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Carbon Cycling and Storage in Semi-arid Environments

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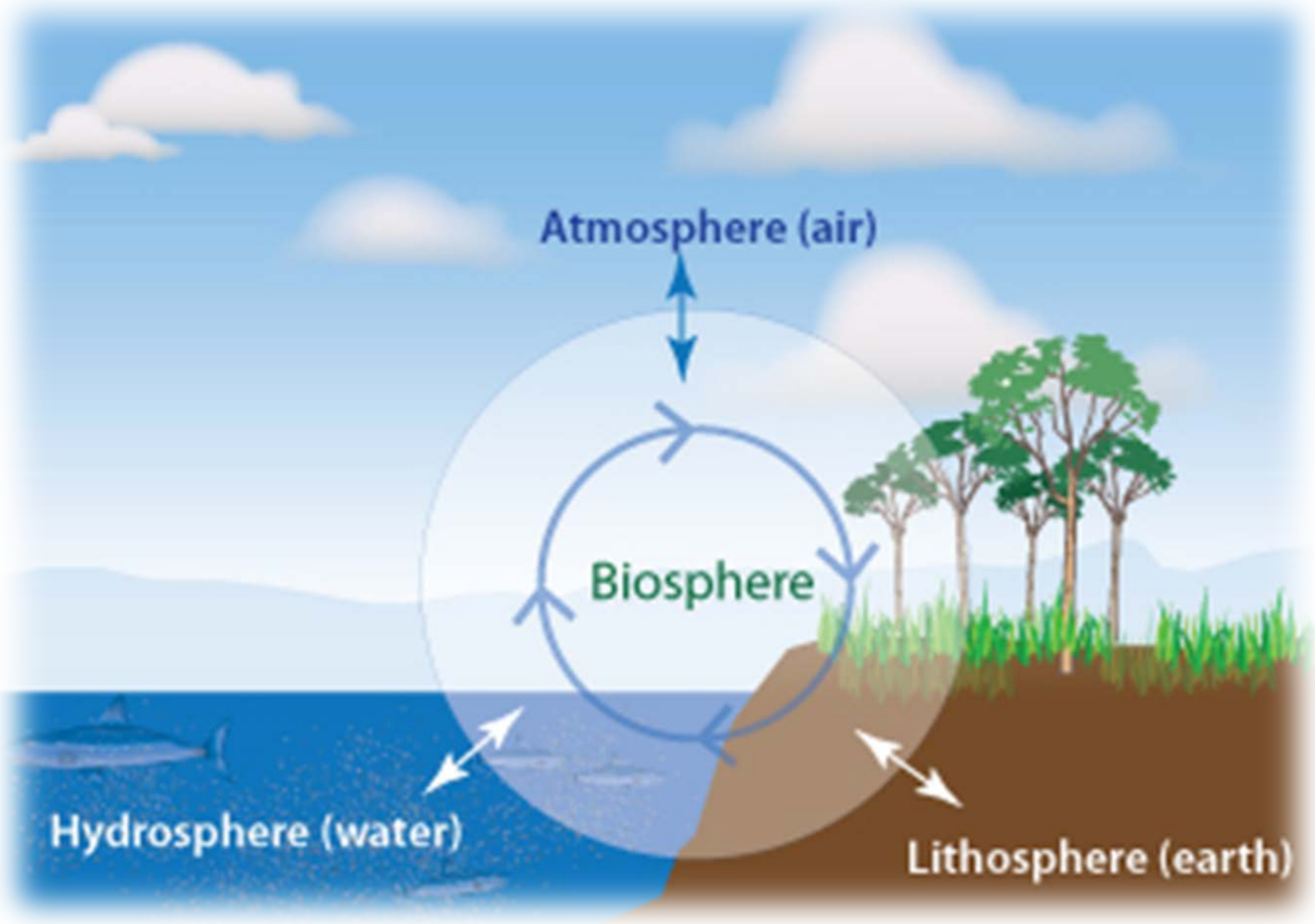
Photo: Hector Valencia

Global Carbon Cycle

Biogeochemical cycle by which C is exchanged between the *biosphere*, *geosphere (lithosphere)*, *hydrosphere*, and *atmosphere*



Global Carbon Cycle

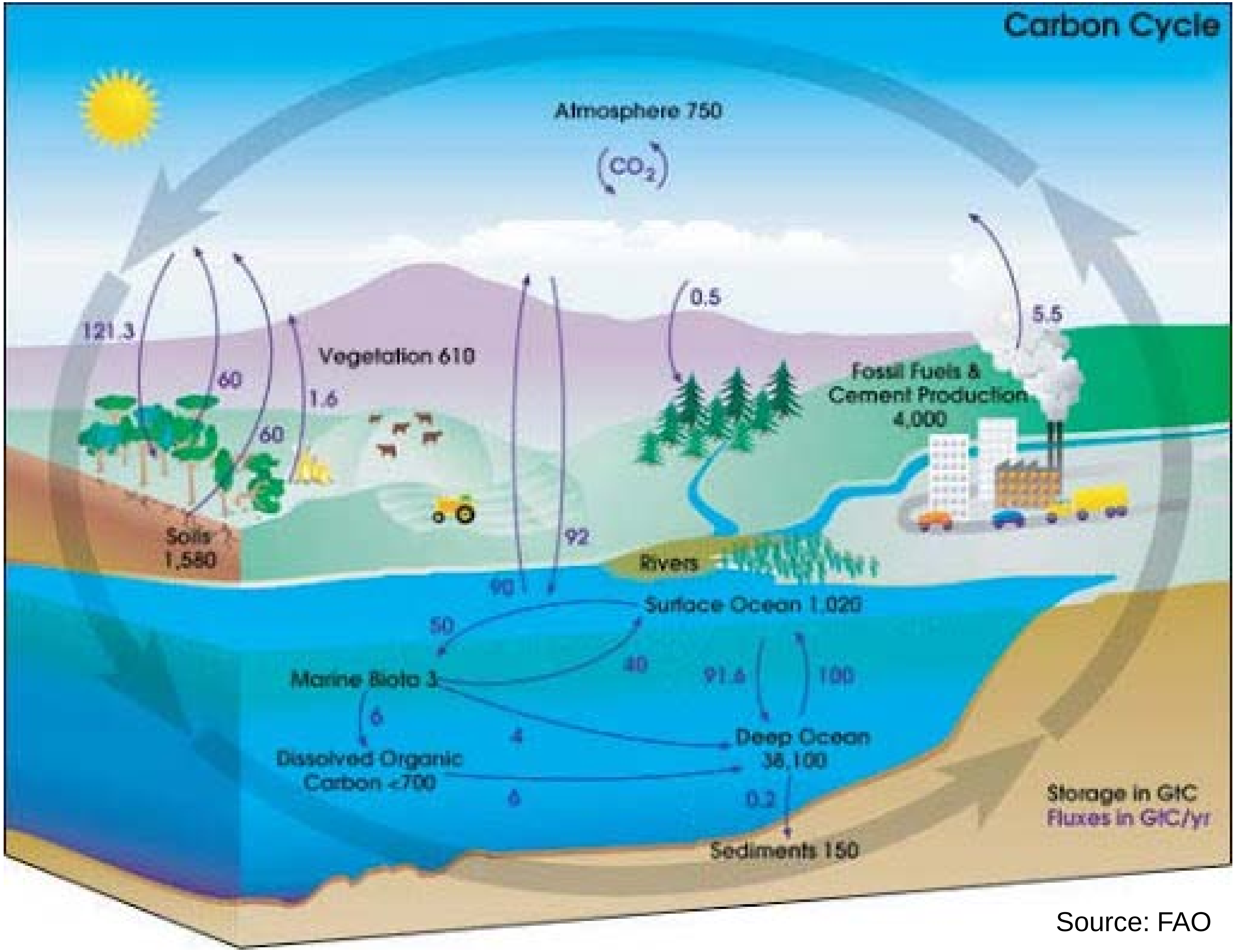
Sources (Gt C/year)

- Ocean release = 90
- Respiration = 60
- Decomposition = 60
- Fossil fuel = 9.3
- Deforestation = 1.0
- *TOTAL SOURCES* = 220.3

Sinks (Gt C/year)

- Photosynthesis = 120
- Ocean uptake = 92.7
- Soil = 0
- *TOTAL SINKS* = 212.7

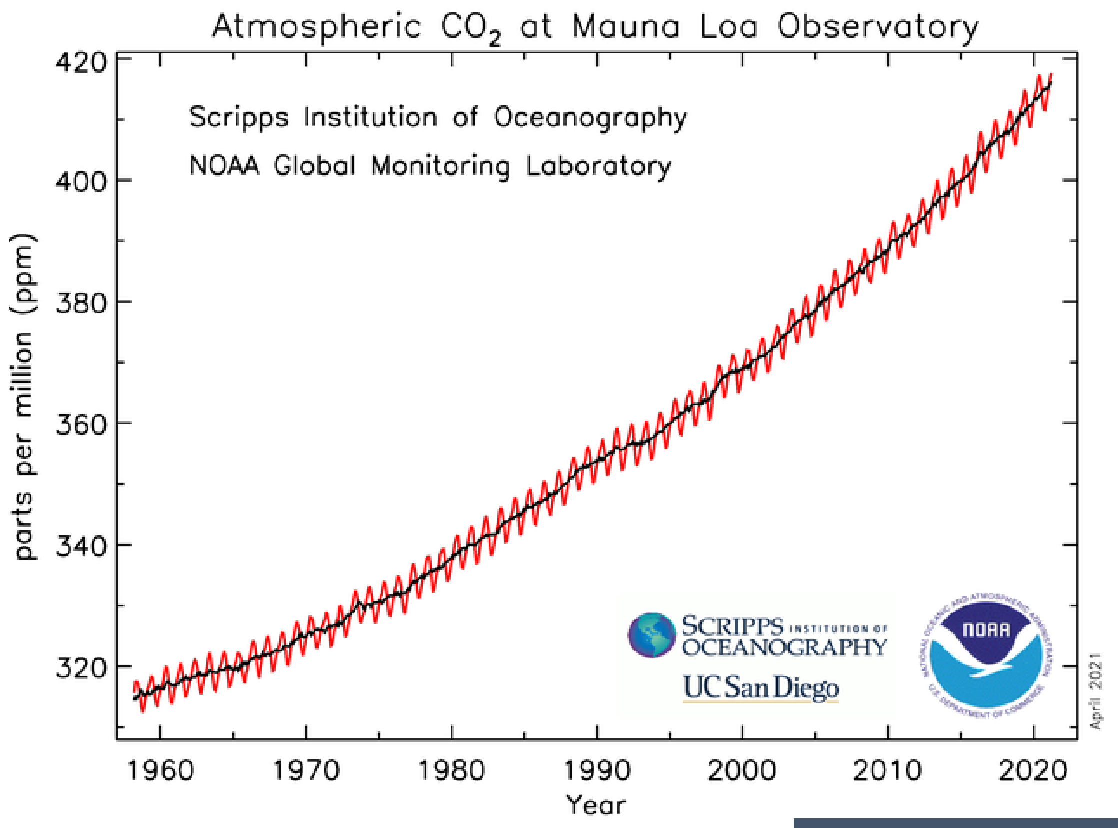
SOURCES – SINKS = 7.6 Gt C added to atmosphere annually

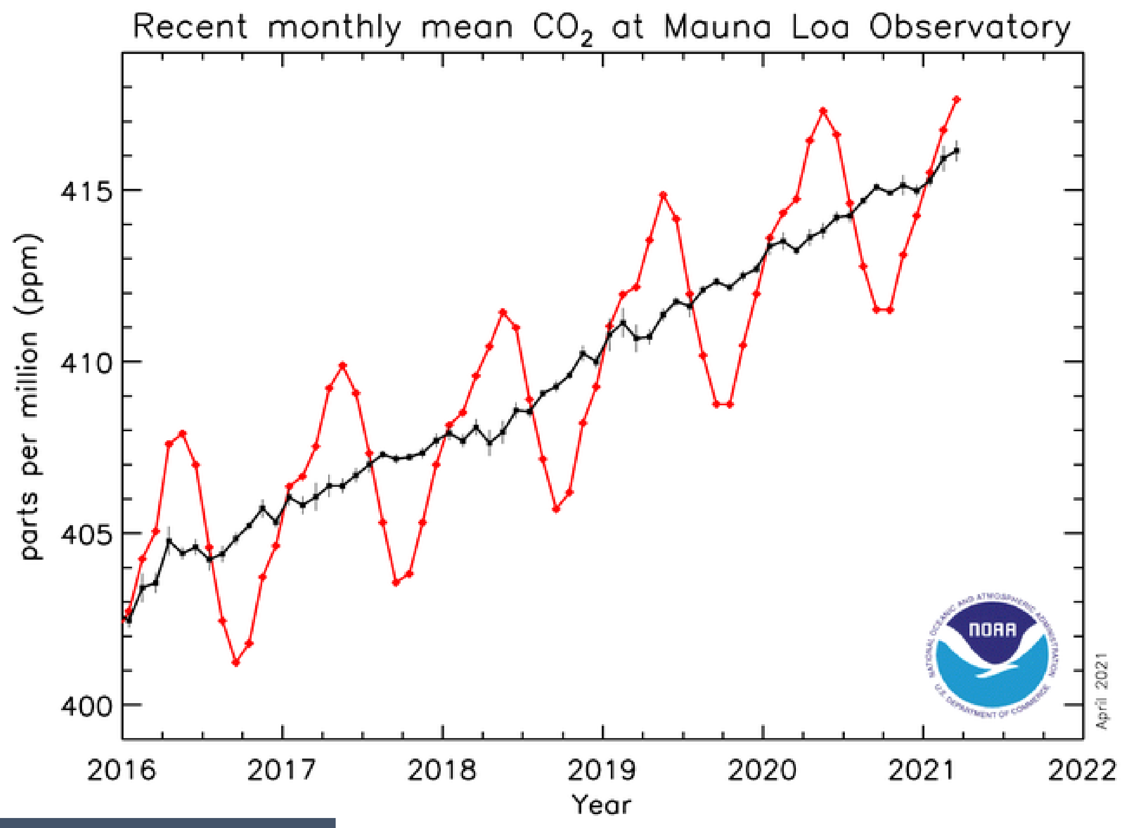


Source: FAO

Global Carbon Cycle

- *SOURCES* – *SINKS* = 220.3 – 212.7 = 7.6 Gt C added to atmosphere annually
- Atmospheric pool increases by 4.5 Gt C annually

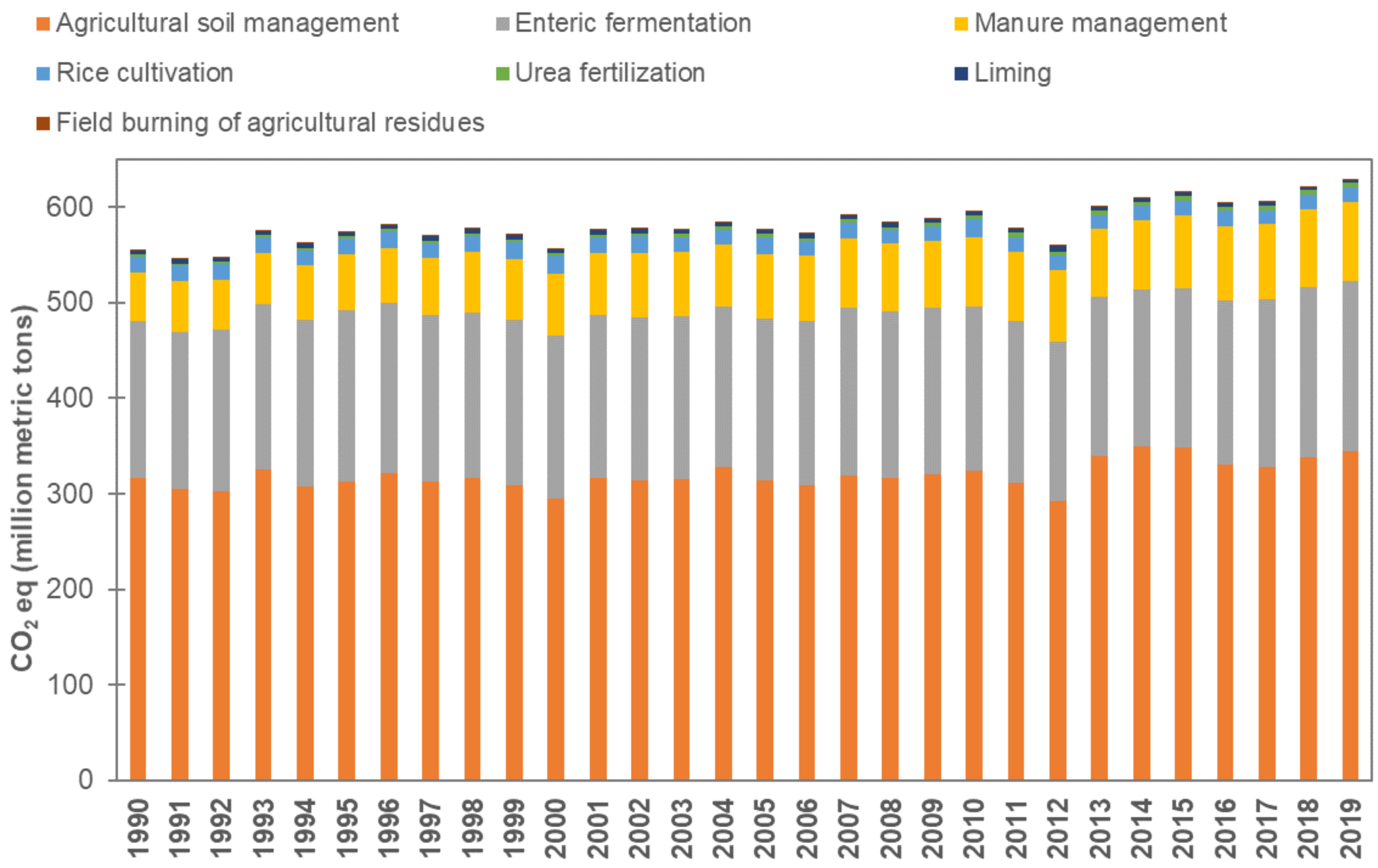




May 2021: 419.13 ppm

May 2020: 417.31 ppm

Greenhouse Gas Emissions (CO_2, N_2O, and CH_4 as CO_2 equivalents)



Agriculture accounts for 10% of total U.S. greenhouse gas emissions.

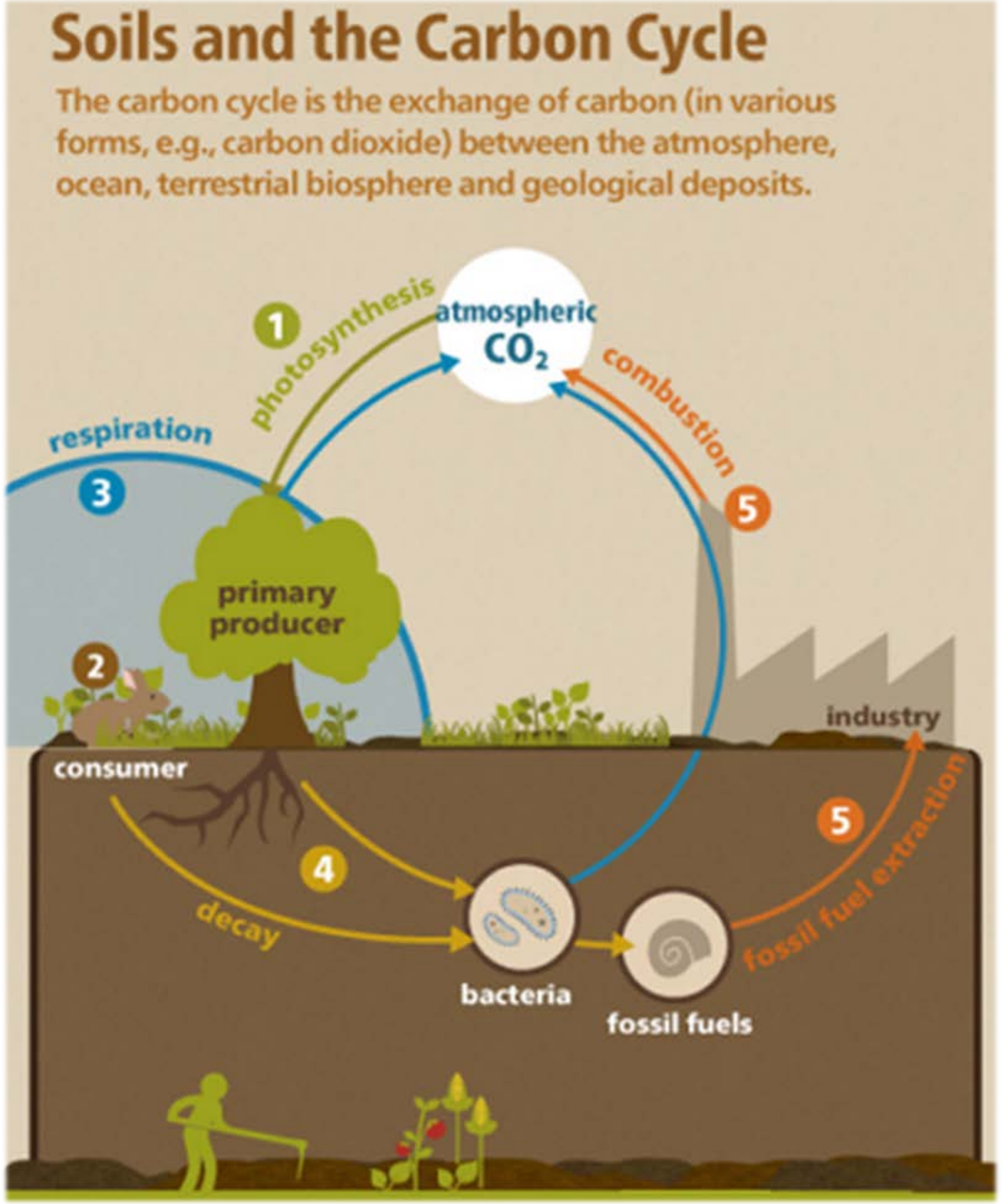
Global Carbon Cycle

- Soil is a major C reservoir, but it could have (may be) the potential to be a sink
  - *Sink* is accumulating C
    (e.g., ocean or atmosphere)
  - *Reservoir (soil)* is not actively accumulating C

    Photosynthesis (120 Gt C/year) =

    Respiration (60 Gt C/year)
    +
    Decomposition (60 Gt C/year)

- Soil organic C (OC) = 1500 Gt C
  - More C than the atmosphere
    (800 Gt C) and terrestrial vegetation (500 Gt C) combined

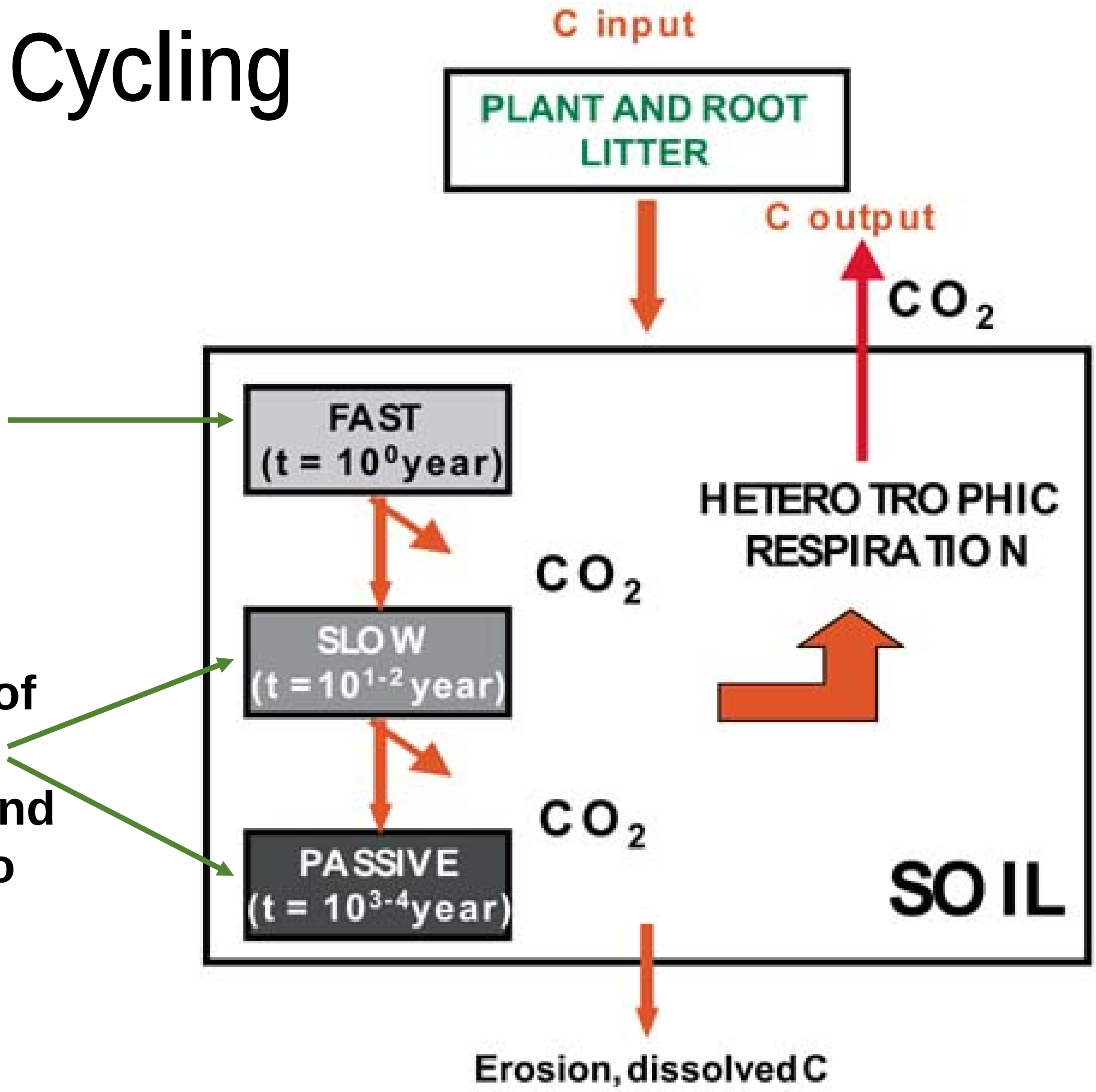


Source: FAO

Soil OC – Cycling

Particulate OC

Physical stabilization of C within aggregates and attachment to minerals

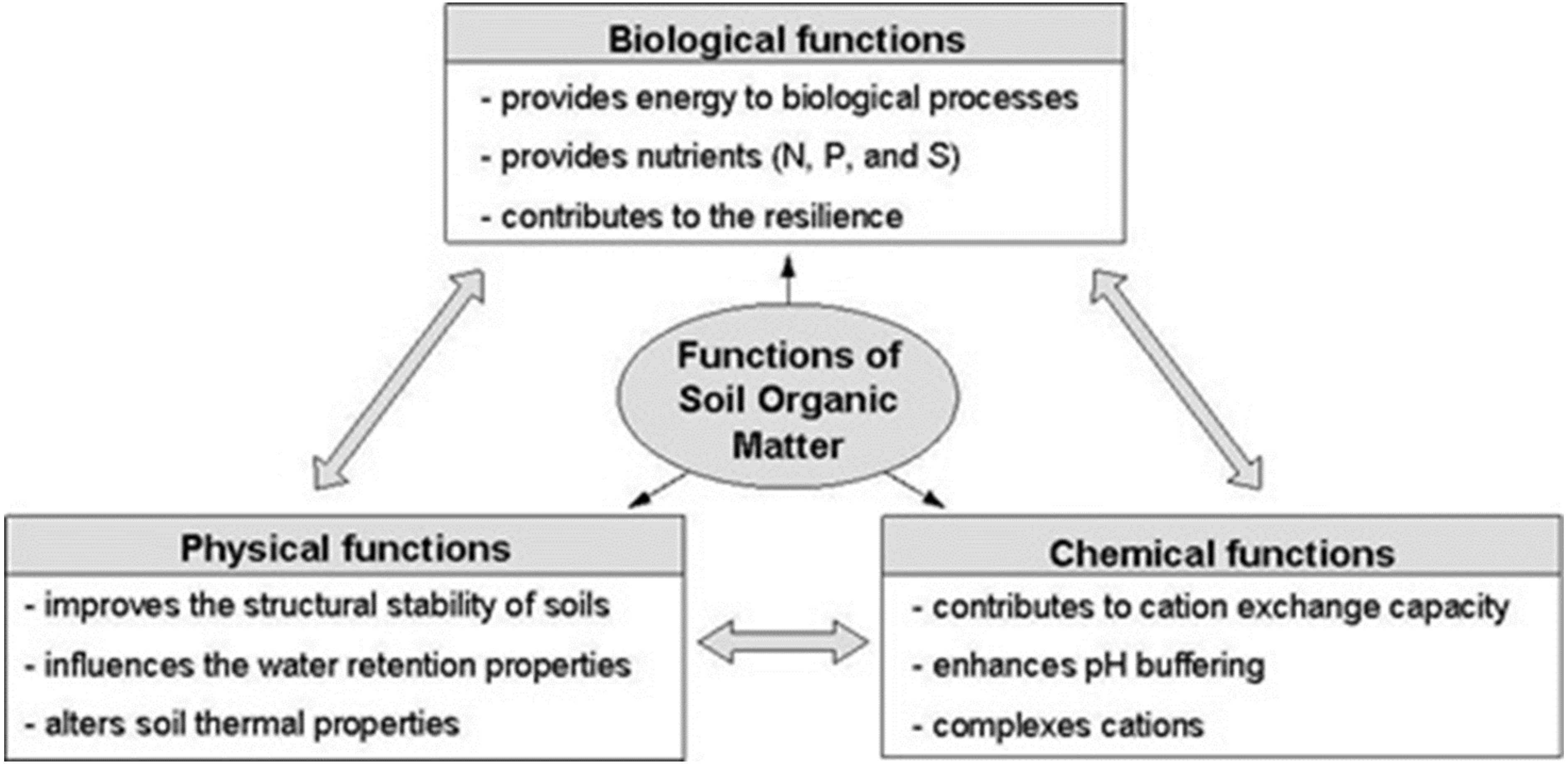


Source: FAO

- Dynamic reservoir – constantly changing due to microbial cycling of soil organic matter (C mineralization)
  - Pools are not created equally
    - Particulate OC (checking account – quick to change)
    - Mineral-associated OM (saving account – slower to change)

Soil OC – Ecosystem Services

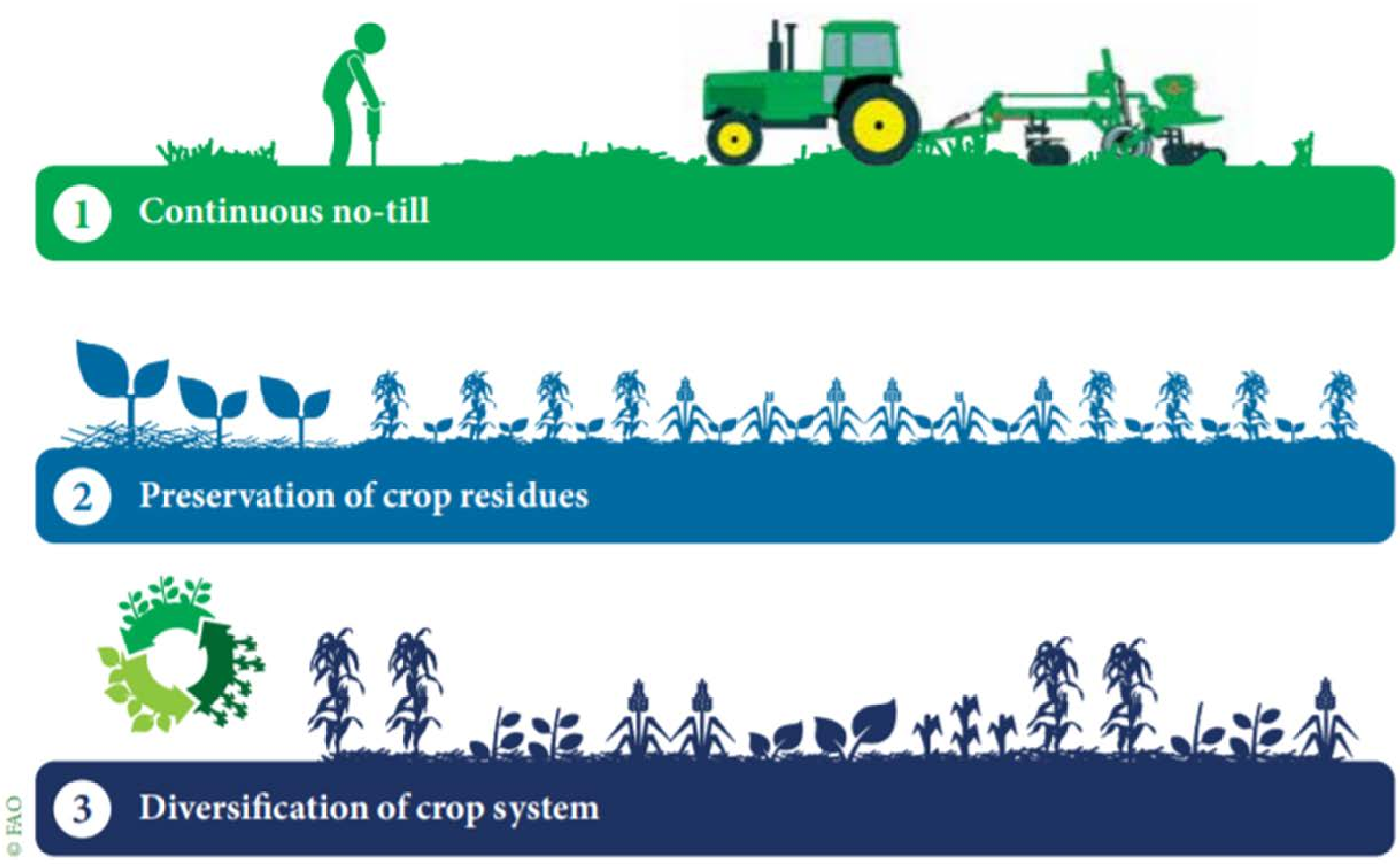
- Functions/benefits are the result of SOM (and SOC) mineralization
  - Quantity added is not indicative of benefits



Soil OC – Managing to Increase Stocks

- Anthropogenic impacts on soil can turn it into either a net sink or net source (lost as C gas)
- C Source: greenhouse gases (GHG) including CO_2 and CH_4
  - CO_2 is most abundant C gas in atmosphere
    - Autotrophic and heterotrophic respiration of CO_2 is second largest terrestrial C flux
  - CH_4 is a 28x more potent GHG than CO_2
    - Released during decomposition of OM under anaerobic conditions (methanogensis)
- Sink or SOC storage in soil involves three stages:
  1. Removal of CO_2 from the atmosphere via plant photosynthesis
  2. Transfer of C from CO_2 to plant biomass
  3. Transfer of C from plant biomass to soil where it is stored as SOC in the most labile pool
- Managing to increase SOC stocks requires looking beyond just capturing atmospheric CO_2 – must find ways to retain C in the slow SOC pool

Soil OC – Managing to Increase Stocks



- Soils depleted of SOC have greatest potential to gain C
- Most soils are far from C saturation threshold
- Potential for increased C inputs and management that protects C stocks to maximize C storage

Soil OC – Measuring, Reporting and Verifying

- C cycling and storage is more active in topsoil
- Stabilized C with longer turnover times makes up a greater proportion of SOC found deep in soil
- Soils at deeper depths have greater capacity of storing additional C
- To more accurately determine C stocks, deep cores will be required
- Reporting systems need to ensure that data collected are:
  - Transparent – documentation is sufficient and clear to allow any stakeholder to understand how data was collected
  - Consistent – methodologies differences should not exist
  - Comparable – one country, state, county, or farm to another
  - Accurate – neither over- or underestimated

Soil OC – Additional Thoughts on C Budgeting

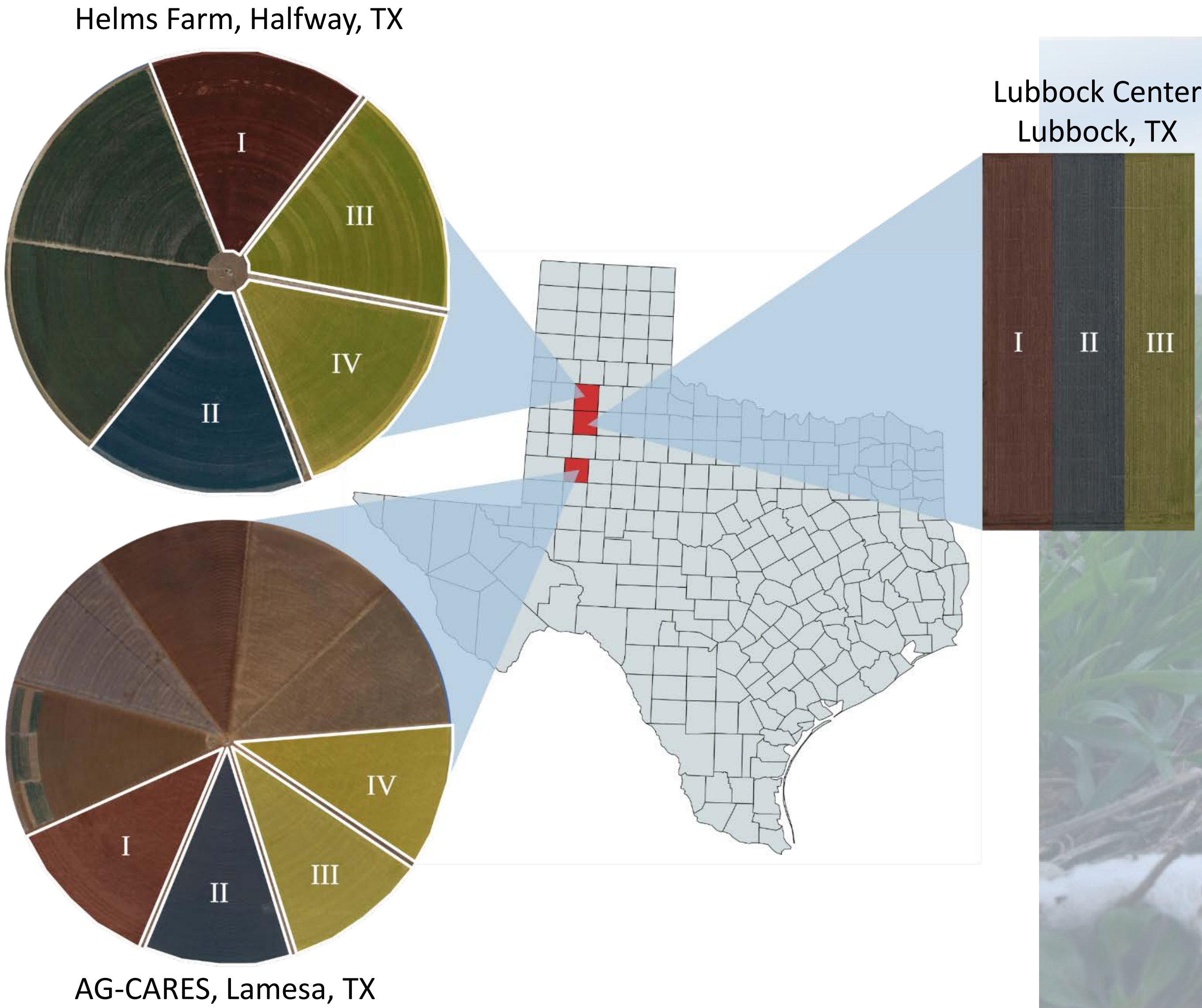
- Additionality – potential to penalize early adopters of conservation practices; this cannot happen, early adopters must be credited for C
- Verification – modeling or actual C measurements… balance between the two, possibly paid for C capture rather than C stock increases
- Data collection –
  - Who is responsible?
  - Time required to collect samples/data on that scale
  - Methods to determine OC (e.g. dry combustion vs. loss on ignition OM)
  - Designated labs
- Stability of C – what happens if field is accidentally plowed (e.g. new tractor driver), and farmer has already been paid for the CO_2 sequestered?
  - N_2O and CH_4 are much more stable than CO_2 – could be paid for emissions that were never released

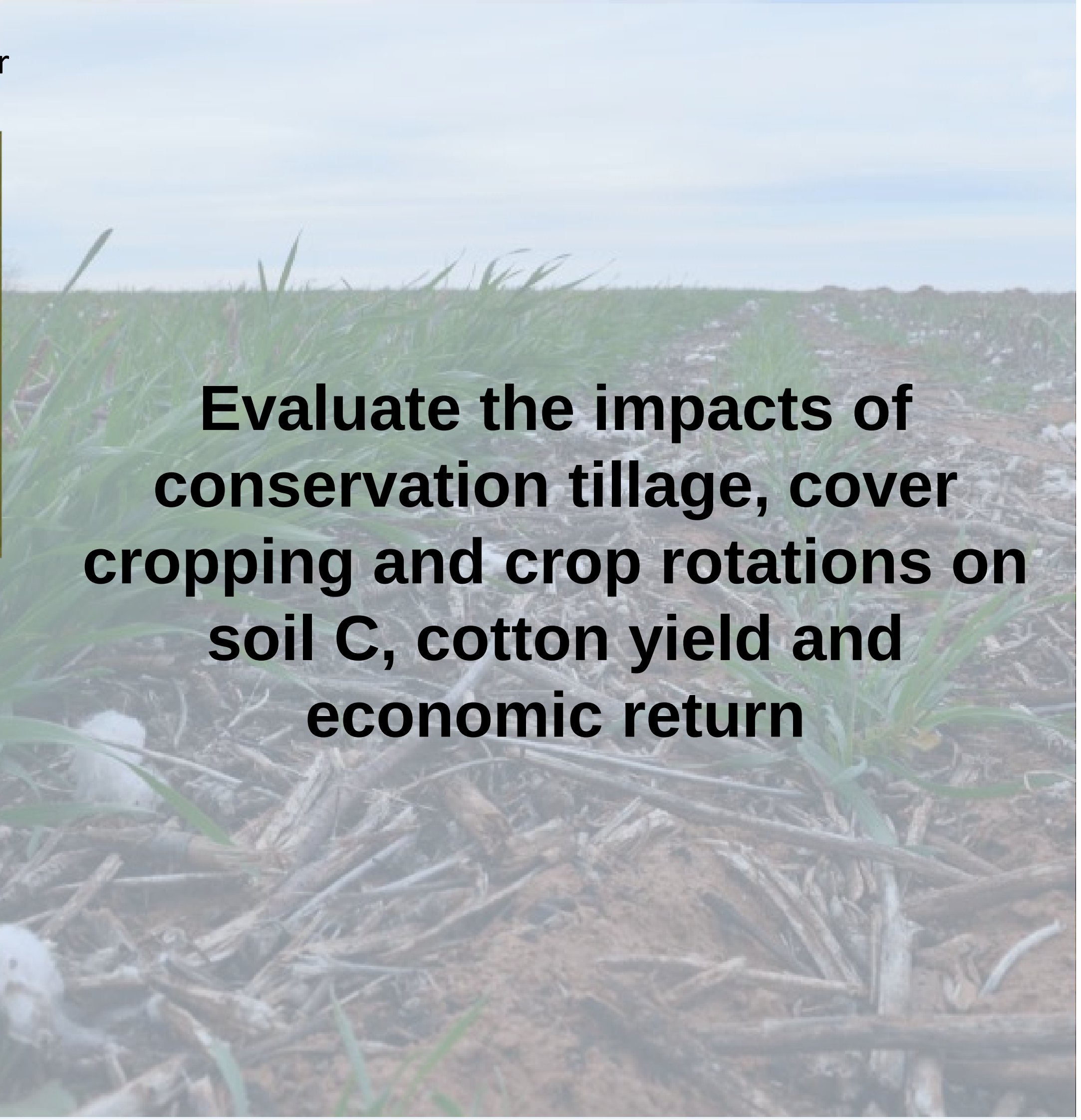
Texas A&M AgriLife Research

Carbon Storage Potential in Texas' High Plains

Katie Lewis, Associate Professor
Wayne Keeling and Paul DeLaune, Professors
Joseph Burke and Mark McDonald, GRA
Christopher Cobos, Research Associate

Conservation Management - Cotton Systems



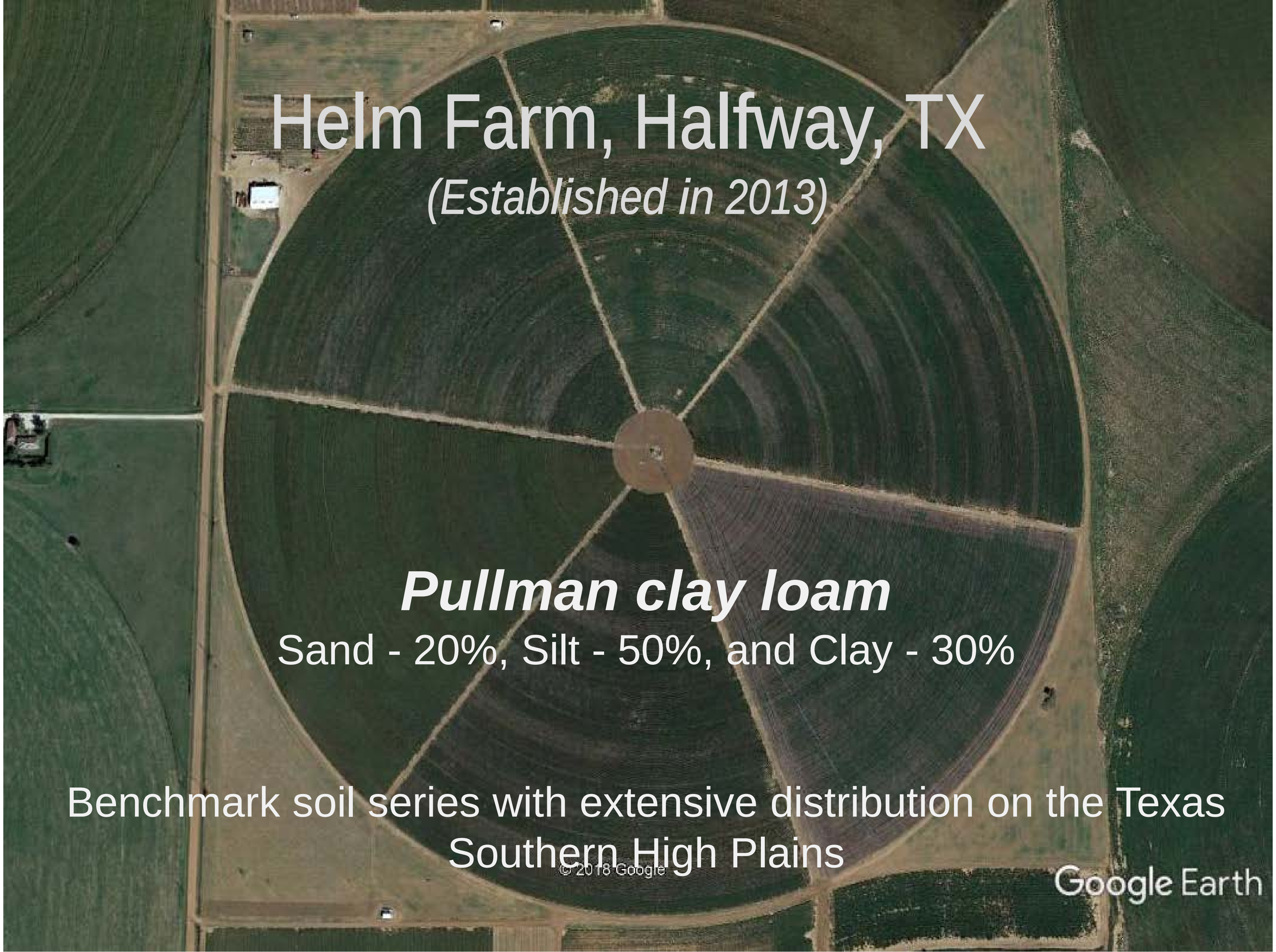


Evaluate the impacts of conservation tillage, cover cropping and crop rotations on soil C, cotton yield and economic return

Texas A&M AgriLife Research

Helm Farm, Halfway, TX

(Established in 2013)



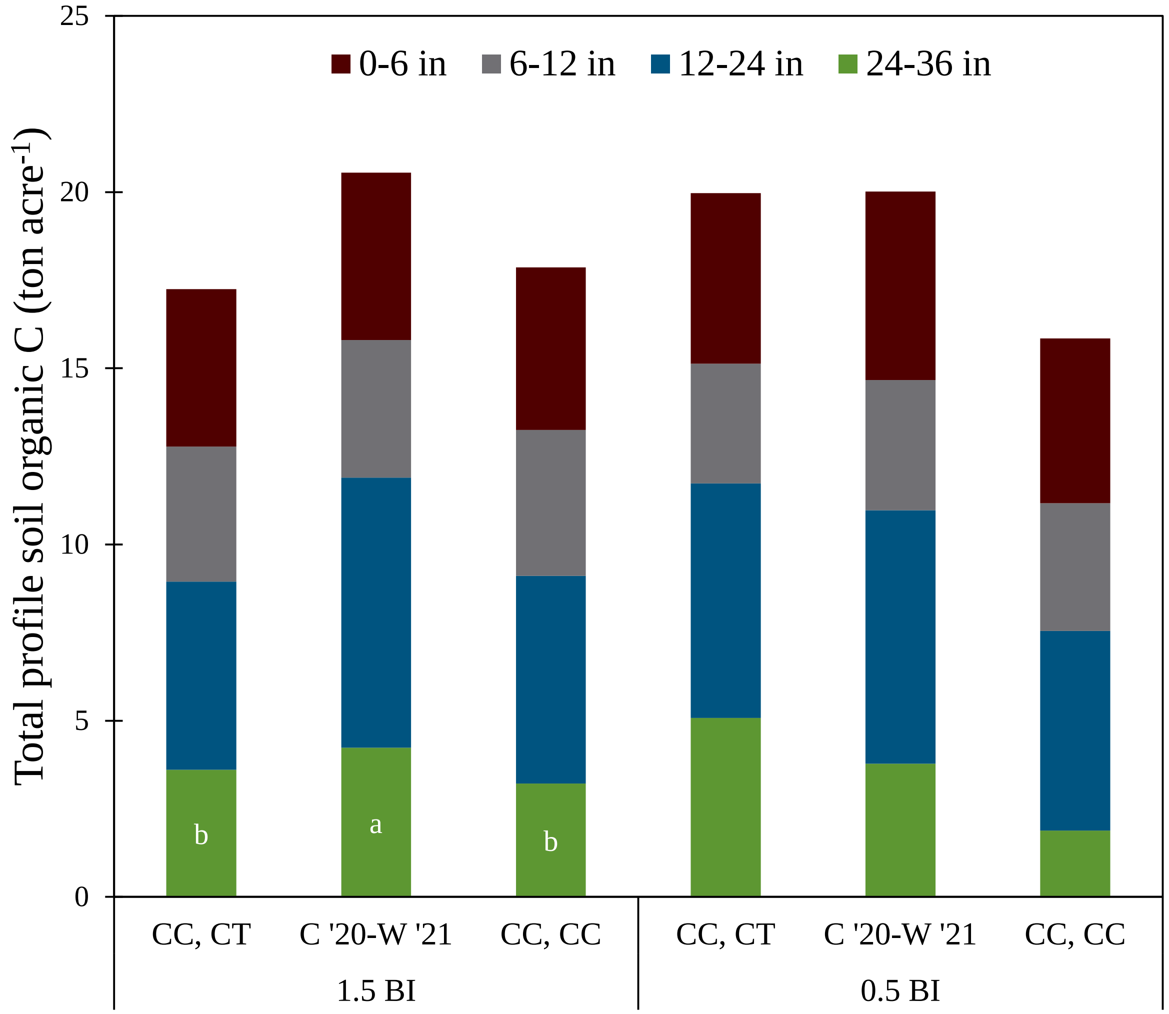
Pullman clay loam

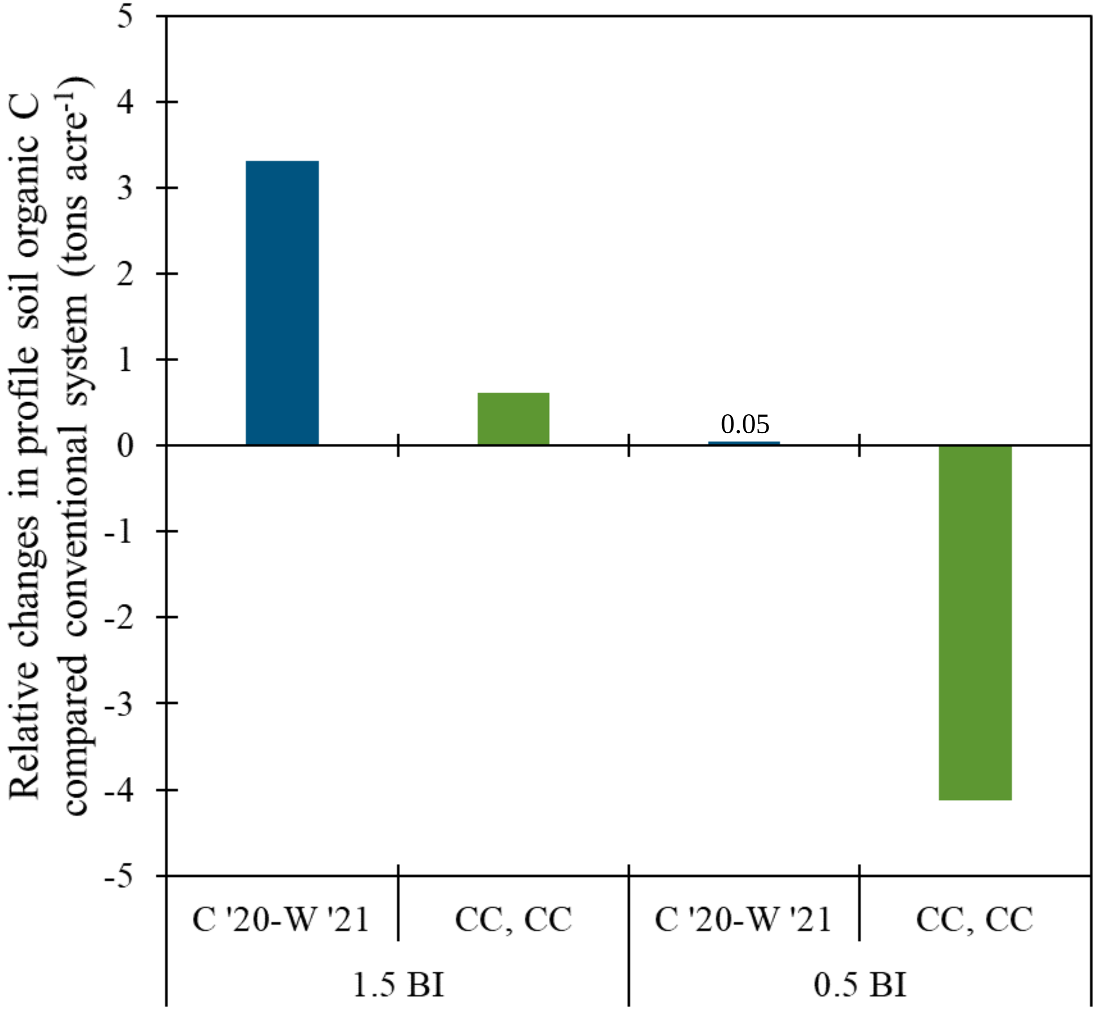
Sand - 20%, Silt - 50%, and Clay - 30%

Benchmark soil series with extensive distribution on the Texas Southern High Plains

Soil Organic C (Helm Farm, est. 2013)

Soil samples collected prior to planting cotton in 2020 at 4 depths (0-6”, 6-12”, 12-24”, and 24-36”)





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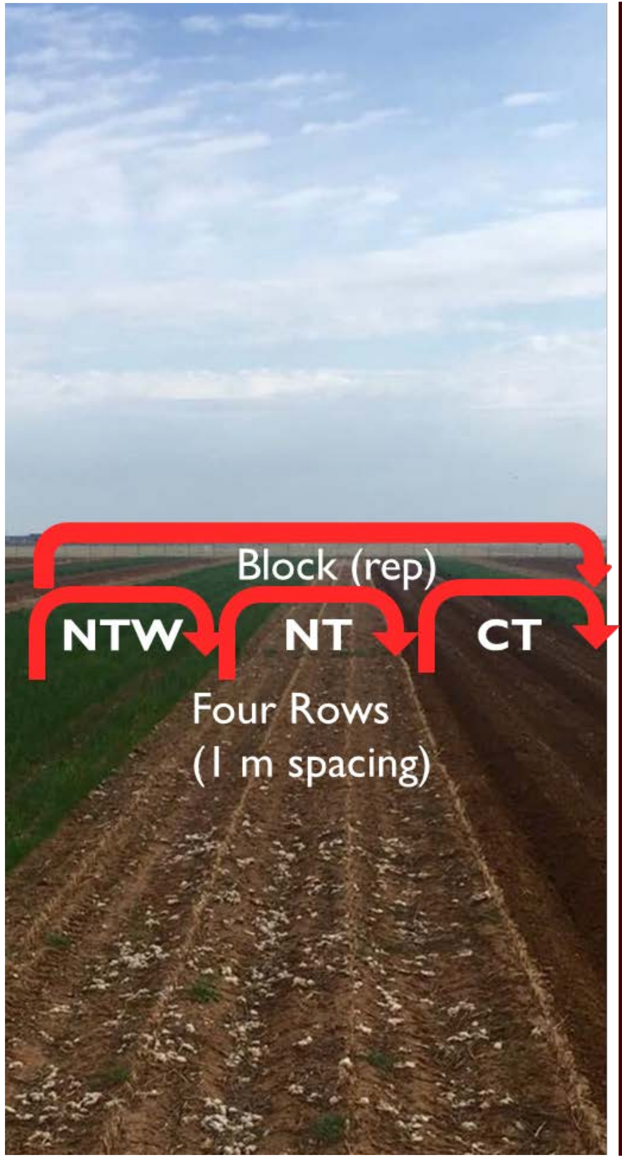
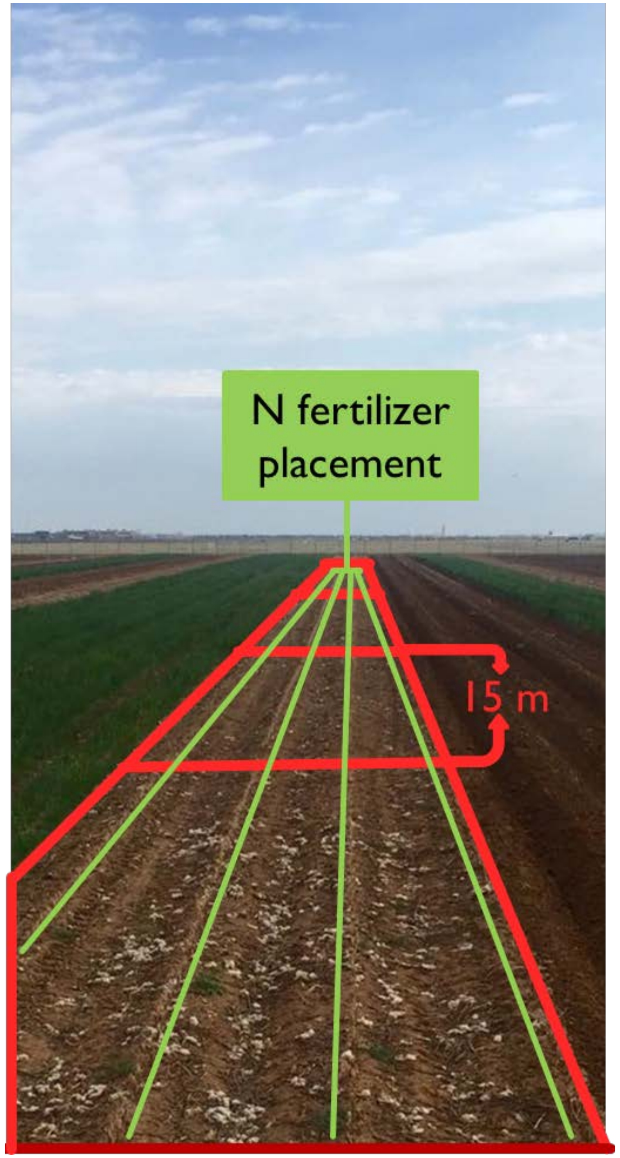


Research Center, Lubbock, TX

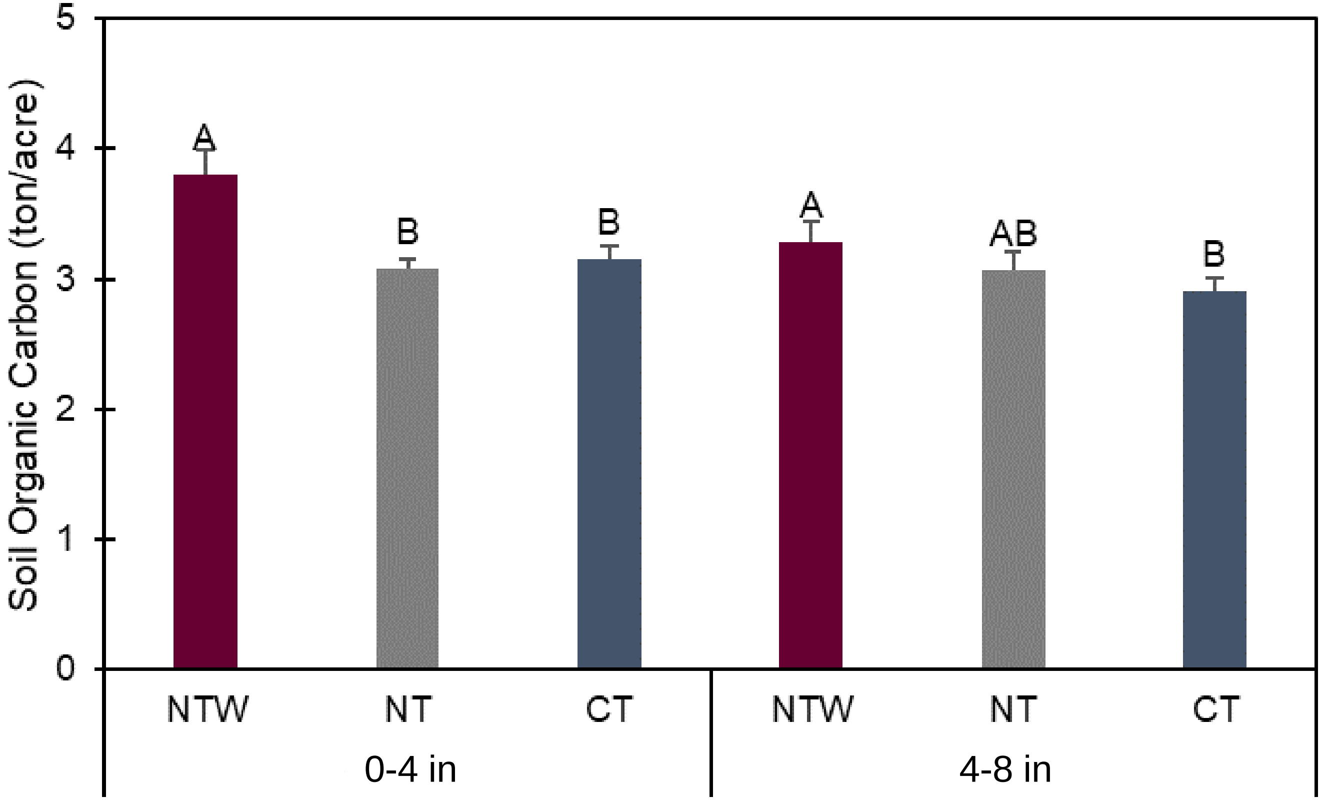
Est. 2015, Acuff loam

- Cover crops and no-tillage systems implemented in November of 2015
  - Site had been under conventional tillage for at least 60 years
- Study design – Split Plot (3 reps)
- Main plot: tillage systems
  - No-tillage with a winter wheat cover crop (NTW)
  - No-tillage winter fallow (NT)
  - Conventional tillage winter fallow (CT)
- Split Plot: nitrogen (N) treatments
  - 100% pre-plant (PP)
  - 40% pre-plant 60% side-dressed (SPLIT)
  - No-N control



Lubbock Research Center, Lubbock, TX

Est. 2015, Acuff loam



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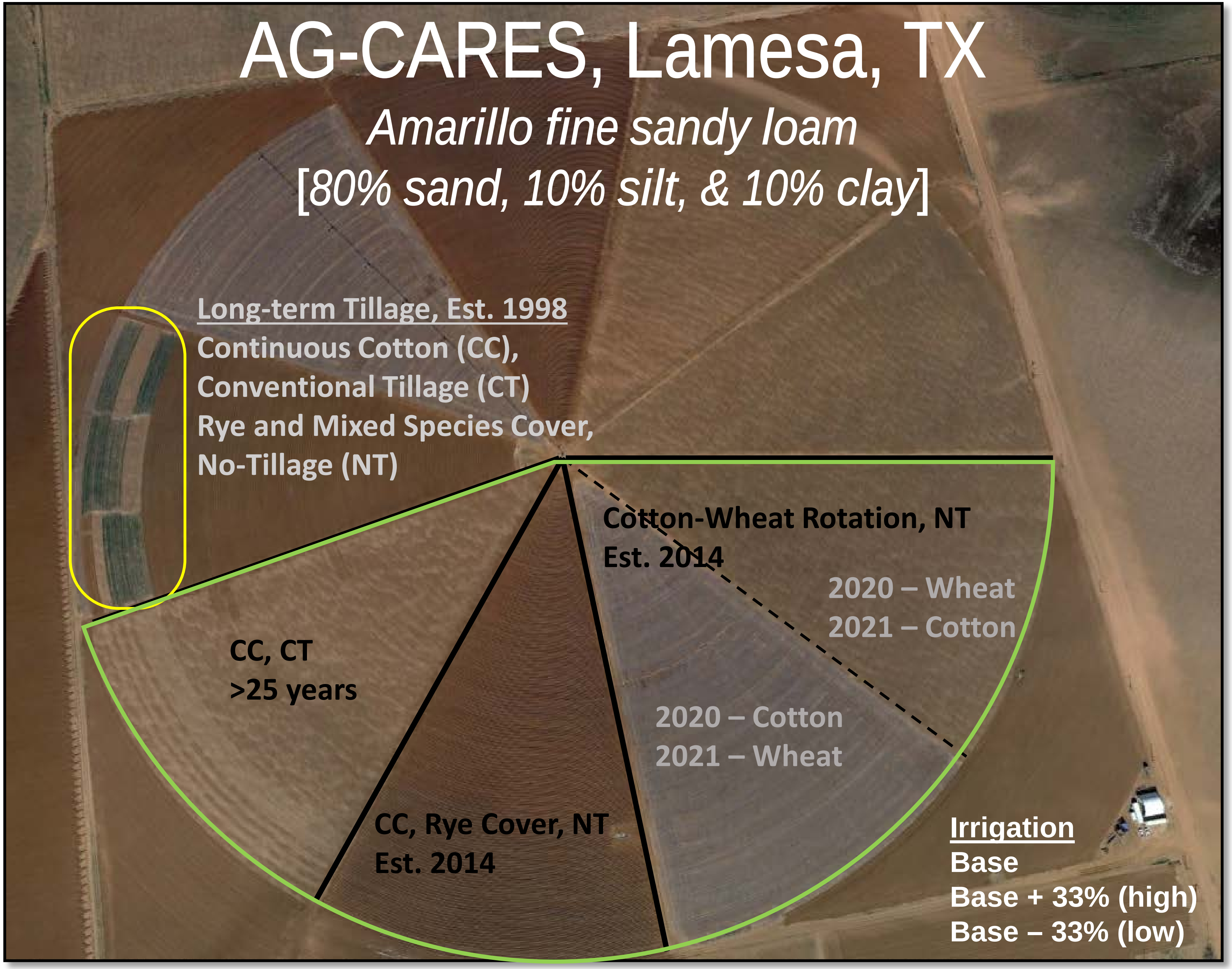
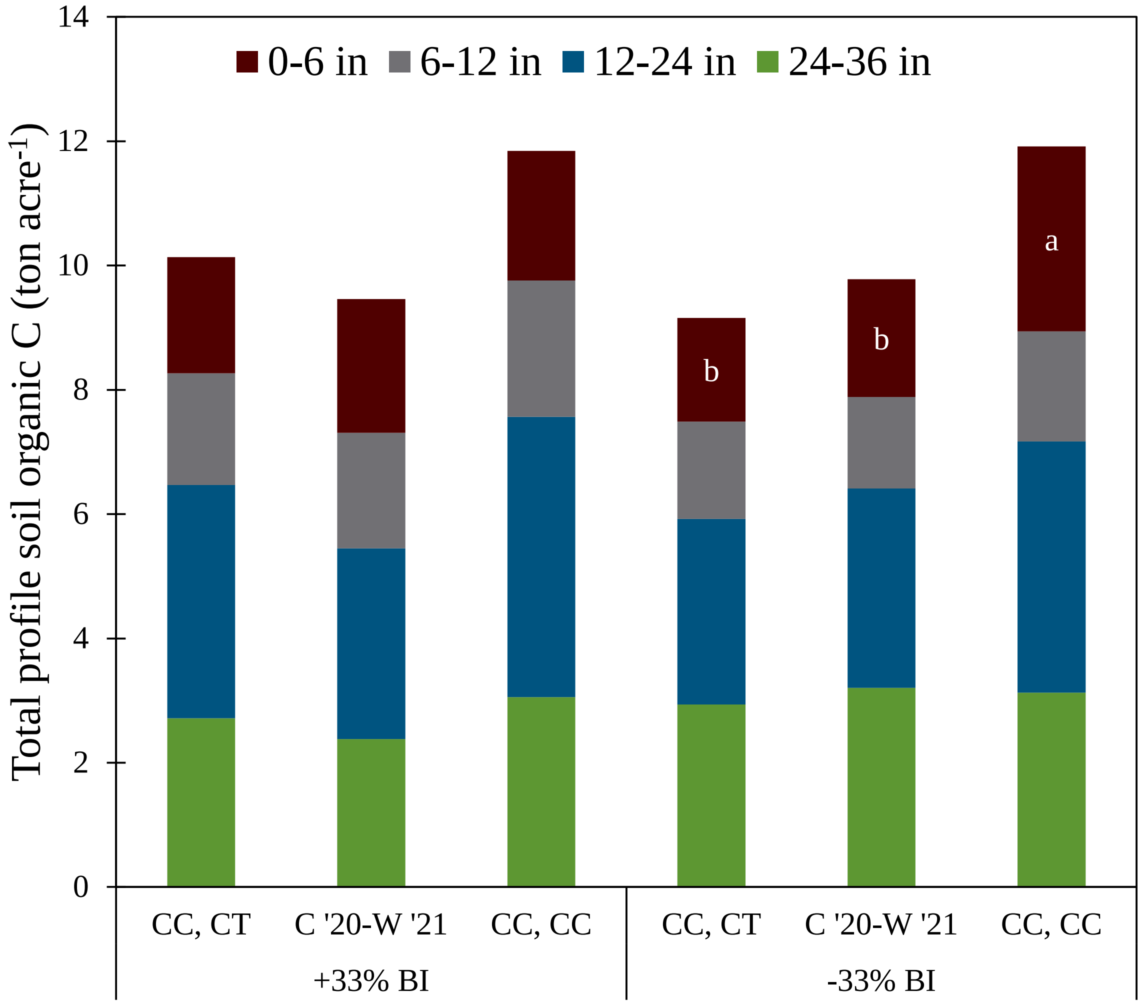
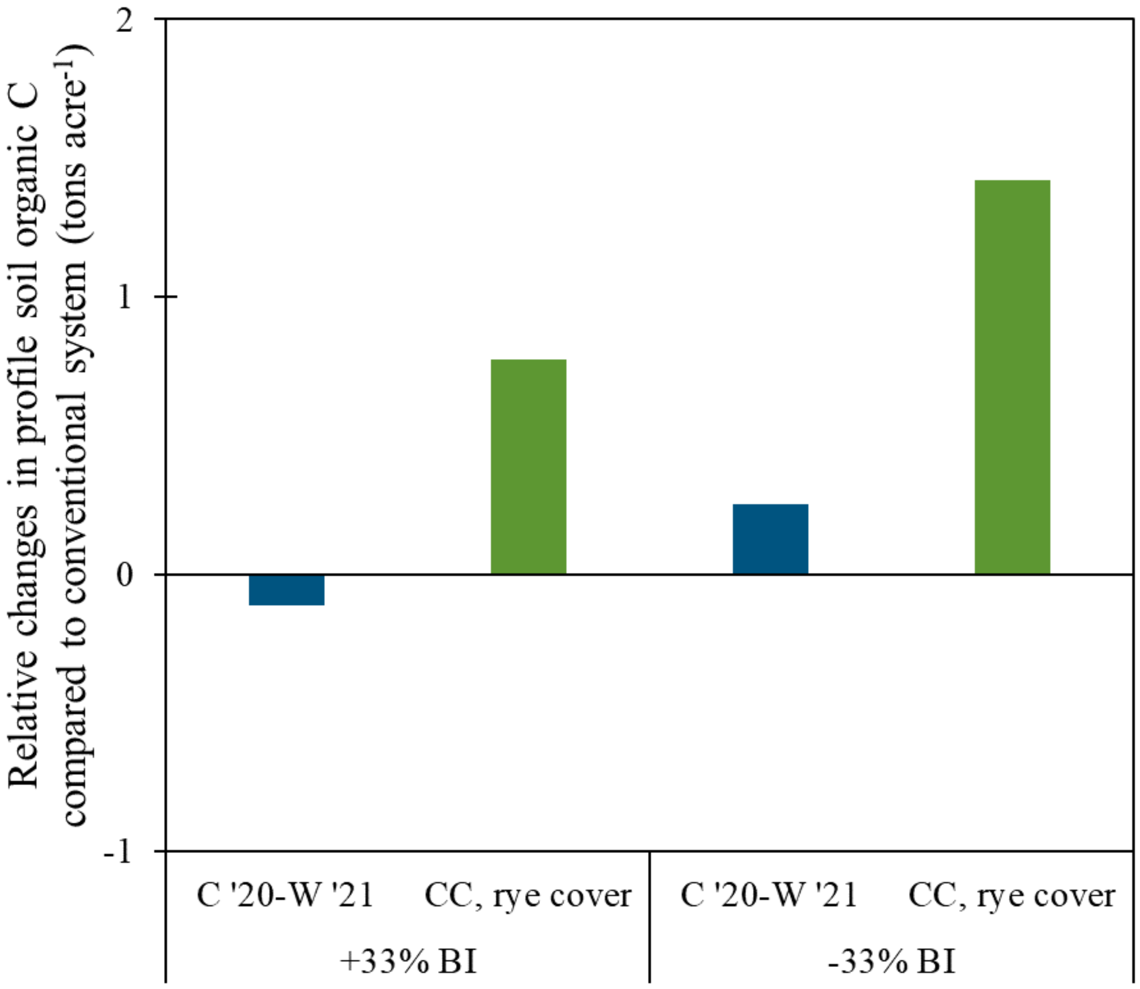
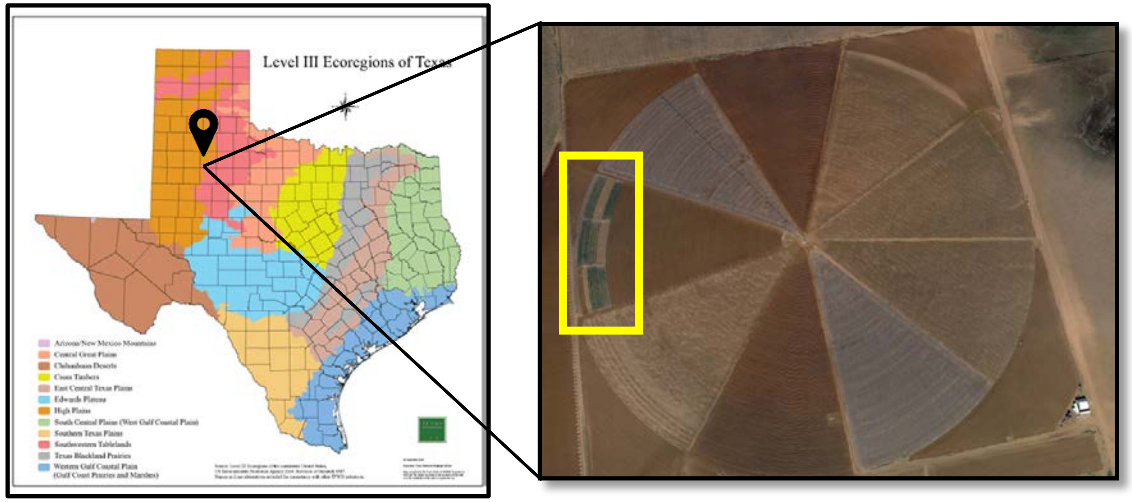


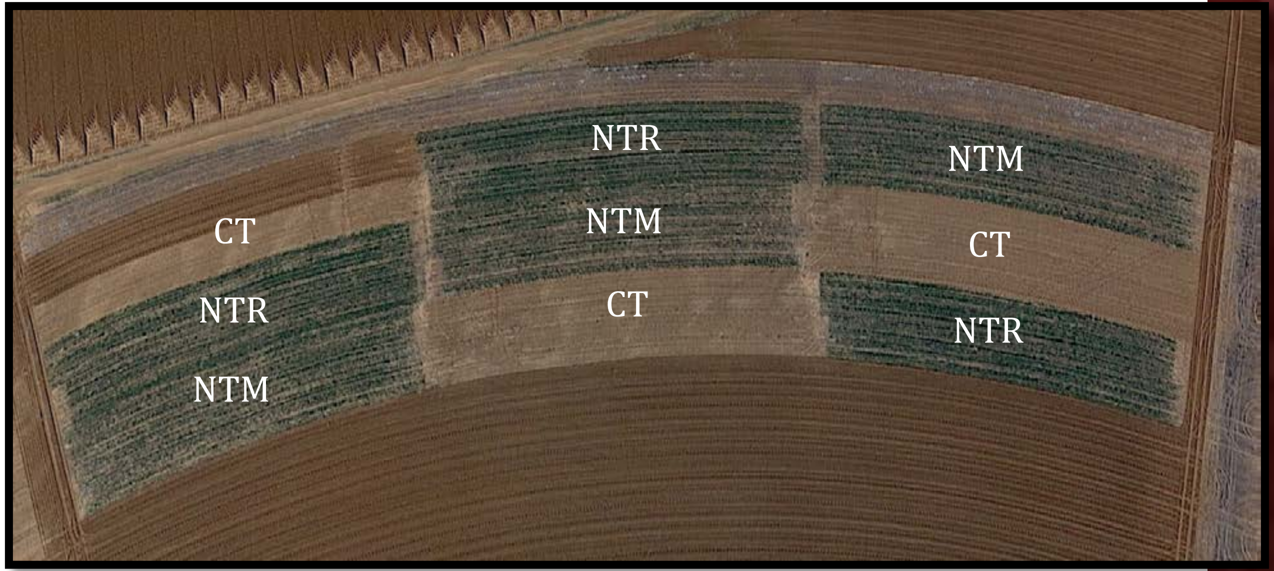
Soil Organic C (AG-CARES, est. 2014)





Longterm site





Research plot design at Ag-CARES in Lamesa, TX

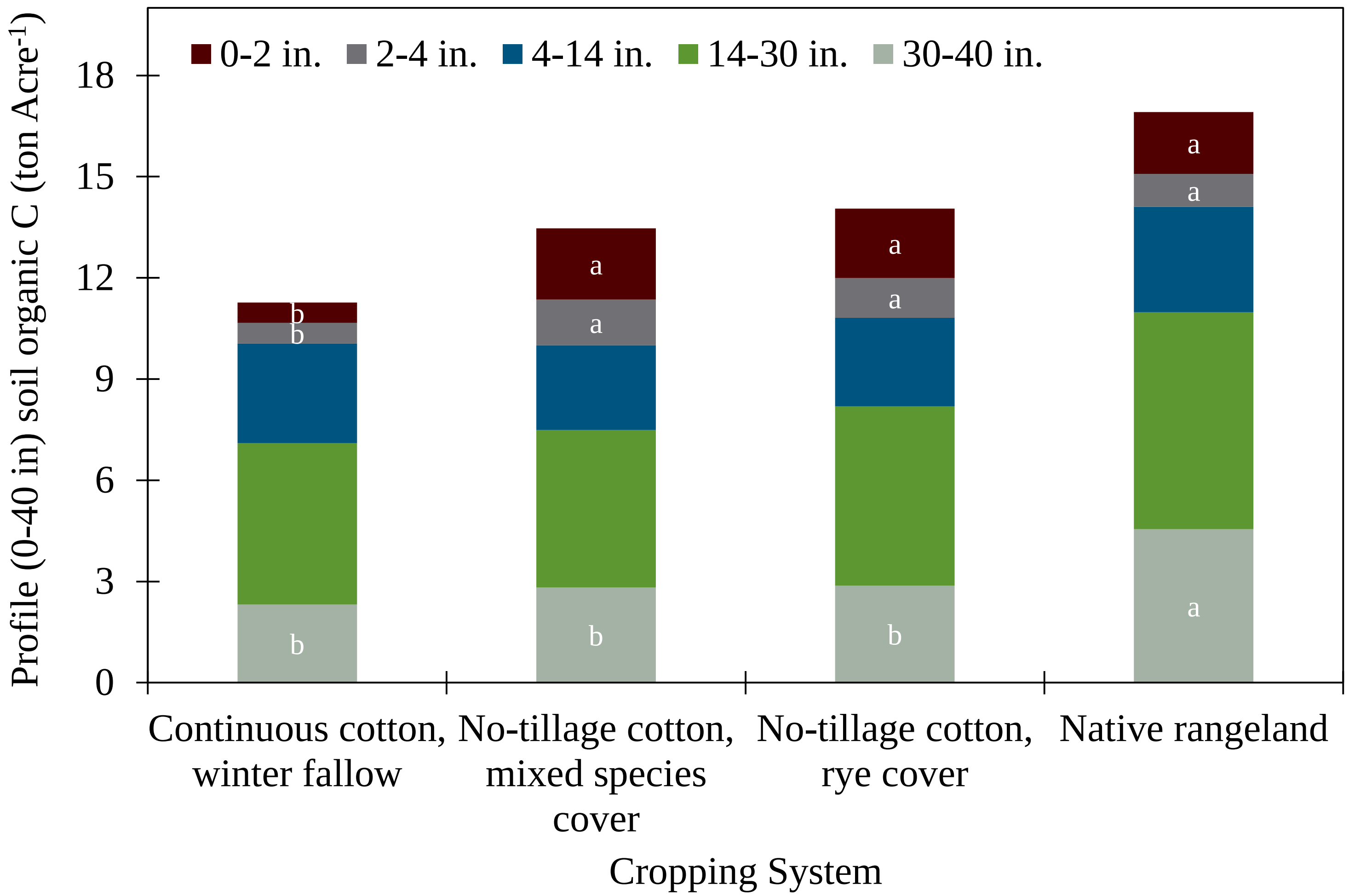
Evaluated systems

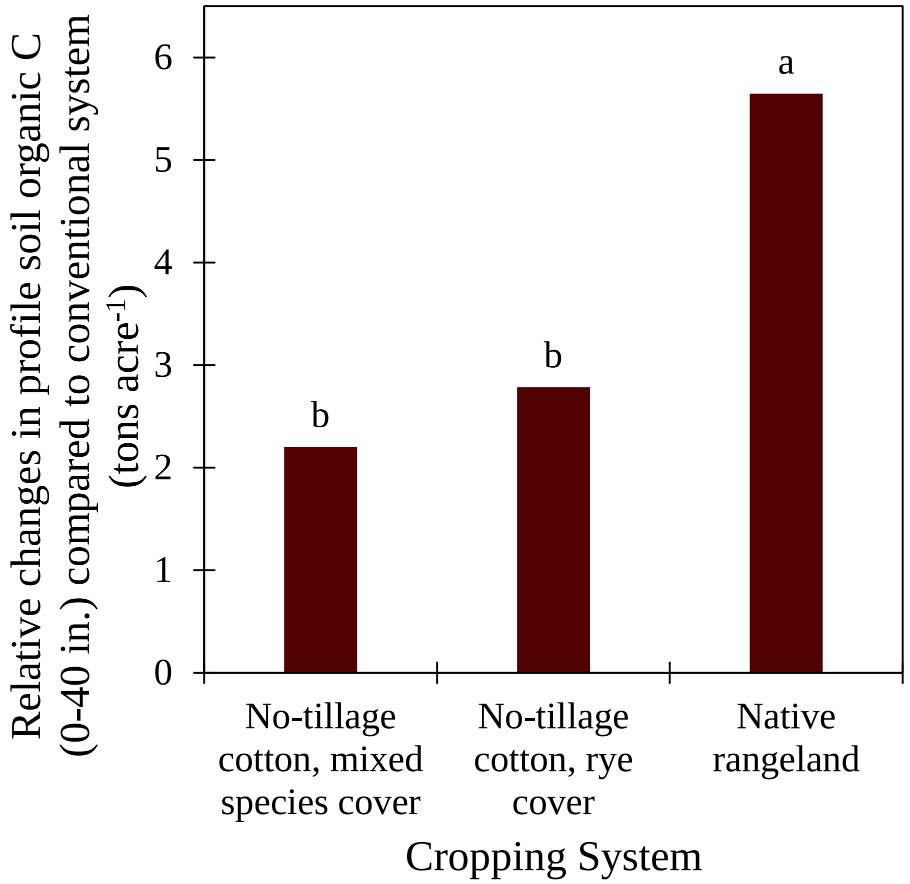
Continuous cotton systems – (est. 1998)

- Conventional tillage, winter fallow (CT)
- No-tillage, Rye cover (R-NT), 45 lb/acre
- No-tillage, Mixed cover (M-NT), 45 lb/acre
  - Rye (50%)
  - Austrian Winter Pea (33%)
  - Hairy Vetch (10%)
  - Radish (7%)
    - by weight
  - Established in November 2014
  - NRCS recommended mixture
- Native site with same soil texture (Wellman, TX)

Plot Size (AG-CARES) – 16 rows by 200 ft long

Soil Organic C (AG-CARES, est. 1998)

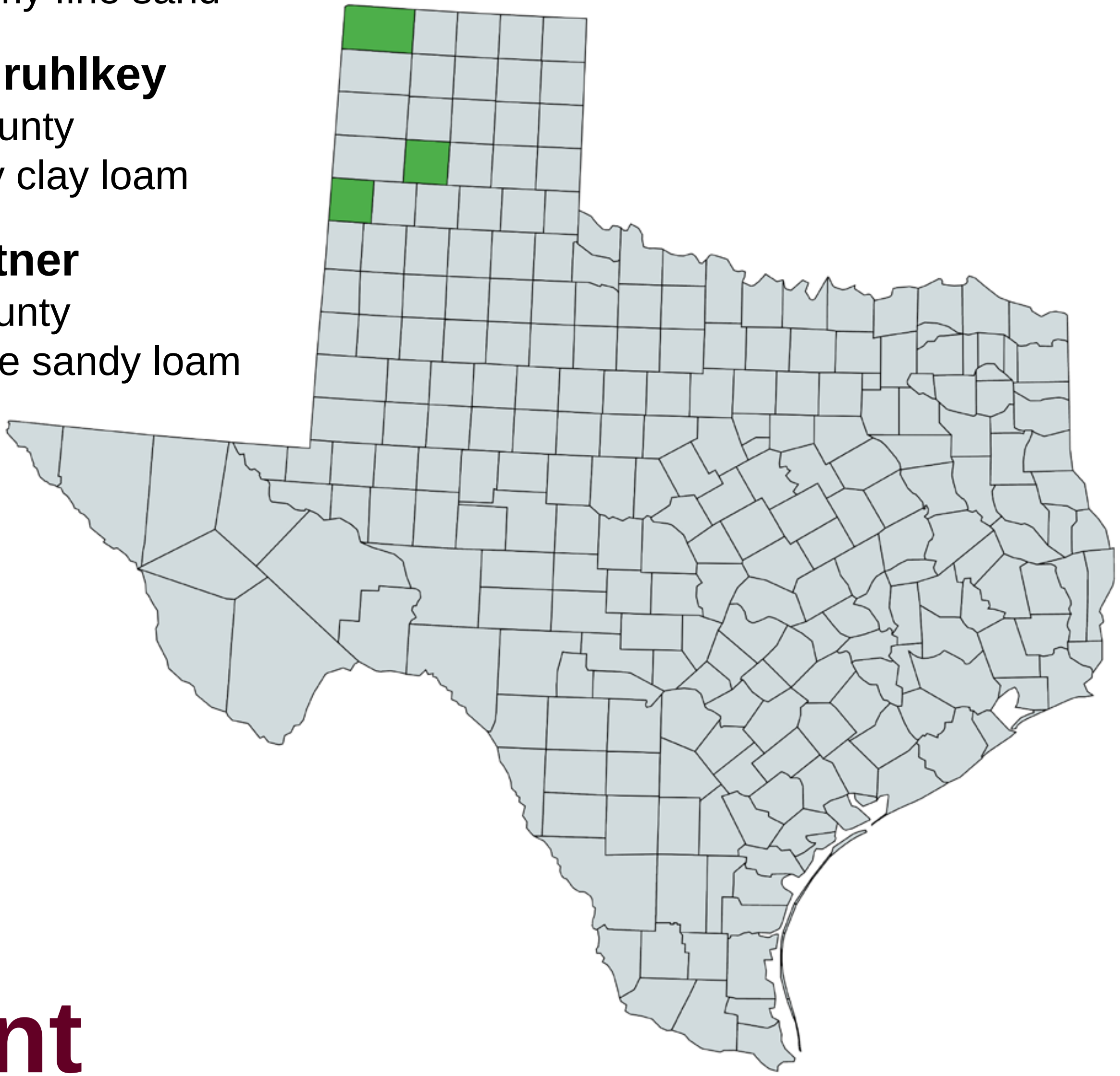




Steve and Zach Yoder
Dallam County
Dallam loamy fine sand

Braden Gruhlkey
Randall County
Pantex silty clay loam

Kelly Kettner
Parmer County
Amarillo fine sandy loam

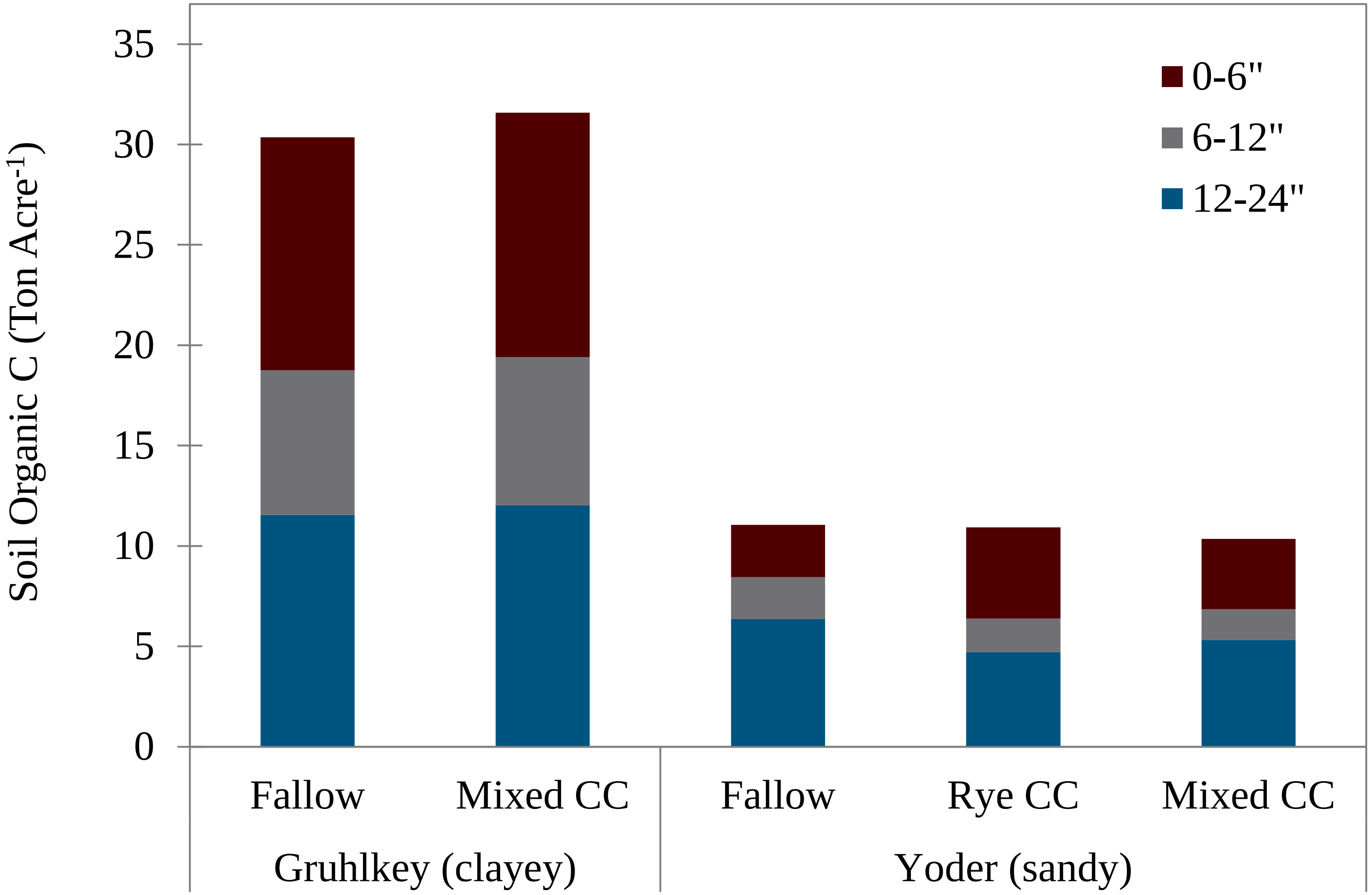


TEXAS A&M AGRILIFE RESEARCH

Conservation Management Corn Systems

Soil Organic C (est. 2017)

Samples collected in April 2020



Summary

Conservation management practices have a variable effect on soil C storage

Soil texture and irrigation capacity have been identified as major drivers behind differences observed in soil C storage

C storage is greater using cover crops in sandy soil and greater with rotation in clayey soil

Potential to sequester 0.14 ton C/acre/year in sandy, semi-arid cotton system using cover crop and no-tillage (23-year system)

While changes might be small, any amount of CO_2 kept in the soil and out of the atmosphere is going to be beneficial

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Photo: Hector Valencia