Storage and Turnover of C in Soil Physical Fractions Following Woody Plant Invasion of Grassland

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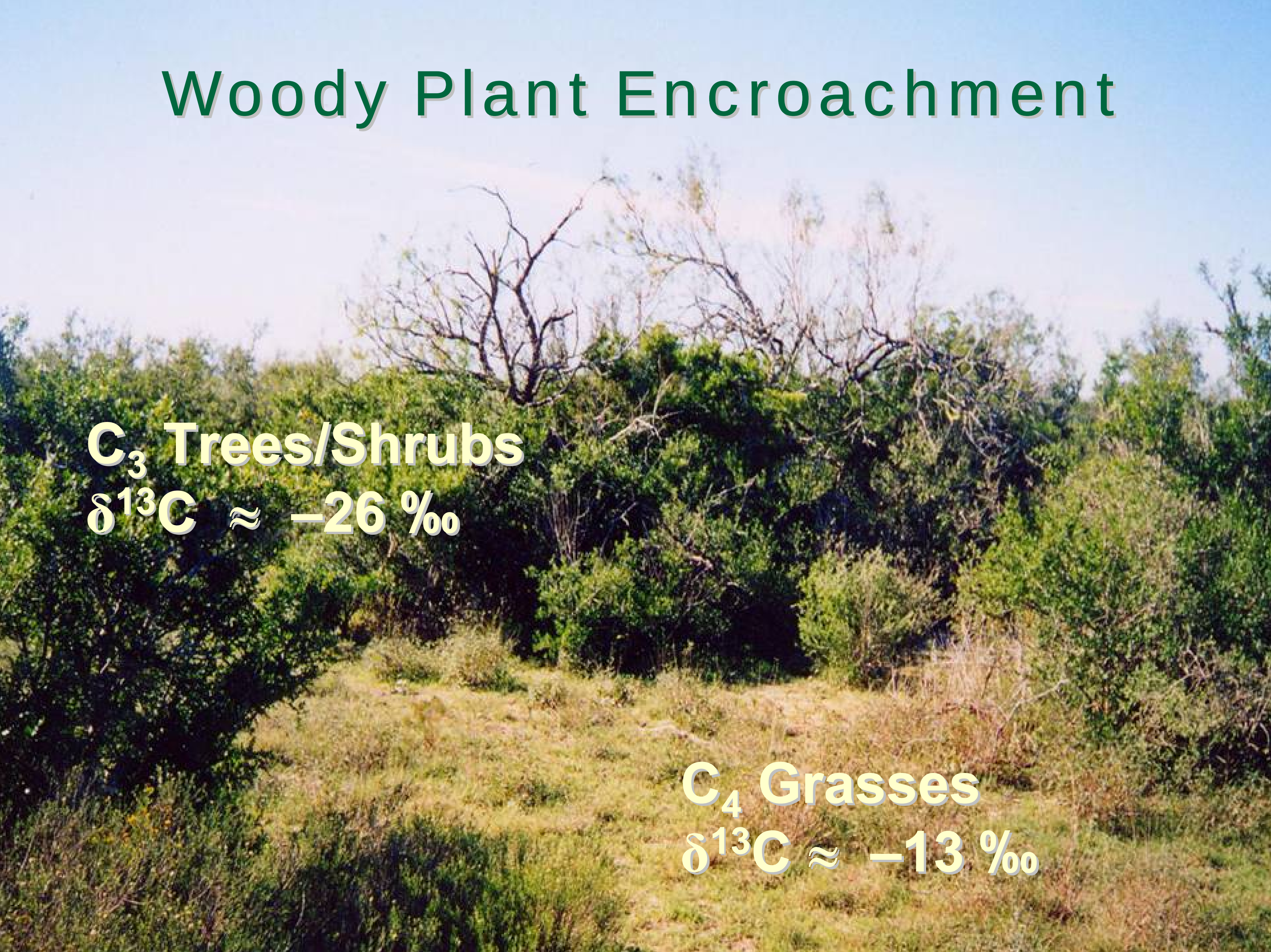
Woody Plant Encroachment



Objectives

- Evaluate physical protection of accrued soil C by determining where organic C is stored relative to aggregate structure

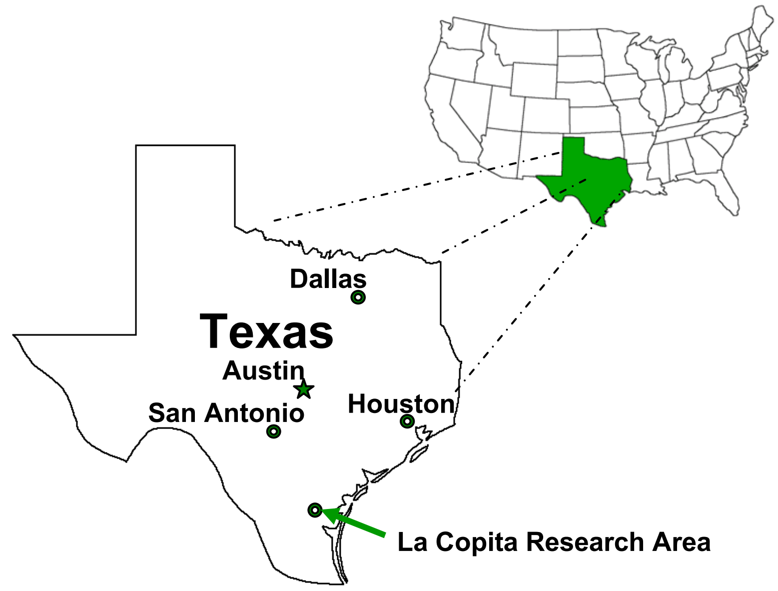
- Utilize the natural carbon isotope difference between C_4 grasses and C_3 woody plants to quantify mean residence time of SOC in specific soil fractions

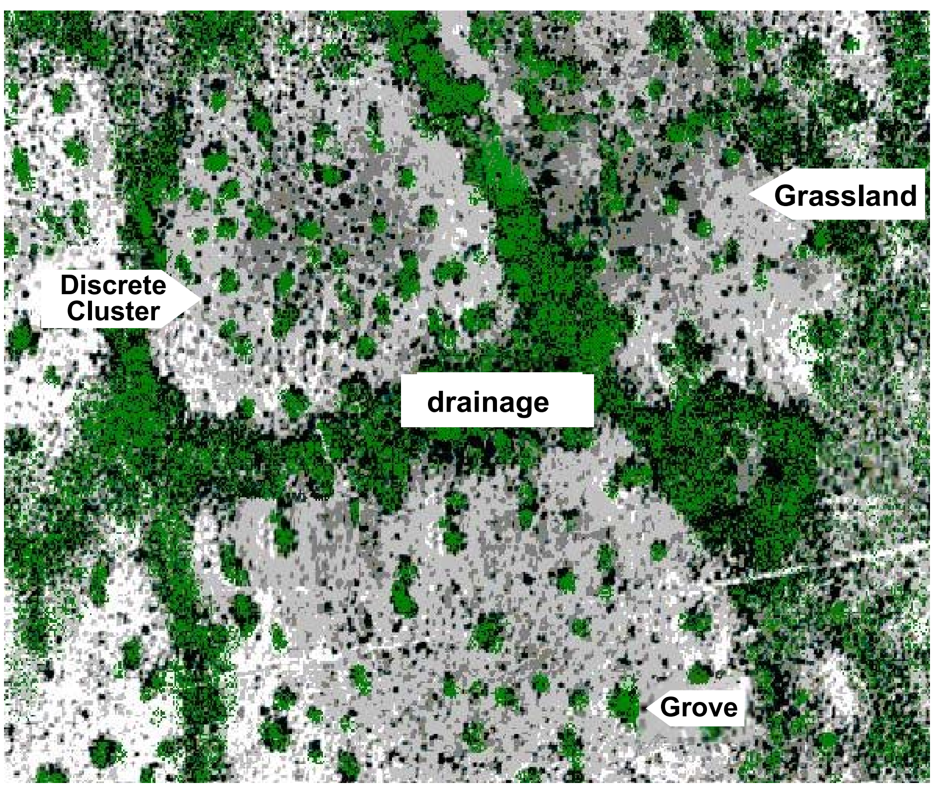
Study Area

Location: 65 km W of Corpus Christi
Land Use: Livestock grazing since 1850
MAT: 22.4°C
MAP: 716 mm
Soils: Mollisols

Uplands: 81% sand, 11% silt, 8% clay

Drainages: 66% sand, 15% silt, 19% clay



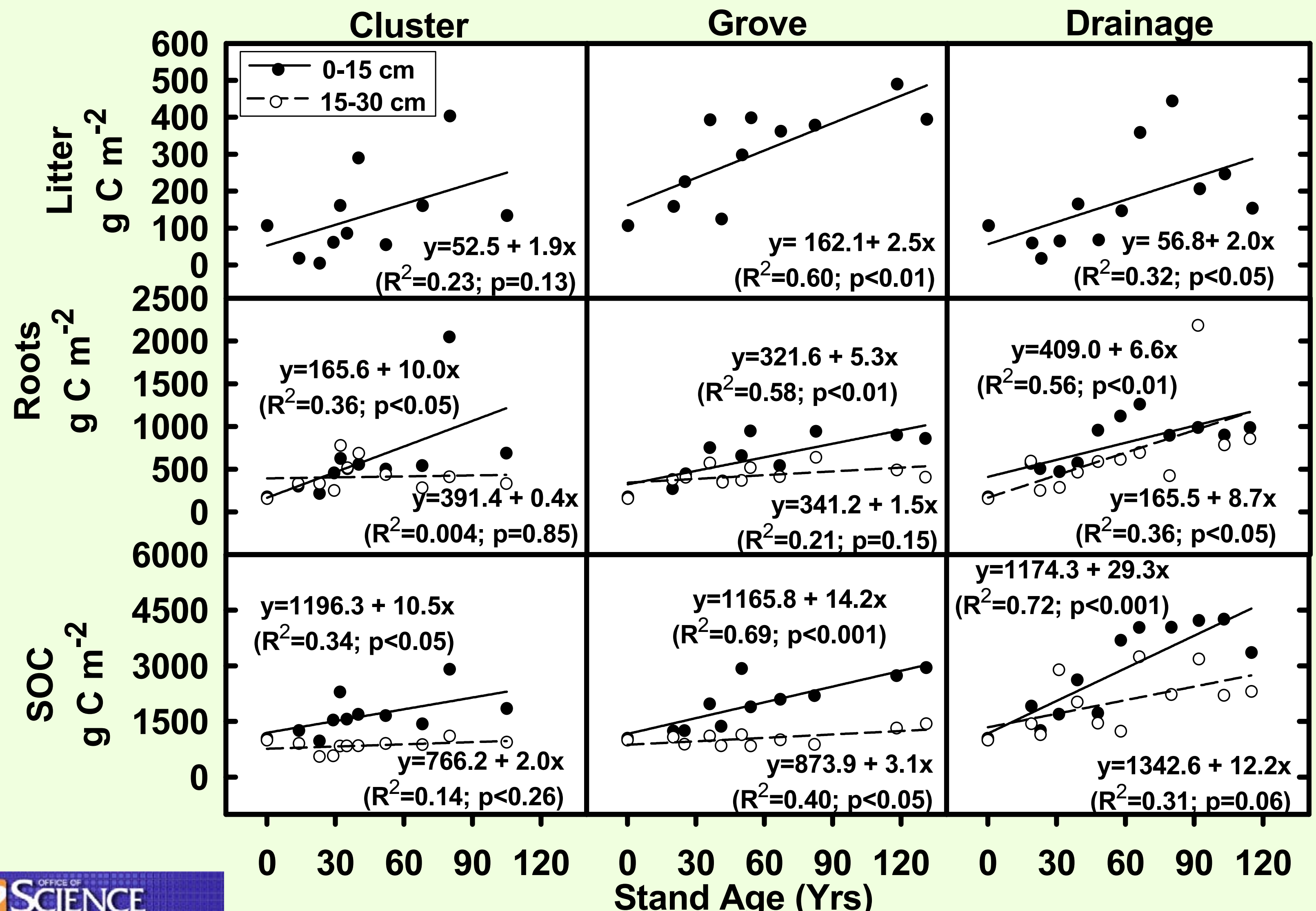


- All wooded landscape elements dominated by honey mesquite (*Prosopis glandulosa*), a N-fixing tree legume.
- ***Uplands:*** Remnant C4 **grasslands** interspersed with small, discrete **clusters** of woody plants, which may coalesce to form larger woody **groves**
- ***Drainages:*** Closed-canopy **woodlands**

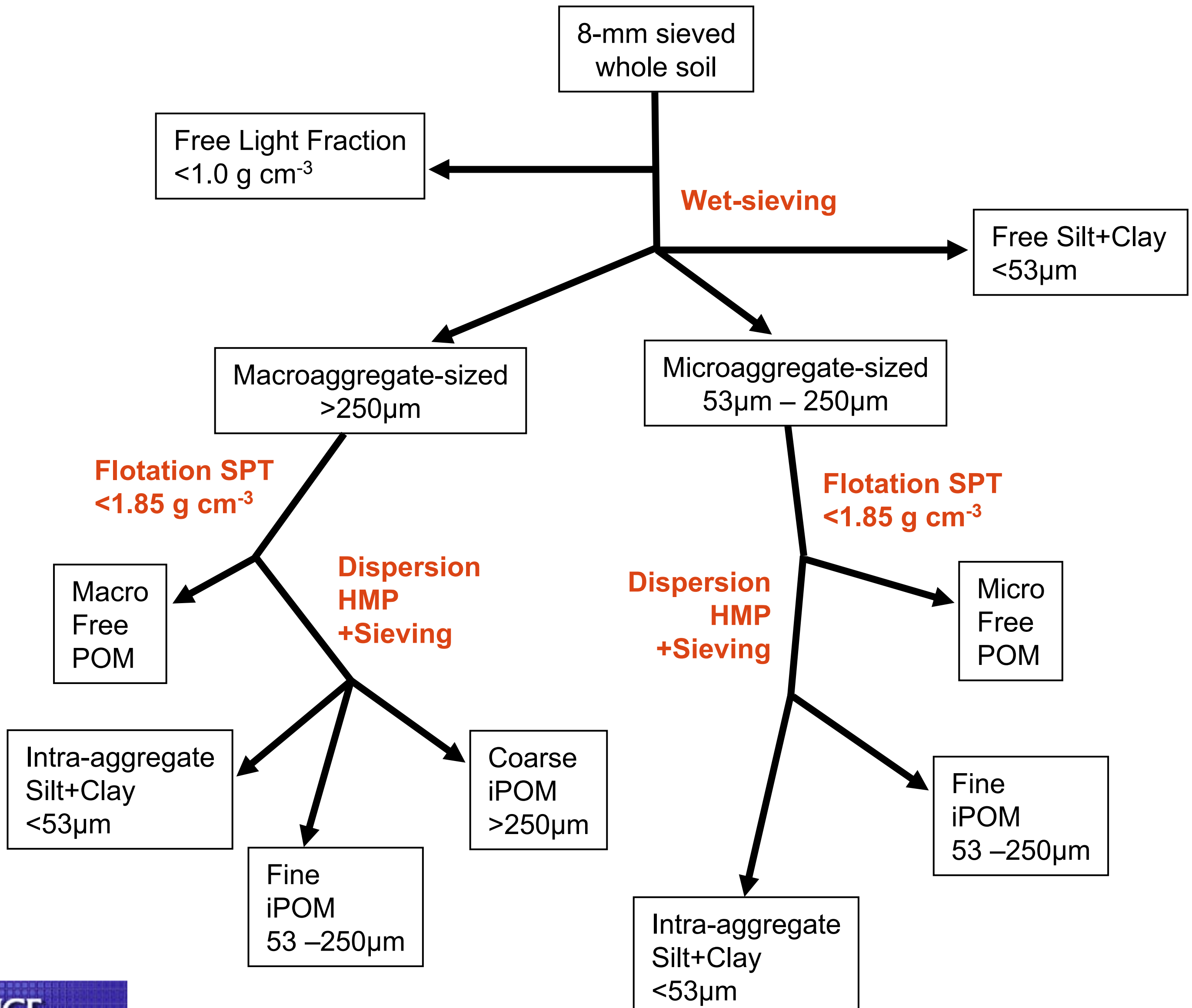
Methods

- ***Chronosequence approach:***
  - Grasslands represent Time 0
  - Wooded patches range in age from 10-130 yrs; stand age determined by dendrochronology
- ***Soil sampling:***
  - Four soil cores (0-30 cm) from each of 10 aged sites in each of the four landscape elements
  - Cores sectioned into 0-15 and 15-30 cm depth increments and pooled

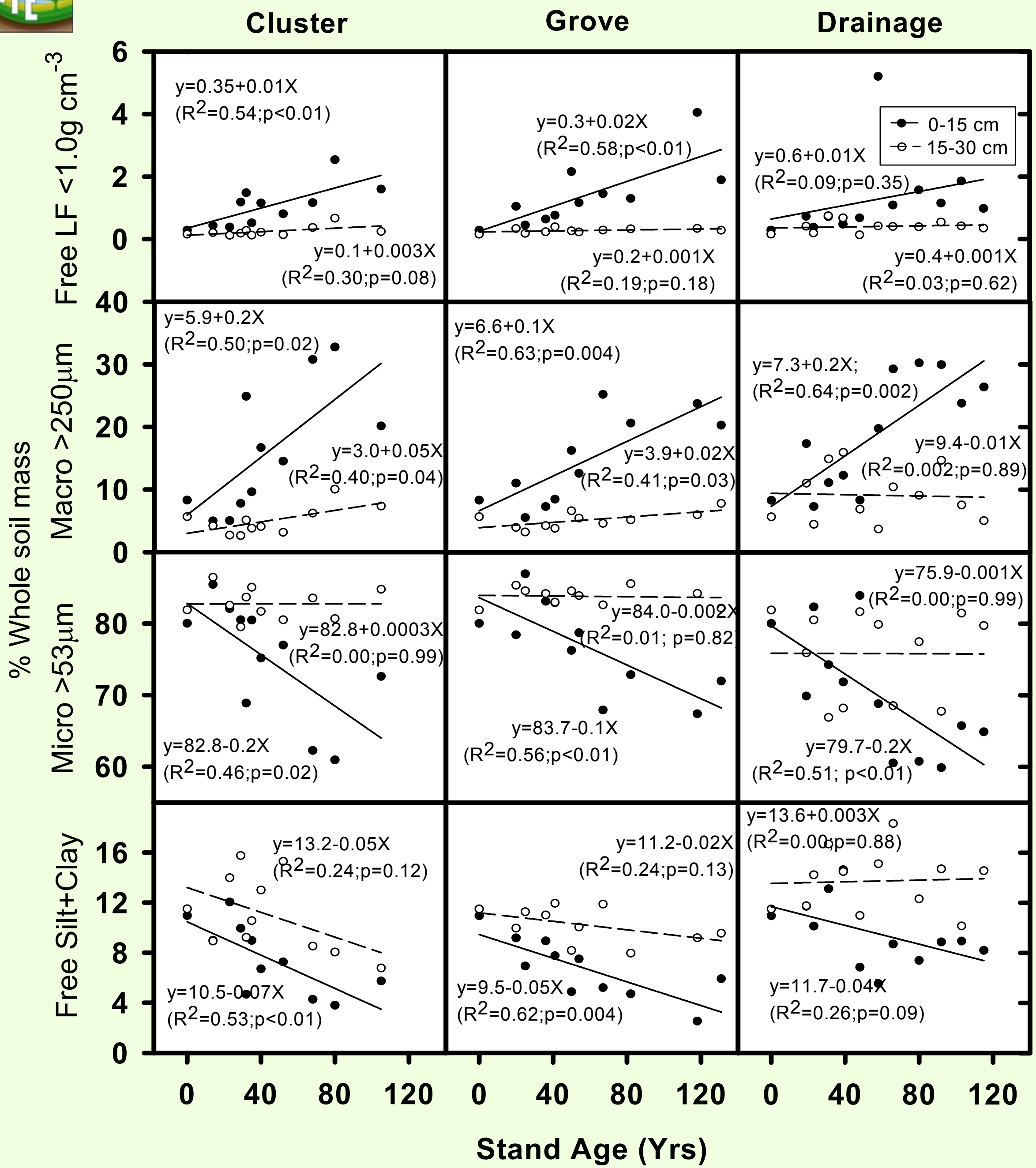
Inputs and SOC increase with time in all wooded landscape elements



Soil Fractionation Scheme



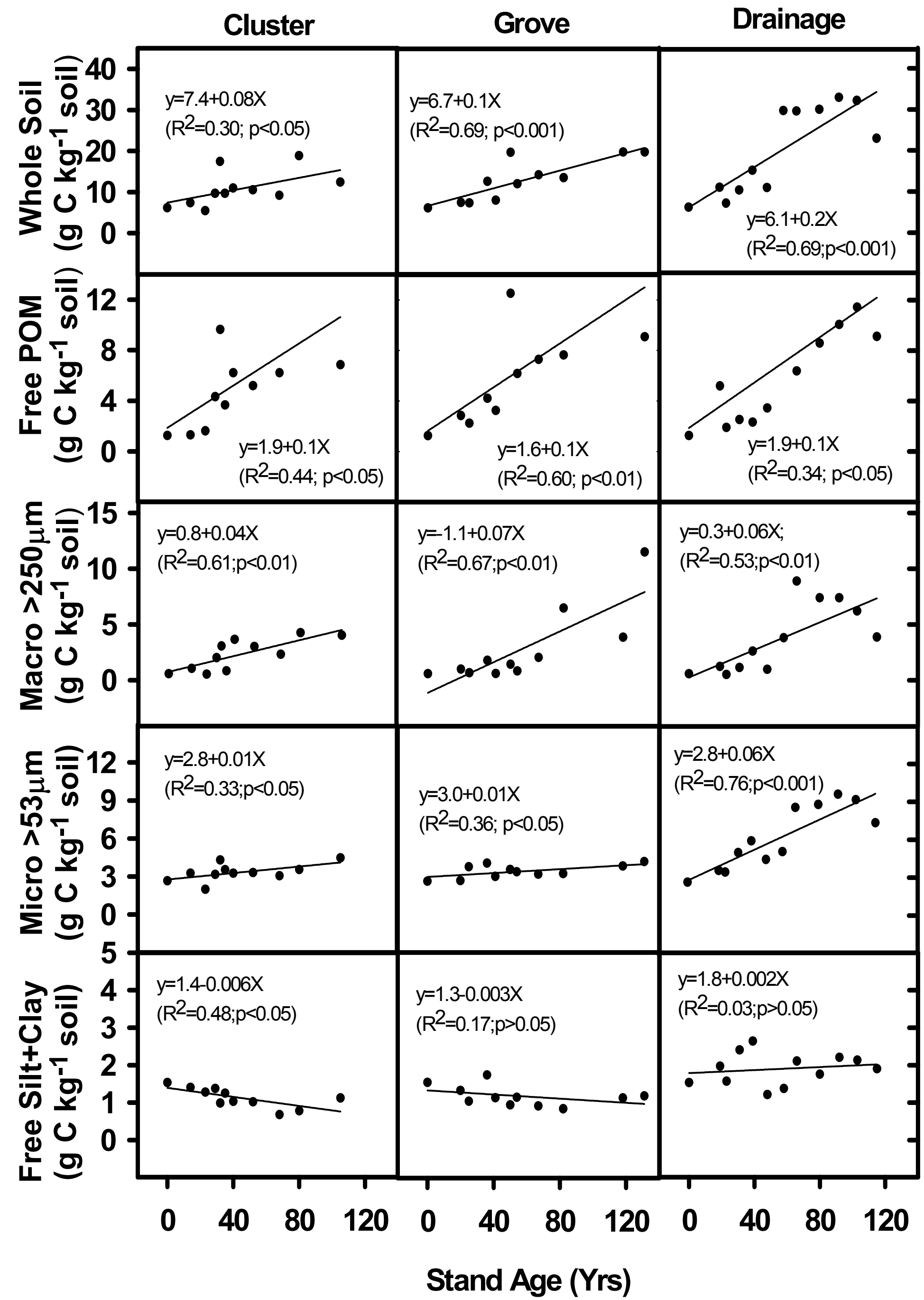
Change in aggregate mass distribution over time



- Macroaggregates and free LF increase at 0-15 cm
- Microaggregates and free silt+clay decline (incorporated into macroaggregates)
- Little change at 15-30 cm

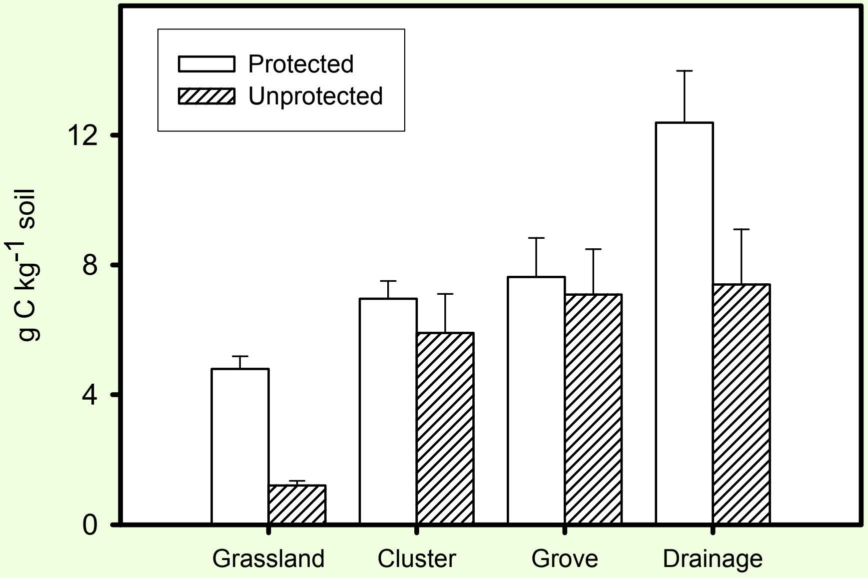
Changes in fraction C

- Whole soil C increases with woodland size; limited to surface 15 cm except in drainage
- C accrual occurs mostly in free POM and macroaggregates
- Drainage soils (more clays) also accrue C in microaggregates



Comparison of C in protected vs. unprotected pools

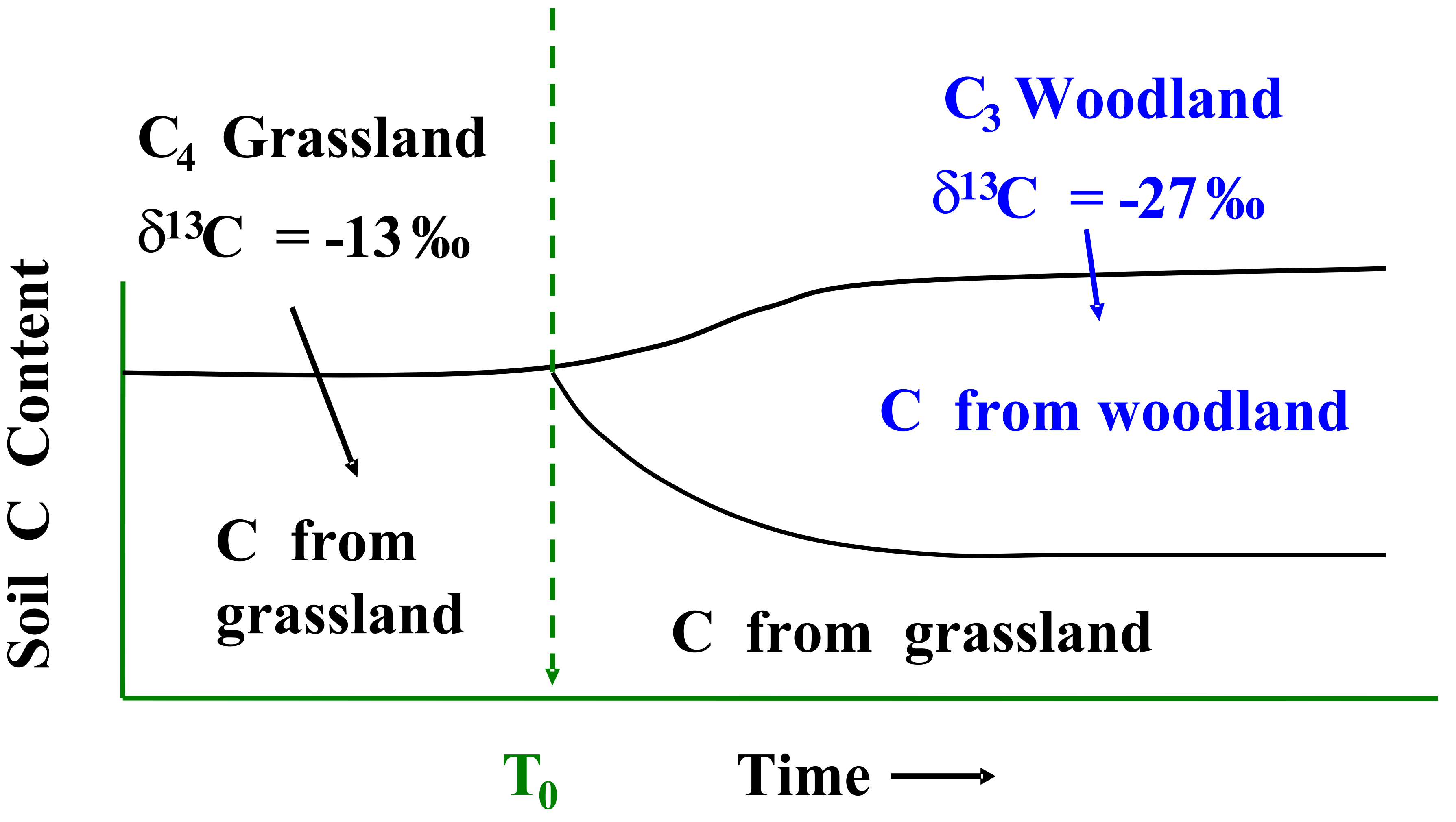
- Protected pools calculated as microaggregate-associated C plus C associated with free and macro silt+clay
- Much of the woodland accrual is in unprotected pools
- Drainage soils (more clays) accrue more C in protected pools



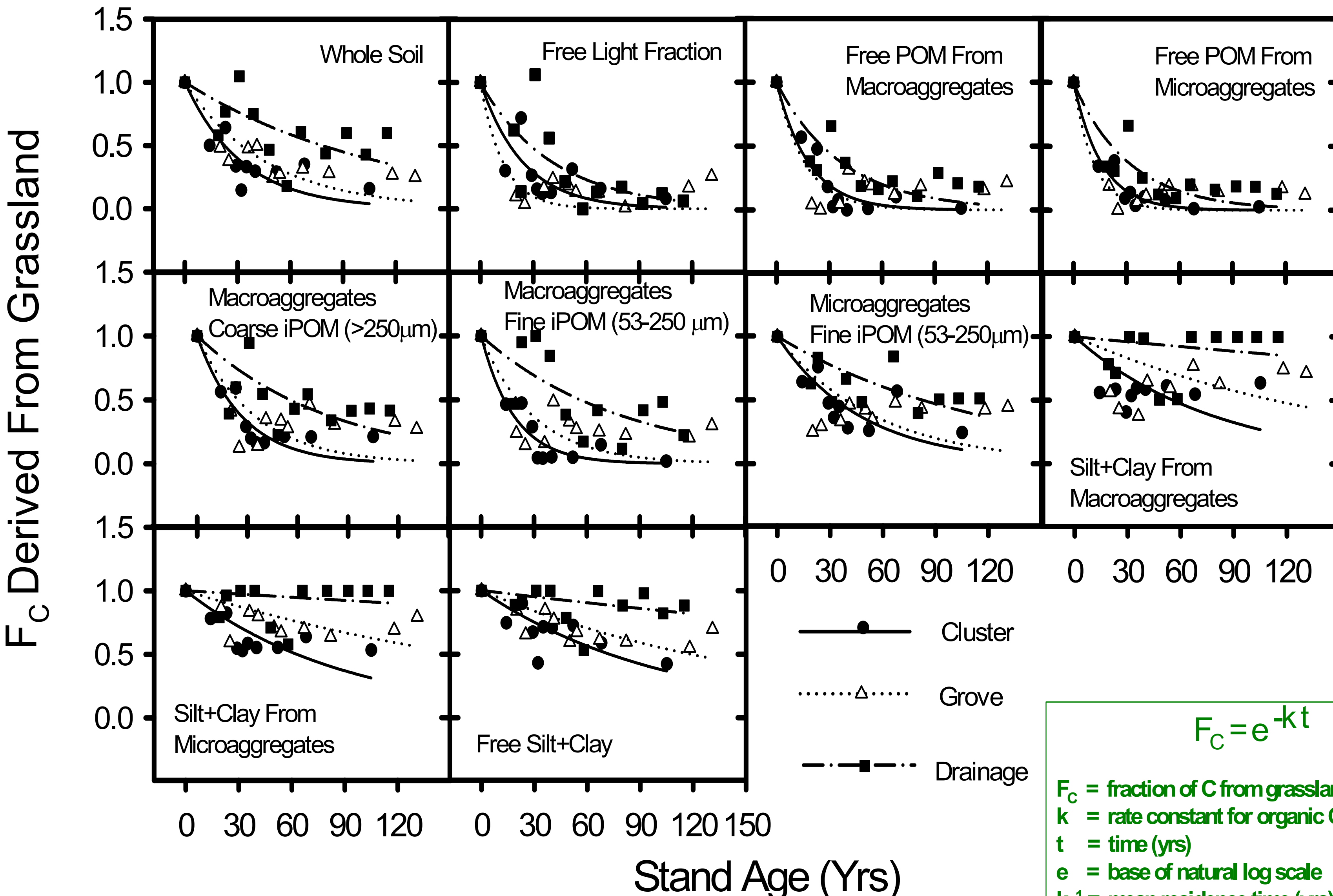
Carbon Sequestration in Size/Density Fractions

	C Accumulation Rates (g C m^{-2} yr^{-1})		
	Cluster	Grove	Drainage
	0-15 cm	0-15 cm	0-15 cm
Whole Soil	10.5 (4.9)	14.2 (3.2)	29.3 (5.7)
Free POM	12.7 (4.5)	12 (3.2)	11.1 (4.7)
density<1.0g cm^{-3}	5.5 (2.5)	7.4 (2.2)	4 (3.0)
density<1.85g cm^{-3} (>250μm)	6.5 (2.0)	3.6 (1.2)	4.9 (1.9)
density<1.85g cm^{-3} (53-250μm)	0.7 (0.4)	1.1 (0.2)	2.2 (0.4)
Macro	5.3 (1.4)	10.1 (2.5)	7.9 (2.4)
CiPOM	1.5 (0.4)	0.5 (0.1)	1.1 (0.3)
FiPOM	0.6 (0.1)	0.2 (0.05)	0.9 (0.1)
iS+C	1.5 (0.4)	0.6 (0.1)	4.5 (1.0)
Micro	1.4 (1.4)	5.7 (1.5)	6.5 (1.4)
FiPOM	0.2 (0.3)	-0.1 (0.2)	0.7 (0.4)
iS+C	0.3 (0.4)	-0.03 (0.4)	6 (1.3)
Free S+C	-1.2 (0.4)	-0.7 (0.3)	-0.5 (0.7)

Vegetation Change



Loss of old (C4) grassland C fitted to

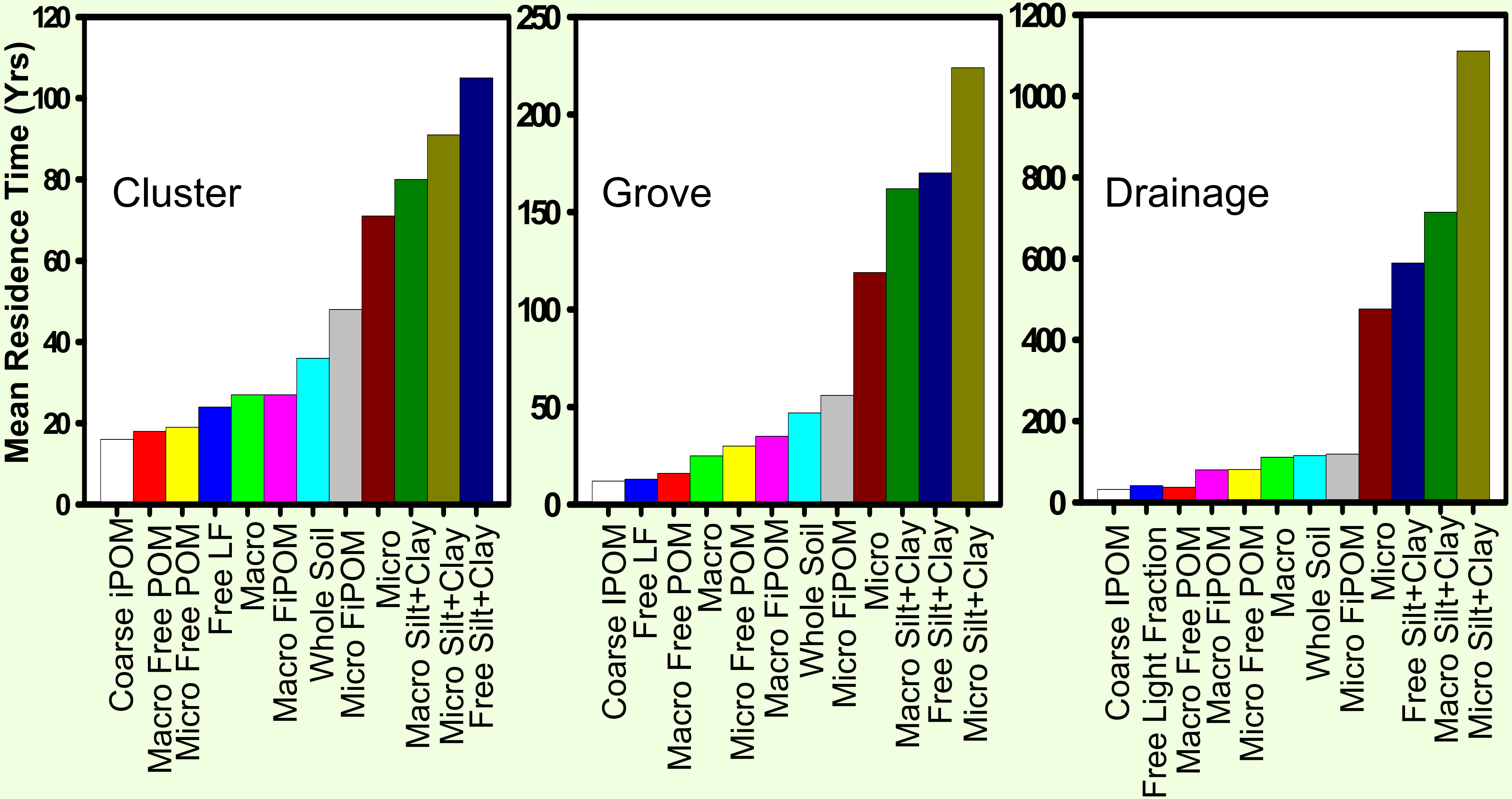


$$F_C = e^{-kt}$$

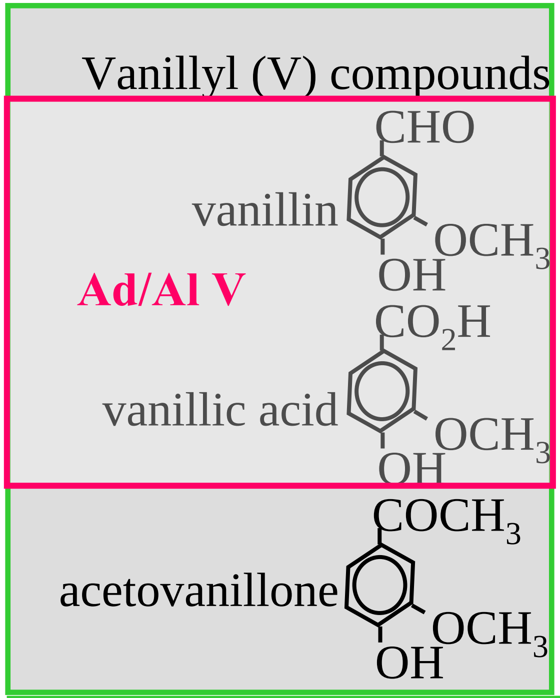
F_C = fraction of C from grassland
k = rate constant for organic C decay (yr^{-1})
t = time (yrs)
e = base of natural log scale
k^{-1} = mean residence time (yrs)

Mean Residence Times of Soil Fractions

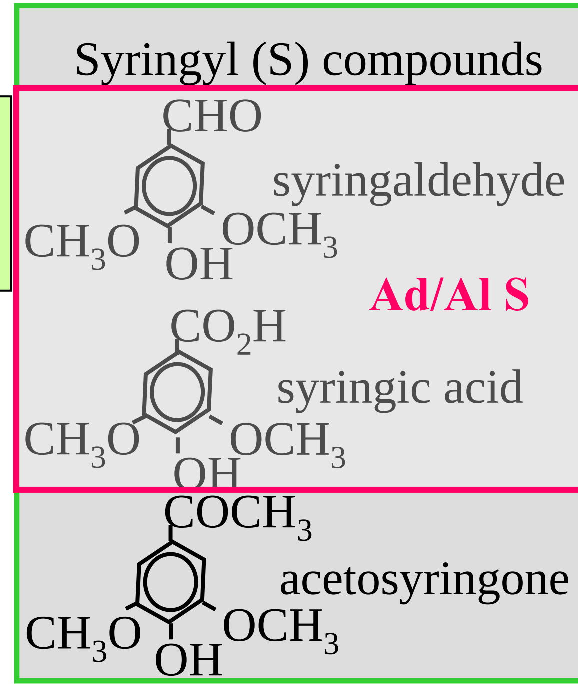
- ⇨POM fraction MRTs similar but silt+clay MRTs increase with woodland size
- ⇨Coarse iPOM turns over more rapidly than fine iPOM (coarse iPOM not protected)
- ⇨Fine iPOM turnover affected by protection; micro iPOM MRT (gray) is longest
- ⇨Silt+clay has slowest turnover; micro silt+clay longest in grove/drainage

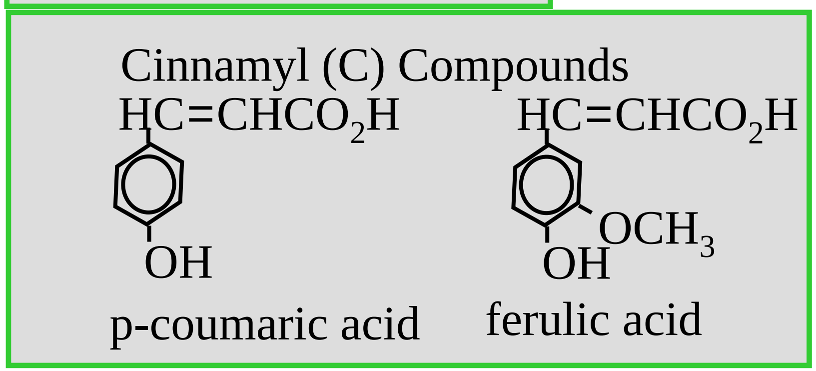


Lignin Biomarker Analysis



Undegraded Plants
Ad/Al < 0.2





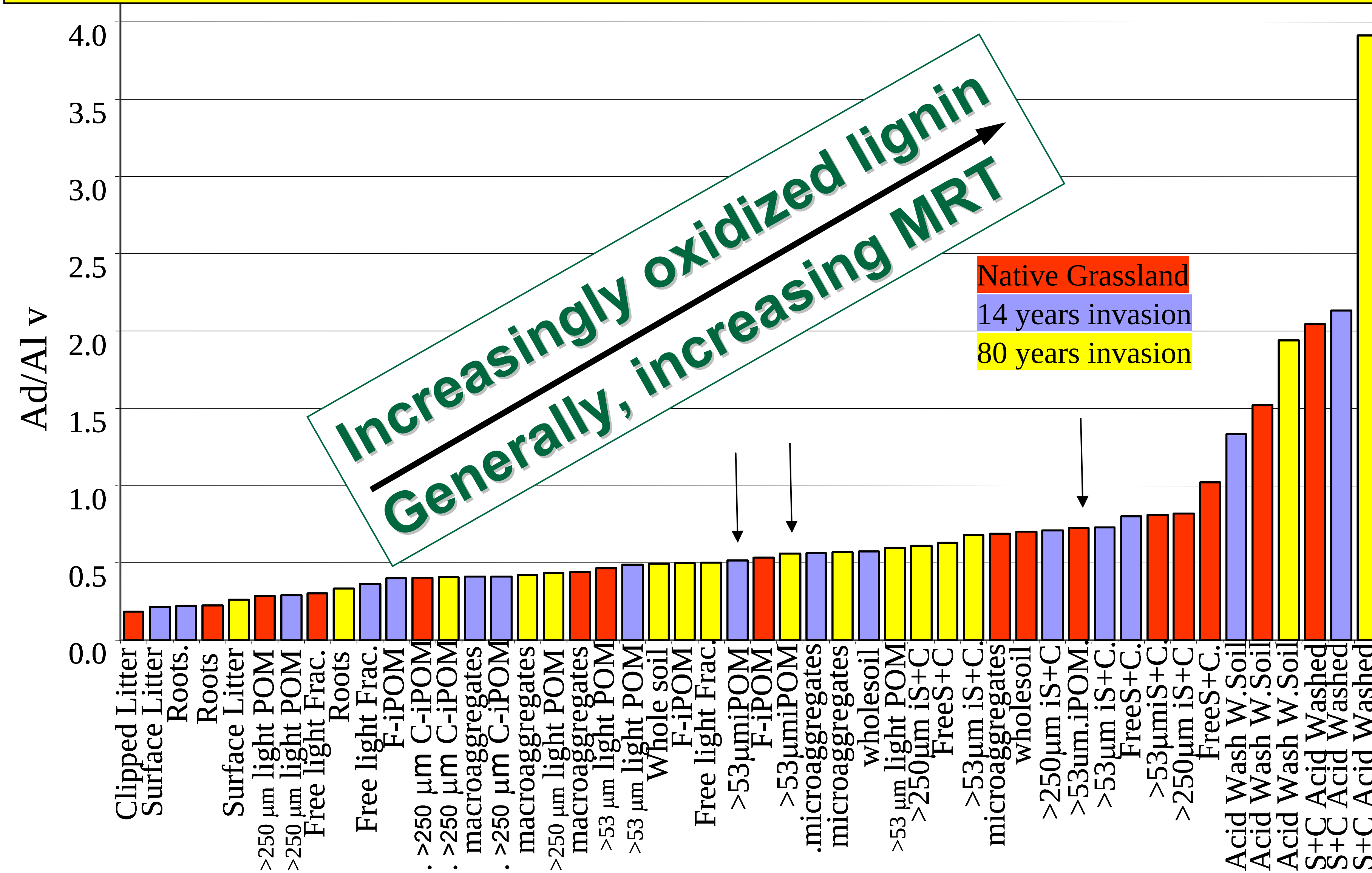
$\Lambda 8 = \Sigma S + V + C$
(with grass input)

C/V (High=lots of grasses)

S/V (High = no gymnosperms)

Soil fractions analyzed for lignin phenols using alkaline CuO quantitation. Parameters for lignin yield, **Λ8**, lignin source, **C/V** and **S/V**, and relative oxidation state, **Ad/Al** ratio for vanillyl and syringyl monomers, determined for fractions and source plant litter.

Fractions with long MRTs show high Ad/Al and low Λ8 indicating lignin in these “slow turnover pools” has been decomposed extensively by microbes



Summary & Significance

- Increases in macroaggregates related to increased root production
- Most of the C accumulation occurred in unprotected free POM, which also had the shortest MRTs (~35 y)
- MRTs of C in silt+clay (369 y) were longest and did not vary with aggregate position
- MRT of C in microaggregates (185 y) was >3 times longer than in macroaggregates (49 y) due to proportionally more clay and older, more degraded iPOM
- Grassland → woodland transformations are geographically extensive, suggesting significant potential C sequestration is occurring (with long-term retention dependent on silt+clay content, continued inputs, and POM degradability)