landfill.
- Was carbon sequestered in the soil at this site? YES!

Sampling Summary and Statistical Evaluation of Results

Stafford



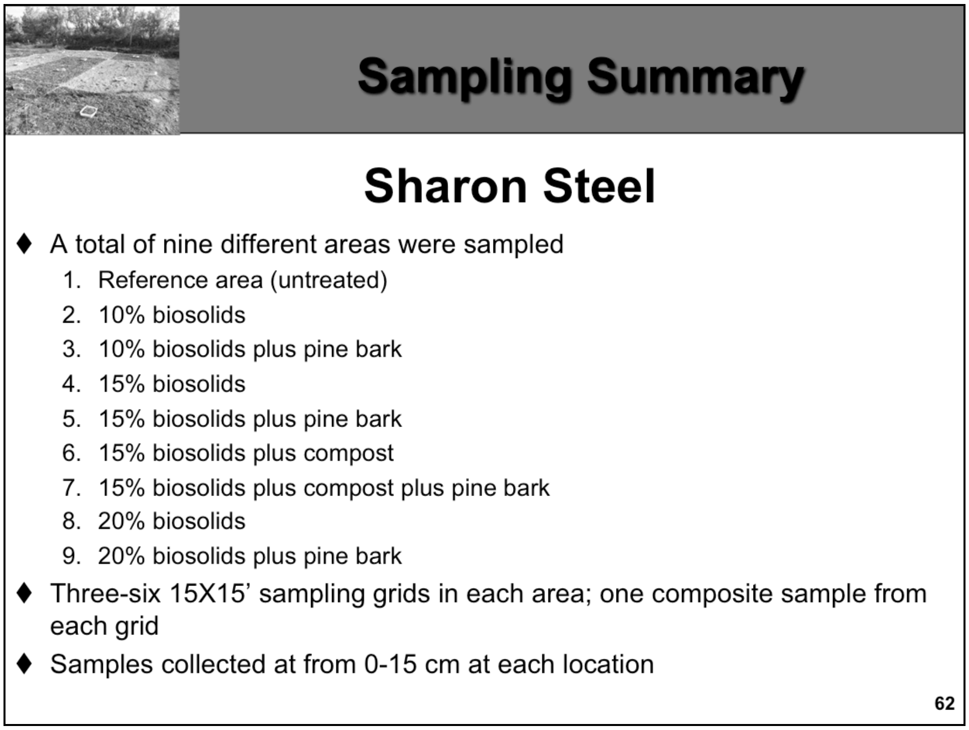
- One treated area and one control area sampled
  - SC – untreated control
  - SH – high biosolids application area (121 tons/acre)
- Three 40X40’ sampling grids in each area; 5 composite samples from each grid (0-15 cm and 15-30 depths)
- For the 0-15 cm depth samples, a t-test confirmed that the mean of 16 Mg C/ha for the SC area was significantly higher than the mean of 6 Mg C/ha at 95% confidence



What do the results mean?

Stafford

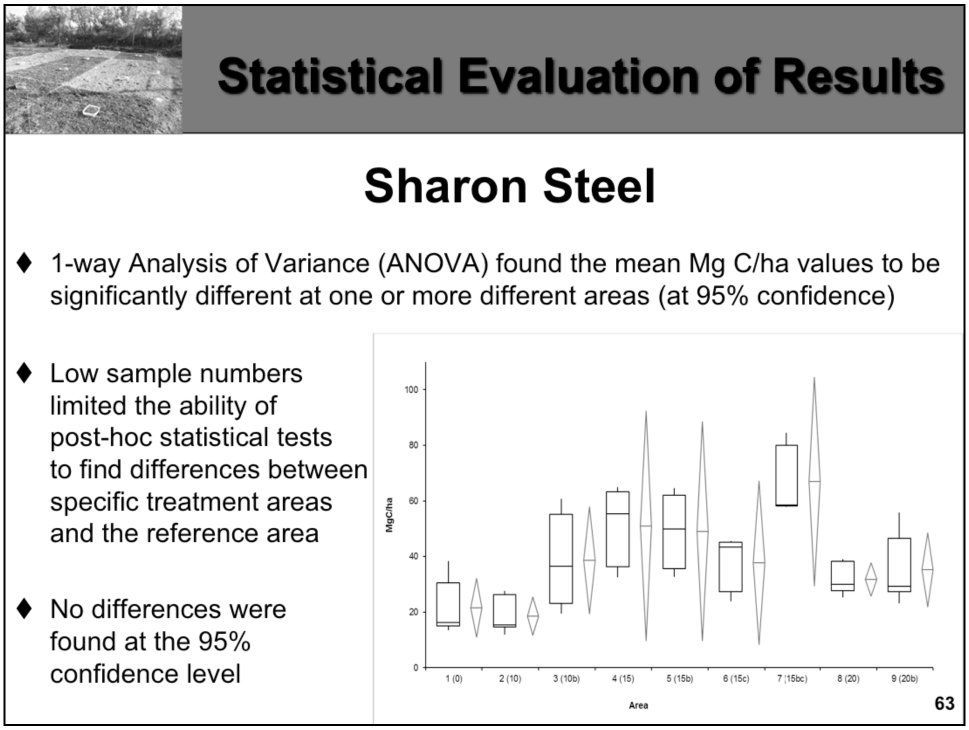
- Amended 275 acres with a gain of 15 metric tons of CO_2 per acre.
- Over the 6 years since treatment, this rate amounts to 2.5 metric tons of CO_2/acre/year.
- Equivalent to the amount of CO_2 emissions associated with 280 gallons of gasoline consumed per year.
- Was carbon sequestered at this site? YES!



Sampling Summary

Sharon Steel

- A total of nine different areas were sampled
  1. Reference area (untreated)
  2. 10% biosolids
  3. 10% biosolids plus pine bark
  4. 15% biosolids
  5. 15% biosolids plus pine bark
  6. 15% biosolids plus compost
  7. 15% biosolids plus compost plus pine bark
  8. 20% biosolids
  9. 20% biosolids plus pine bark
- Three-six 15X15' sampling grids in each area; one composite sample from each grid
- Samples collected at from 0-15 cm at each location



Statistical Evaluation of Results

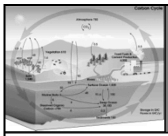
Sharon Steel

- 1-way Analysis of Variance (ANOVA) found the mean Mg C/ha values to be significantly different at one or more different areas (at 95% confidence)
- Low sample numbers limited the ability of post-hoc statistical tests to find differences between specific treatment areas and the reference area
- No differences were found at the 95% confidence level

What do the results mean?

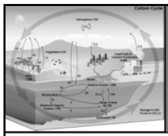
Sharon Steel

- Up to 99 metric tons of CO_2 per acre as compared to the control of 32 metric tons of CO_2 per acre.
- Sequestration appeared highest in the 15% biosolids areas (57-99 Mg/acre), but sample size was low
- Remediation of half the site is estimated to sequester 9,200 metric tons of CO_2
- Was carbon sequestered in the soil at this site? Appears probable, but additional data are needed.



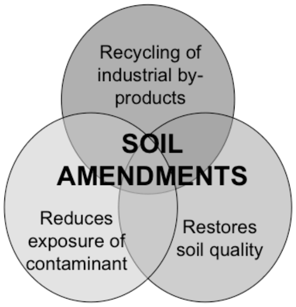
Carbon Accounting at Soil Amendment Sites

Carbon Sinks (i.e. storage)	**GHG Emission Sources (i.e. CO_2, CH_4, NO_x)**
Vegetation: living biomass (above/ below ground), non-living biomass	Transportation of materials to site
Soil: organic soil matter, inorganic soil matter	Stationary machinery and other equipment not covered under transportation
Carbon-rich soil amendments	Biomass burning for site preparation and management
	Fertilizer use
	Soil off-gassing



Conclusions

- ♦ Benefits of Soil amendments
  - Remediation & revitalization
  - More cost-effective cleanups
  - Recycling by-products
  - Jump-starts ecosystem
  - Terrestrial carbon sequestration

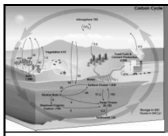


Recycling of industrial by-products

SOIL AMENDMENTS

Reduces exposure of contaminant

Restores soil quality

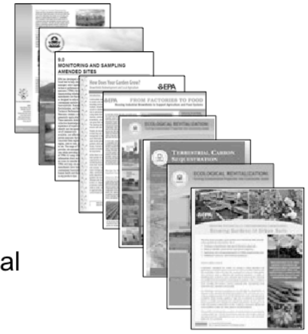


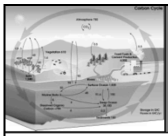
Related Published and Online Tools

EcoTools Tools for Ecological Land Reuse

http://www.cluin.org/ecotools

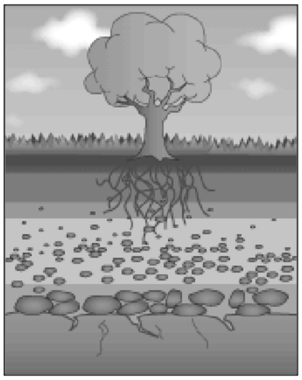
- Publications
  - Ecological Revitalization Case Studies, Fact Sheets and Database
  - Terrestrial Carbon Sequestration
  - Urban Gardening
- Presentations, Workshops, and Training
- Land Revitalization Assistance
  - Connect with experts in the ecological reuse field
- Resources
  - EPA, government and non-government websites
  - Glossary

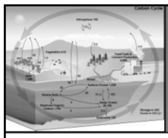




Part 3: Modeling Ecosystem Services – Pilot Study

Carlos Pachon, OSRTI
Caitlin Andersen, Tetra Tech

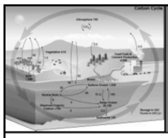




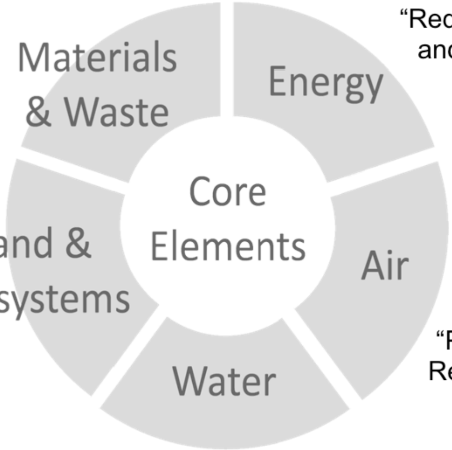
What is “Green Remediation”?

The practice of considering all environmental effects of remedy implementation and incorporating options to minimize the environmental footprints of cleanup actions

This is an incremental improvement in the implementation of EPA’s cleanup programs



Green Remediation
“Core Elements”



Core Elements

Materials & Waste

“Minimize, Reuse, and Recycle…”

Energy

“Reduction, Efficiency, and Renewables…”

Air

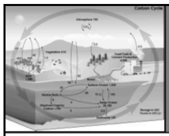
“Protect Air Quality; Reduce Greenhouse Gases…”

Water

“Improve Quality; Decrease Quantity of Use…”

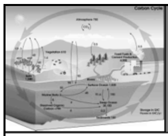
Land & Ecosystems

“Conserve, Protect, and Restore…”

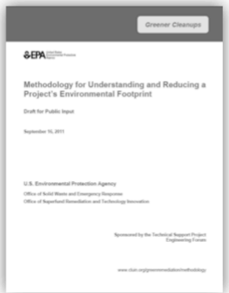


EPA Green Remediation Policy

- EPA OSWER “Principles for Greener Cleanups”
  - “… we can optimize environmental performance and implement protective cleanups that are greener by increasing our understanding of the environmental footprint and, when appropriate, taking steps to minimize that footprint”
  - Intended to improve the decision-making process for cleanup activities in a way that ensures protection of human health and the environment
- National “Superfund Green Remediation Strategy”
  - Aims to reduce the demand placed on the environment during cleanup actions and to conserve natural resources
  - Specifies 40 actions undertaken by EPA’s Superfund Program to implement green remediation measures within the CERCLA and NCP frameworks
  - Establishes a process for measuring improvements to environmental outcomes of Superfund cleanups



What about Ecosystem Services?



Greener Cleanups

EPA

Methodology for Understanding and Reducing a Project's Environmental Footprint

Draft for Public Input

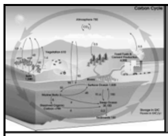
September 16, 2011

U.S. Environmental Protection Agency
Office of Solid Waste and Emergency Response
Office of Superfund Remediation and Technology Innovation

Sponsored by the Technical Support Project
Engineering Forum

www.cluin.org/greenremediation/methodology

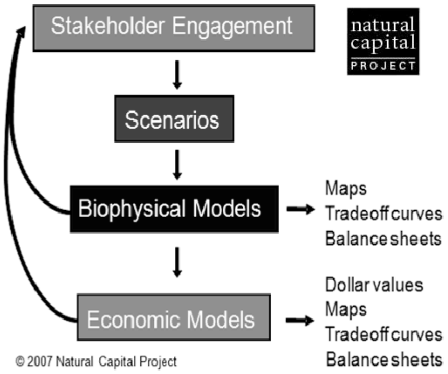
- EPA released a draft Methodology for Understanding and Reducing a Project's Environmental Footprint (September 2011) www.epa.gov/superfund/greenremediation/
- The methodology addresses 4 of 5 core elements of green remediation as defined in EPA's Policy
- Development of the ecosystems footprint presents challenges related to scale, boundaries and metrics
- The following material is extracted from one of the pilot studies we undertook to evaluate options
- For the purpose of this Webinar we only present carbon sequestration and storage



InVEST

Integrated **V**aluation of **E**cosystem **S**ervices and **T**radeoffs

- Model and map the delivery, distribution, and economic value of specific ecosystem services
- Visualize and compare the impacts of potential remedial decisions



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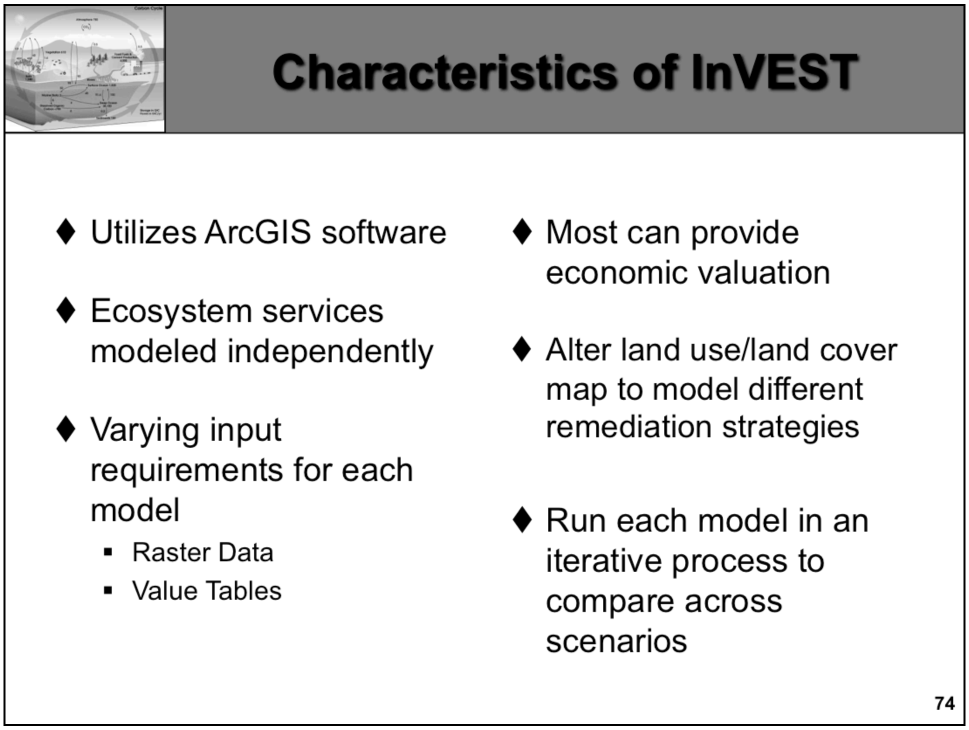
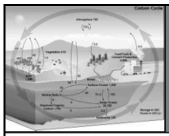
http://naturalcapitalproject.org/InVEST.html



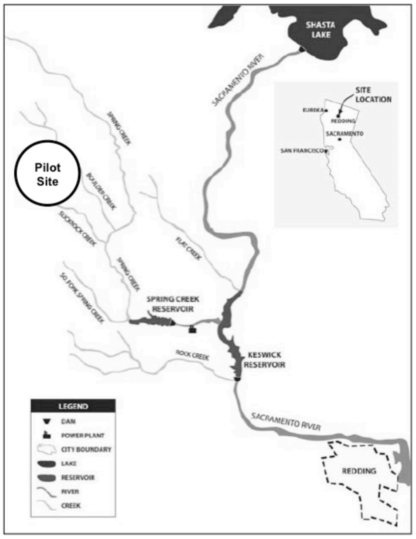
Characteristics of InVEST

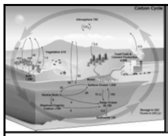
- Utilizes ArcGIS software
- Ecosystem services modeled independently
- Varying input requirements for each model
    - Raster Data
    - Value Tables
- Most can provide economic valuation
- Alter land use/land cover map to model different remediation strategies
- Run each model in an iterative process to compare across scenarios



Pilot Site

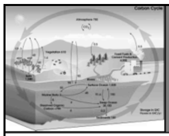
- Mining site in Northern California
  - 4,400 acres comprising several distinct mines
- Three main creeks and tributaries impacted by acid mine drainage
- Remedial actions to date:
  - Clean water diversions
  - Lime neutralization plant
  - Waste pile/tailings removal, consolidation, and capping
  - Sediment dredging



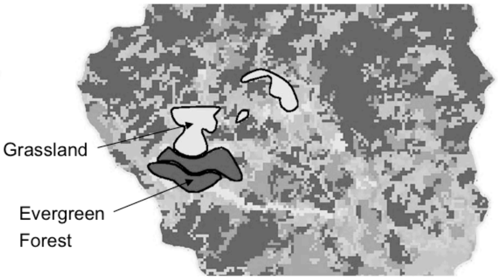


InVEST Parameters Analyzed

- ♦ Biodiversity: Habitat Quality and Rarity
- ♦ **Carbon Storage and Sequestration**
- ♦ Water Purification: Nutrient Retention
- ♦ Avoided Reservoir Sedimentation



InVEST Scenarios

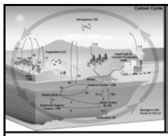


'During Remediation' Scenario

- ♦ 82 acres modeled as 'Barren' land

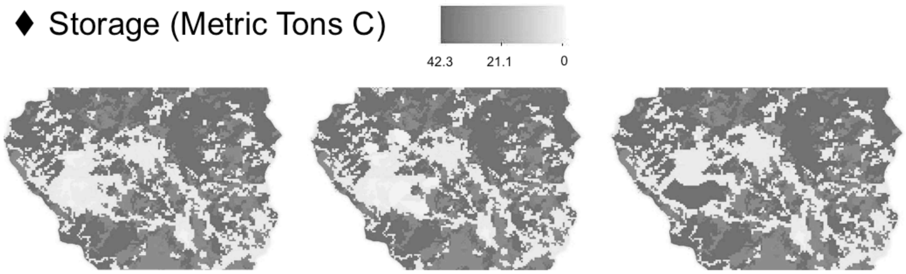
'After Remediation' Scenario

- ♦ 83 acres modeled as 'Grassland'
- ♦ 75 acres modeled as 'Evergreen Forest'

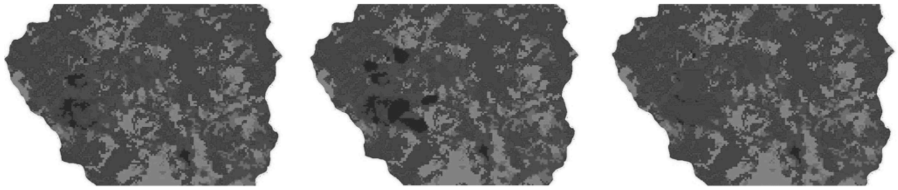


Carbon Storage Results

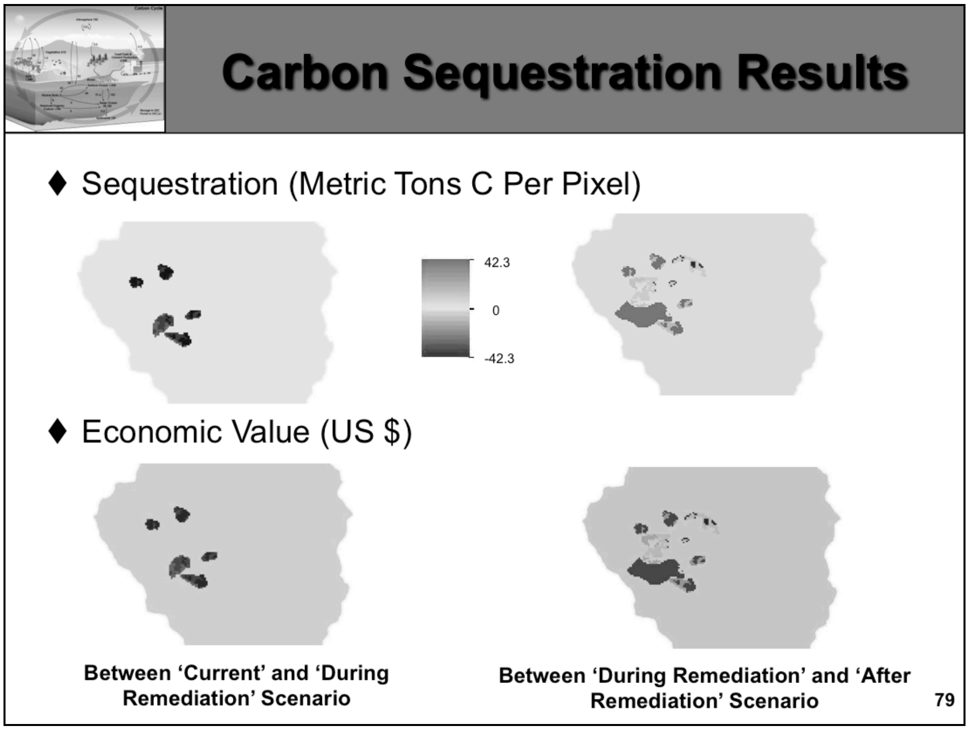
- Storage (Metric Tons C)



- Economic Value (US $)



'Current' Scenario **'During Remediation' Scenario** **'After Remediation' Scenario**

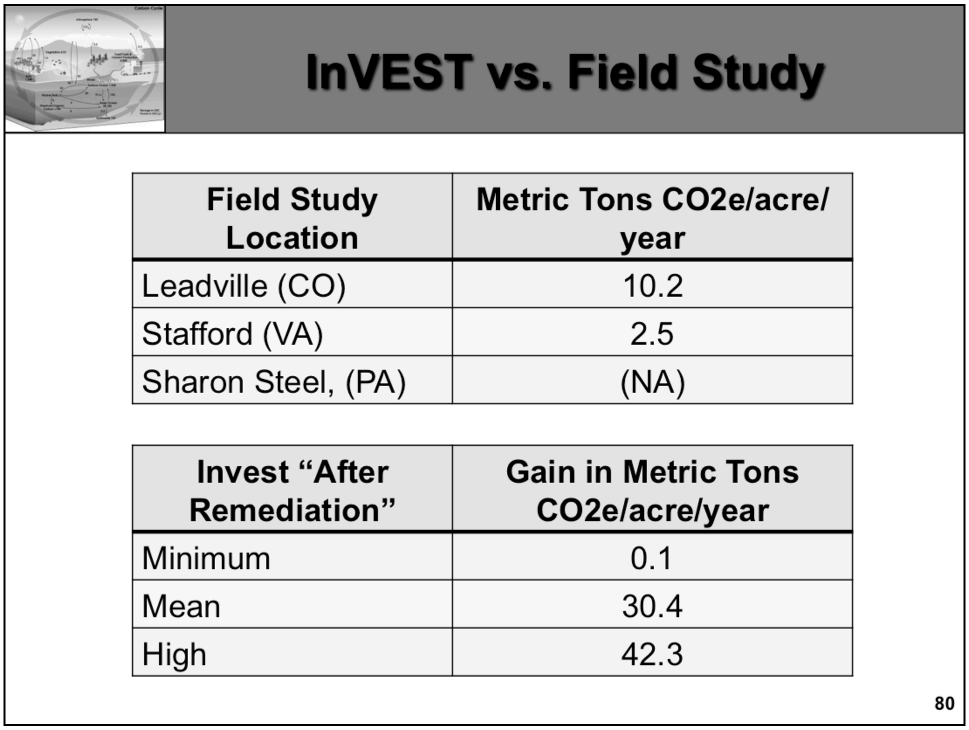


Carbon Sequestration Results

- ♦ Sequestration (Metric Tons C Per Pixel)
- ♦ Economic Value (US $)

Between 'Current' and 'During Remediation' Scenario

Between 'During Remediation' and 'After Remediation' Scenario



InVEST vs. Field Study

Field Study Location	Metric Tons CO2e/acre/ year
Leadville (CO)	10.2
Stafford (VA)	2.5
Sharon Steel, (PA)	(NA)

Invest “After Remediation”	Gain in Metric Tons CO2e/acre/year
Minimum	0.1
Mean	30.4
High	42.3

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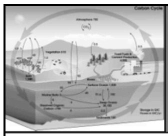

Internet Resources

- ♦ Ecotools website (www.cluin.org/ecotools)
- ♦ Green Remediation Focus Area website (www.cluin.org/greenremediation)

- ♦ Superfund & Green Remediation website (www.epa.gov/superfund/greenremediation)
- ♦ Green Remediation Methodology website (www.clu-in.org/greenremediation/methodology/index.cfm)

Resources & Feedback

- To view a complete list of resources for this seminar, please visit the **Additional Resources**
- Please complete the **Feedback Form** to help ensure events like this are offered in the future

U.S. EPA Technical Support Project Engineering Forum
Green Remediation: Opening the Door to Field Use Session C (Green Remediation Tools and Examples)
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