Restoration of soil organic matter on degraded sites

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- Soil organic matter is key component of soil quality and health
- Also critical means of sequestering C – some SOM pools can sequester C for centuries
- One of the challenges in restoring soils is restoring soil organic matter:

1) after mining

Sokolov mines, Czechia

2) to reverse long-term land degradation

"We are losing 30 soccer fields of soil every minute, mostly due to intensive farming," Volkert Engelsman, an activist with the International Federation of Organic Agriculture Movements told the forum at the FAO's headquarters in Rome. April 2017

CRIBE

SCIENTIFIC AMERICAN

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REUTERS

SUSTAINABILITY

Only 60 Years of Farming Left If Soil Degradation Continues

Generating three centimeters of top soil takes 1,000 years, and if current rates of degradation continue all of the world's top soil could be gone within 60 years, a senior UN official said

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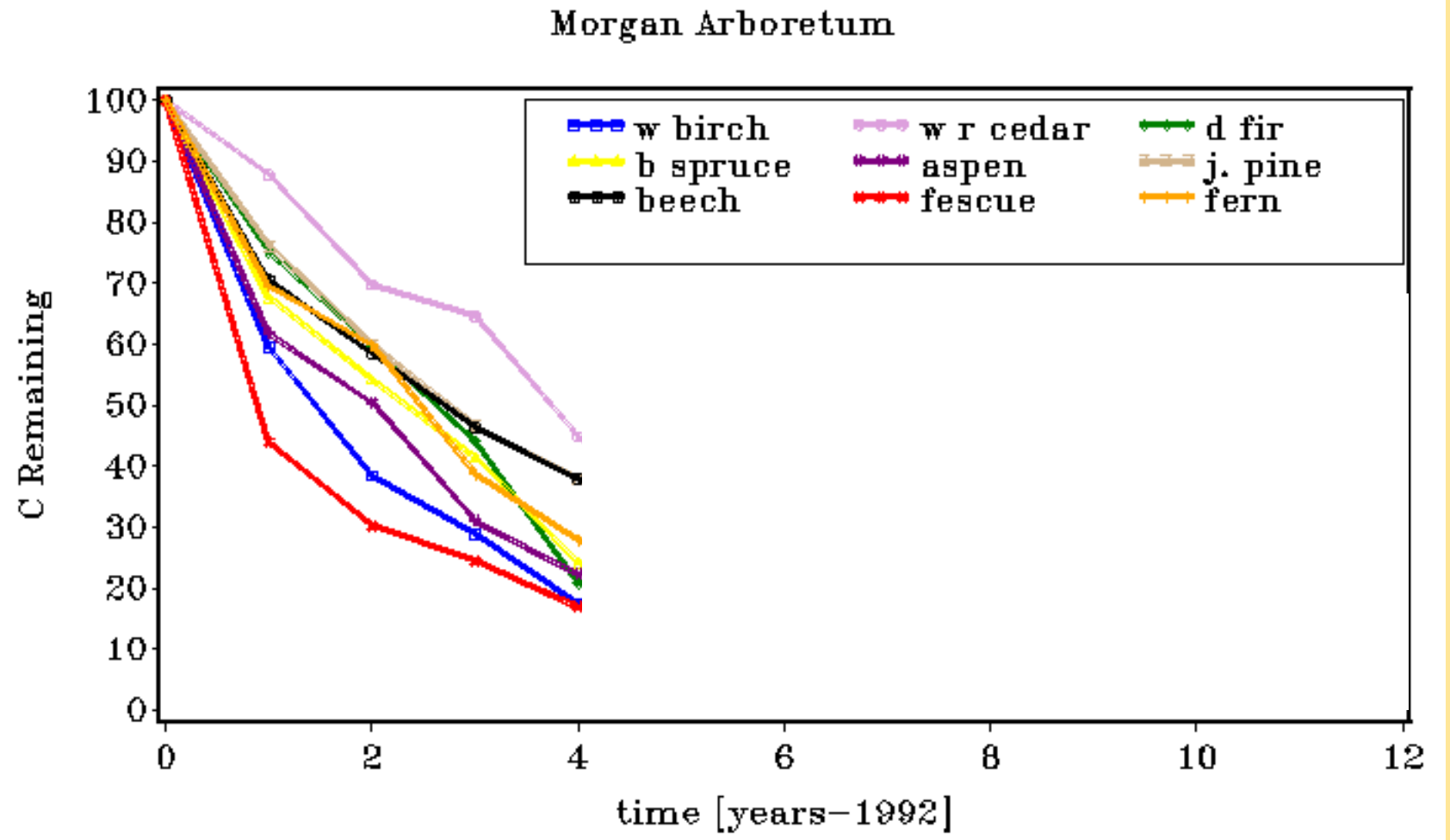
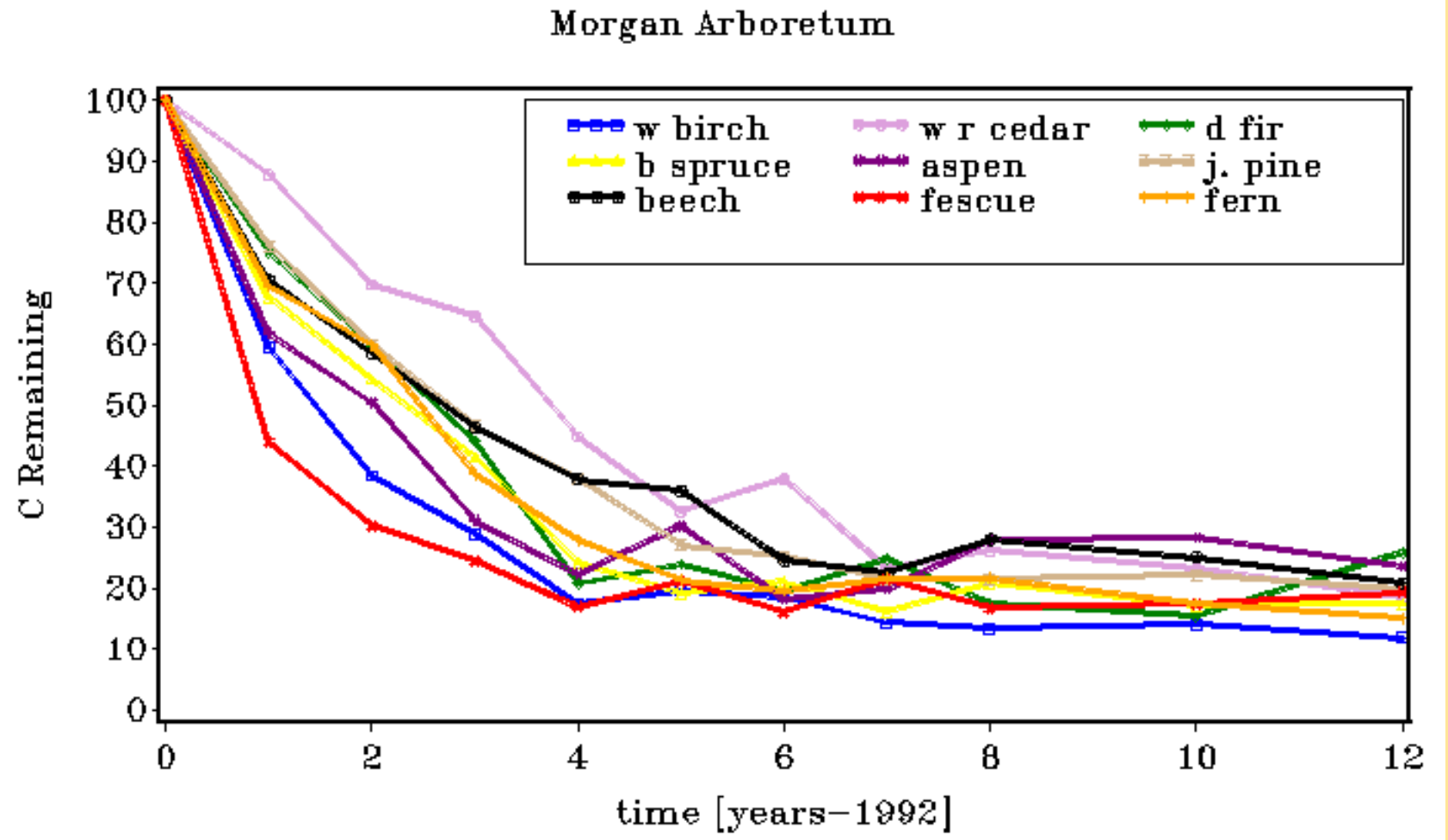
What have we found out about the processes of decomposition, humification and soil organic matter formation that can inform our practices to hasten development of soil organic matter?

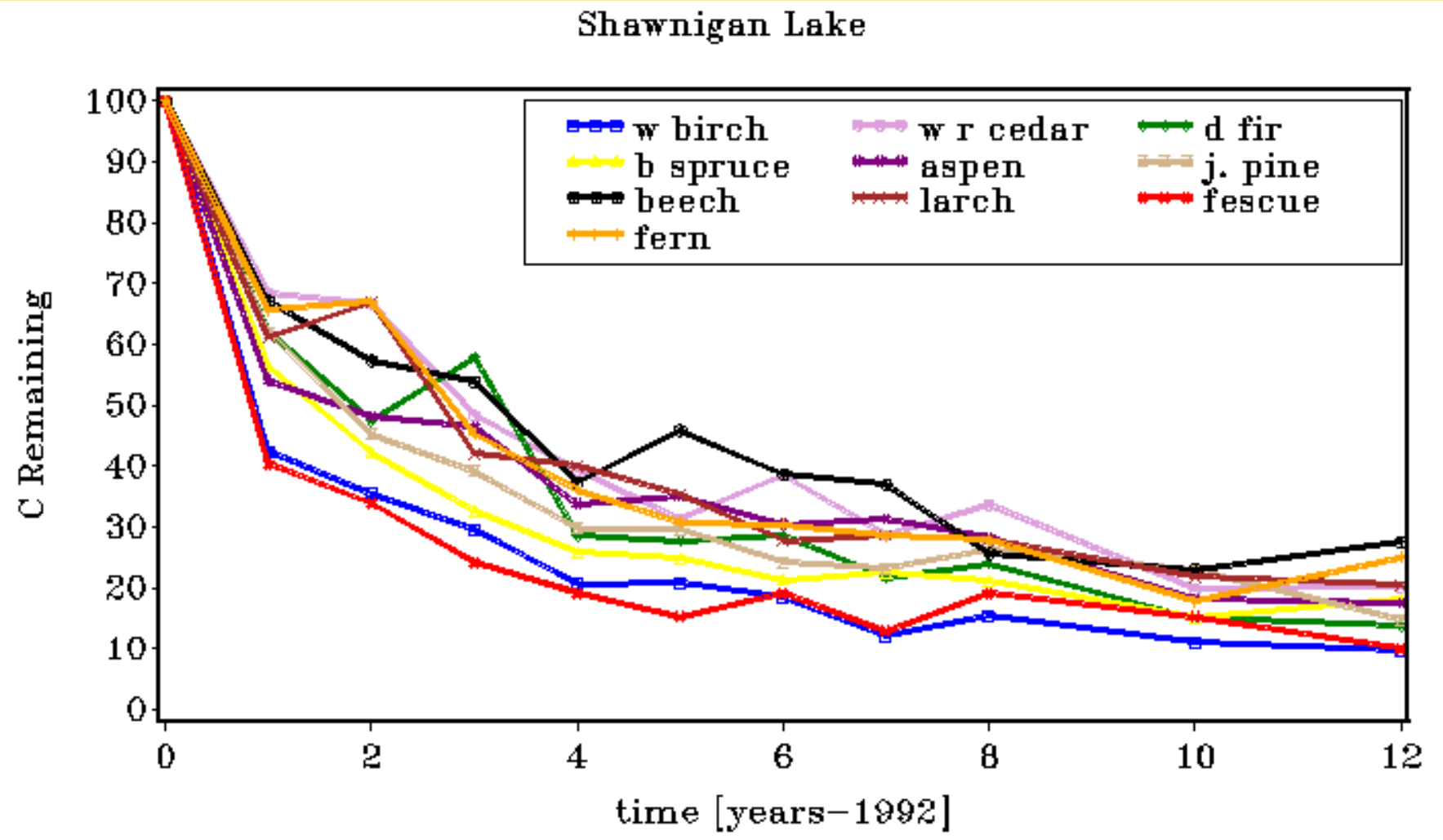
Long-term litter mass loss



Long-term litter mass loss



Moore et al 2006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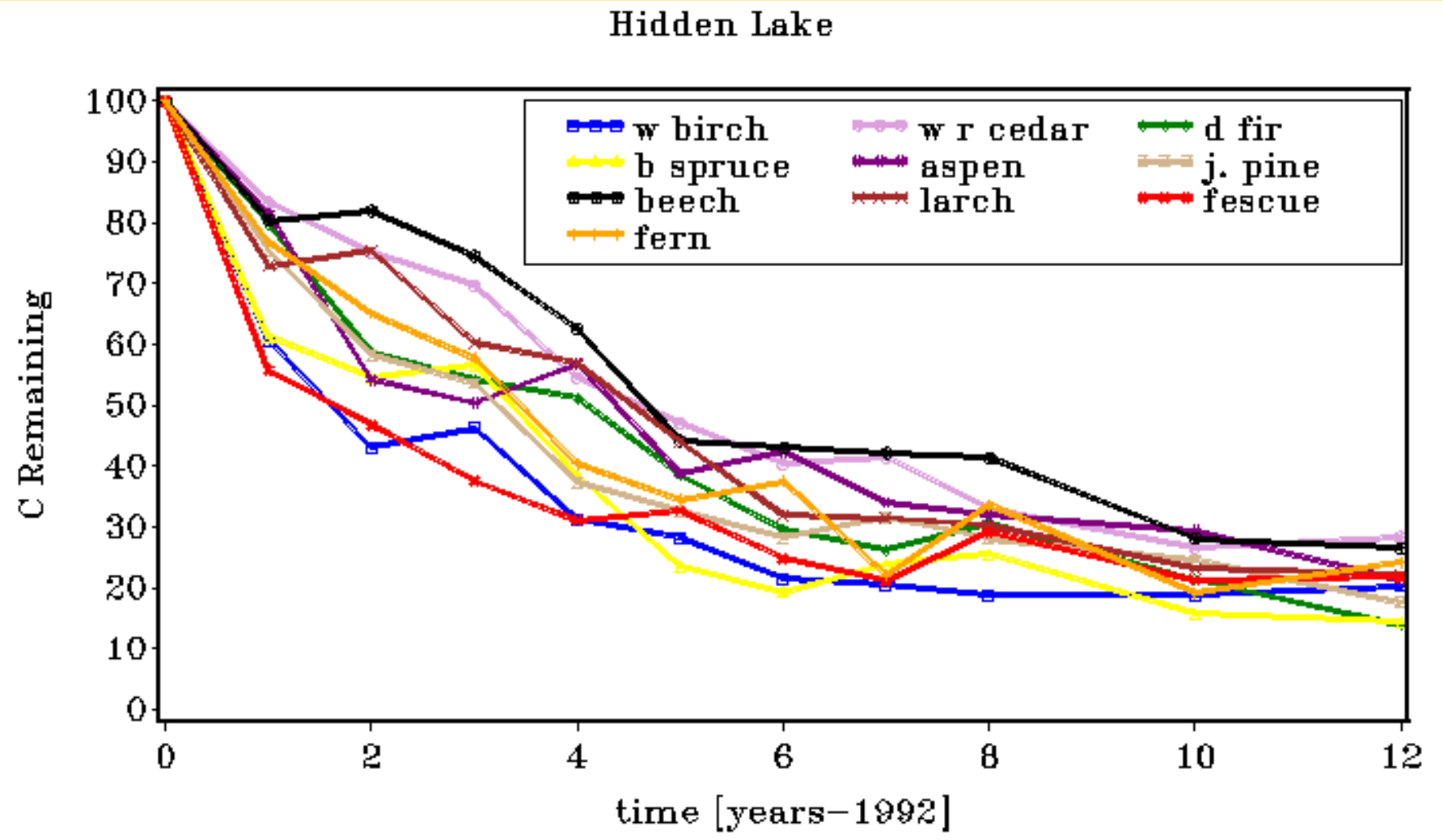
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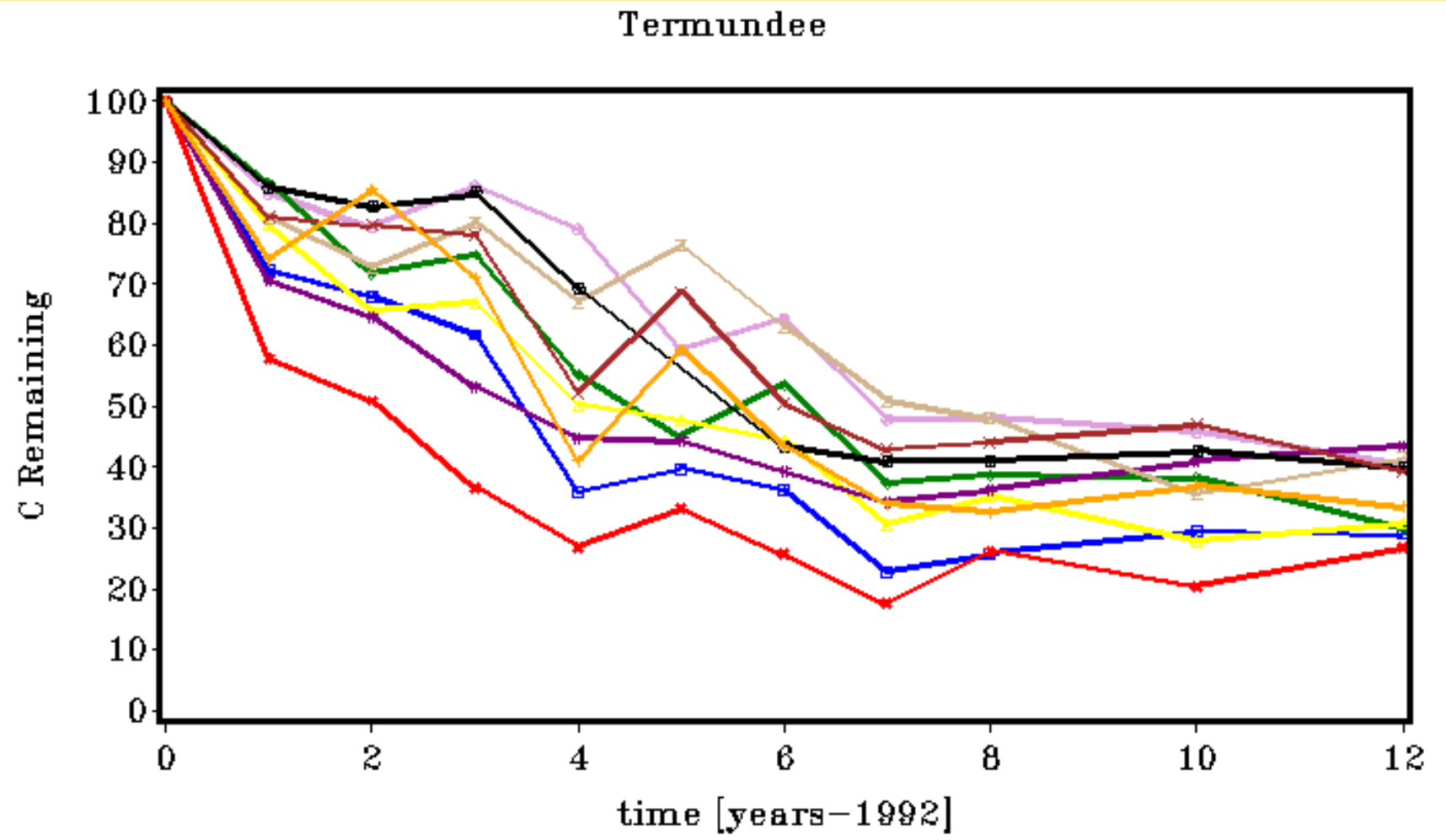
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Late-stage decomposition

- 20-30% of original litter mass is converted to humus in northern forests
- humus decomposes slowly (decades)
- consistent with build-up of surface organic layer (LFH)

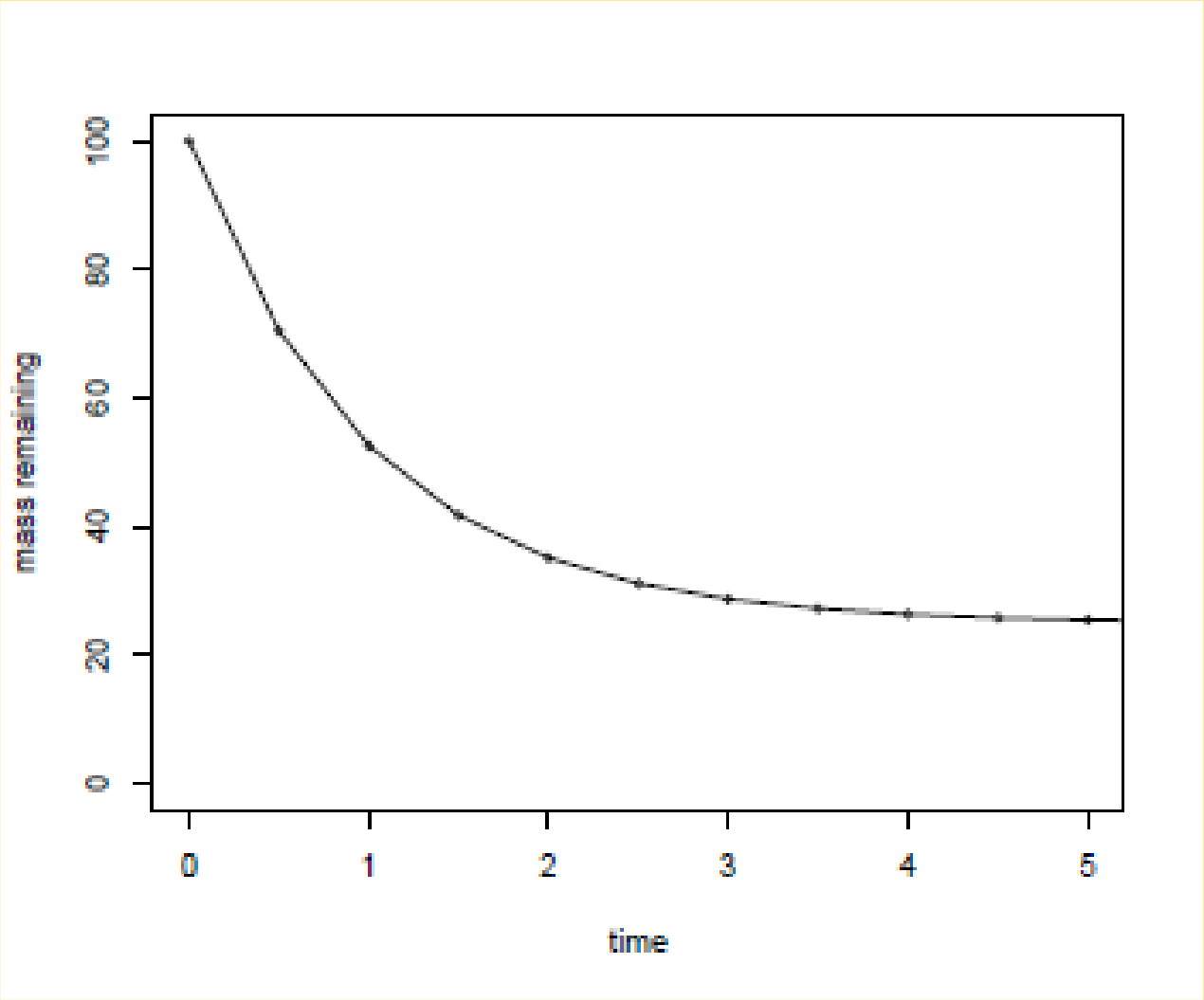
- for humus and SOM development, the proportion of litter that is humified matters more than rate of decomposition

Humus - the ‘new’ view

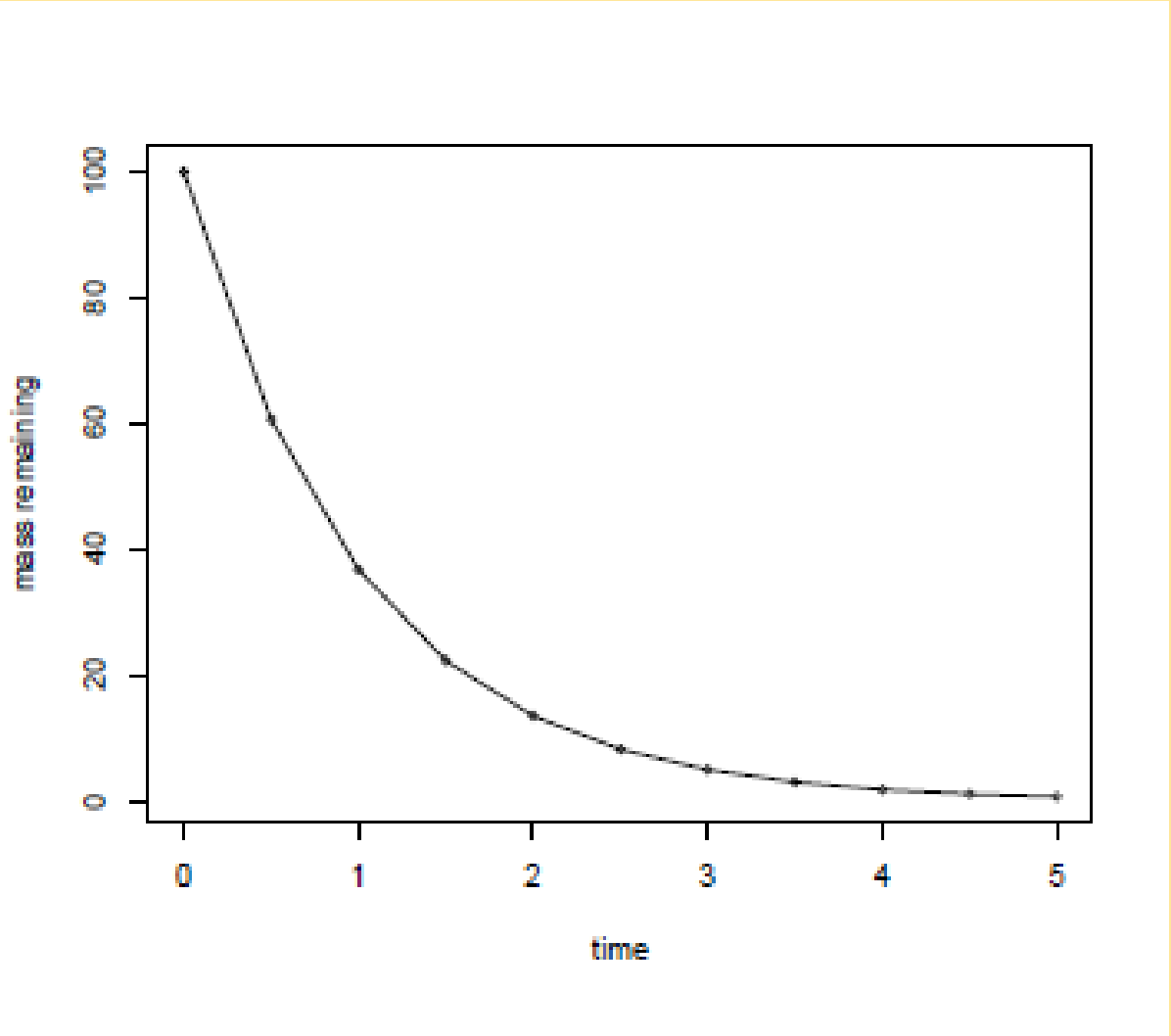
- humus and SOM have large microbial signal
- most stable SOM has been microbiologically transformed
- biological transformations into new materials via soil microorganisms (rather than selective preservation of recalcitrant plant materials) leads to the formation of complex, decay-resistant secondary compounds (humus) and slowing of decay.

Grandy & Neff 2008; Schmidt et al. 2011

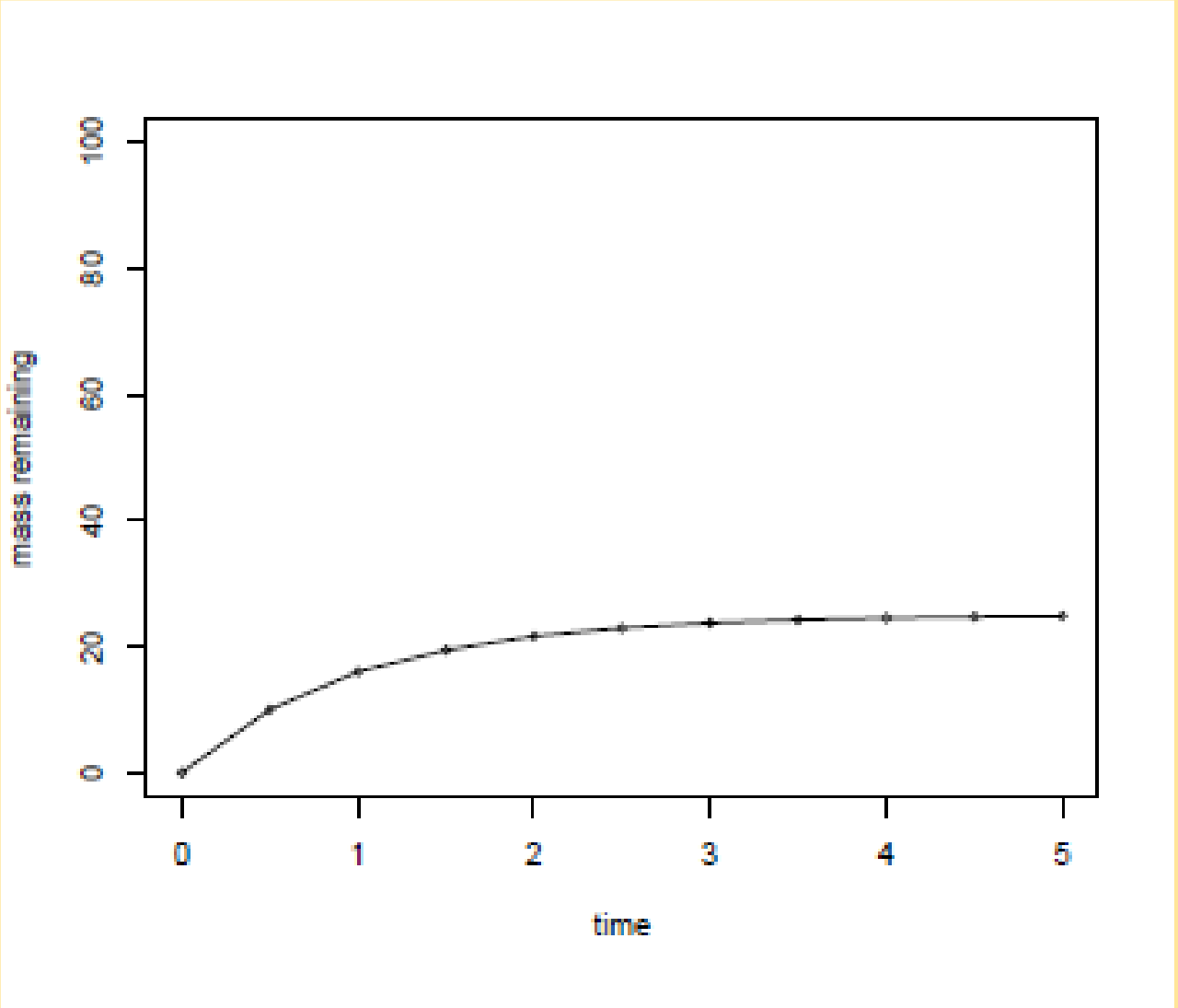
Mass remaining curves are really *net* mass remaining
-result of two simultaneous processes:



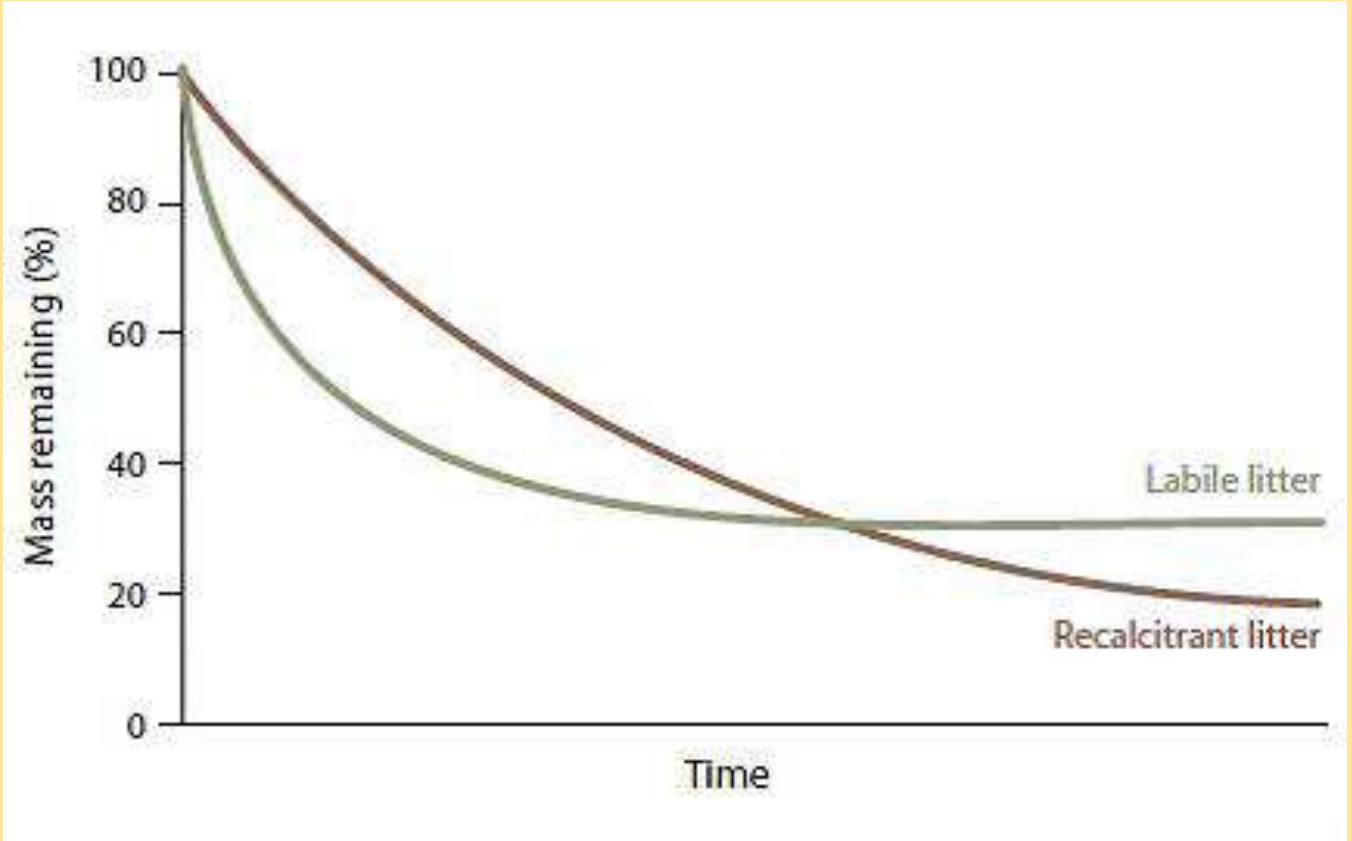
1) decay of plant litter material



2) Transformation into microbial biomass, residues, metabolites + chemical reactions leading to humification



Labile litters may generate more humus by stimulating production of microbial biomass

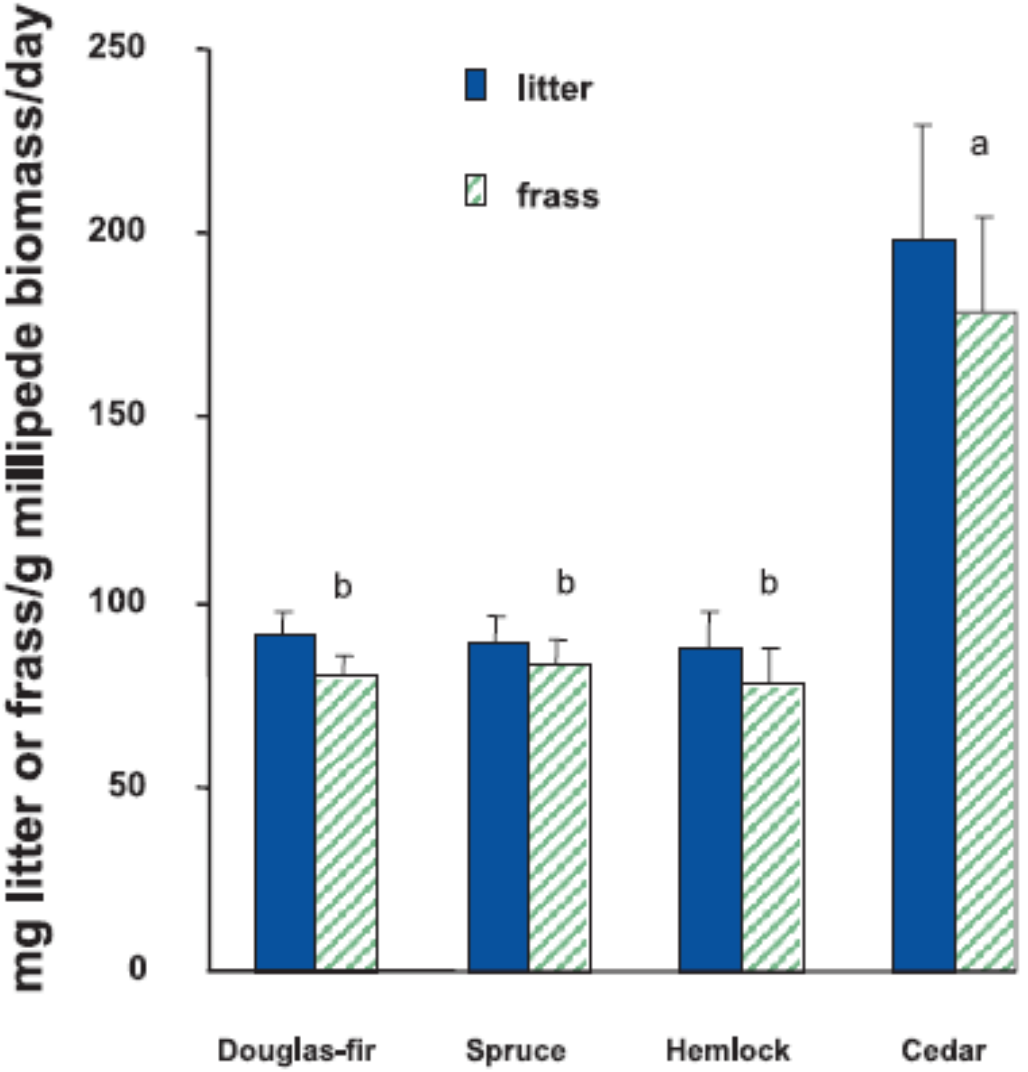


Hypothetical dynamic of mass remaining during decomposition of a labile (i.e. high C quality and N concentration) and a recalcitrant (i.e. low C quality and N concentration) plant litter. Cotrufo et al. (2013), Haddox et al (2015)

Soil macrofauna

transform litter to frass

Fig. 3. Daily litter consumption and frass production in milligrams per gram of millipede biomass per day. Means for either series with different letters are significantly different (LSD test, $P < 0.05$).



Carcamo et al 2001

millipede frass decays slowly

A.J. Rawlins et al. / Soil Biology & Biochemistry 39 (2007) 1202–1205

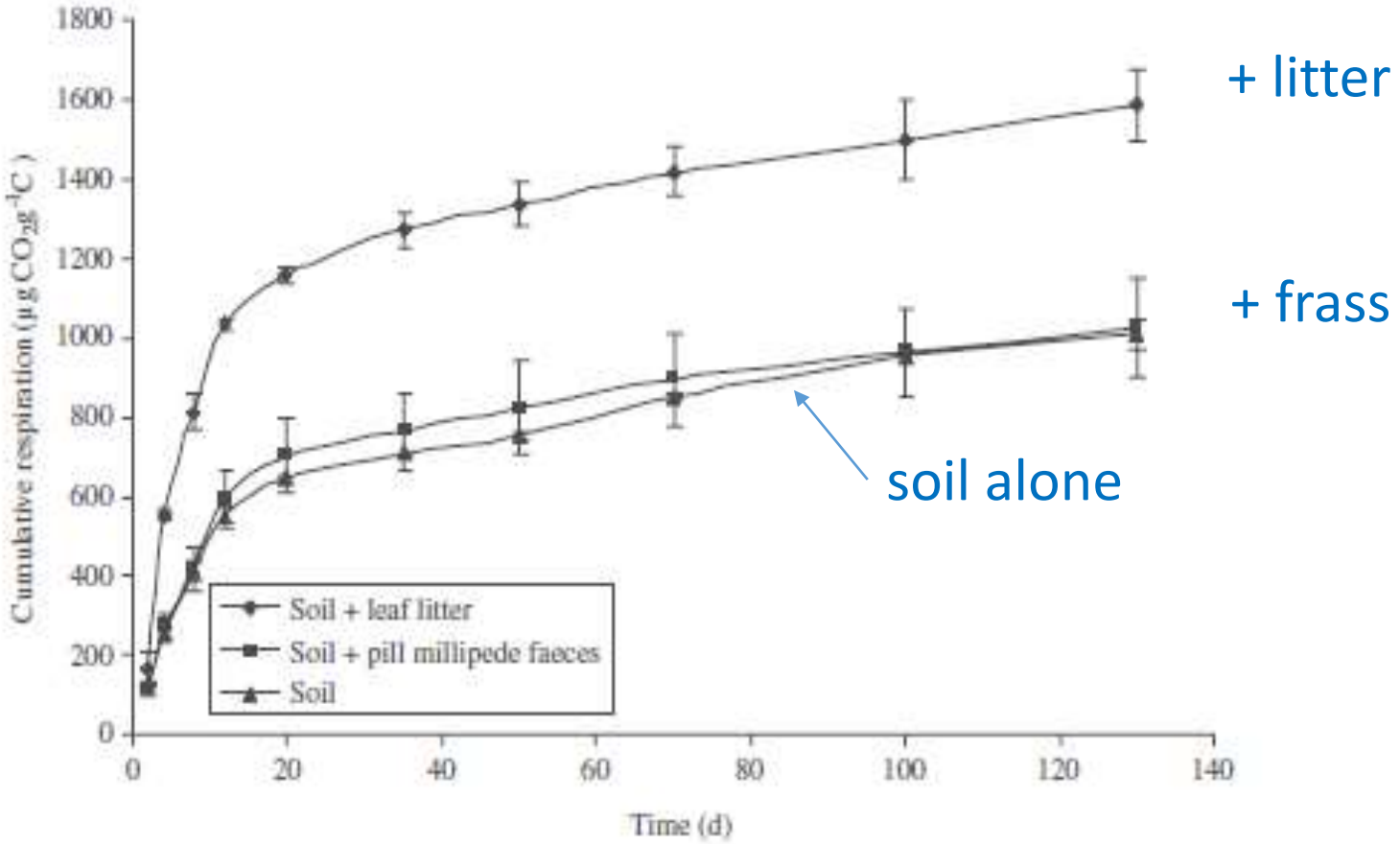


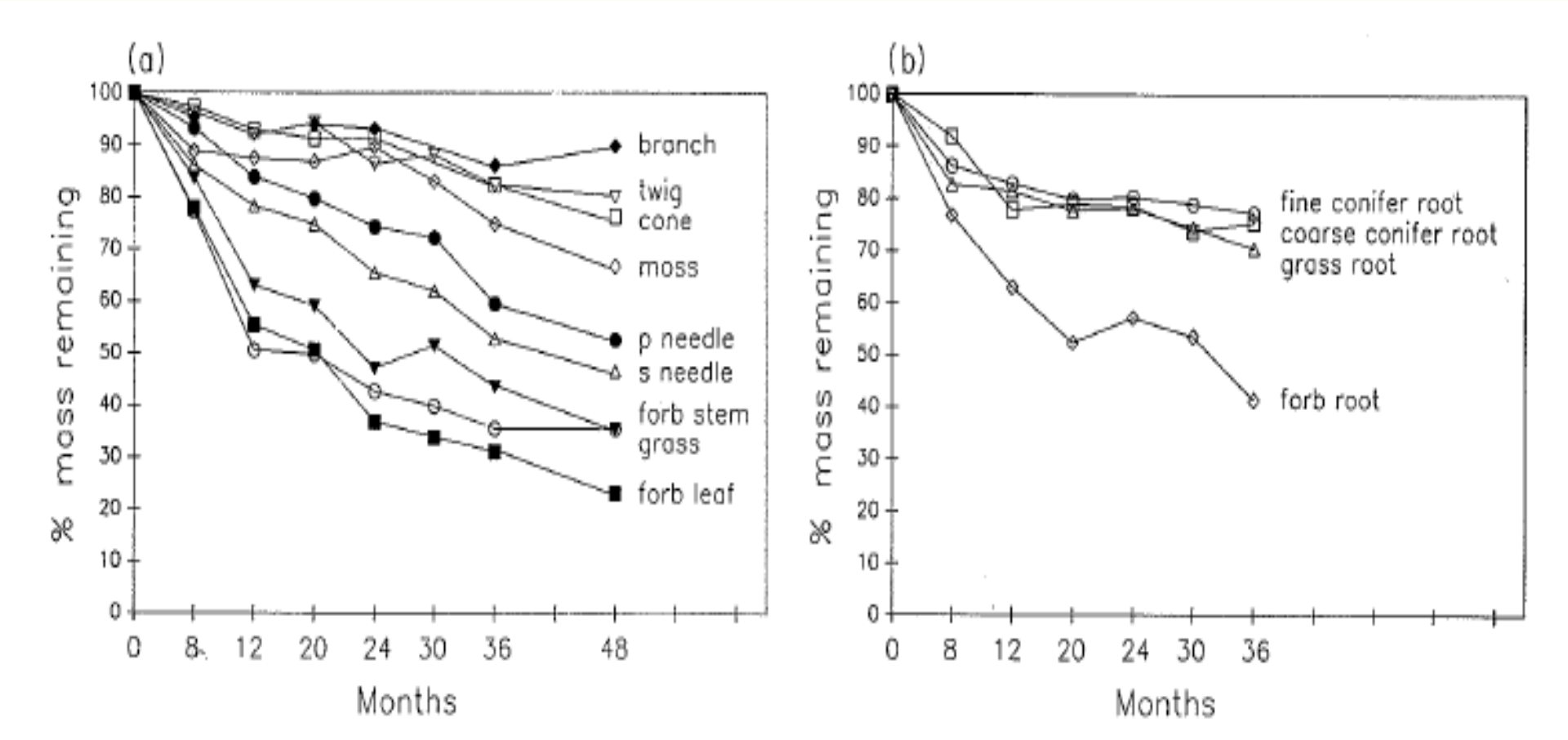
Fig. 2. Cumulative respiration of soil incubated with leaf litter, pill millipede faeces and soil without organic amendment. Bars indicate standard deviation ($n = 3$).

Soil fauna

- Consumption by soil macrofauna transforms litter into more stable form
- Micro-arthropods often have negative or neutral effects on decomposition
  (meta-analysis by Kampichler and Bruckner 2009)

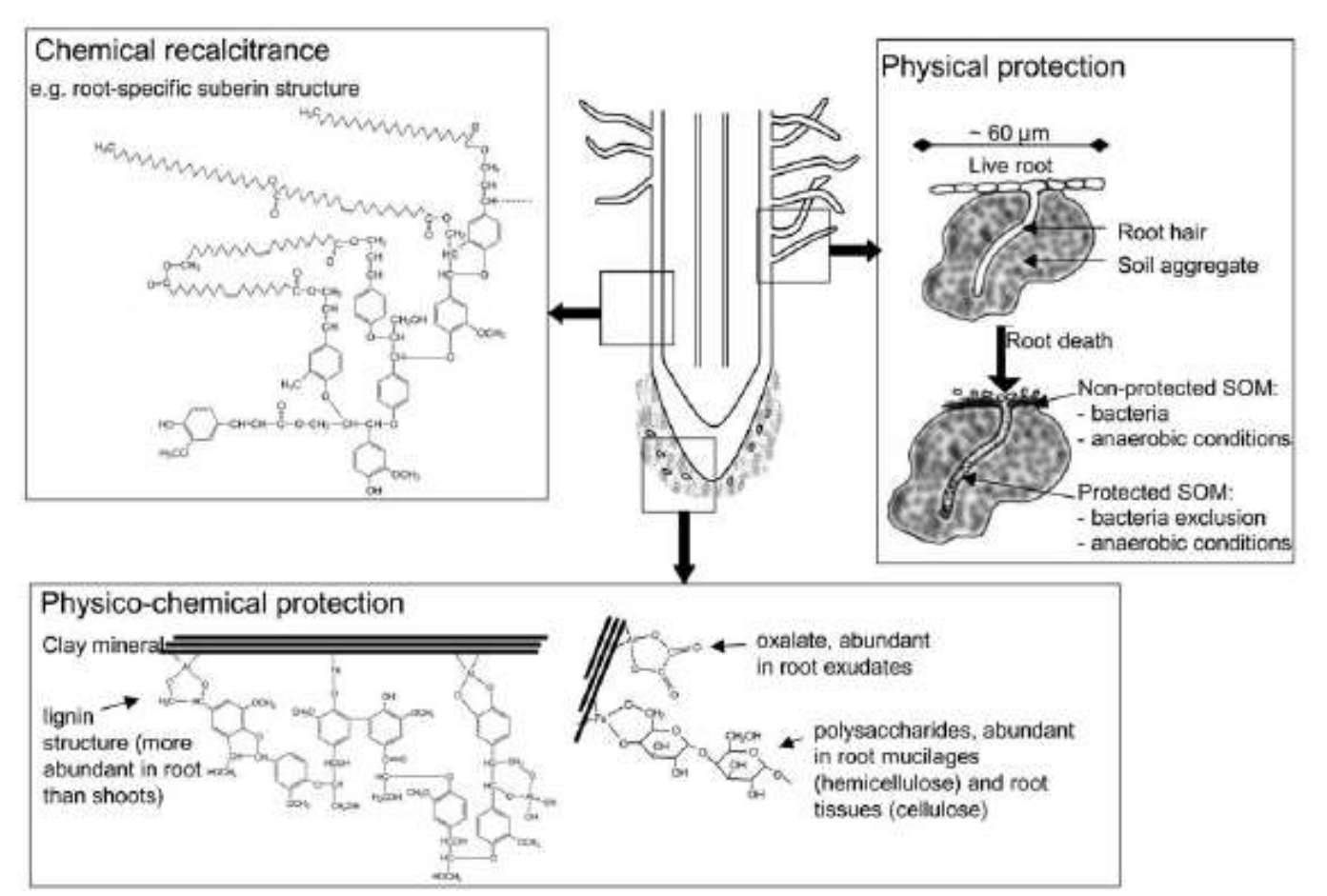
→ Litters that stimulate soil fauna may generate more humus and SOM

Roots decompose slowly and incompletely
- especially fine roots (<2 mm diameter, orders 1&2)



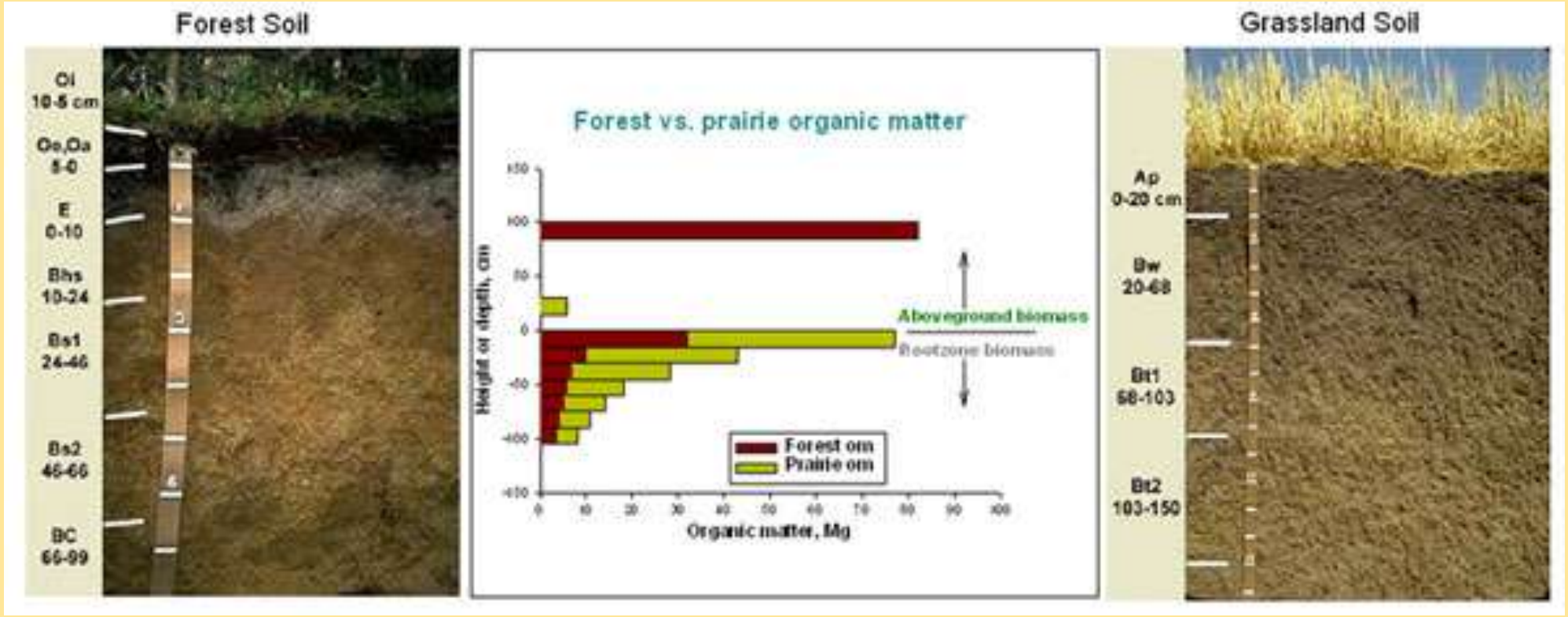
Mass loss from 13 litter types in a Rocky Mountain coniferous forest. Taylor et al (1991)

Root material is more likely to be stabilized in soil



Is soil carbon mostly root carbon? (Rasse et al 2005)

- fibrous root systems of perennial grasses create organic-rich soils



http://proof.nationalgeographic.com/2015/10/15/digging-deep-reveals-the-intricate-world-of-roots/

Exudates

Root exudates – labile C - may stimulate production of microbial biomass, residues, SOM

Arbuscular mycorrhizae stimulate SOM formation by exuding glomalin

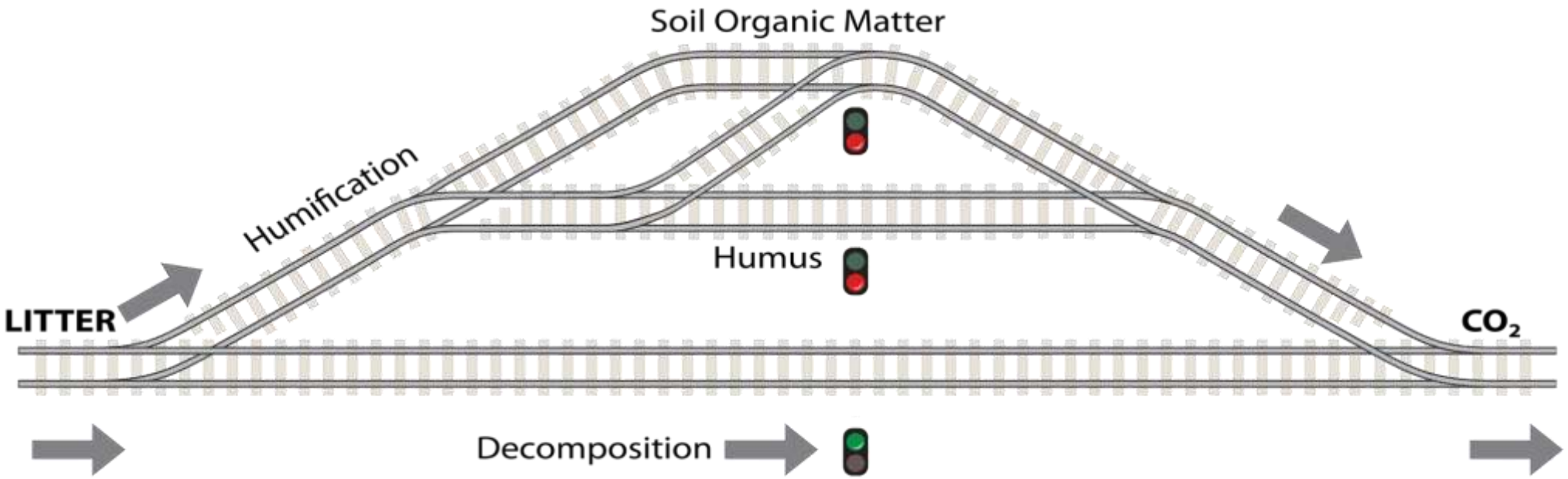
Ectomycorrhizal fungal biomass is major source of humus in northern forests
-especially hyaline fungi

Microbial exudates are substantial source of SOM

How can we promote SOM development?

Rather than reduce rates of decomposition,

divert more litter into humus and soil organic matter



Prescott 2010

How can we promote humification and SOM development?

- use N-fixing species
- promote mixing of litter and humus into soil
  - soil fauna
  - broadleaves
- roots – litter, exudates, mycorrhizae

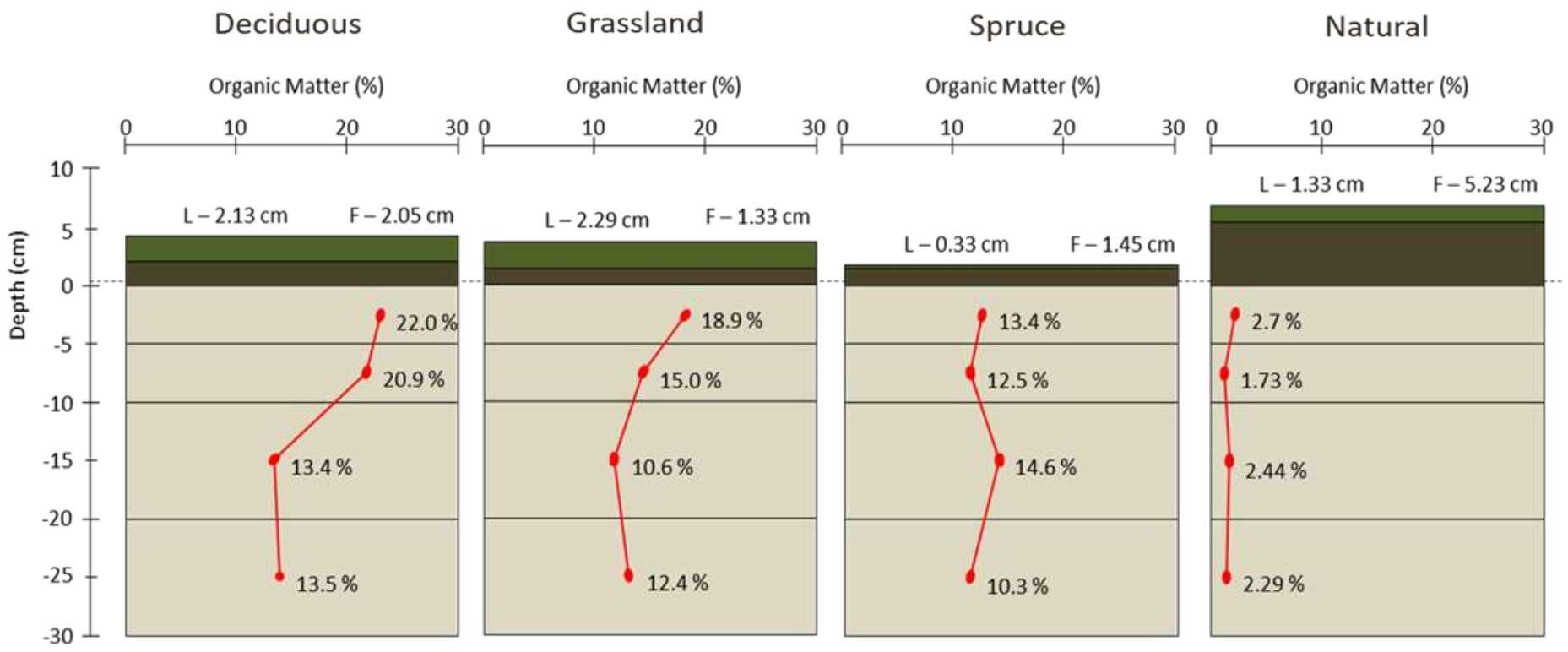
Nitrogen-fixing plants

- greater accumulations of soil organic matter are consistently associated with N-fixing plants
- results from both greater accretion of new SOM and greater retention of old SOM
- leaf litter from N-fixing species does not decompose significantly faster than that of non-N-fixers
- enhanced availability of ammonium in soil promotes humification

Broadleaves

Broadleaf litter:

1) is transformed by macrofauna and converted to soil organic matter



Anderson et al poster

Broadleaves

Broadleaf litter:

2) leaches more labile material which can be metabolized by soil microbes and converted into soil organic matter

Roots and exudates

Which plants species generate the most roots and root litter ?

What conditions promote root development ?

- nutrient deficiency

Monitor root production, biomass and turnover when soil development is critical aspect of restoration

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