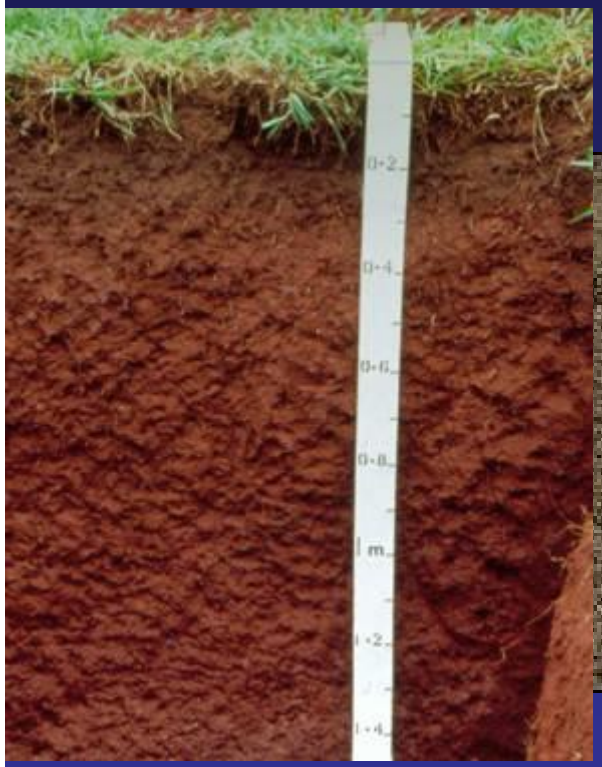
Direct effects of bioenergy systems on soil carbon



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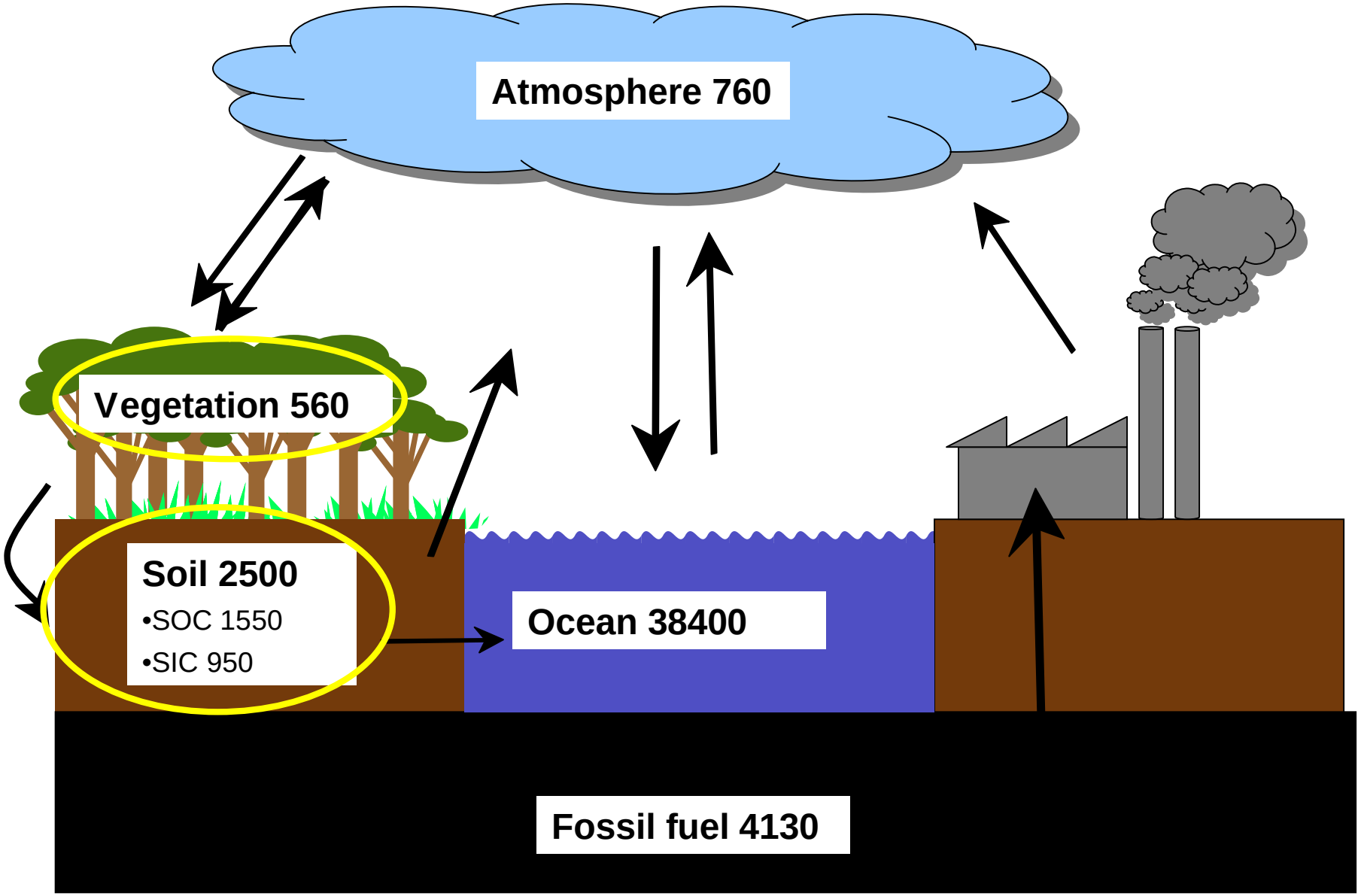
Outline

- Factors that affect soil carbon
- Why soil carbon matters
- Quantifying soil carbon change
- Some results from modelling
- Managing soil carbon

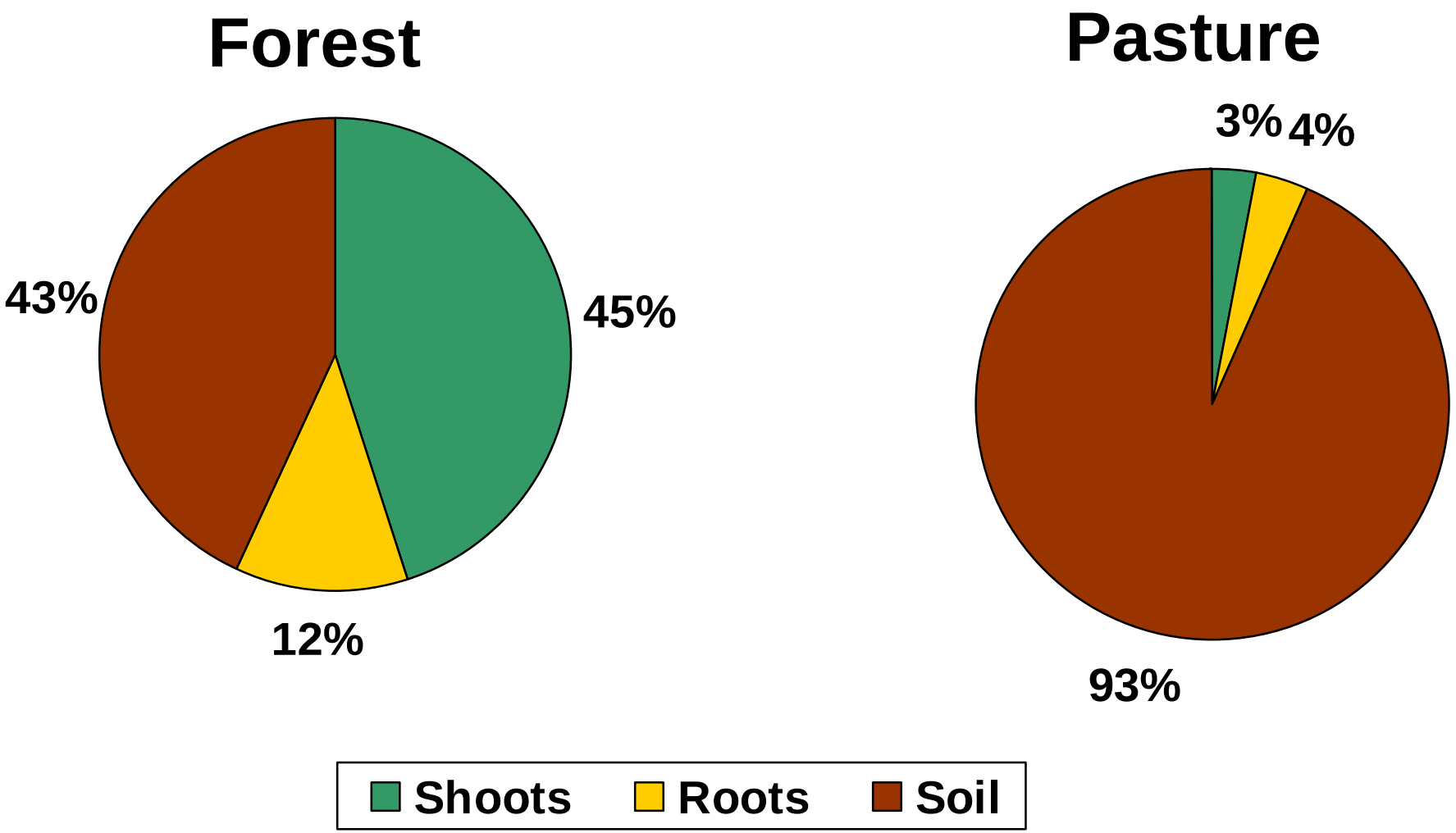
Global carbon pools

Units are Pg C (10^{15}g or Gt)

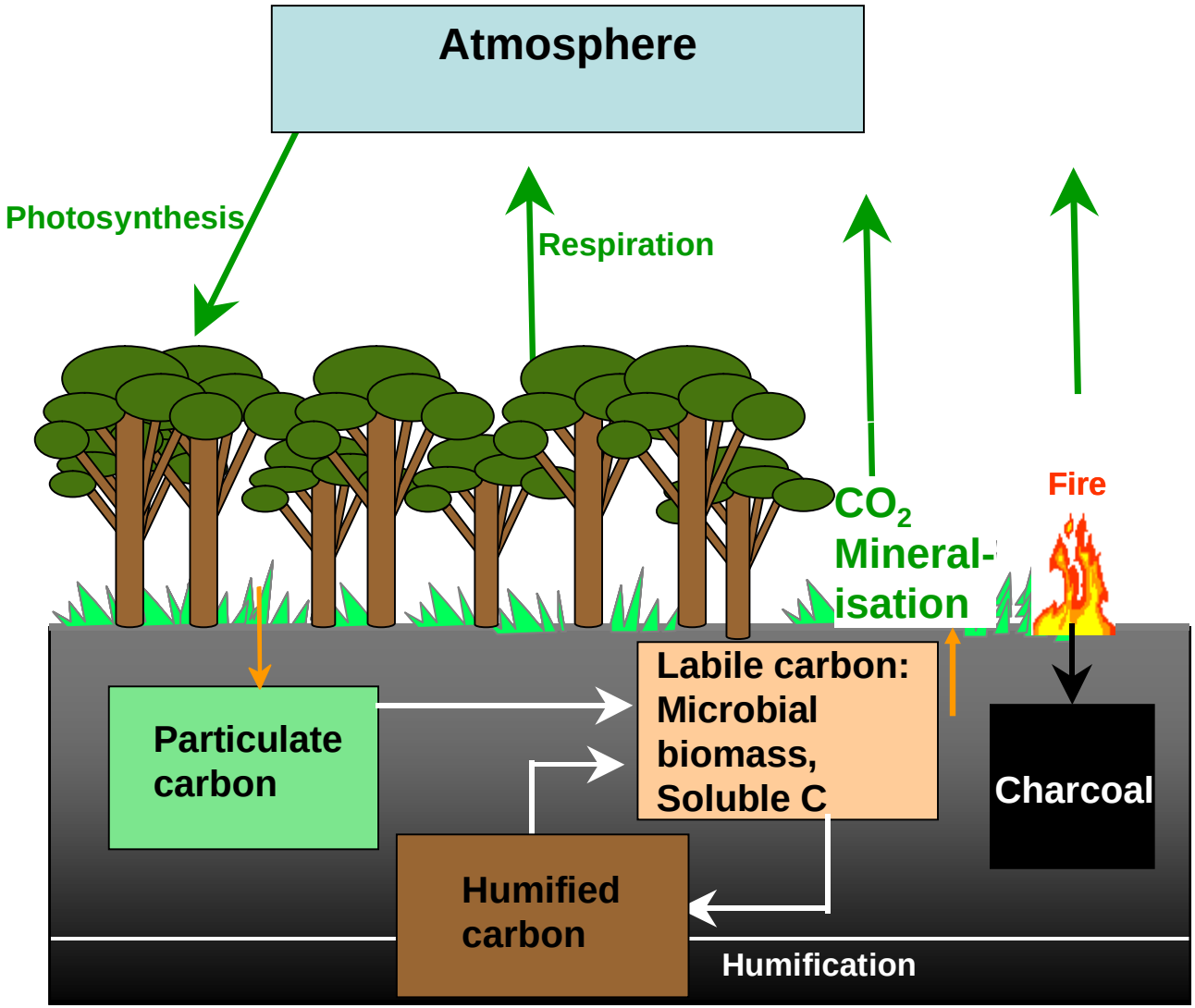


After Carlson et al 2001; data from Lal, 2008

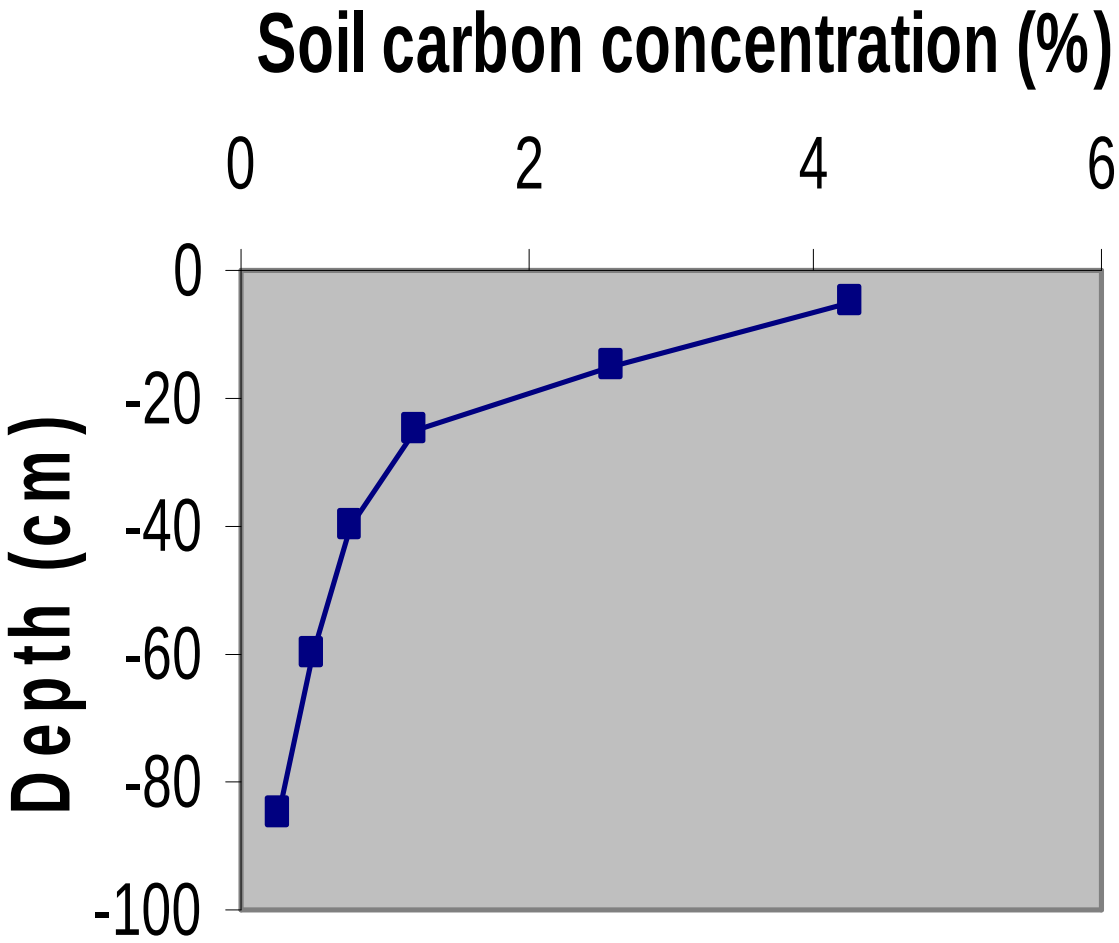
Carbon pools



Terrestrial Carbon Cycle



After J. Skjemstad, CRC Greenhouse Accounting



Soil carbon is determined by balance of input (plant growth) and losses (decomposition)

- Climate
  - rainfall
  - temperature
- Soil properties
  - water holding capacity
  - fertility
  - clay, Al

High soil carbon

- High inputs: fast plant growth
  - fertile soil
  - warm, wet climate
- Low outputs: slow decomposition
  - low oxygen
  - low temperature
  - high clay, Al

Low soil carbon

- Low inputs:
  - Low productivity: dry or cold climate
  - Low fertility soil type: light, shallow
- High decomposition:
  - warm, wet climate

Management affects soil carbon

Input rate: species, fertiliser, herbicide, irrigation, planting density, frequency of disturbance, organic matter addition

Rate of loss: biomass harvest, residue burning, cultivation

Actions that influence soil carbon

Soil carbon stock = Input - Loss

Reduce carbon

- Land clearing
- Regular cultivation
- Stubble burning

Build carbon

- Healthy plant cover
- Minimum disturbance
- Stubble retention
- Organic matter application

High risk of soil carbon loss

- Climate that favours decomposition: warm, wet but not waterlogged
- Soil type that minimises OM protection
- High initial soil carbon, large proportion decomposable
- Frequent cultivation: intermittent inputs, erosion, disturbance

Role of soil carbon

Biological

- Energy for biological activity
- Nutrient cycling

↑ Soil carbon =
↑ Soil health
↑ Resilience

Chemical

- Nutrient holding capacity
- Buffer against pH change

Physical

- Structural stability
- Erosion resistance
- Water infiltration
- Water holding capacity

Biomass for bioenergy

3 options:

- Use existing biomass (crops, residues)
- Intensify biomass harvest under existing use
- Change land use

Bioenergy systems:

- Non-woody: Annual crops/pasture
- Short rotation woody crops
- Forest for timber plus biomass

Soil C in Bioenergy systems

- More biomass removed
- More nutrients removed
- May increase soil disturbance

SO

- Risk of short term loss
- Possible decline in equilibrium soil C

Soil C in Bioenergy systems

BUT

- Inputs occur throughout growth cycle
- Coarse residues decay at surface
- Residues often burned on site

…. Coarse residues decay at surface

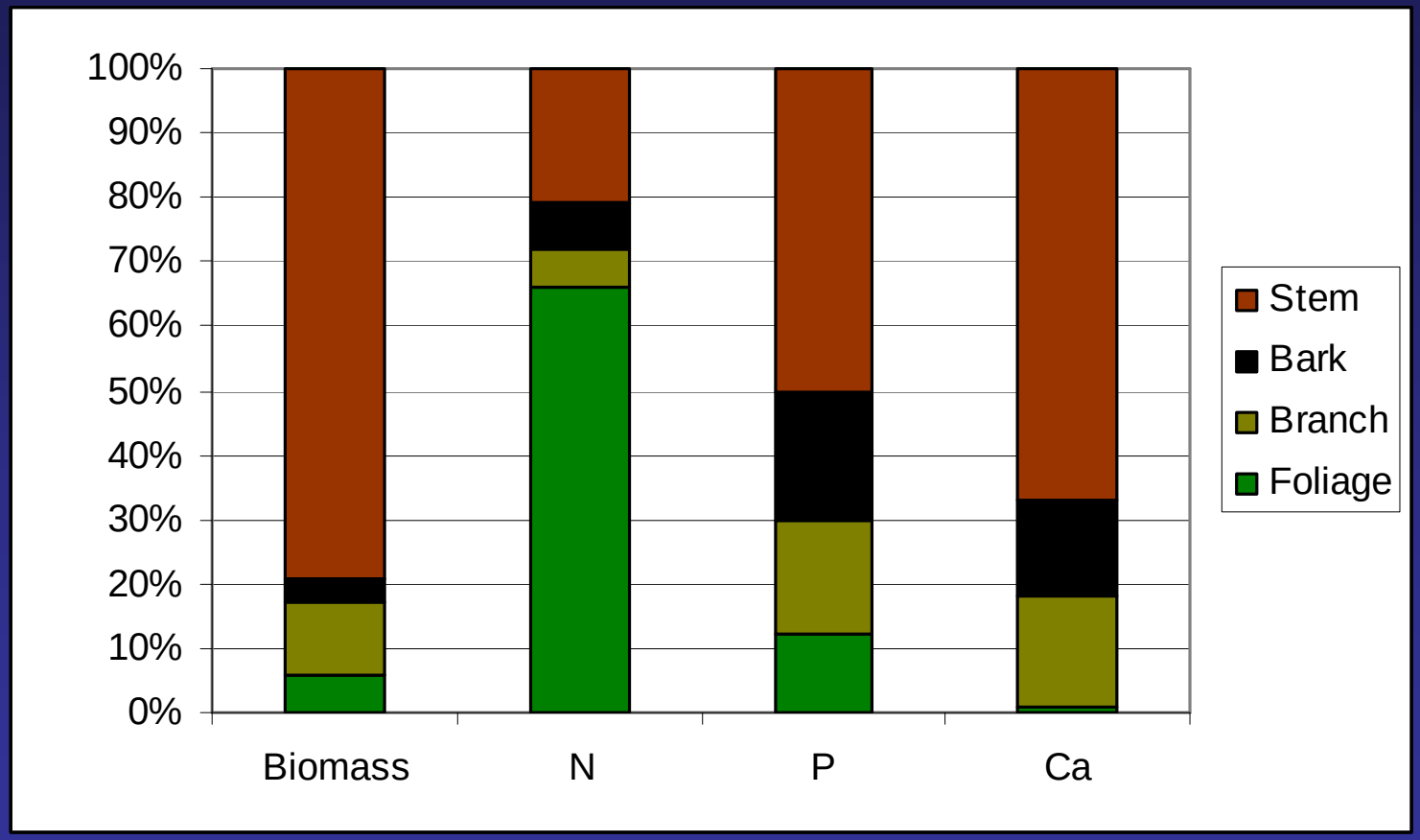
…. Residues often burned on site

Soil C in Bioenergy systems

BUT

- Inputs occur throughout growth cycle
- Coarse residues decay at surface
- Residues often burned on site
- Nutrients concentrated in foliage, bark

Nutrient distribution



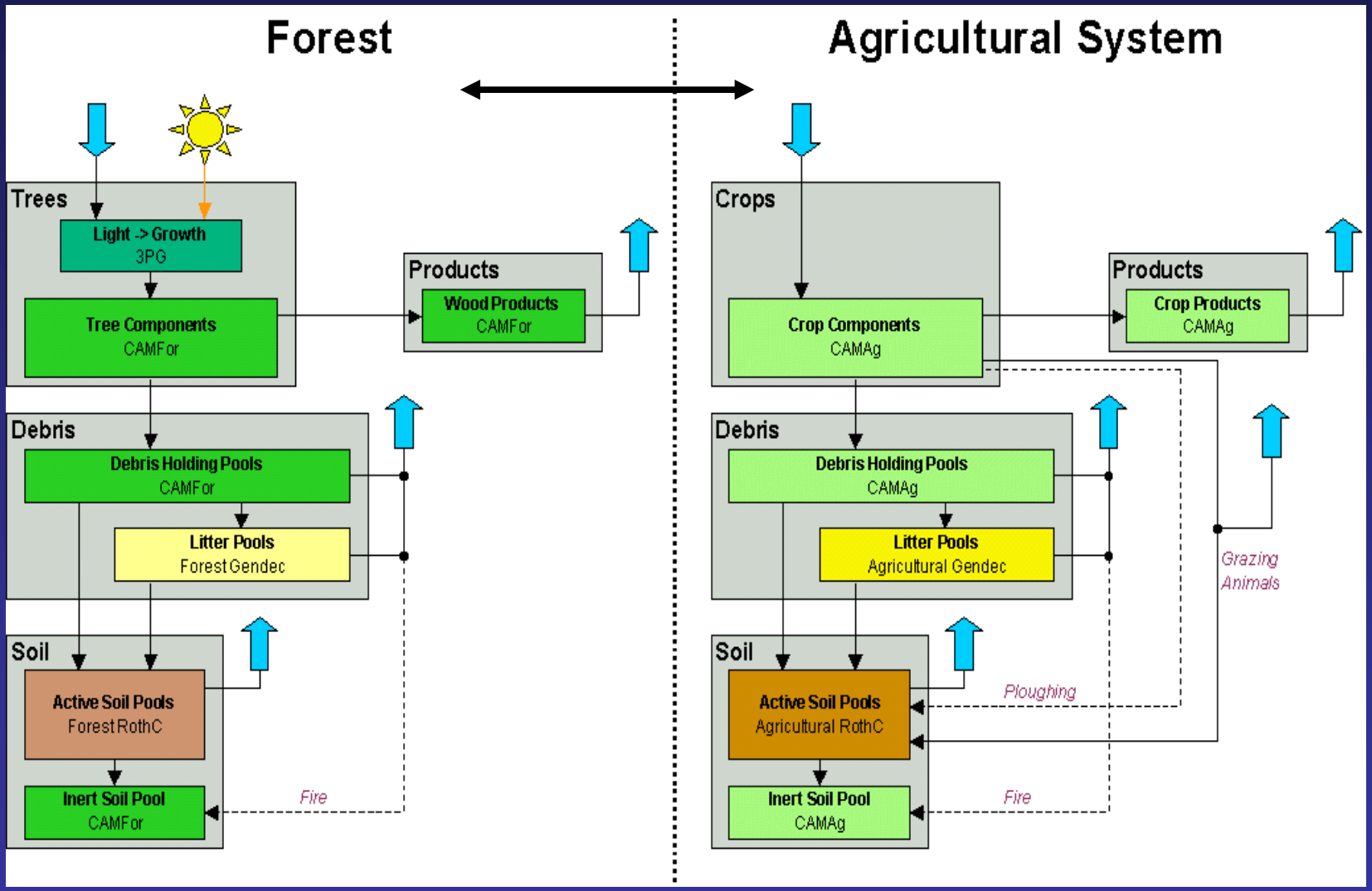
Evidence for impacts?

- New systems, no long-term research
- Some extrapolation possible
- Modelling?

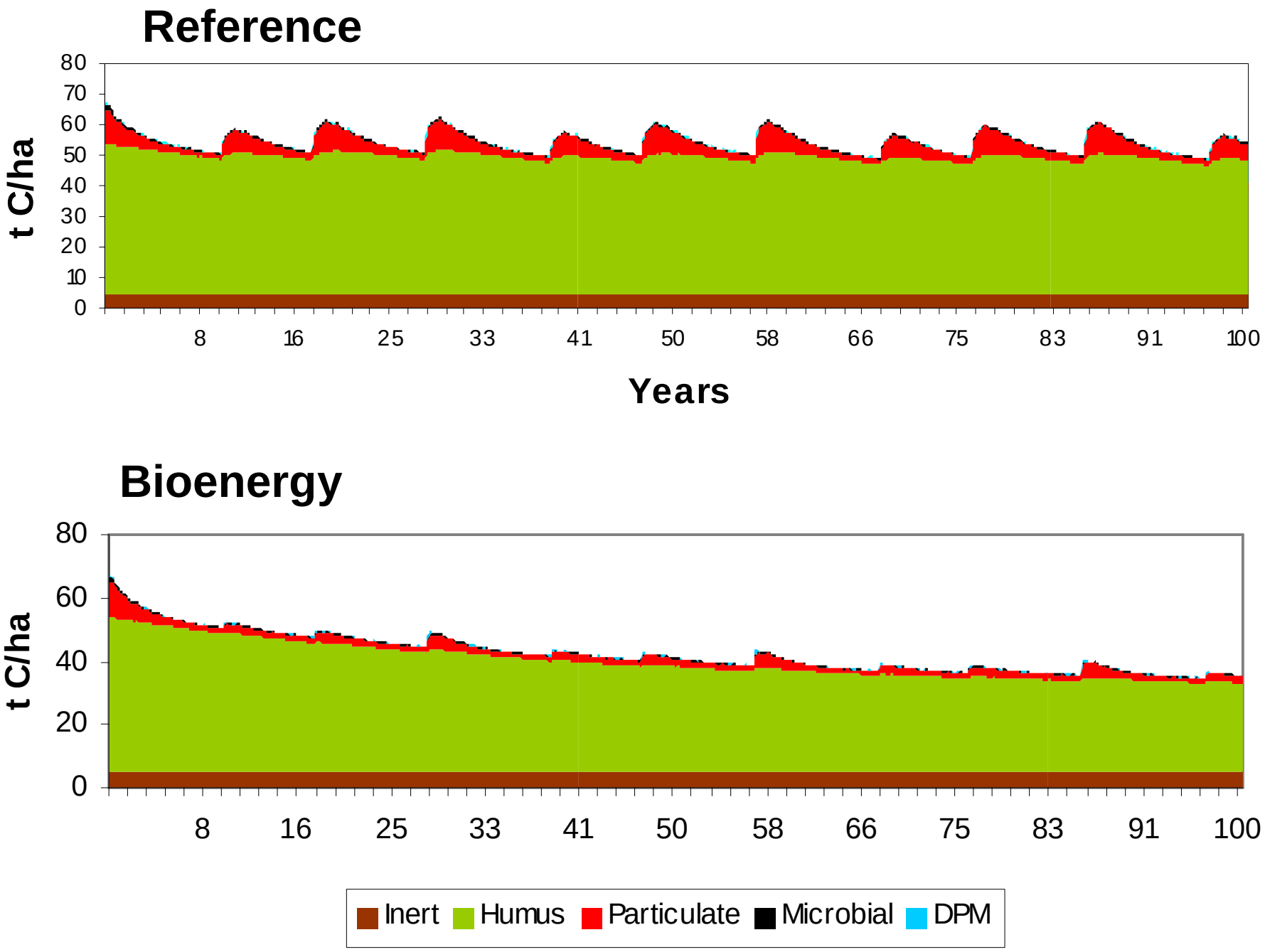
Modelling soil carbon

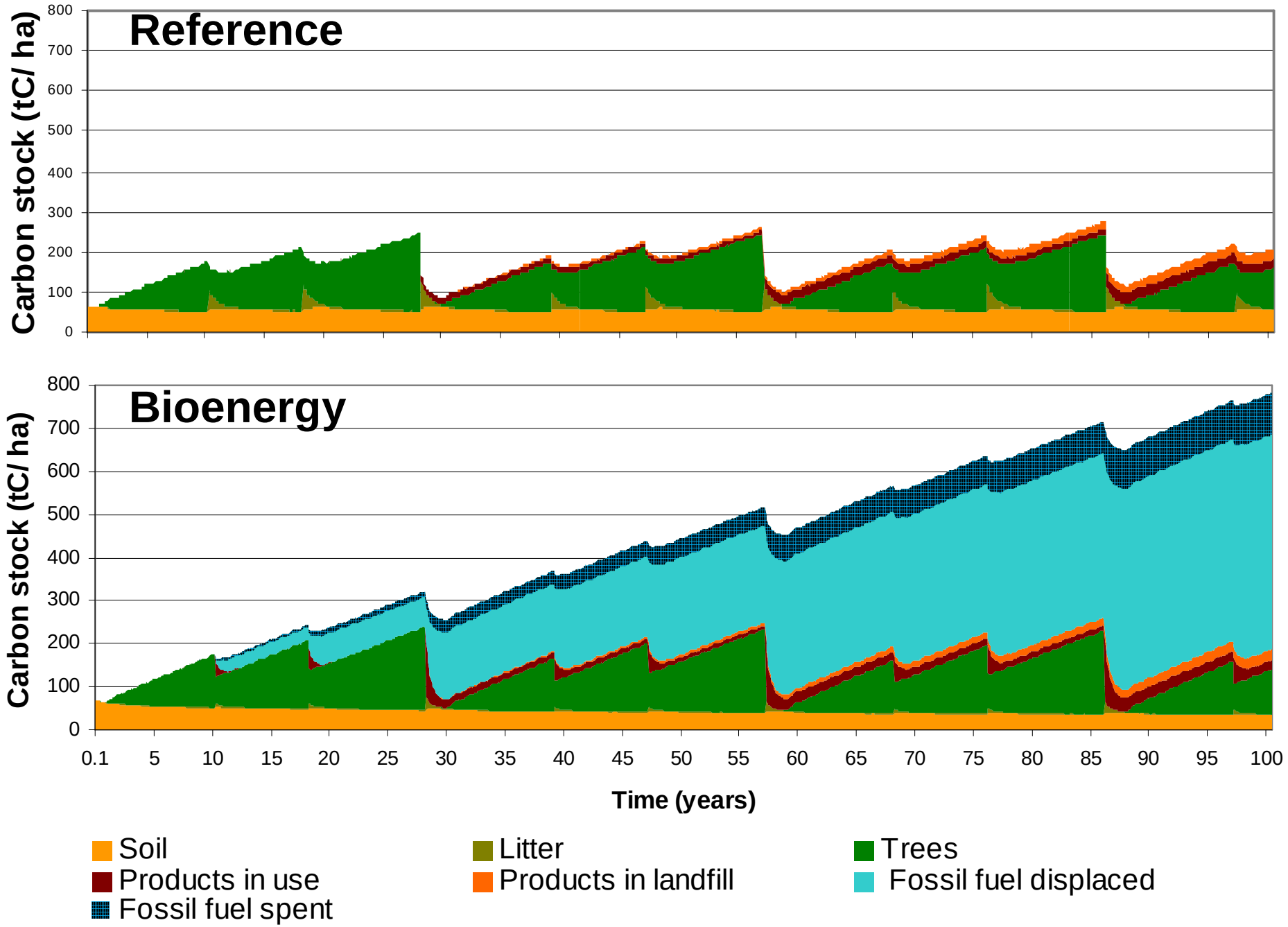
- Site characterisation
  - soil type
    - Fractionation – C pools
  - climate
  - land use
- Model application
  - model plant growth
  - model soil C dynamics eg Roth C, Century

FullCAM Model



Australian Greenhouse Office – now Department of Climate Change





Effect of bioenergy on soil carbon?

- Yes, some decline is possible
- Depends on land use change
- Should include in GHG accounting
- Predict from models

For forest systems modelled: **Loss in soil C is minimal compared with the bioenergy benefit**

Managing soil carbon

- Retain foliage
- Return ash?
- Add organic matter?
- Maximise growth rate
  - species selection
  - site preparation
  - fertiliser
  - mixed species?

Managing soil carbon

- Low input, organic farming

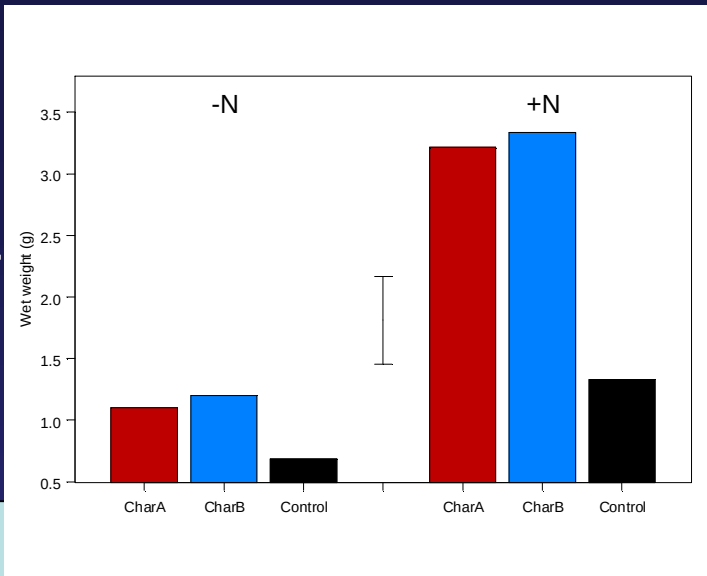
vs high-tech precision farming

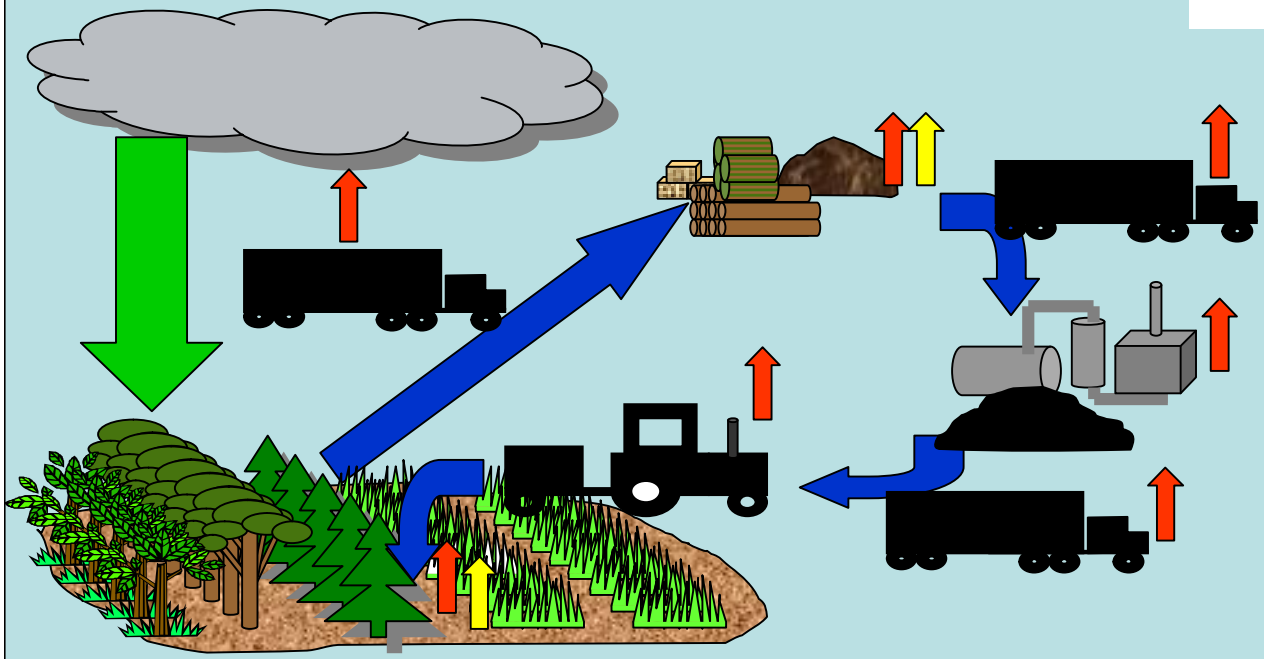
- tradeoff between sustainability and yield?

- Biochar?

Bio-Char for carbon sequestration

Impact of Char 10t/ha on wheat biomass at 52 days





- Long term carbon storage
- Decreased N_2O
- Increased biological activity, nutrient cycling, water holding capacity
- Reduced fertiliser requirement
- Increased plant growth

Impact of bioenergy on soil carbon

- Short term decline in soil carbon is possible, temporary?
- Loss most likely in systems with high labile carbon
- Annual crops and short rotation woody crops have greatest risk
- Management can minimise SOC decline

Impact of bioenergy on soil carbon

- Need to include soil C in GHG accounting
  - temporal pattern is important
  - GHG accounting should consider long term average change in carbon stock to avoid perverse outcomes
- Limited experimental data
- Process-based models useful

For forest systems modelled:

Loss in soil C is minimal compared with the bioenergy benefit