

Comprehensive
carbon accounting
for forests: issues
of time and space

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University
and SLU
(thanks to KSLA
and Wallenberg
professorship)



Three conclusions for today:

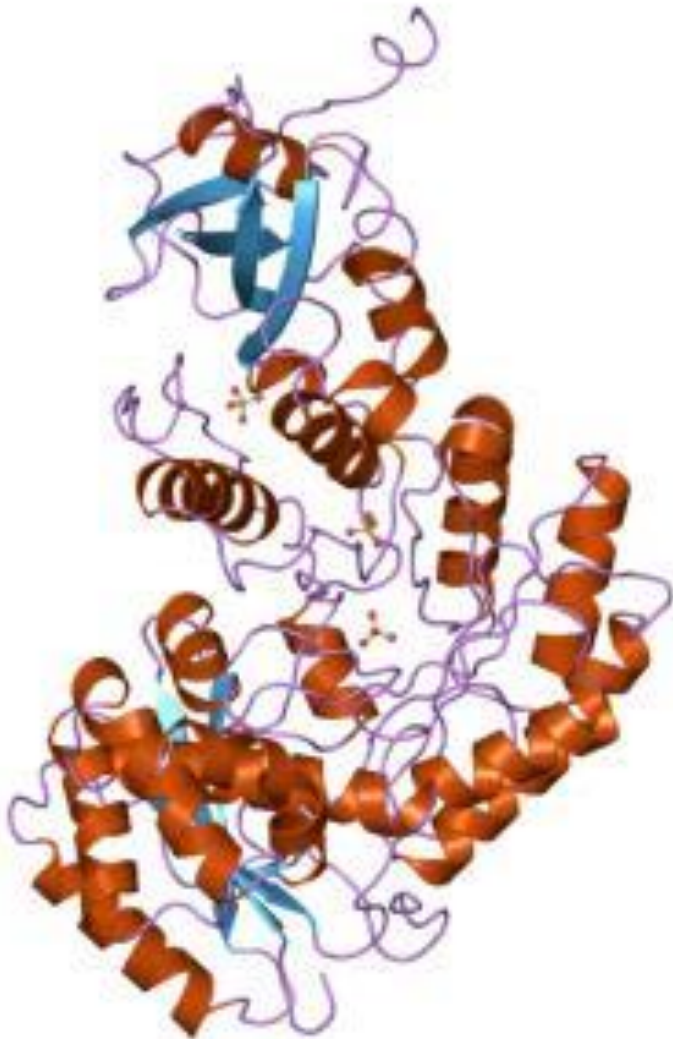
The flows of C in forests are complex:
big flows (fluxes) are rapid;
changes in pool sizes are slow.

Big changes in C accumulation occur in the trees, not so much in the soils

The net C accumulation in forests is very important in Sweden's C budget, but not so large for Planet Earth

Temporal scales

Photosynthesis: RuBisCO
enzyme is the most
abundant
protein on
Earth



Catalyzes the
addition of one
molecule of CO_2 onto a sugar
at a rate of 3-10 times/second

- Temporal scales

Photosynthesis adds about 10 g C/m^2 in a day in a productive forest

The trees allocate about 4 g C/m^2 to the soil daily

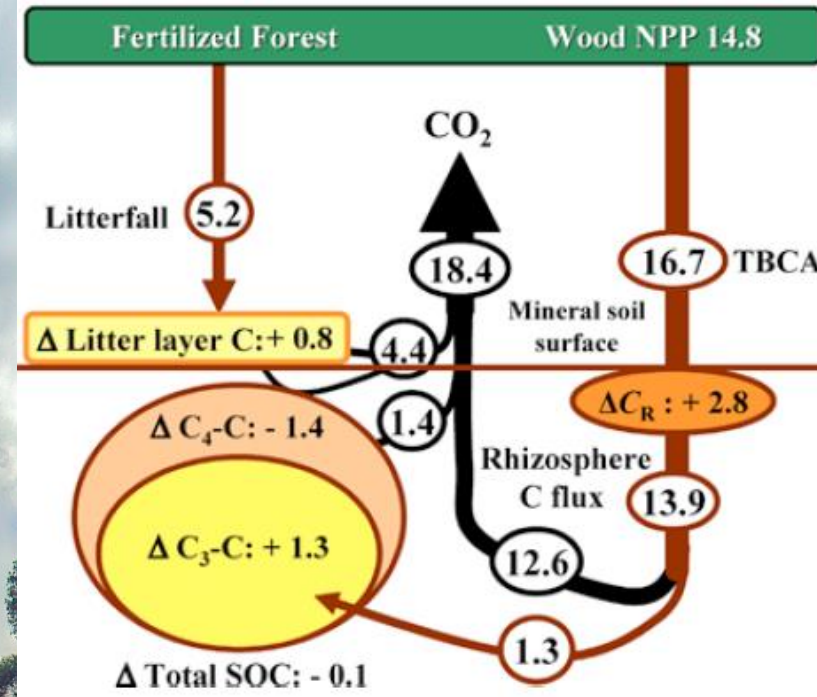


- Temporal scales

The trees allocate about 4 g C/m^2 to the soil daily

How much of that will still be in the soil 1 year later? Perhaps only 0.8 g C/m^2 (20%)

Meanwhile, the soil loses 0.8 g C/m^2 from “older” soil C – so there’s no net change.



The net C stocks in our forests develop from small net differences between very large flows of C in and C out

Carbon Absorbed and Released by the Forest Over the Lifecycle

 Carbon Release

 Carbon Uptake

 Felling

 Annual Growth
(Forest Cubic Metres)

The principle of how a forestry ecosystem takes up and releases carbon. The area shaded in green indicates that the forest is taking up more carbon than it releases. The area shaded in orange indicates where the opposite is the case.



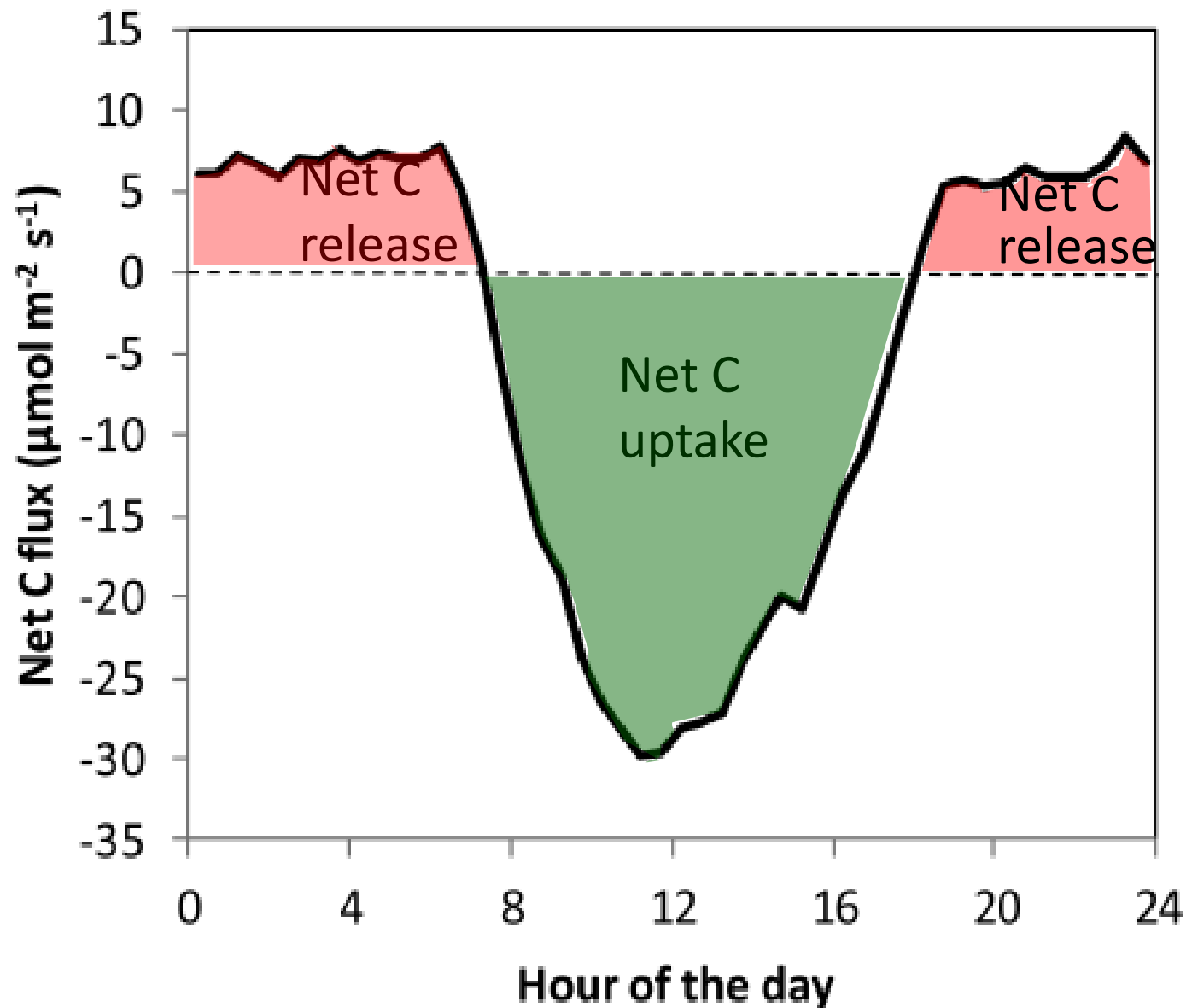
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Source: SLU (The Swedish University of Agricultural Sciences)

How does the uptake and release of C change when we clearcut and regrow this Eucalyptus forest?



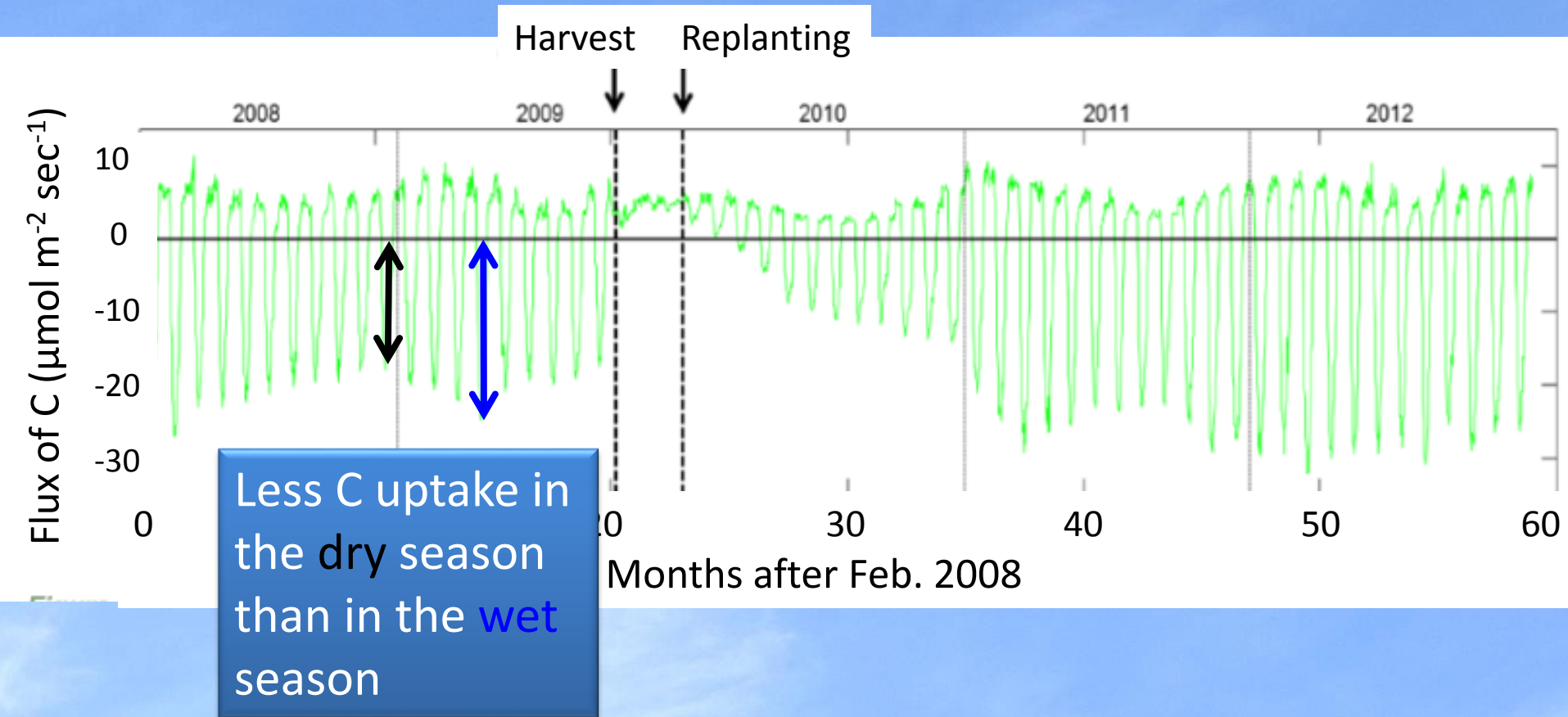
Eddy Covariance (or flux): Measure wind direction and speed, CO₂ concentrations in air above forest



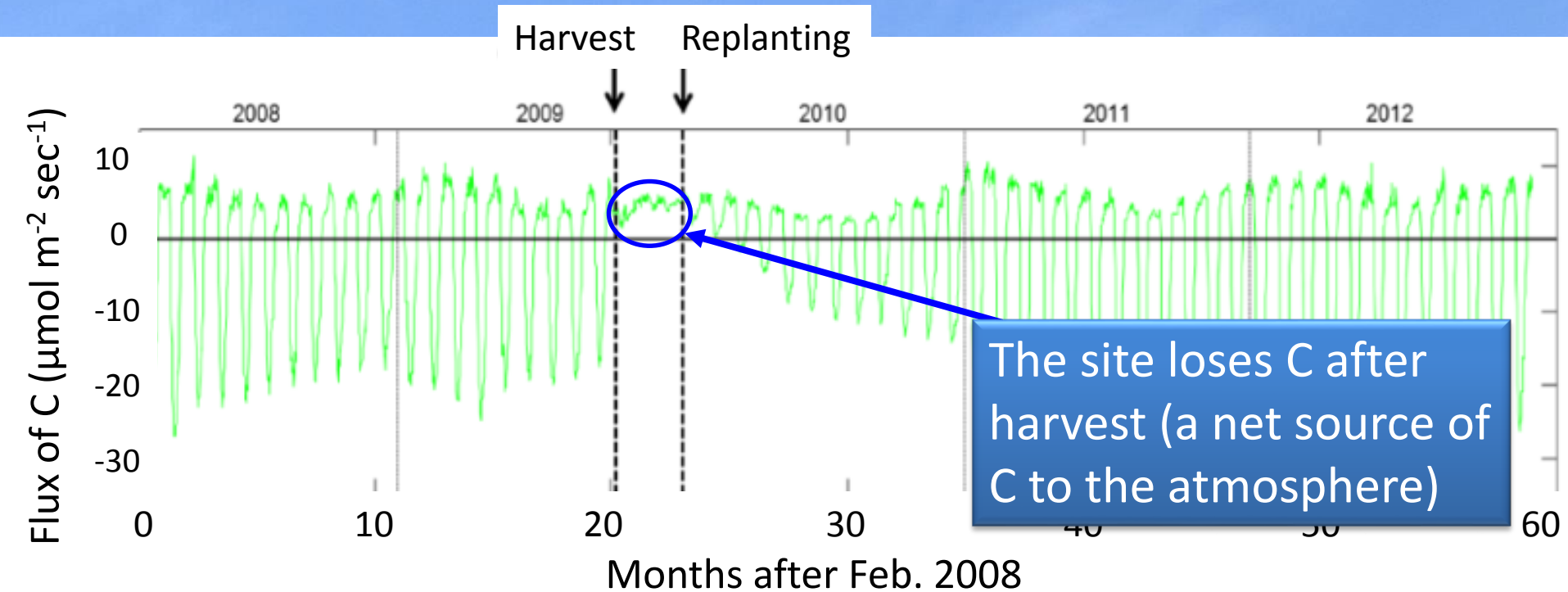
From Yann
Nouvellon and
colleagues



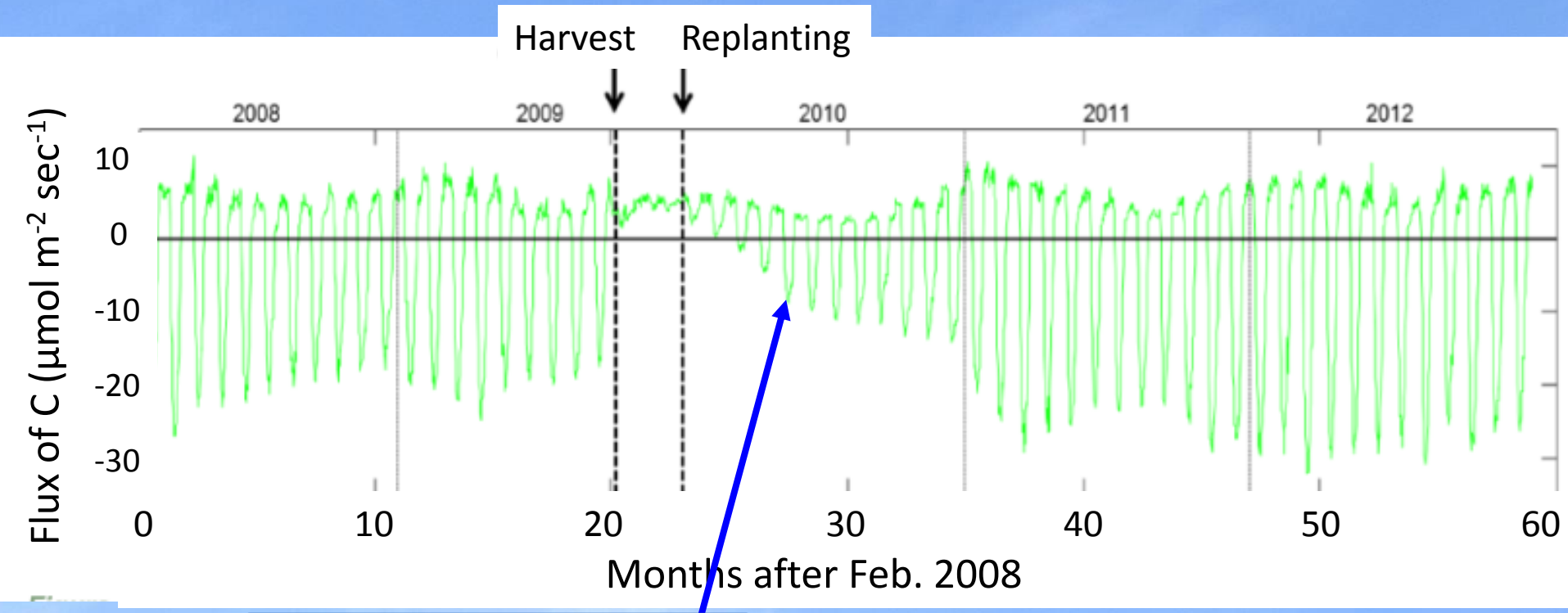
Average daily pattern for each month:



Average daily pattern for each month:



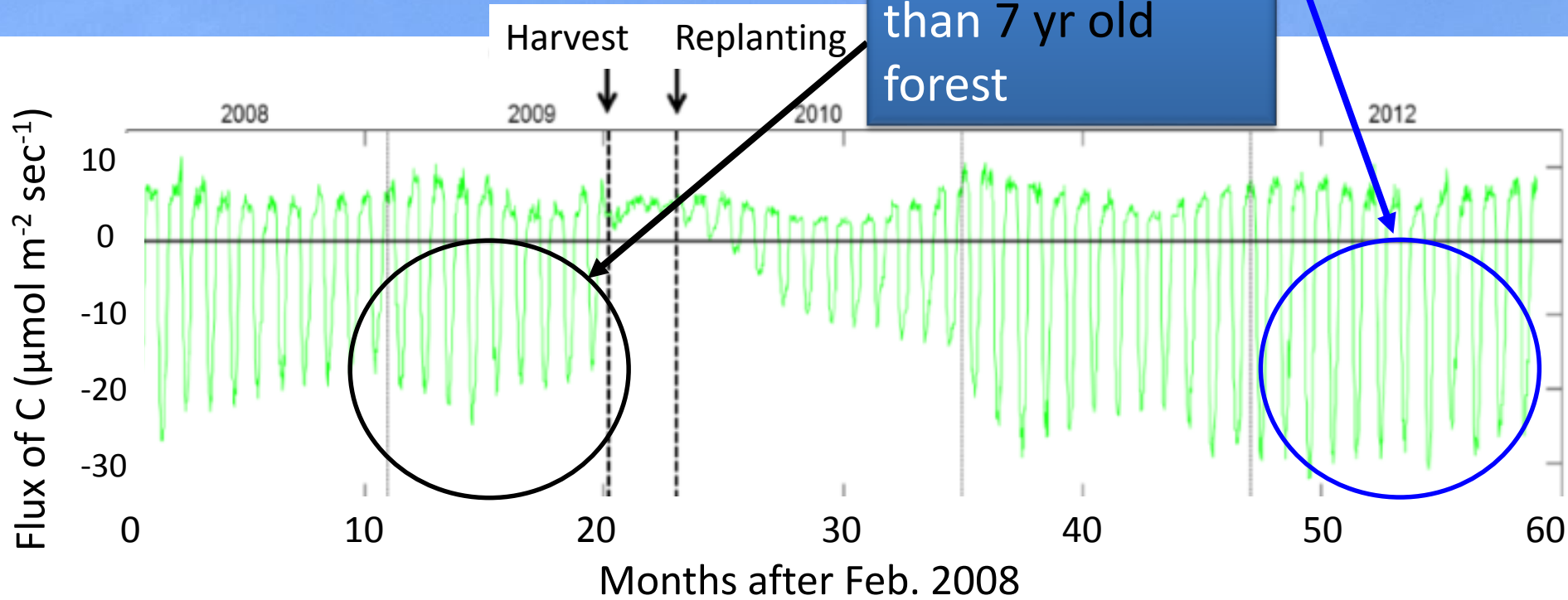
Average daily pattern for each month:



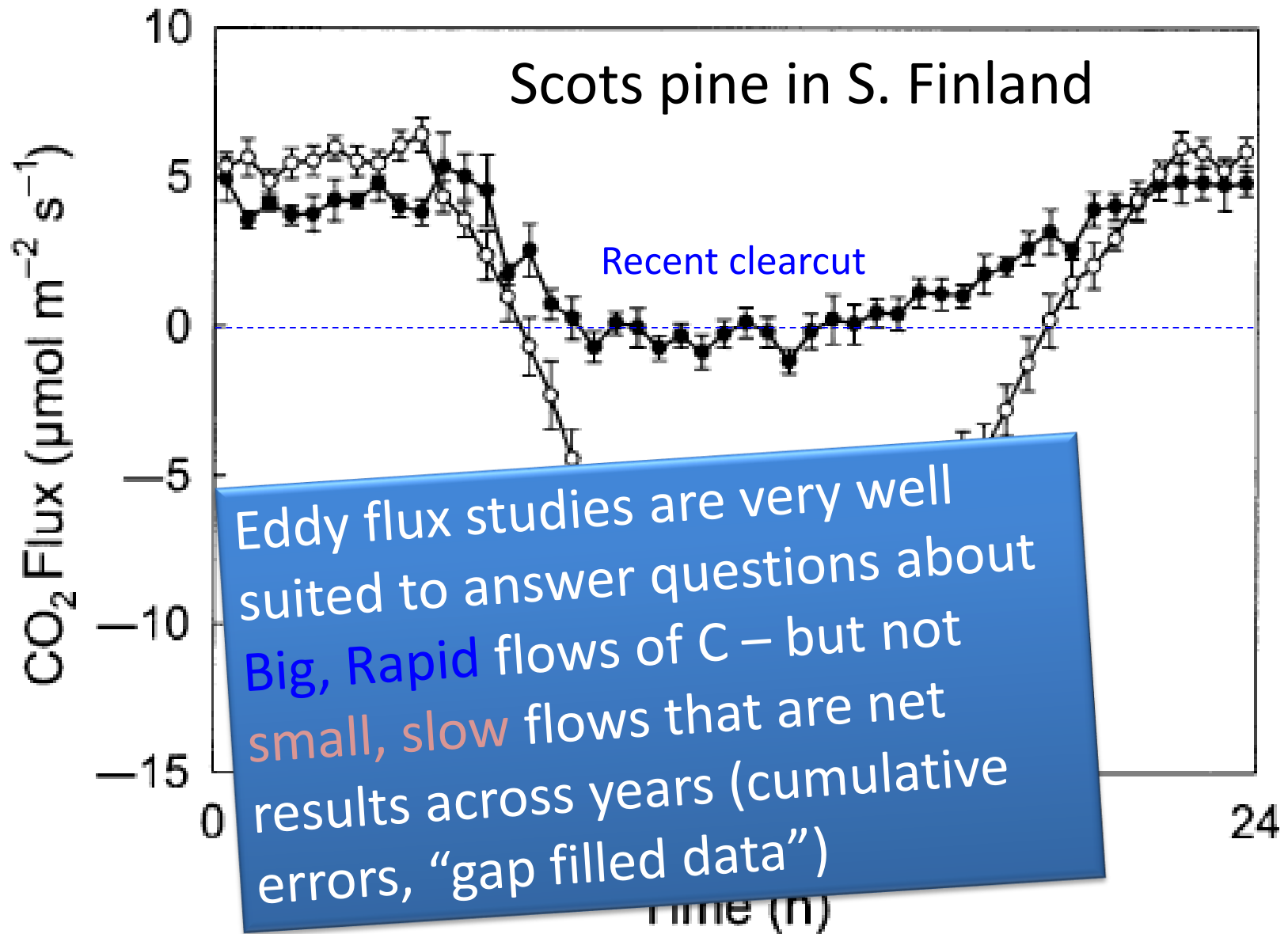
The replanted forest
became a net sink for
C about 6 months
after planting

Average daily pattern for each month:

2 year-old forest
better C sink
than 7 yr old
forest



A Nordic example:

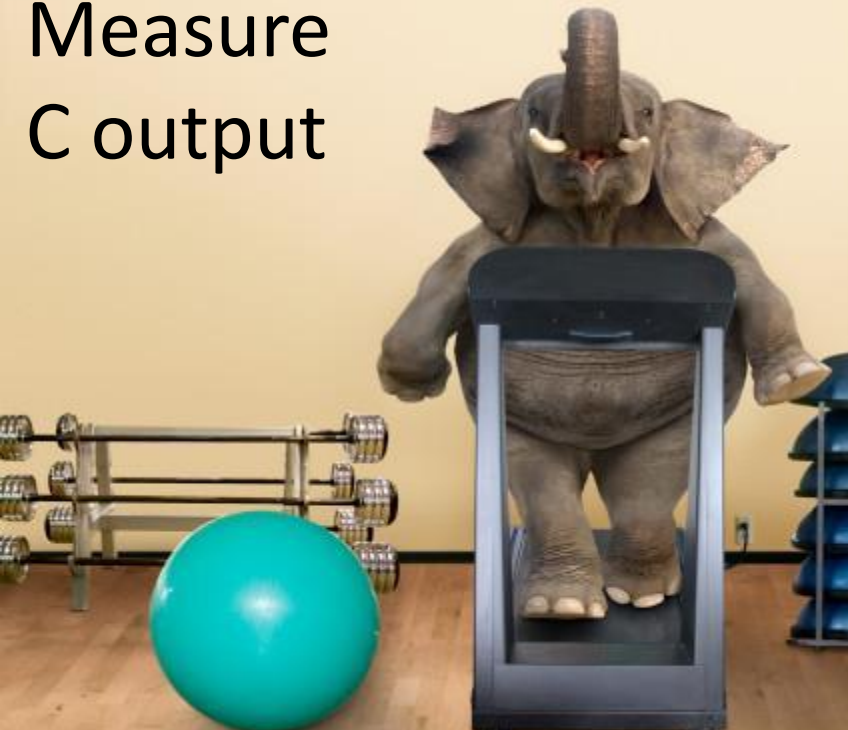


The right method for the time scale of the question:

How much energy did this elephant expend *today*? Measure C intake




Measure C output



What was the elephant's net change in mass for a *year*? Daily input/output could be summed, but any errors accumulate and give poor long-term estimate

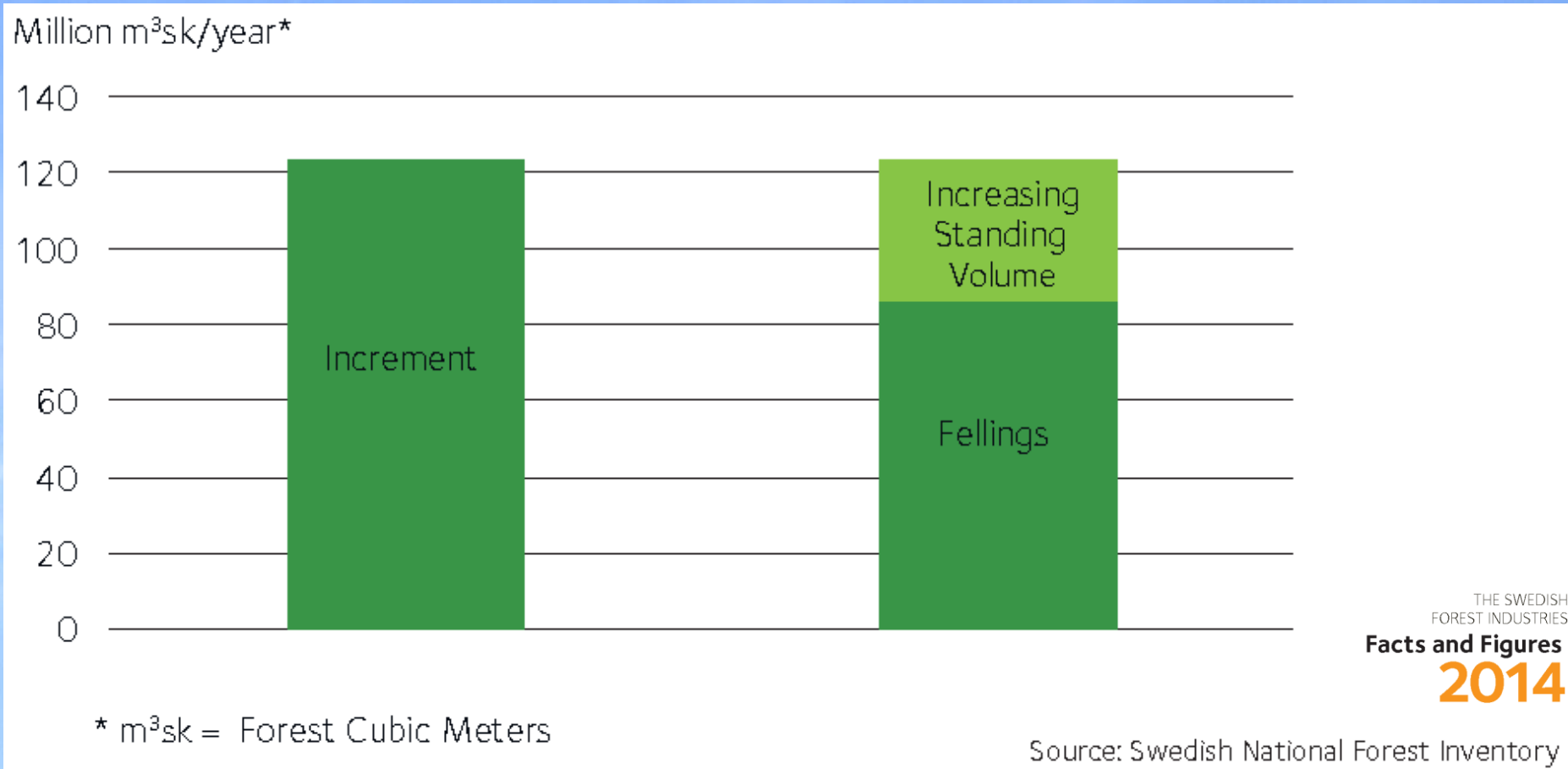
January 1

December 31



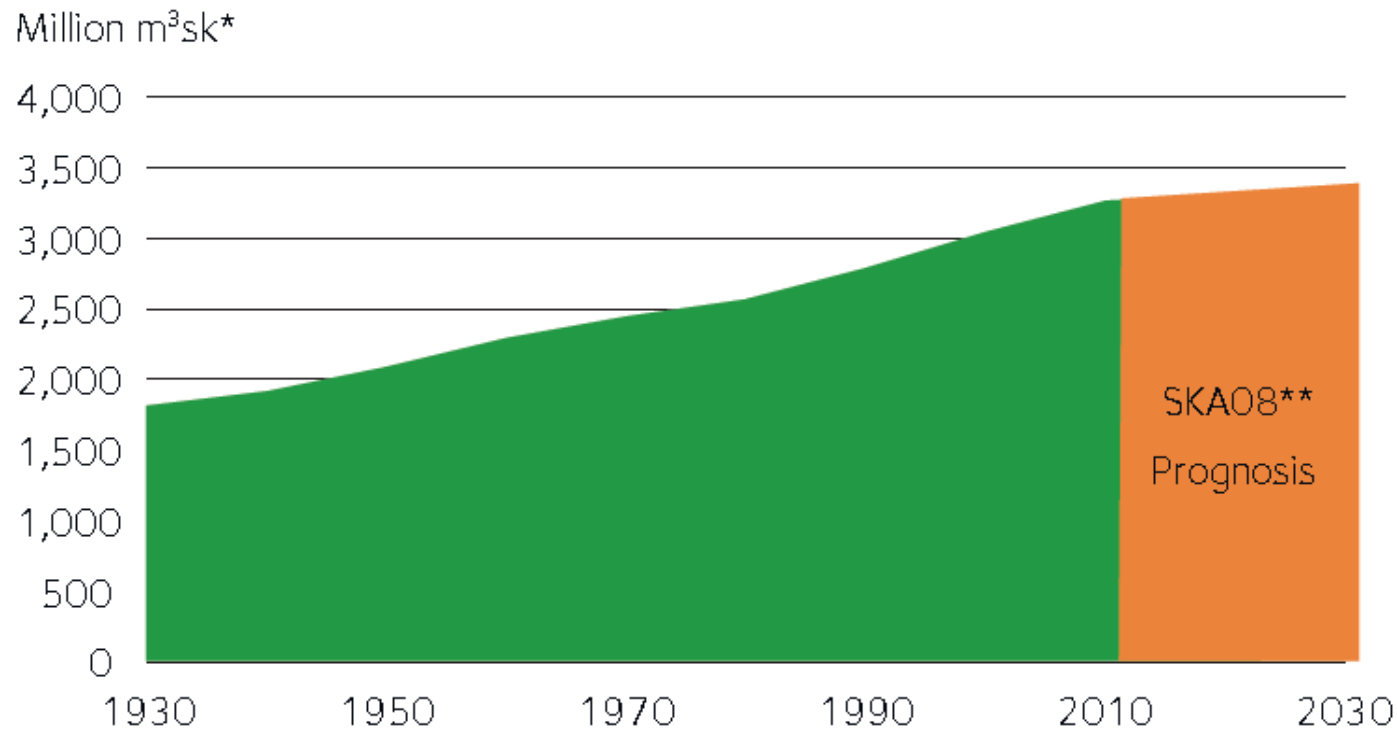
Long term (inventory) sampling of trees and soils are more reliable, with far better geographic representativeness

At the geographic scale of the entire country and a single year (2013), the C stock of Swedish forest biomass grows faster than harvests:



At the geographic scale of the entire country and a century: The C stock of Swedish forest biomass doubles

Development of the Swedish Standing Stock of Timber



* m³sk = Forest Cubic Meters

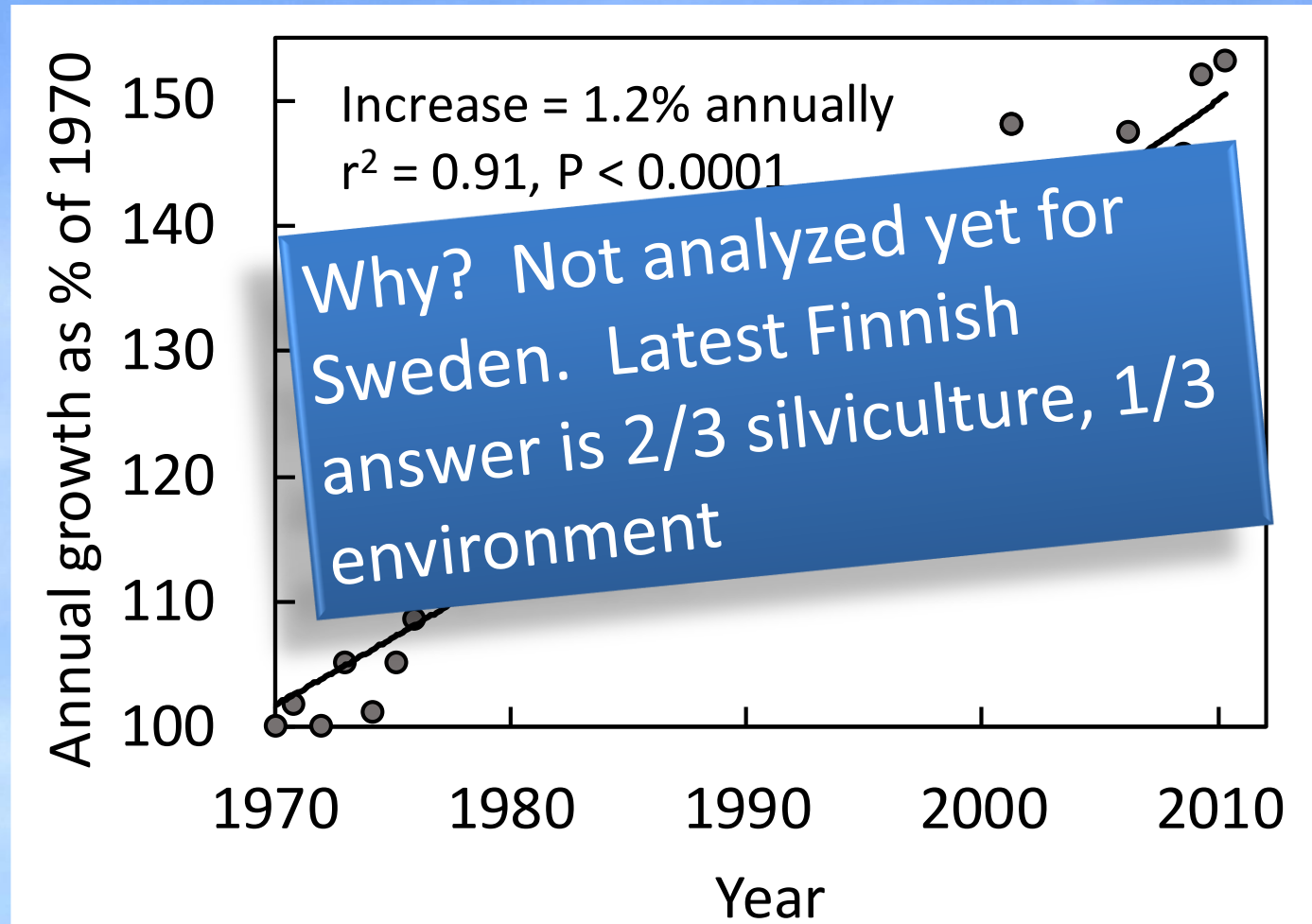
** SKA 08 = A National Forest Prognosis Project

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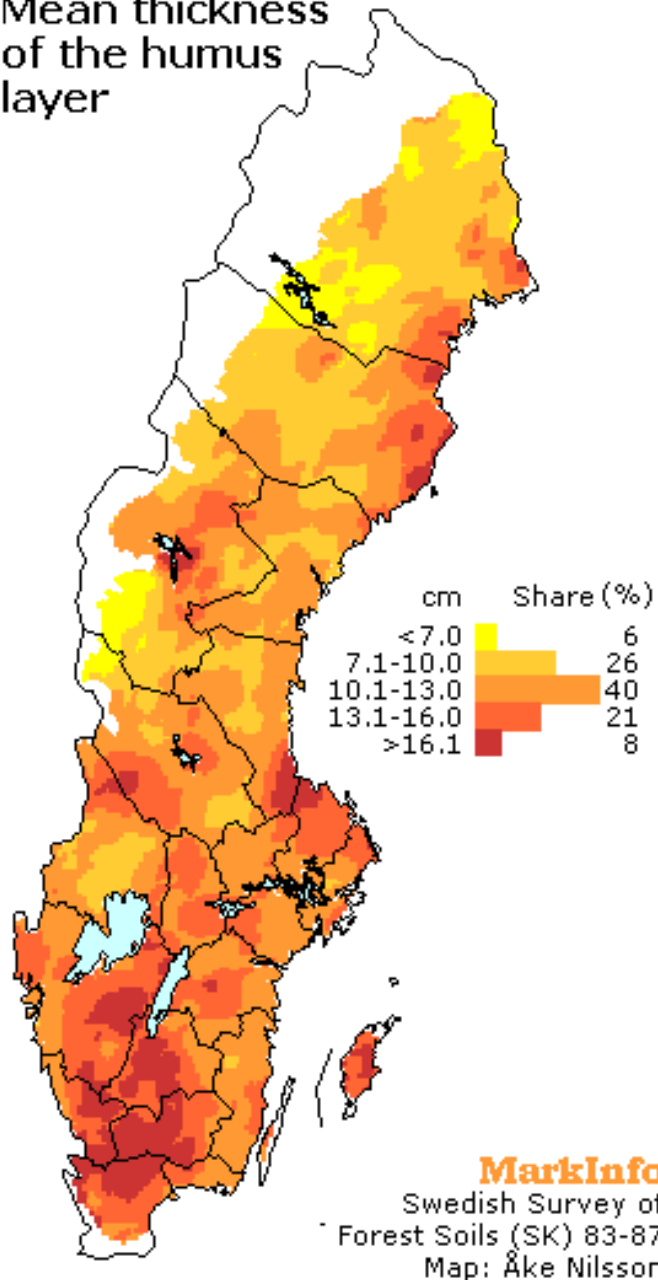
Source: Swedish Forest Agency

Does the increased C stock of Swedish forests result from low harvests – or from accelerating growth?

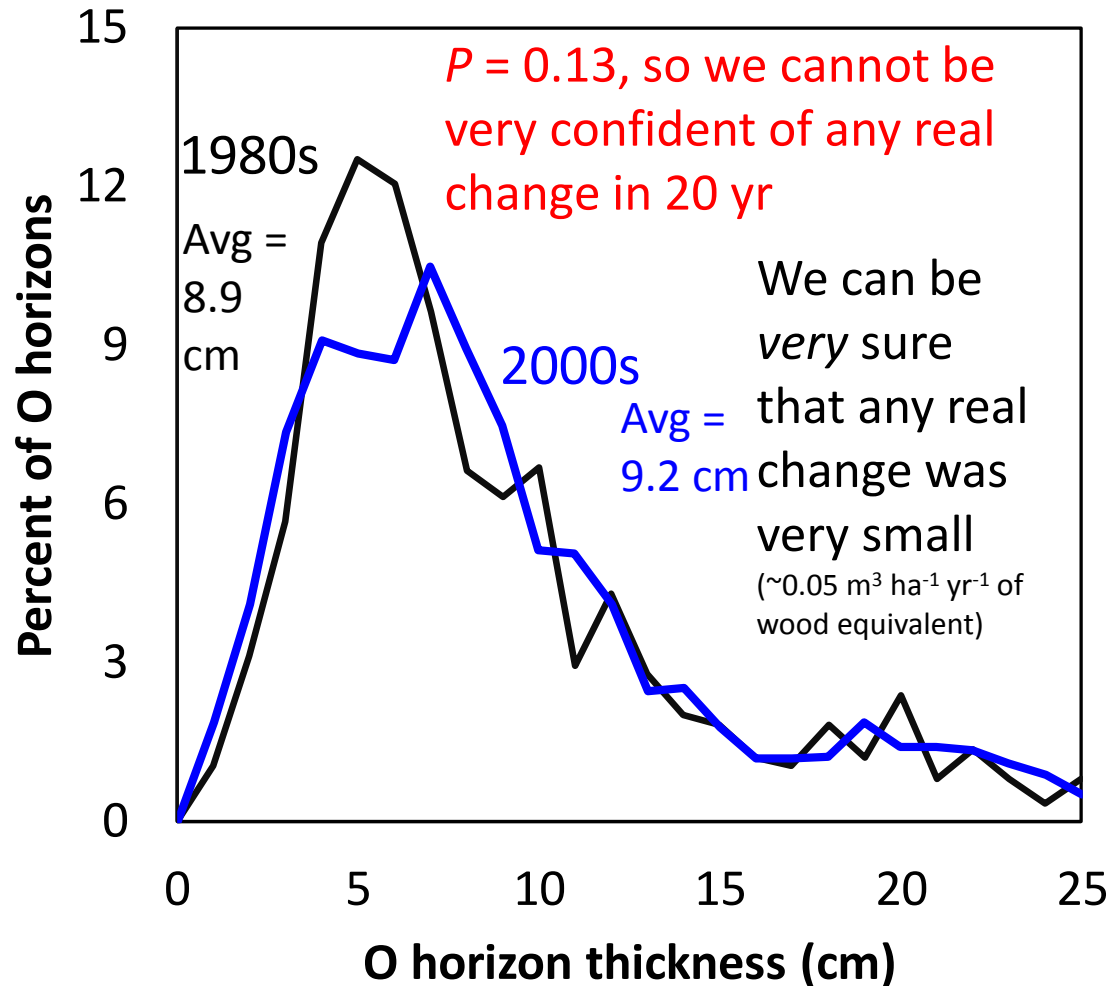
One of the most important facts about Swedish forests:
growth is increasing dramatically



Mean thickness
of the humus
layer

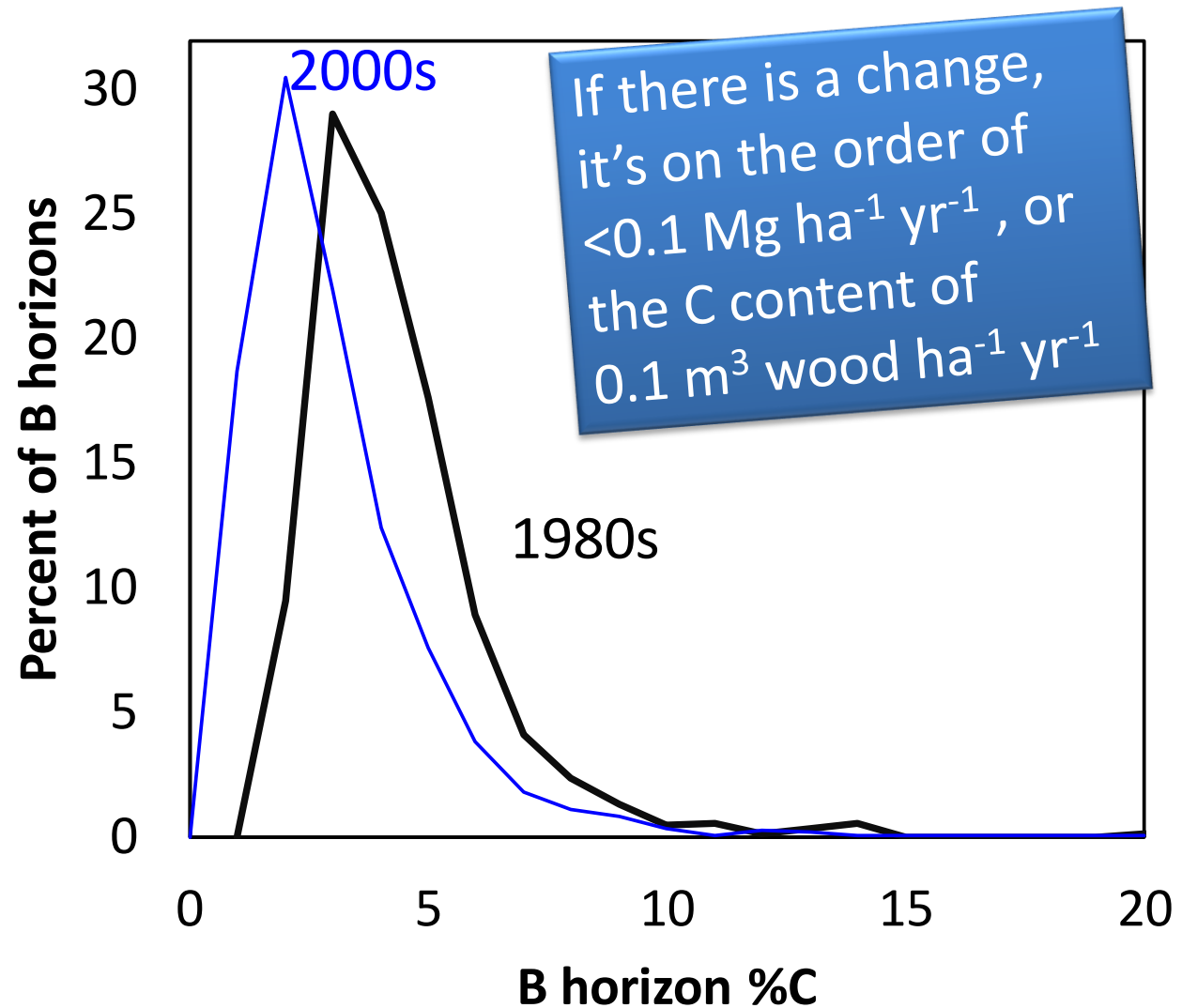


How fast does the C content of forest soils change?



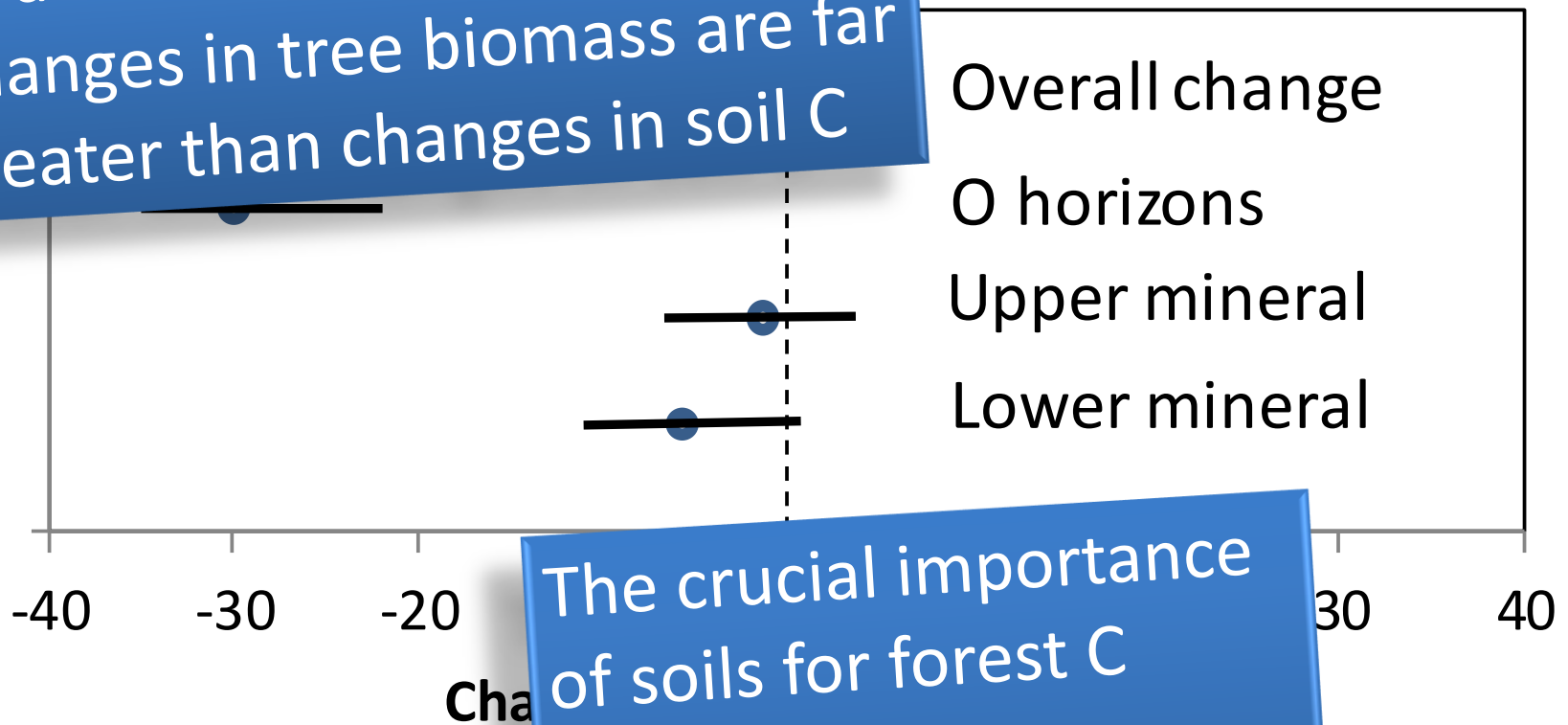
raw, preliminary data provided by J. Stendahl,
National Forest Soils Inventory

Is soil C content of mineral soils changing? A little?



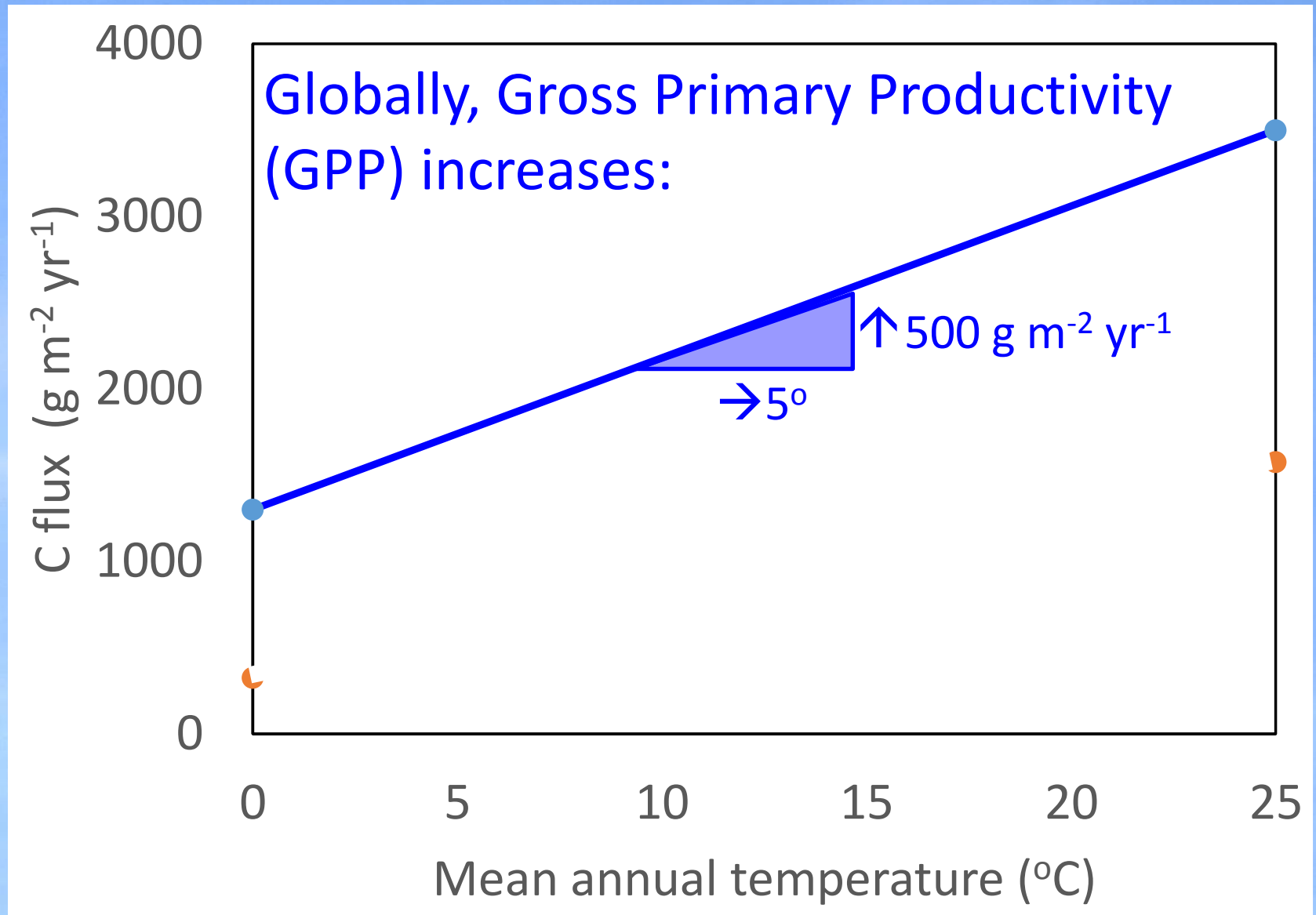
The timescale of a forest rotation includes harvesting: how does soil C change with clearfelling? A meta-analysis:

At a time scale of decades, changes in tree biomass are far greater than changes in soil C

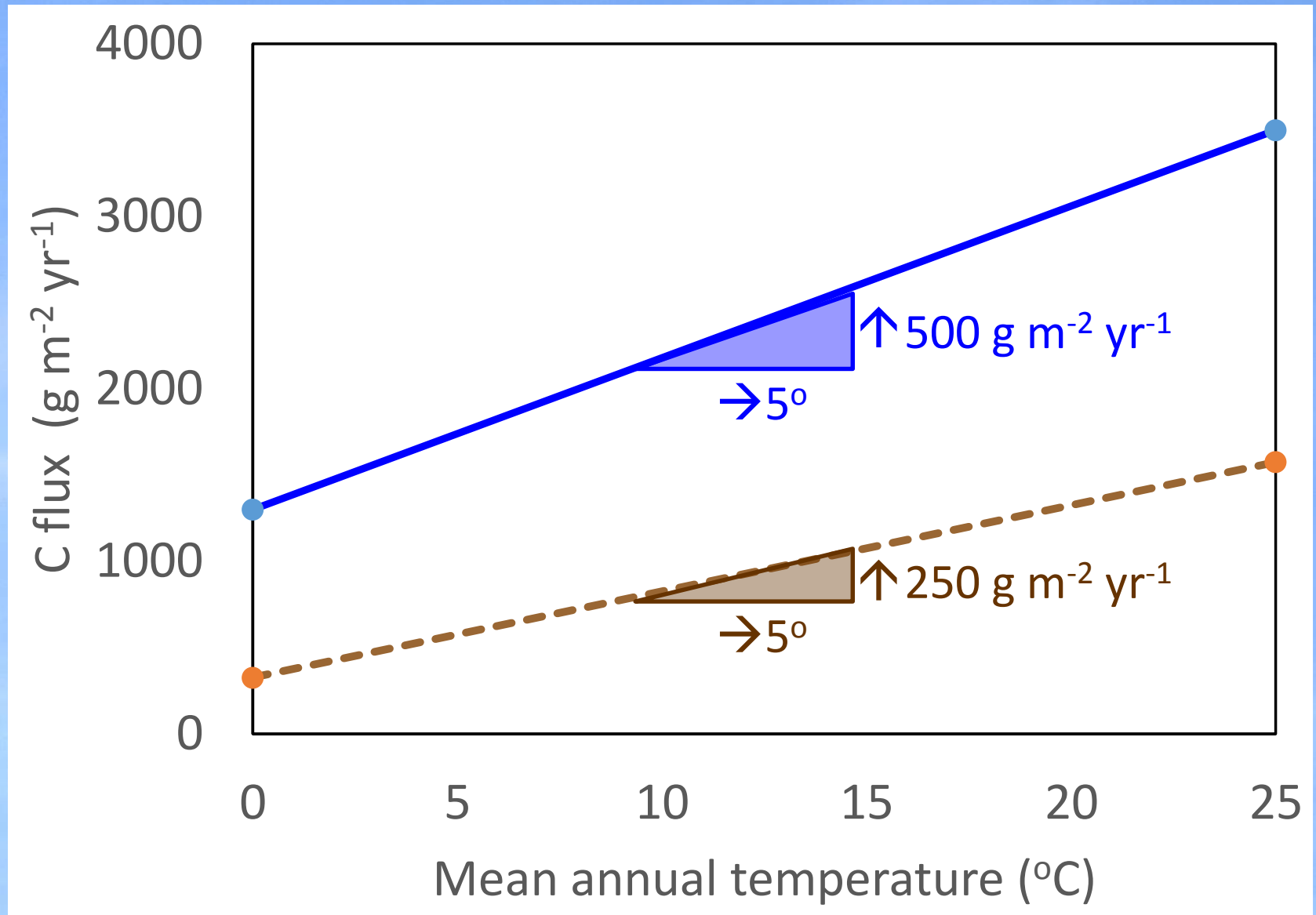


The crucial importance of soils for forest C budget hinges on supporting tree growth, not on soil C storage

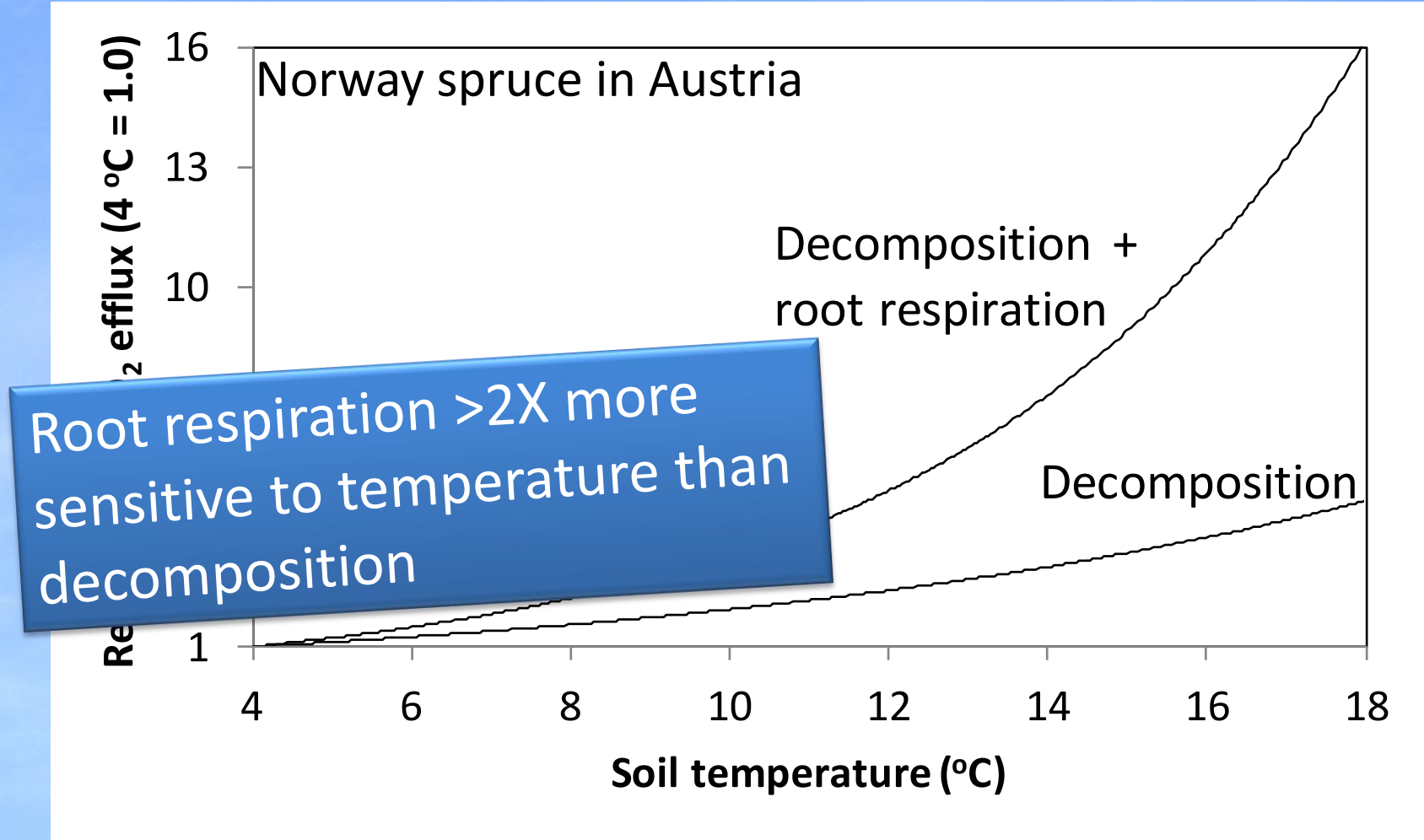
But what if the climate changes?



...and total belowground C flux (TBCF) also increases



Soil heating increases the flow of CO₂ out of soils – BUT, much of the increase is extra root production and respiration – NOT loss of soil organic matter.



The bottom line: Sweden's forests are the country's major sink for C

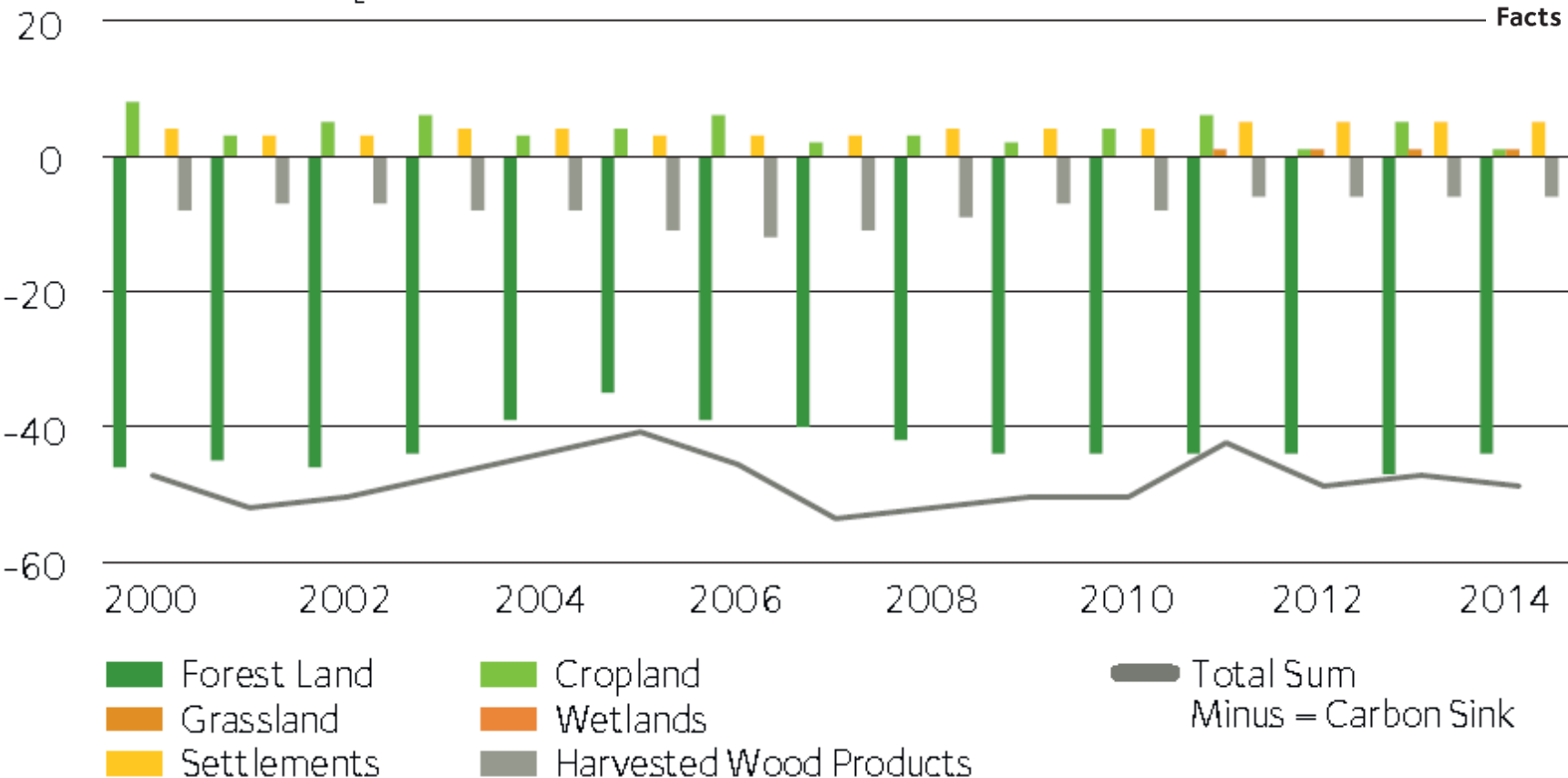
Emissions and Removals of Greenhouse Gases from Land Use, Land Use Change and Forestry in Sweden

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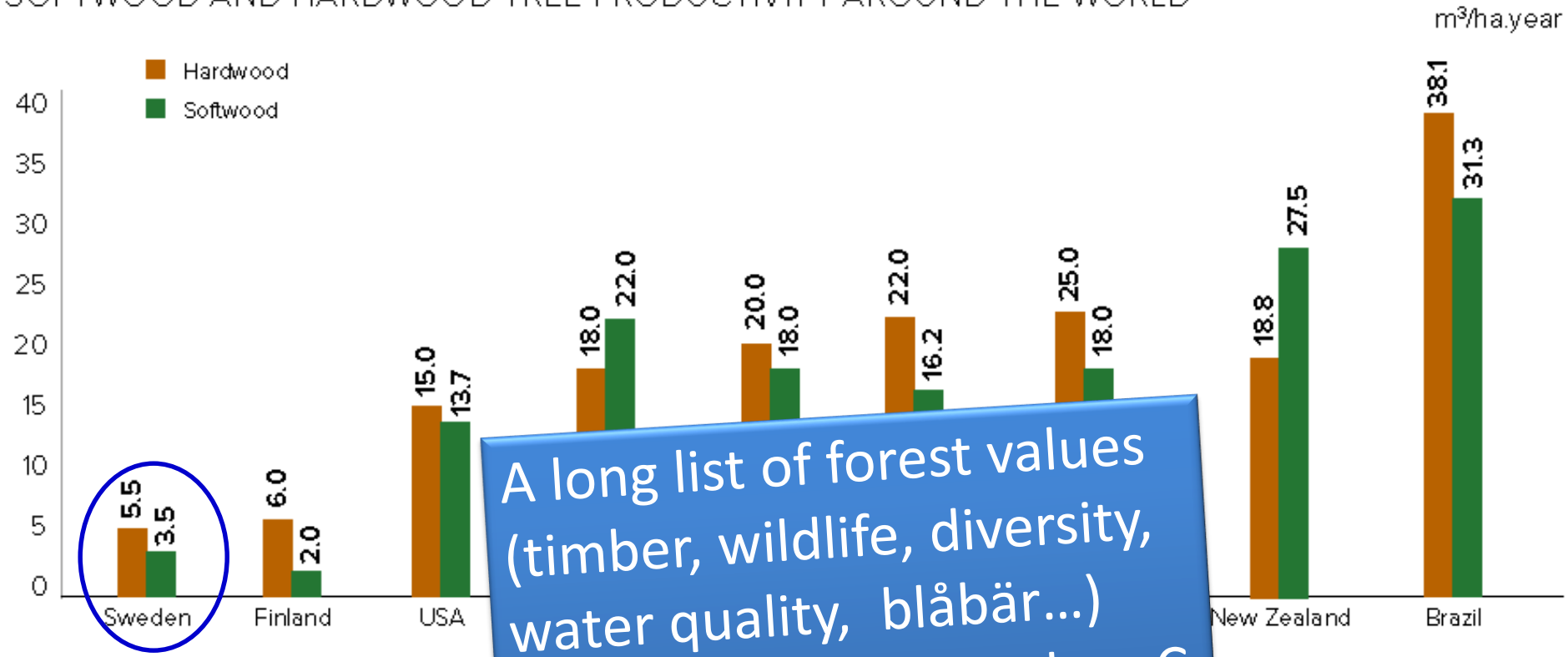
Million Tonnes of CO₂ -equivalants



Source: Swedish Environmental Protection Agency

But: We can't ask Sweden's forests to save the world's climate

SOFTWOOD AND HARDWOOD TREE PRODUCTIVITY AROUND THE WORLD



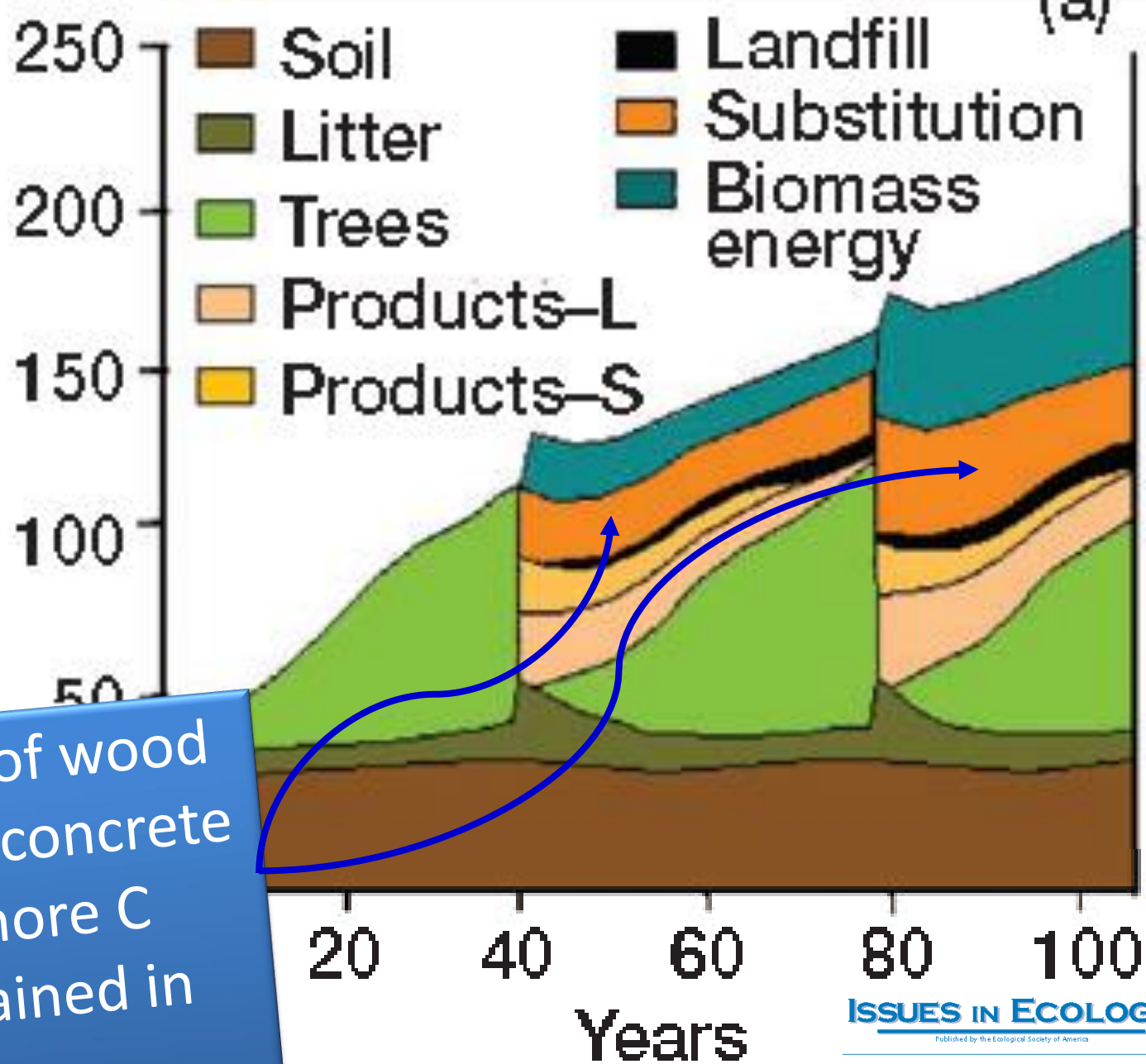
A long list of forest values (timber, wildlife, diversity, water quality, blåbär...) are more important than C for decisions made about Sweden's forests





Carbon “kept out” of the atmosphere over 3 rotations:

Cumulative carbon (Mg/ha)



Substitution of wood products for concrete can “save” more C than is contained in the wood

ISSUES IN ECOLOGY
Published by the Ecological Society of America

**A Synthesis of the Science on
Forests and Carbon
for U.S. Forests**

Michael G. Ryan, Mark E. Harmon, Richard A. Birdsey, Christian P. Giardina,
Linda S. Heath, Richard A. Houghton, Robert B. Jackson, Duncan C. McKinley,
James F. Meentemeyer, Brian G. Mizner, Diane E. Pataki, and Kenneth E. Skogerboe