Land management and soil carbon pools: patterns and processes

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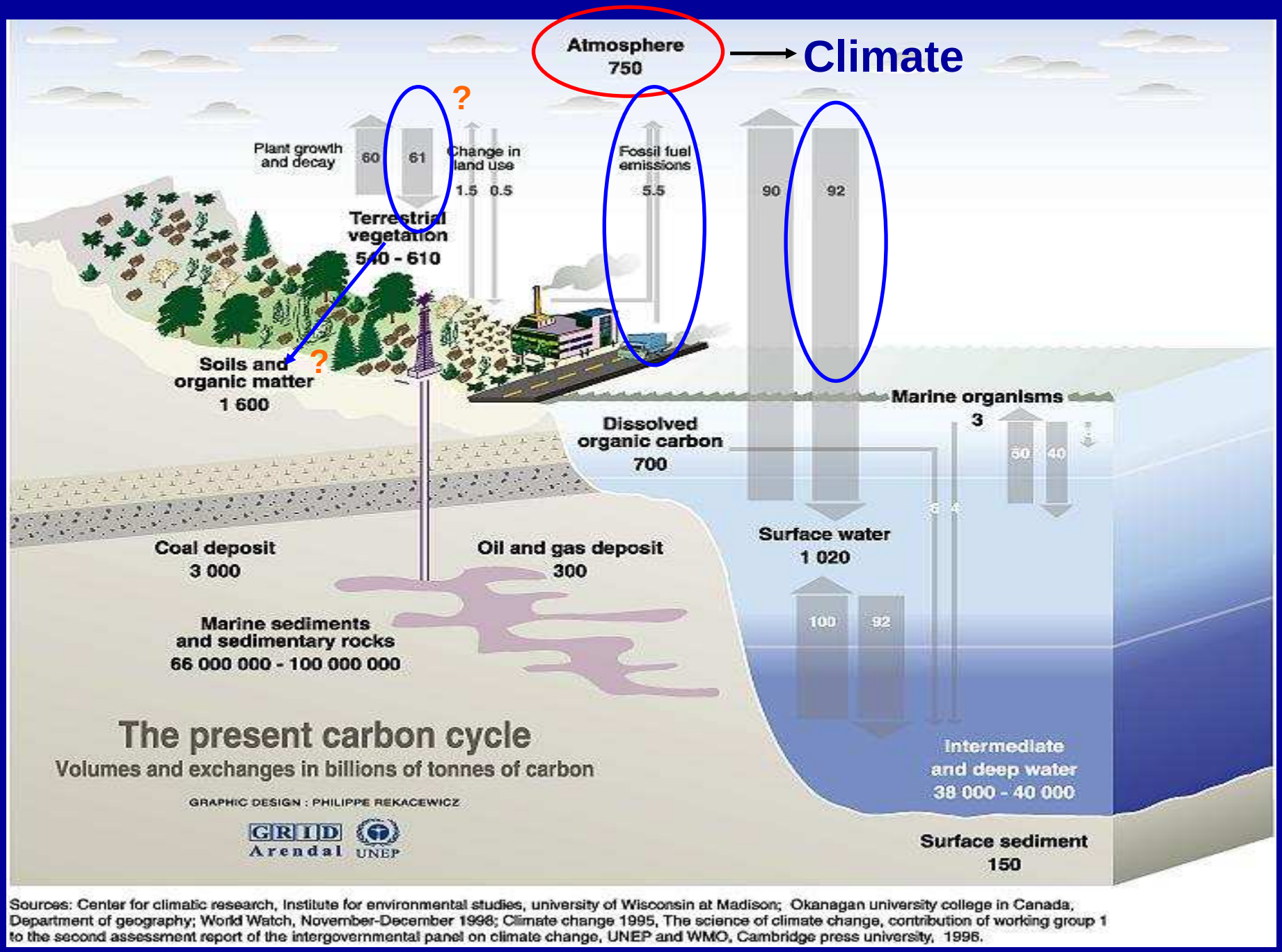


Sources: Center for climatic research, Institute for environmental studies, university of Wisconsin at Madison; Okanagan university college in Canada, Department of geography; World Watch, November-December 1998; Climate change 1995, The science of climate change, contribution of working group 1 to the second assessment report of the intergovernmental panel on climate change, UNEP and WMO, Cambridge press university, 1996.

Intergovernmental Panel on Climate Change, 2001

US Carbon Sink

Pacala et al. 2001, Science

- US C sink ~0.30-0.58 Pg C yr^{-1}
  - Forest trees -- 0.11 - 0.15
  - Woody encroachment -- 0.12 - 0.13
  - Other forest organic matter -- 0.03 - 0.15
  - Exports (rivers + trade) -- 0.07 - 0.13
  - Wood products -- 0.03 - 0.07
  - Sedimentation -- 0.01 - 0.04
  - Cropland soils -- 0.00 - 0.04

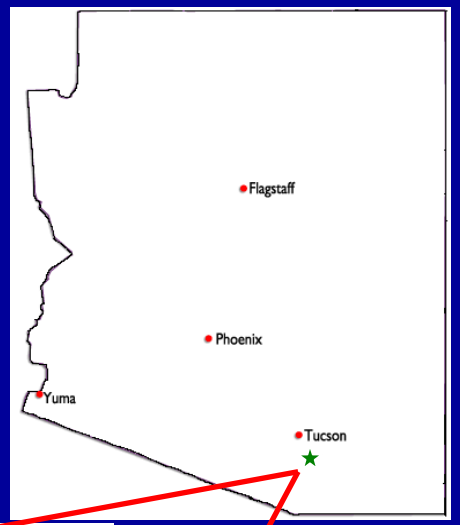
Woody encroachment

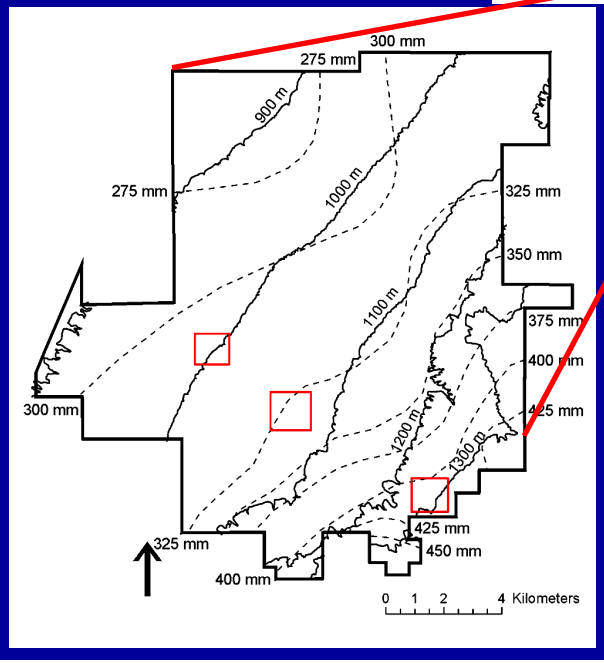
- Increased trees & shrubs in grasslands & savannas
- ~40% terrestrial land area worldwide
- Importance:
  - changes in land value (grazing, wildlife, recreation)
  - long-term C storage in woody tissues & soils

Rob Wu, Santa Rita Experimental Range

Santa Rita Experimental Range

- Semi-desert grassland
- Precipitation gradient, mid-elevation MAP ≈ 325mm/yr
- Woody encroachment
  - Velvet mesquite (*Prosopis velutina*)
  - *Acacia* spp.
  - Cacti





Land Management at SRER

- Grazing
- Brush removal treatments over past 70 years
- Goals:
  - decreased mesquite cover
  - increased cattle yield

SRER photo archives

Brush Removal at SRER

70 years since cutting

45 years since herbicide

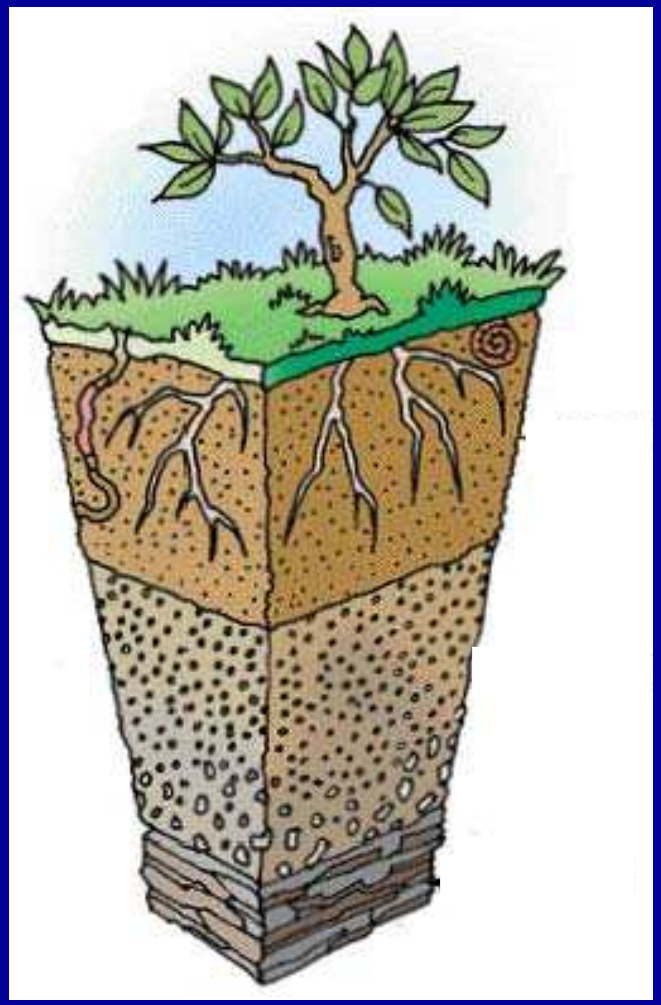
How do woody encroachment and land management affect belowground C pools?

I. Leaf litter inputs

II. Decomposition rates

III. Spatial patterns of soil organic carbon

IV. Long-term SOC dynamics



I. Leaf Litter Inputs

- Litter traps → spatial & temporal distribution of inputs
  - litter type
  - C:N
  - tree size

II. Leaf Litter Decomposition

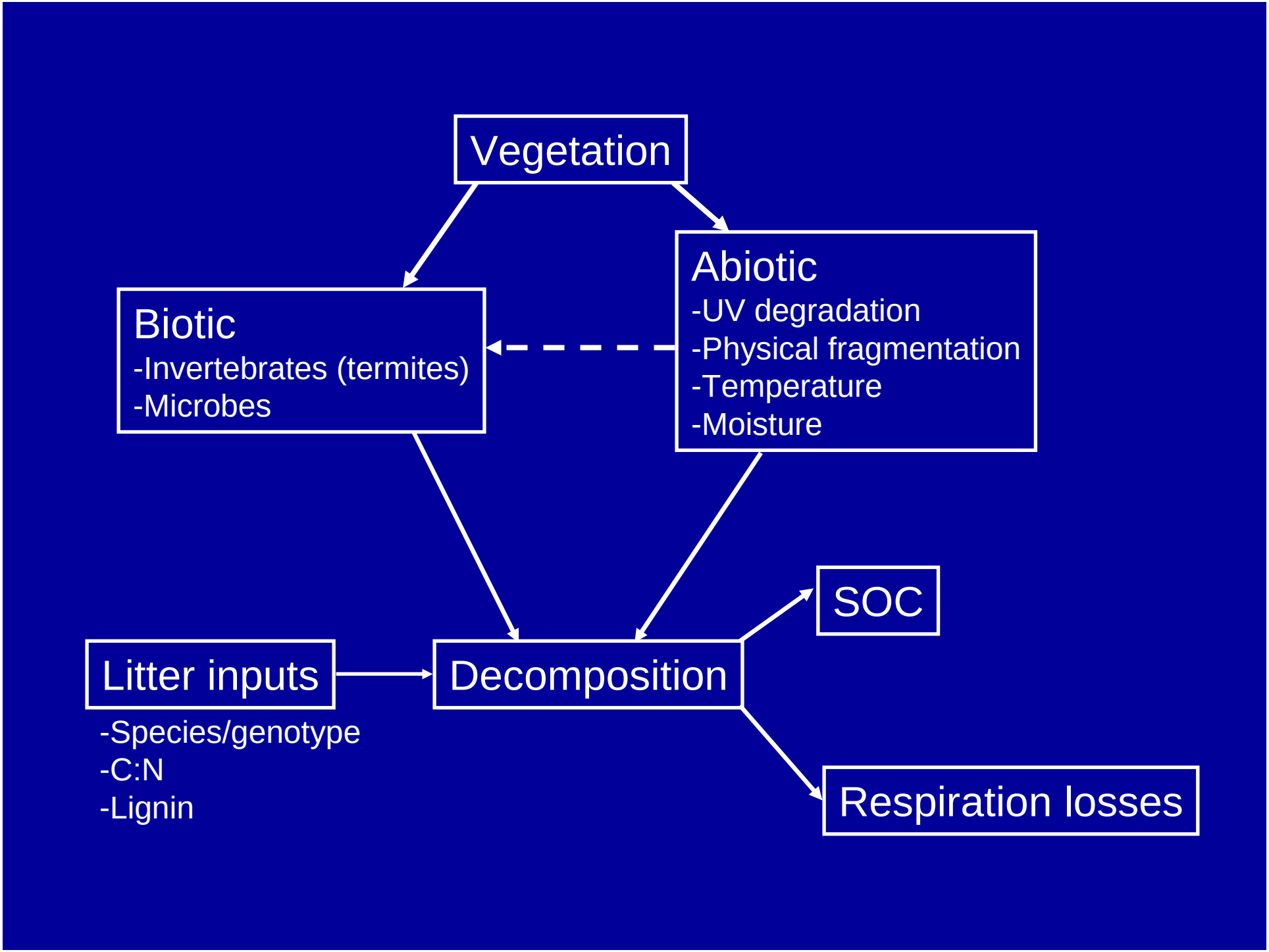
- Litterbag study

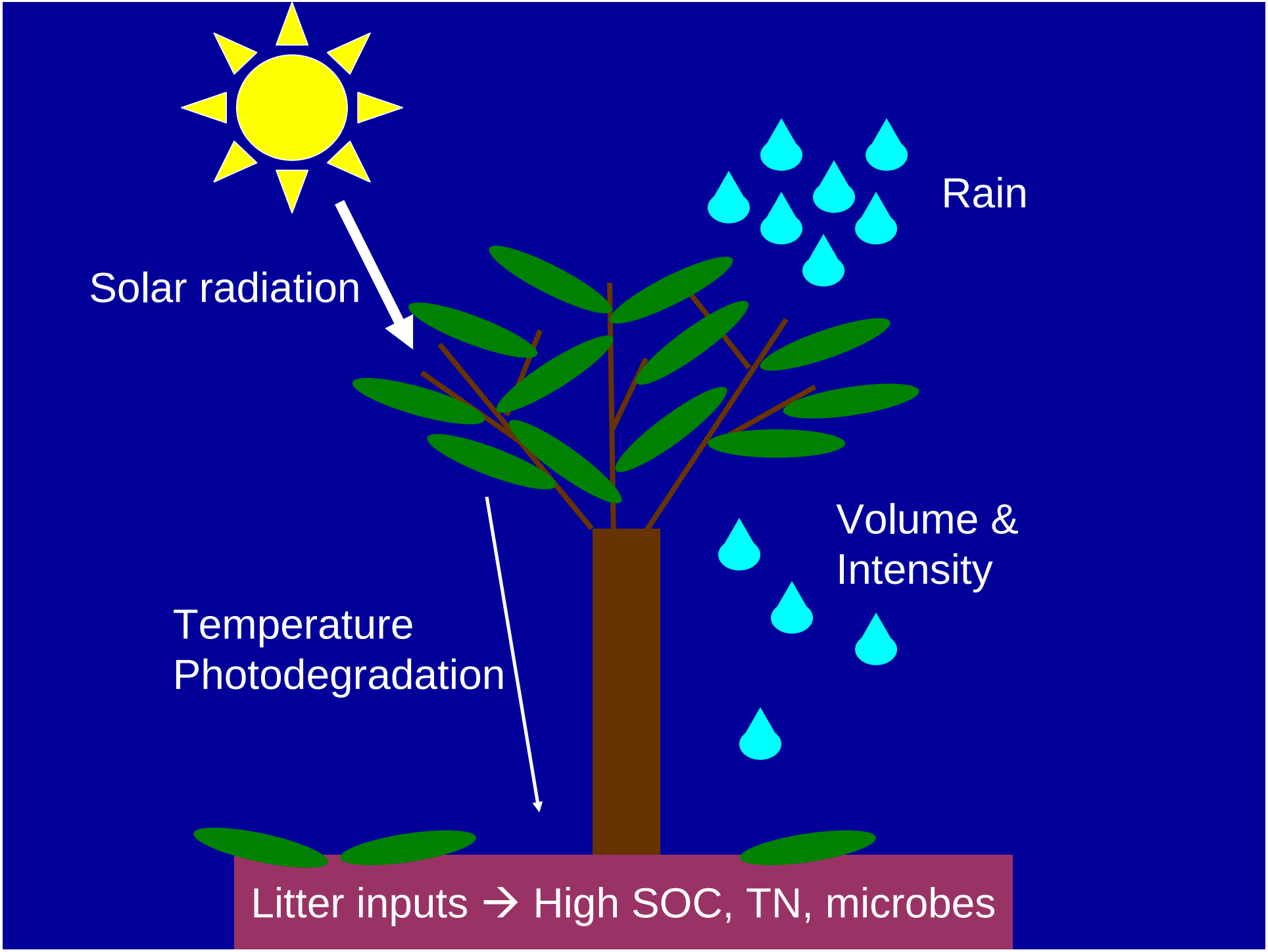
- 2 litter types
    - -mesquite
    - -Lehmann lovegrass

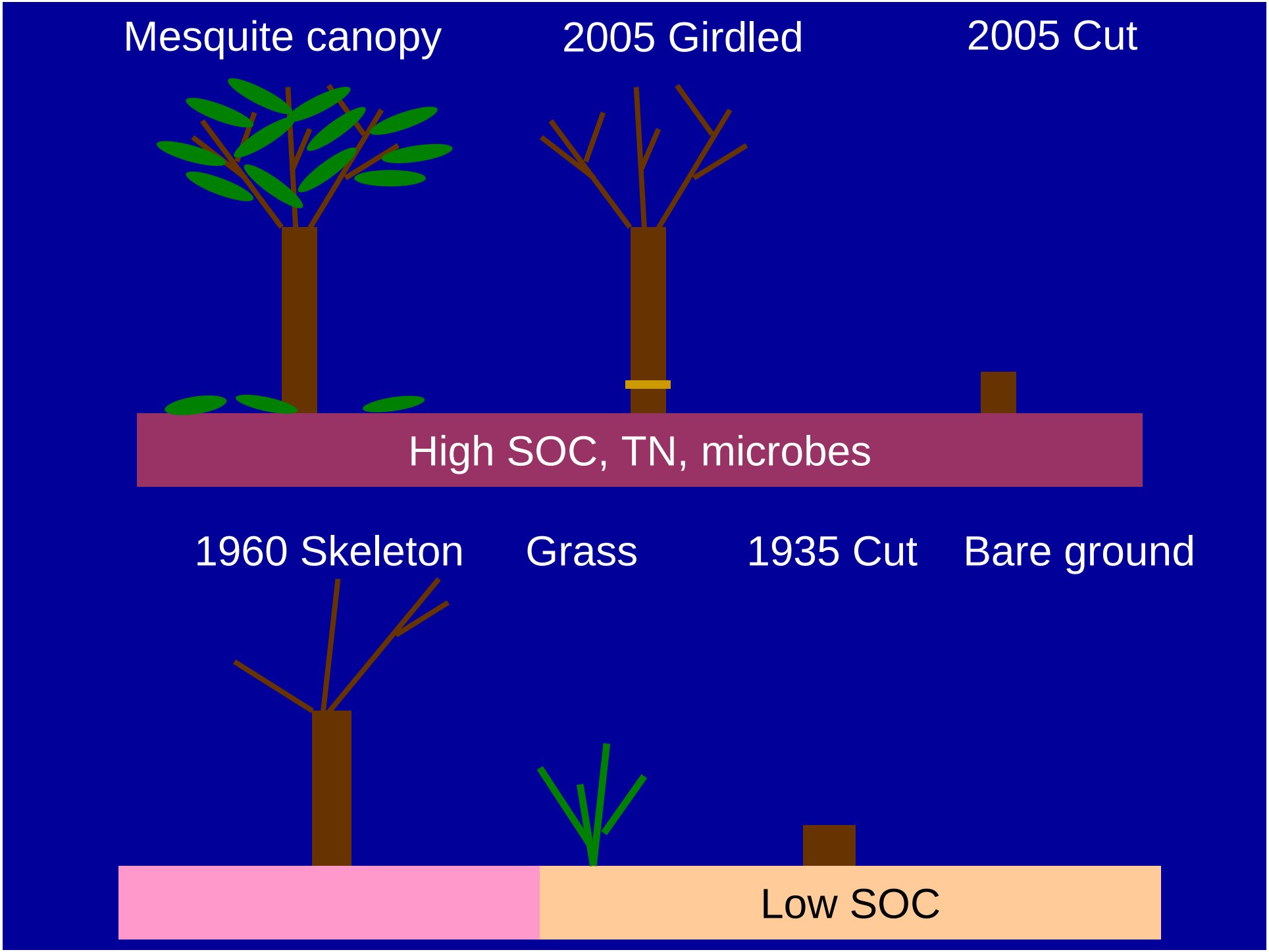
- 7 land cover trts

- Bags deployed 0, 1, 3, 6, 12 months

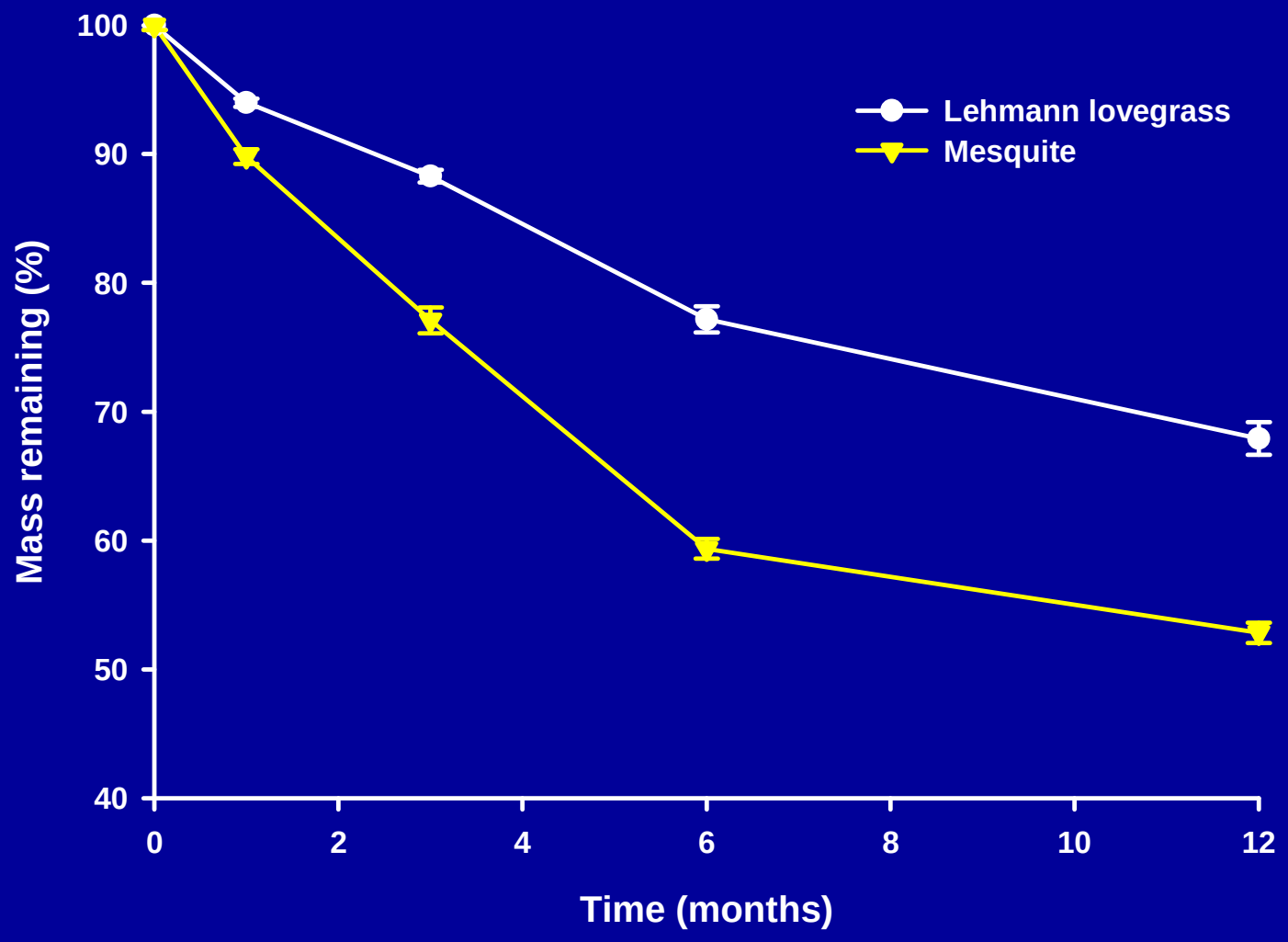
- Analyses: mass, %C, %N


Vegetation
Abiotic
-UV degradation
-Physical fragmentation
-Temperature
-Moisture
Biotic
-Invertebrates (termites)
-Microbes
SOC
Litter inputs
Decomposition
-Species/genotype
-C:N
-Lignin
Respiration losses

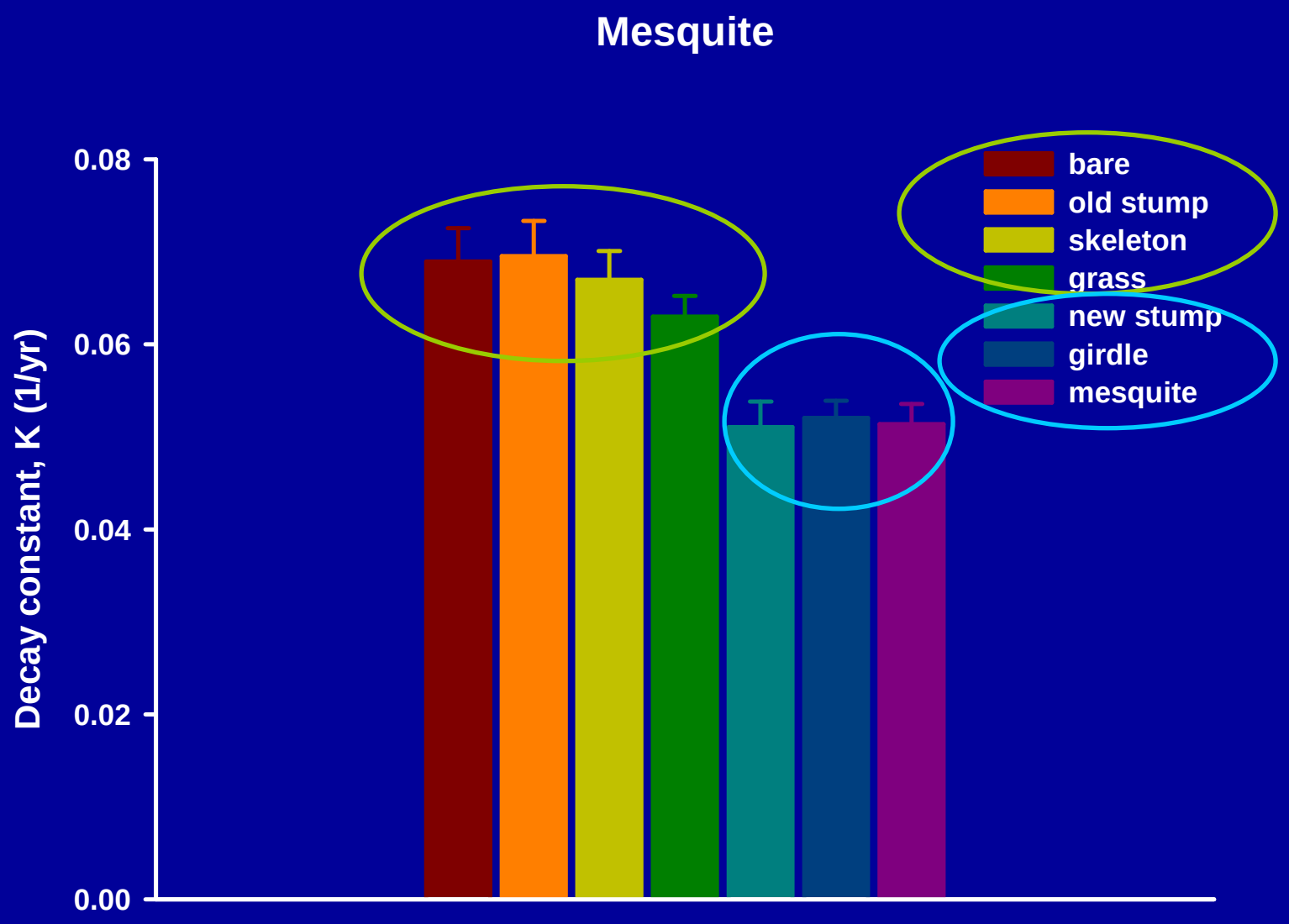

Solar radiation
Rain
Volume &
Intensity
Temperature
Photodegradation
Litter inputs → High SOC, TN, microbes

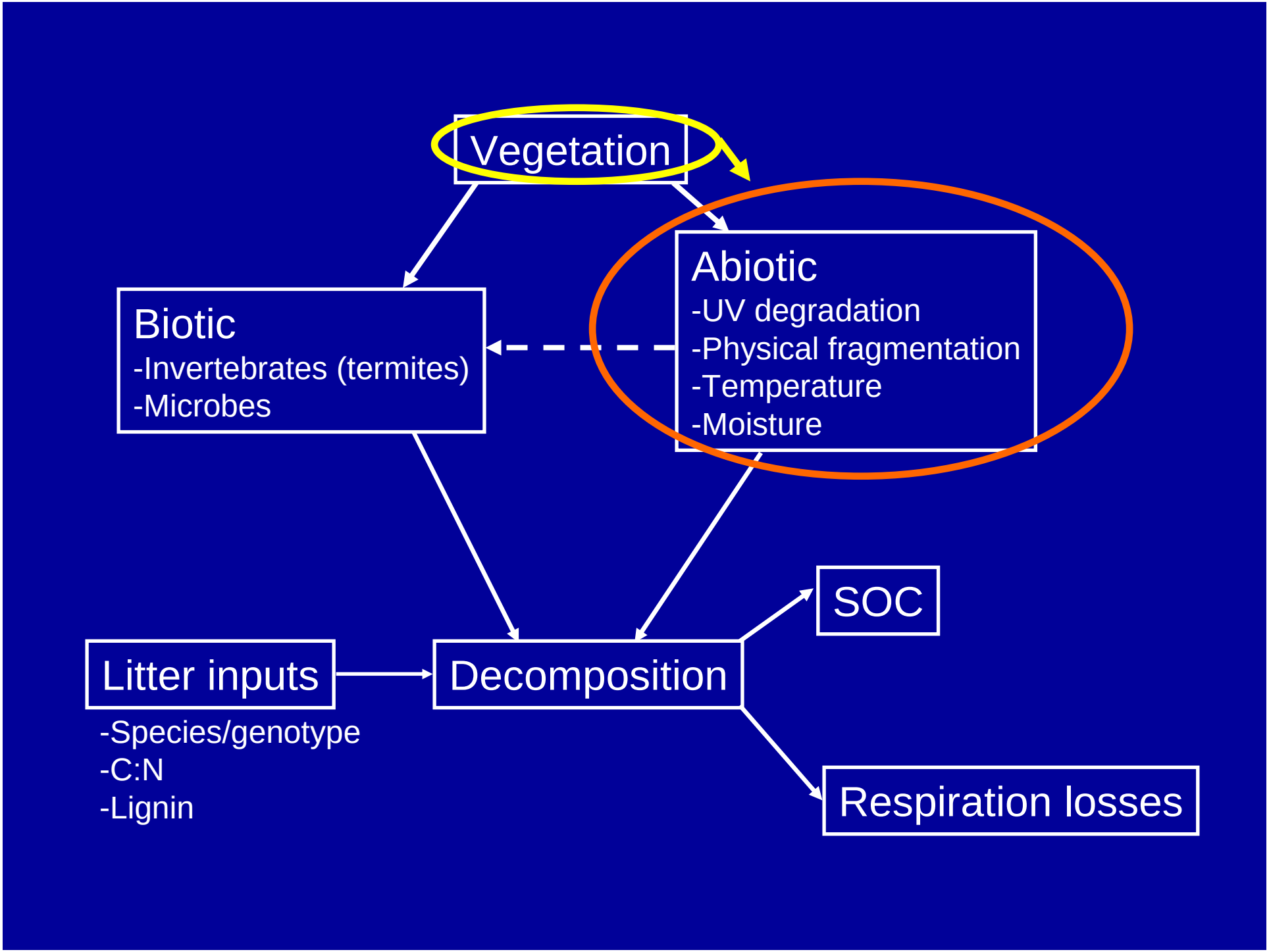

Mesquite canopy
2005 Girdled
2005 Cut
High SOC, TN, microbes
1960 Skeleton
Grass
1935 Cut
Bare ground
Low SOC

Mass Loss


Lehmann lovegrass
Mesquite
Mass remaining (%)
100
90
80
70
60
50
40
0
2
4
6
8
10
12
Time (months)

Single exponential decay model

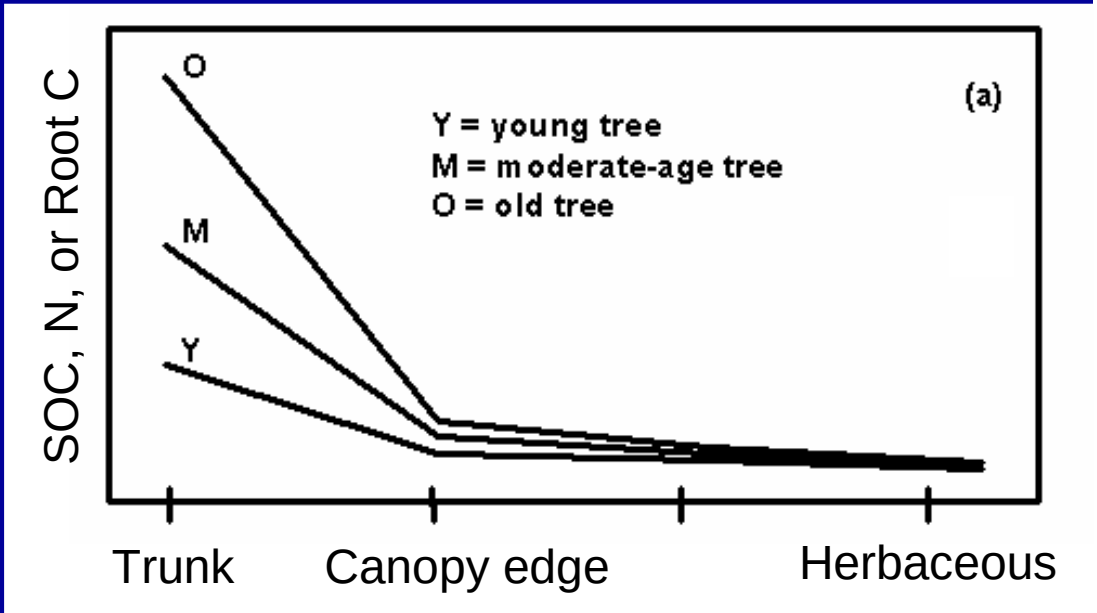


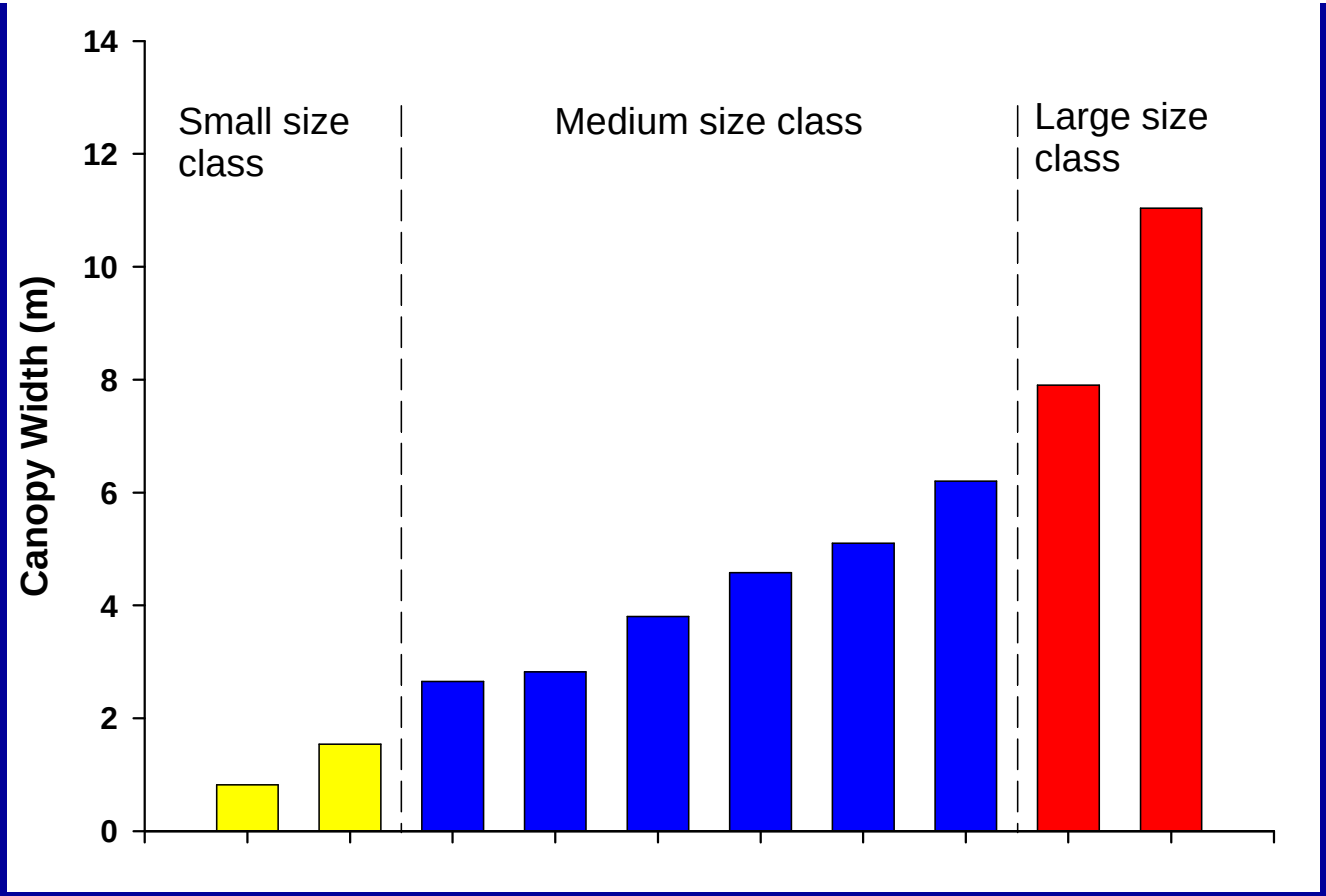

Vegetation
Biotic
-Invertebrates (termites)
-Microbes
Abiotic
-UV degradation
-Physical fragmentation
-Temperature
-Moisture
SOC
Litter inputs
Decomposition
-Species/genotype
-C:N
-Lignin
Respiration losses

III. Spatial Patterns of Soil C

- Spatial analysis of SOC, N, & root pools
- Target trees
  - Live (small → large)
  - Dead (different sizes & time since death)
  - Grazed/ungrazed
- Precipitation gradient

Hypothesized SOC Distribution



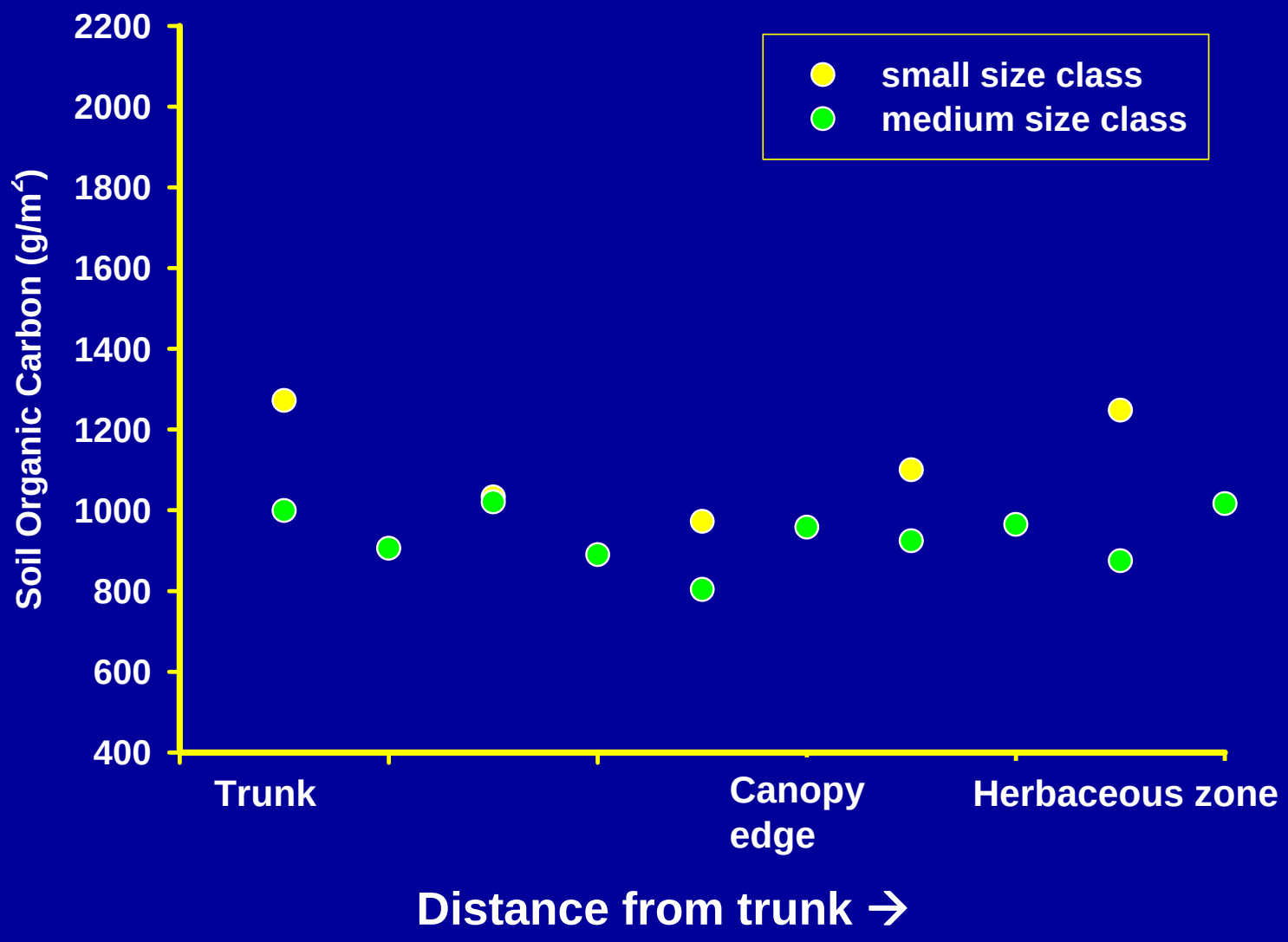

Canopy Width (m)
0
2
4
6
8
10
12
14
Small size class
Medium size class
Large size class

Small

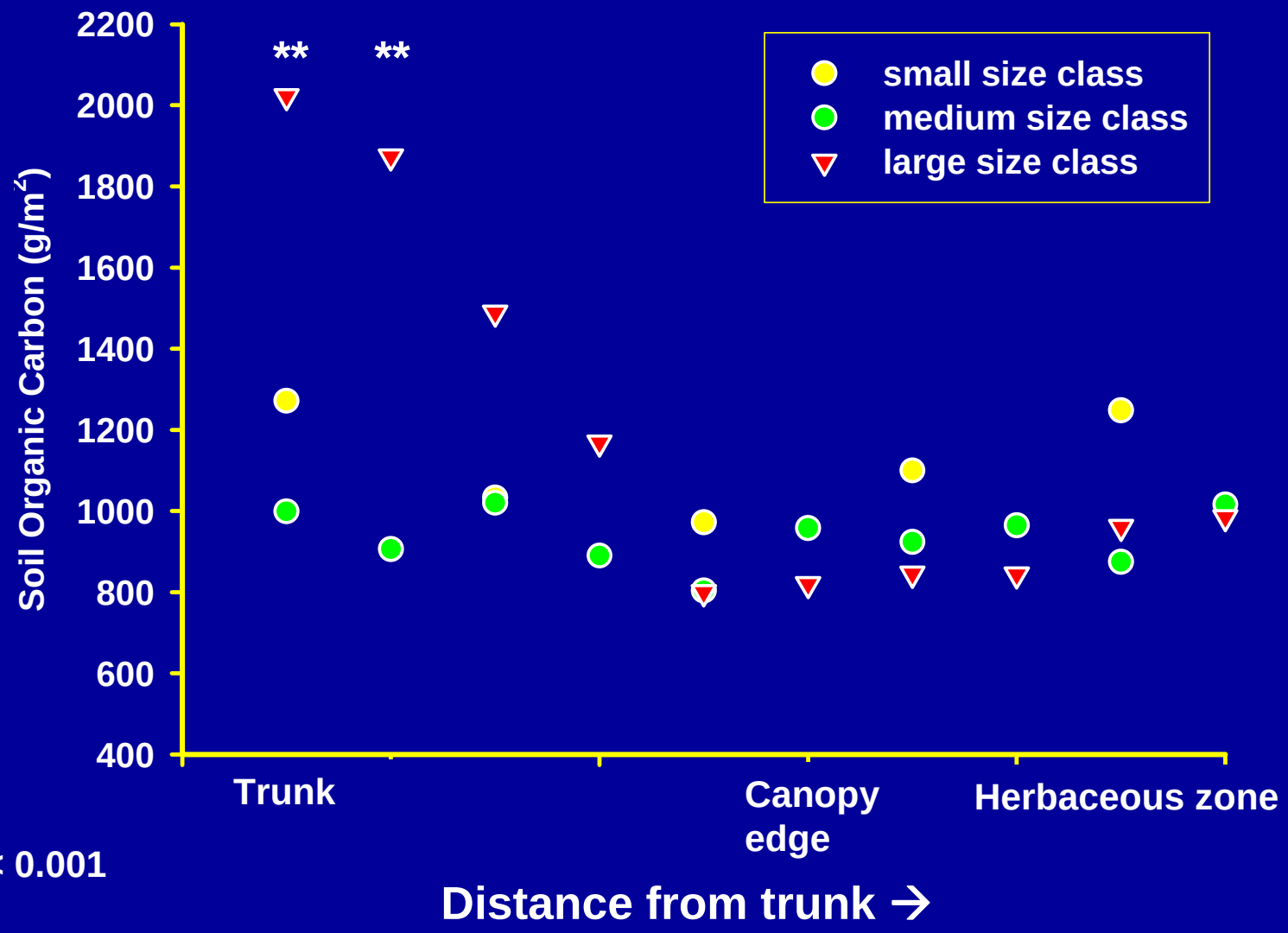
Medium

Large

Soil Organic Carbon

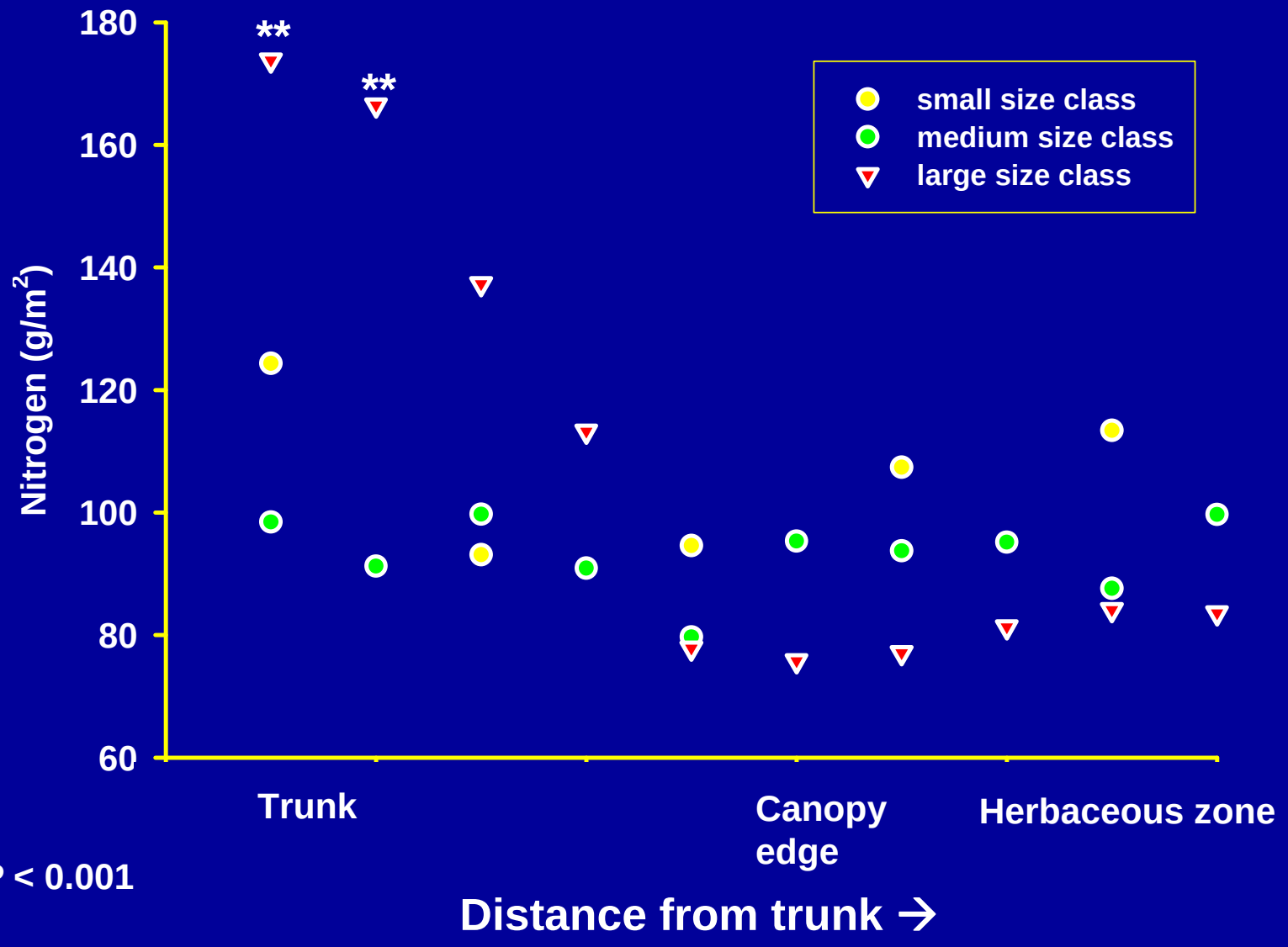


Soil Organic Carbon



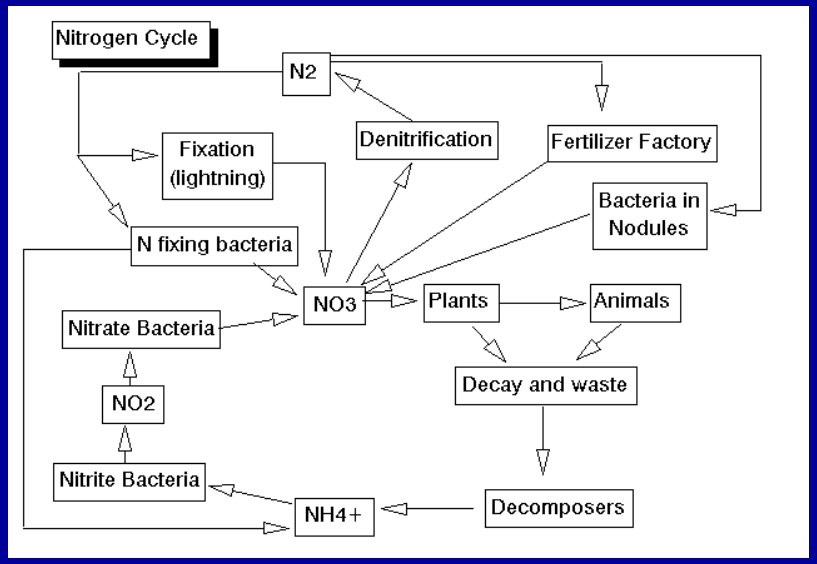
** $P < 0.001$

Soil Nitrogen



** $P < 0.001$

IV. Long-term SOC dynamics



- Vegetation change is long-term, large-scale process → experimental work difficult
- Ecosystem modeling as a predictive tool
  - large temporal and spatial scales
  - management & climate change scenarios
  - directions for future experiments

Ecosystem Modeling at SRER

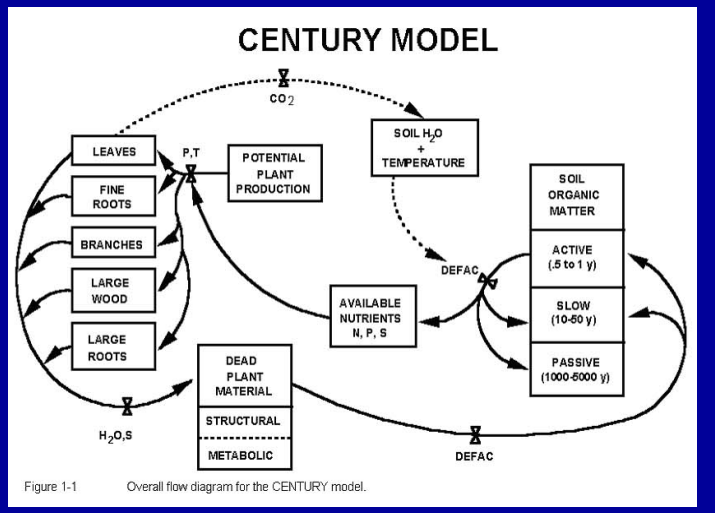
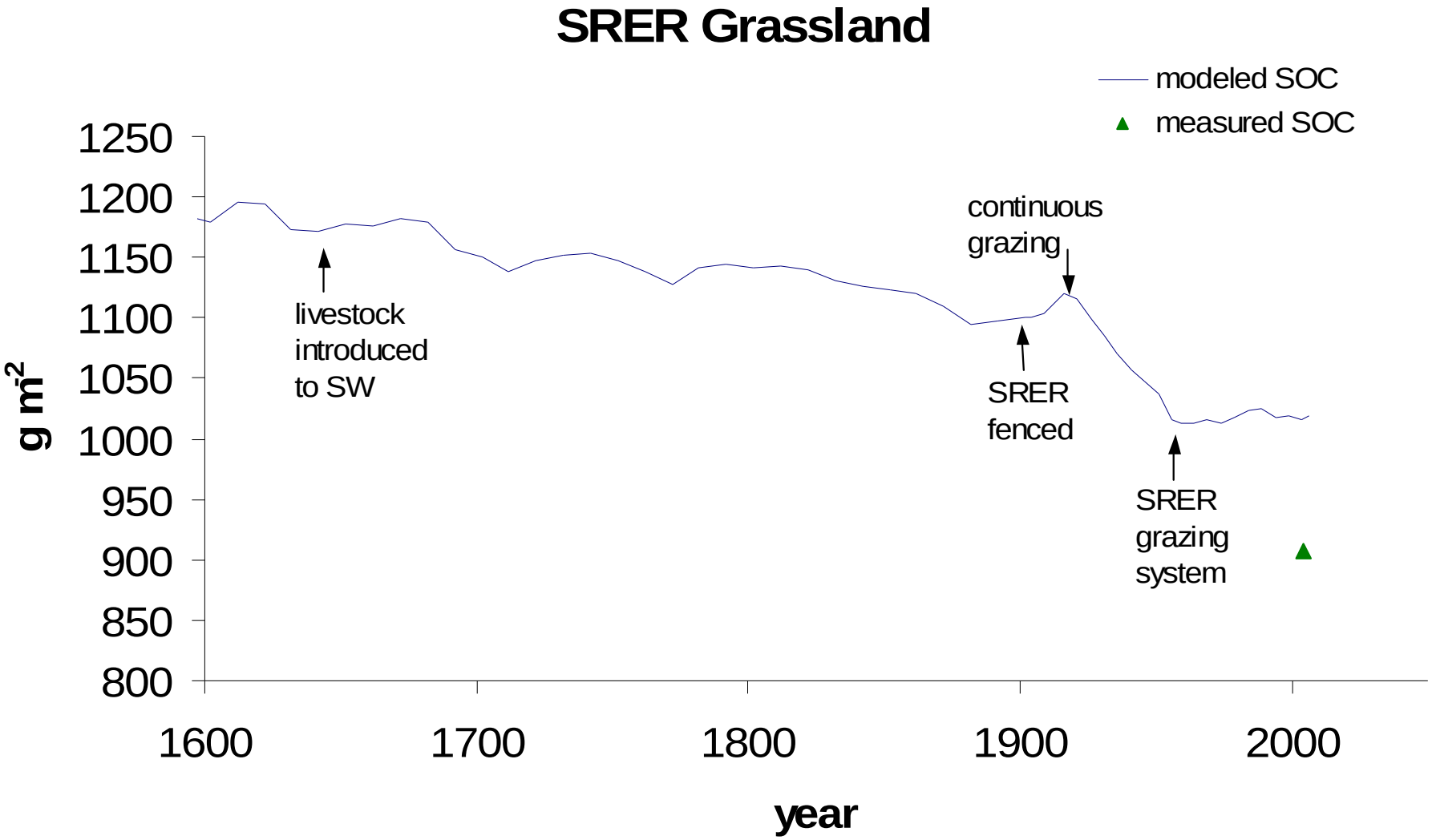


Figure 1-1 Overall flow diagram for the CENTURY model.

- CENTURY model
  - parameterization
  - adapt for arid systems
- Land-use history & C pools
  - simulation of past SRER management (grazing, brush management)
  - predictive modeling of current & novel management strategies (e.g., C sequestration credits)
- Climate change scenarios


SRER Grassland
modeled SOC
measured SOC
1250
1200
1150
1100
1050
1000
950
900
850
800
g m-2
livestock introduced to SW
continuous grazing
SRER fenced
SRER grazing system
1600
1700
1800
1900
2000
year

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