Estimating Carbon Emissions from Historical Changes in Global Agricultural Land

Figure courtesy of IFPRI

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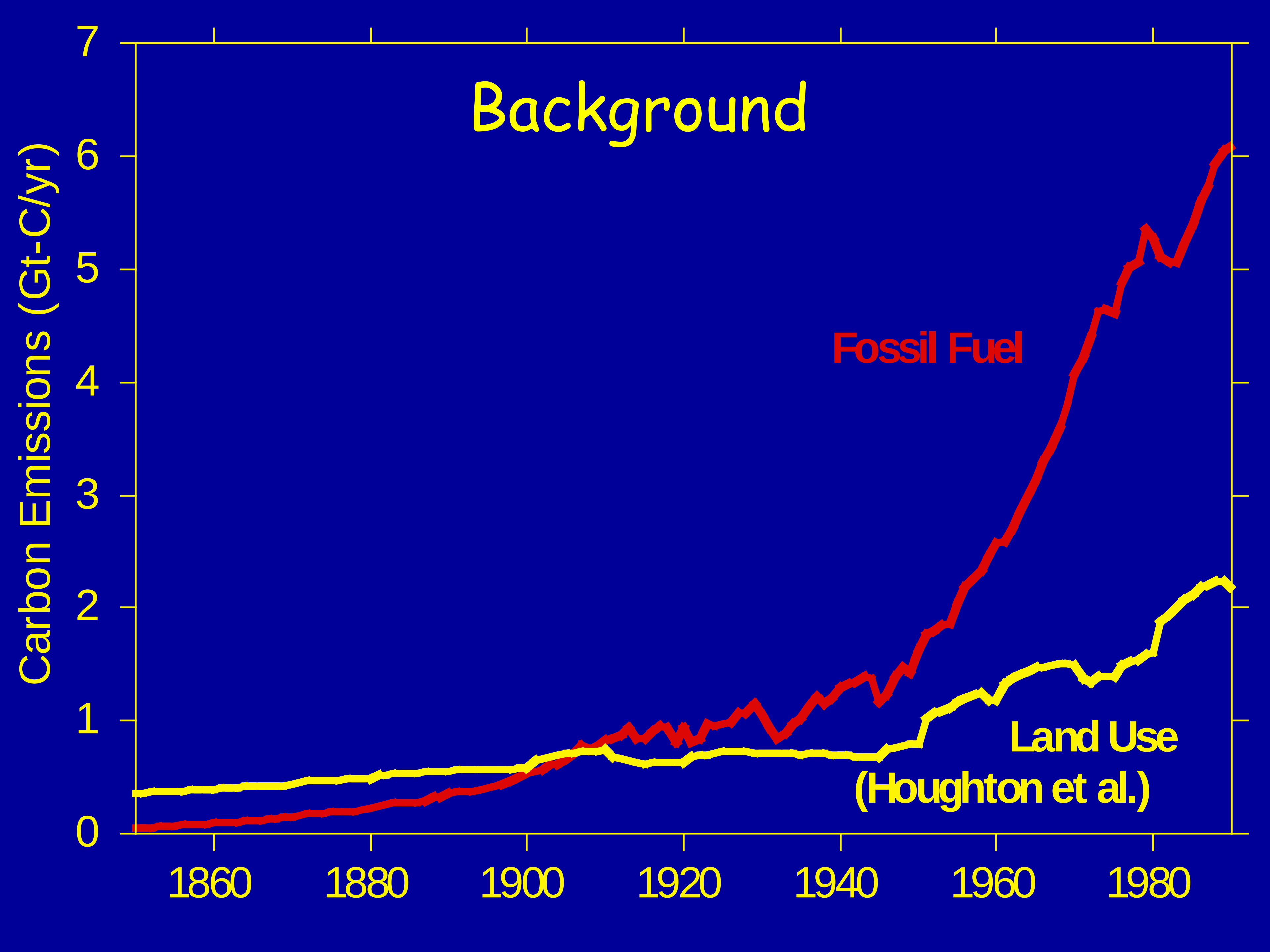
Ruth DeFries, Univ. of Maryland

Richard Houghton, Woods Hole Research Center


Background
Carbon Emissions (Gt-C/yr)
Fossil Fuel
Land Use
(Houghton et al.)
0
1
2
3
4
5
6
7
1860
1880
1900
1920
1940
1960
1980

Land use C emissions

- *New satellite-based estimates are now available for the last two decades*

Pg-C/yr	1980s	1990s	Method
Houghton	2.0	2.2	Land cover inventory
McGuire	0.9-1.6	–	Cropland inventory
DeFries	0.6	0.9	AVHRR deforestation
Achard	–	<1.0	Landsat deforestation

- Comparing apples to oranges…
  - different <u>extents</u> (global, humid tropics, pan-tropics,…)
  - different <u>land covers</u> (deforestation, cropland change)
  - confusion between <u>gross</u> and <u>net</u> deforestation
  - <u>different approaches</u> / models for emissions
    - Historical land use included or not
    - Current flux versus “committed flux”
    - Soils included in some & not others

- <u>Revisit</u> the 1980s & 1990s tropical budget, in collaboration with UMD and Woods Hole

Many Uncertainties..

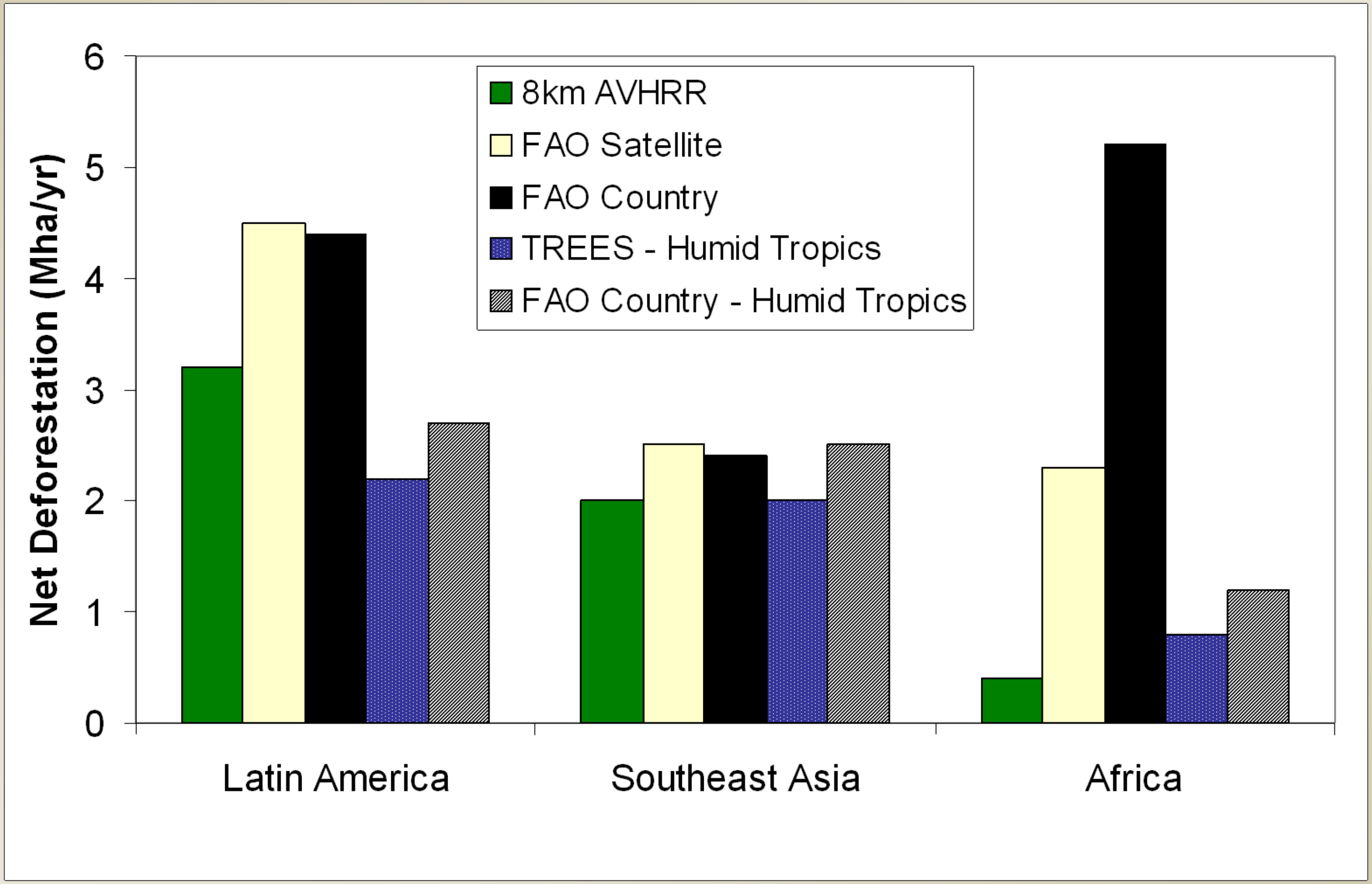
- Rates of land cover change
- Initial carbon stocks in vegetation and soil
- Vegetation & soil carbon dynamics upon clearing
- Fate of cleared carbon

==> Uncertain rates of tropical deforestation account for more than half of the range in estimates of the global carbon flux

(Houghton and Goodale, forthcoming)

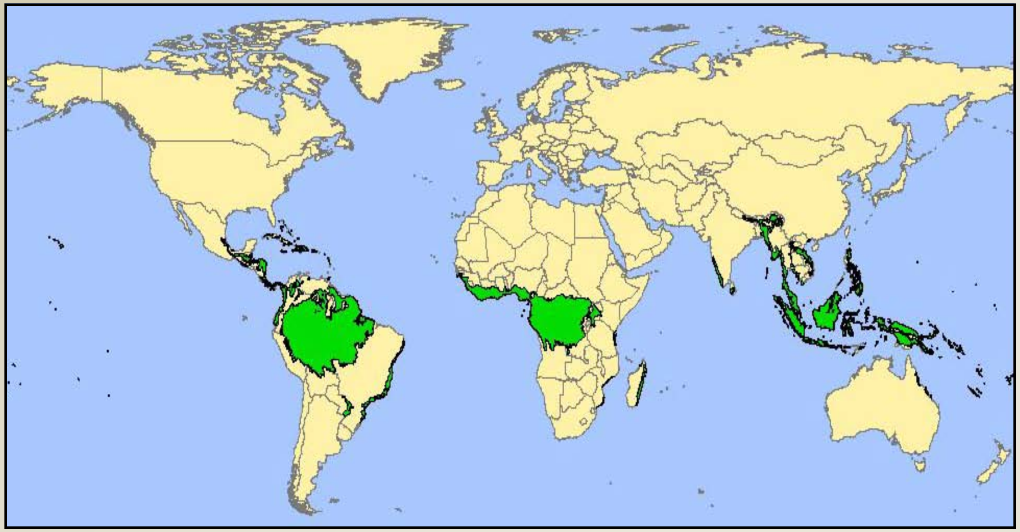
NET Estimates of Deforestation for 1990s

Disagreement in estimates for 1990s



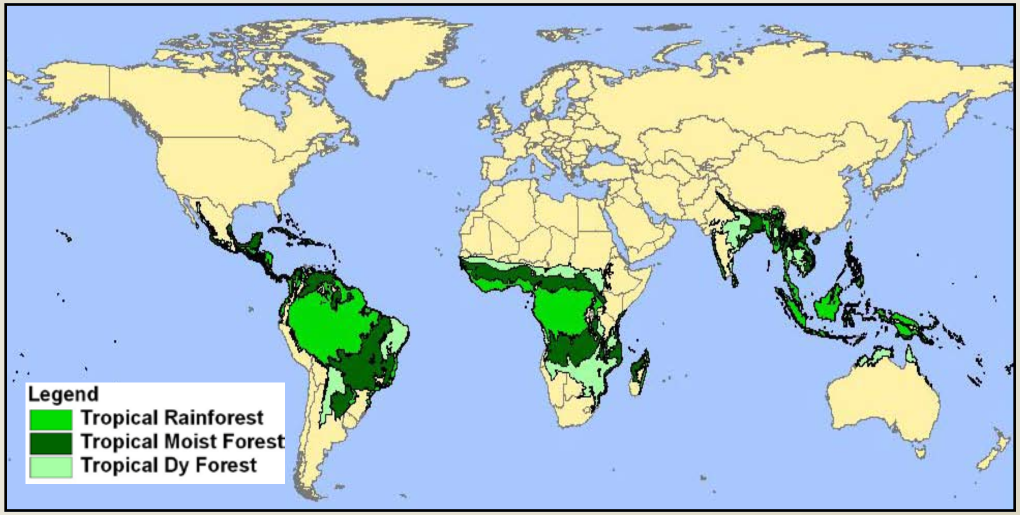
Data from DeFries et al. 2002, Achard et al. 2002, FRA 2000

Different domains…



TREES domain
Humid Tropics

TREES excludes ~50% of geographic area of AVHRR and FAO



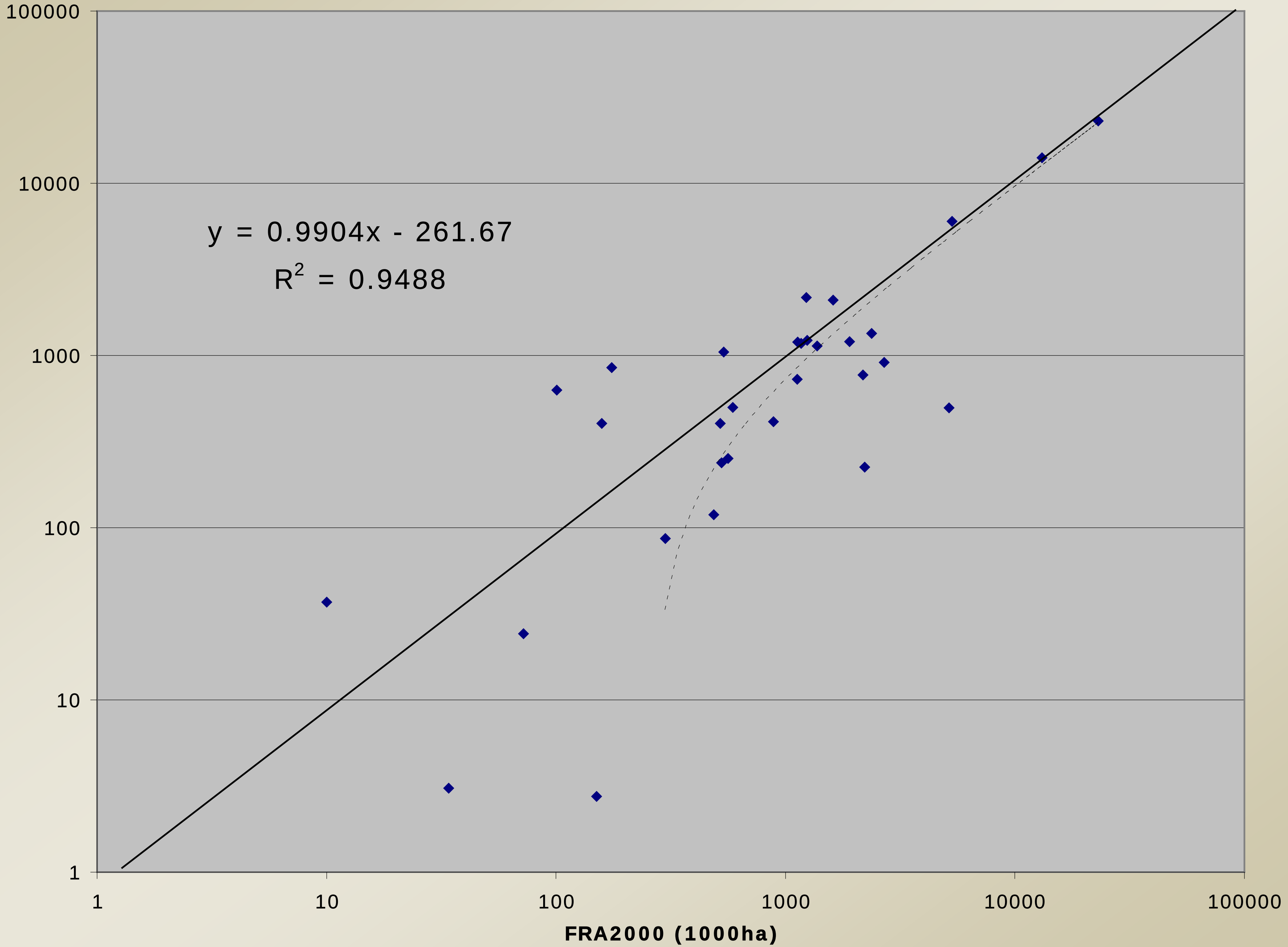
AVHRR & FAO domain
Total Tropics

Finding a consensus estimate

Different baselines, time periods, extents, and methods = different estimates

- *Triangulate* to produce consensus (best?) estimate -- a probability distribution, rather than single estimate.

- Mixed results
  - Moderate success in humid tropics
  - Dry tropics remain problematic


100000
10000
1000
100
10
1
y = 0.9904x - 261.67
R2 = 0.9488
1
10
100
1000
10000
100000
FRA2000 (1000ha)

Can remote sensing data capture land cover change?

- Unless spatial resolution is at stand level, may be capturing *net*, not *gross* deforestation.

- Since canopies can close in 5-10 years, while biomass accumulation continues for 50-100 years, even high resolution remote sensing may miss forest dynamics unless we monitor every year.

- Do not accurately track the fate of land *following* deforestation.

Net vs. Gross deforestation

Time 1

Time 2

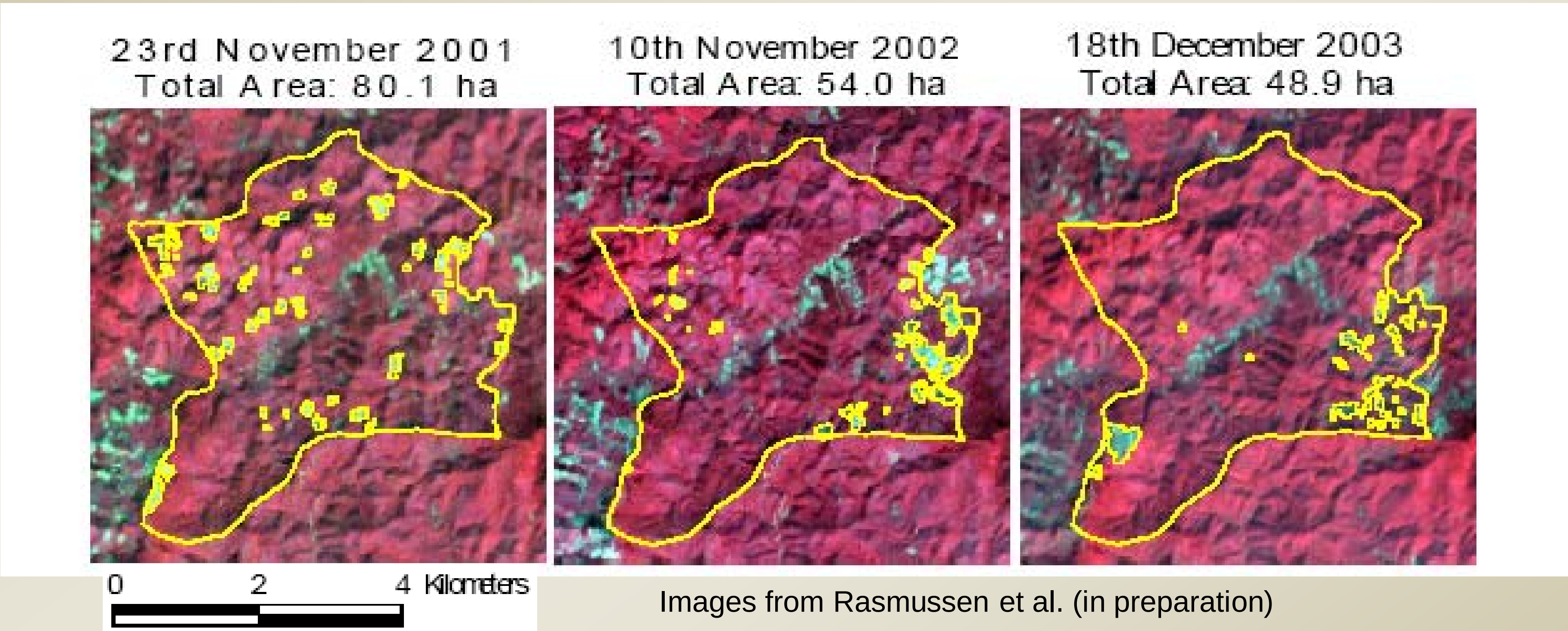
8km

8km

Net Change?	**ZERO**
Total Change?	25% decrease in forest & 25% increase in regrowing or planted forest

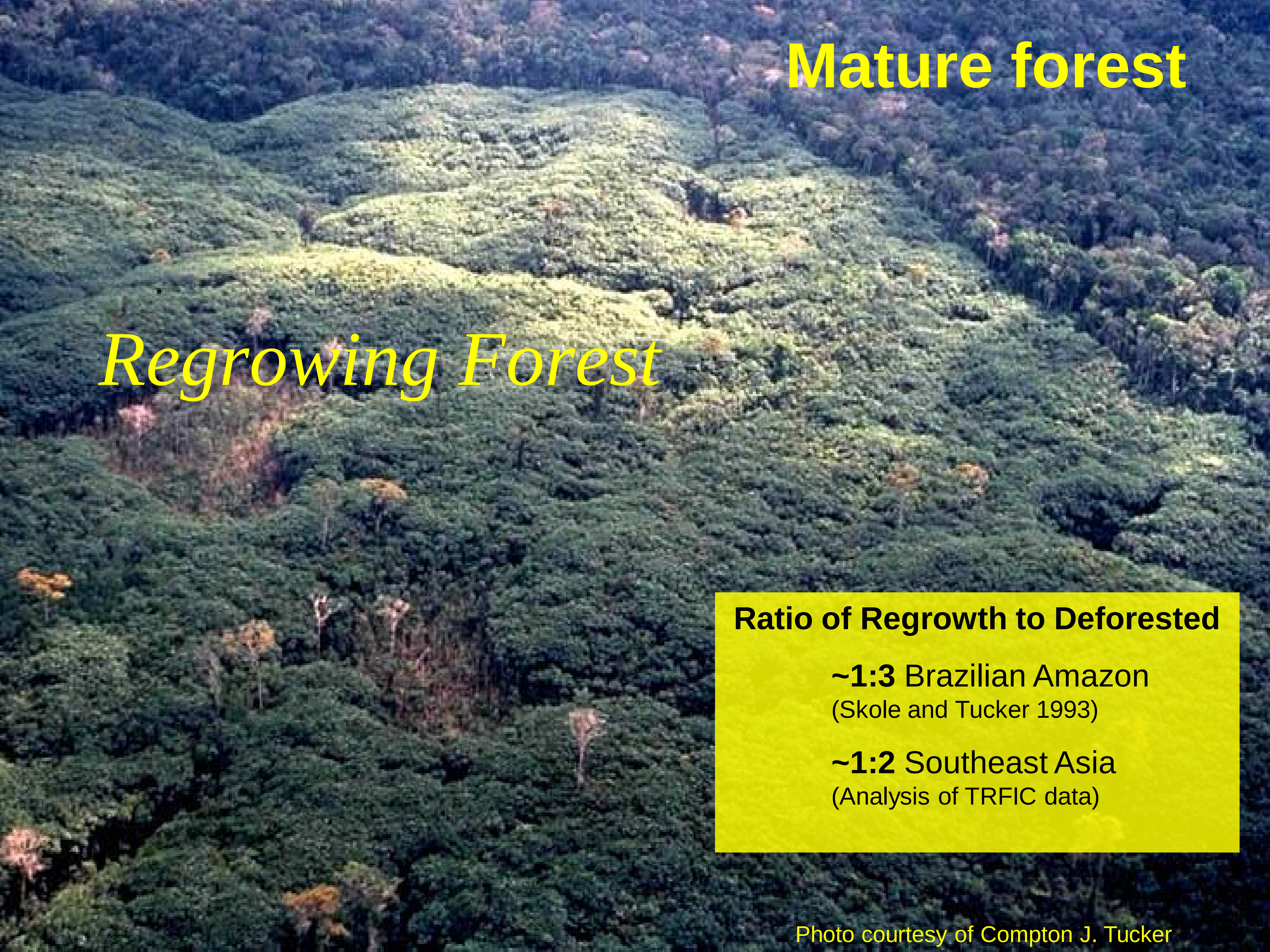
What's missing in decadal snapshots?

Shifting cultivation in highlands of Vietnam

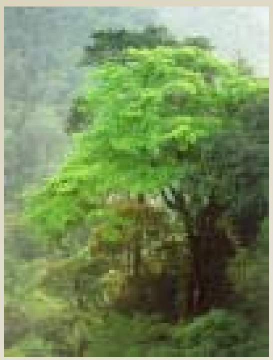


Images from Rasmussen et al. (in preparation)

To directly observe changes we may need to monitor every 2-3 years.


Mature forest
Regrowing Forest
Ratio of Regrowth to Deforested
~1:3 Brazilian Amazon
(Skole and Tucker 1993)
~1:2 Southeast Asia
(Analysis of TRFIC data)
Photo courtesy of Compton J. Tucker

Need to track fate of cleared land



CLEARING

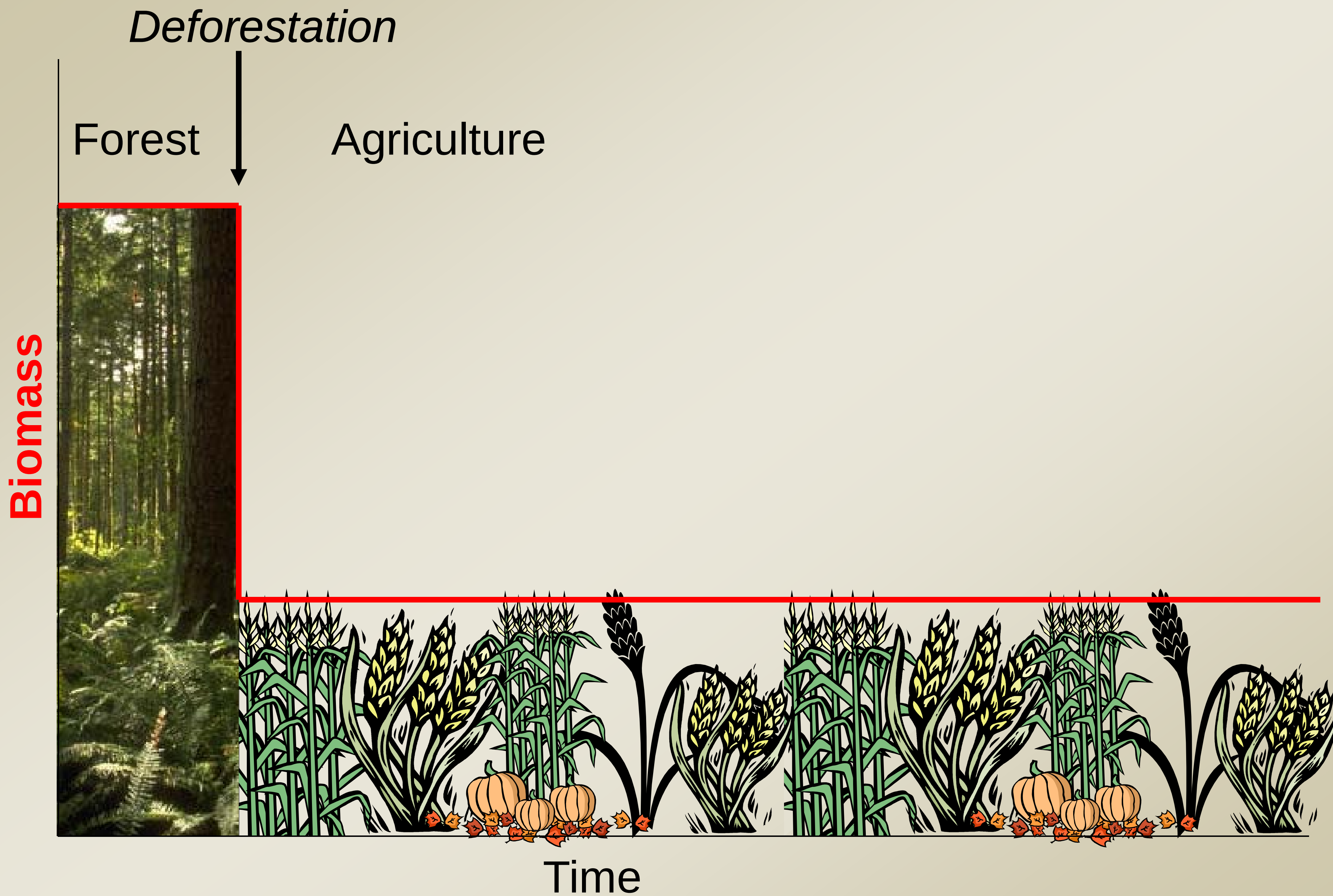
What is the mode of clearing? How long are typical fallow cycles? How much land is abandoned to secondary forest?

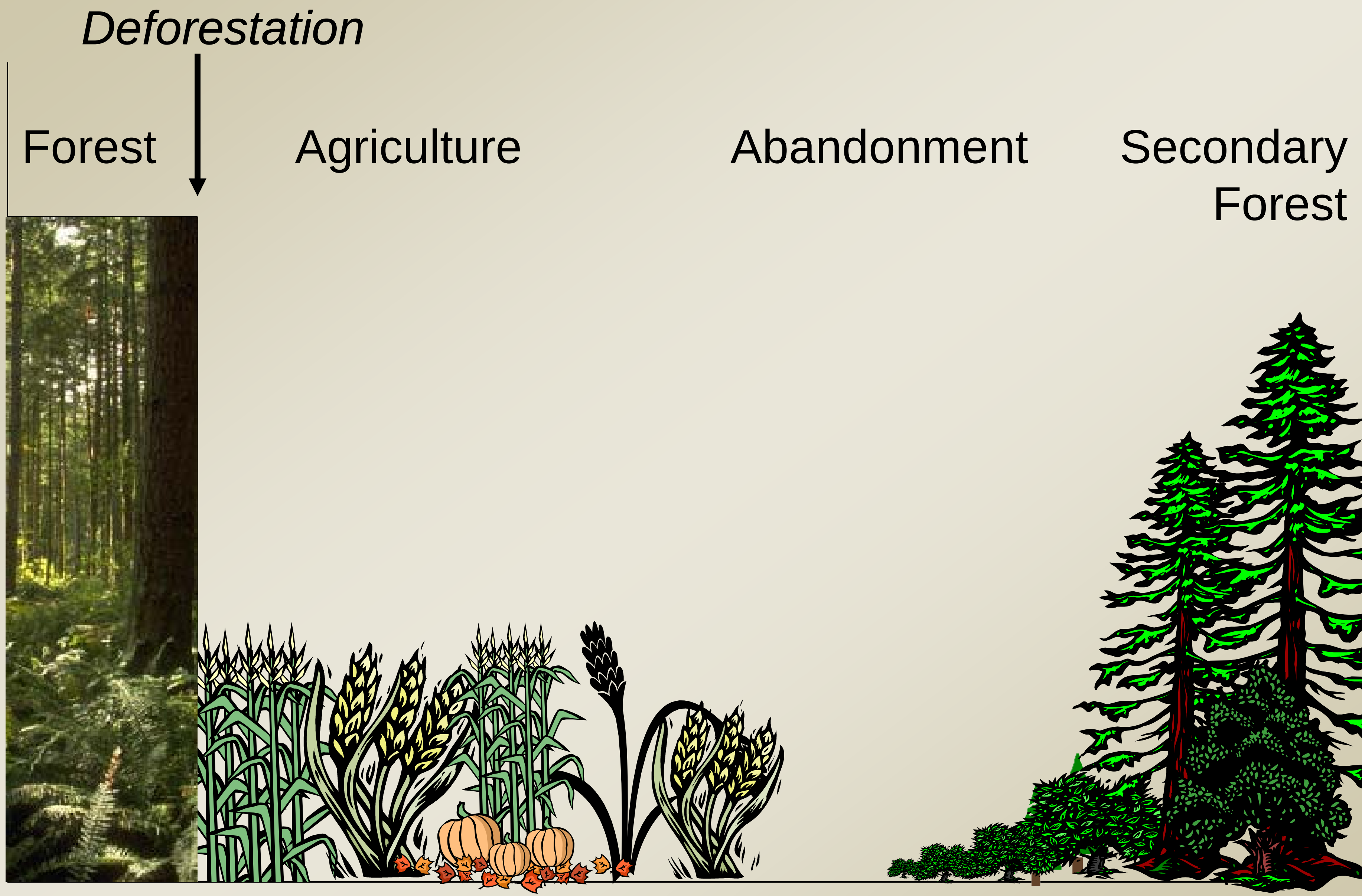
Pictures from Facts on File, Inc. and Focus on Africa, UW

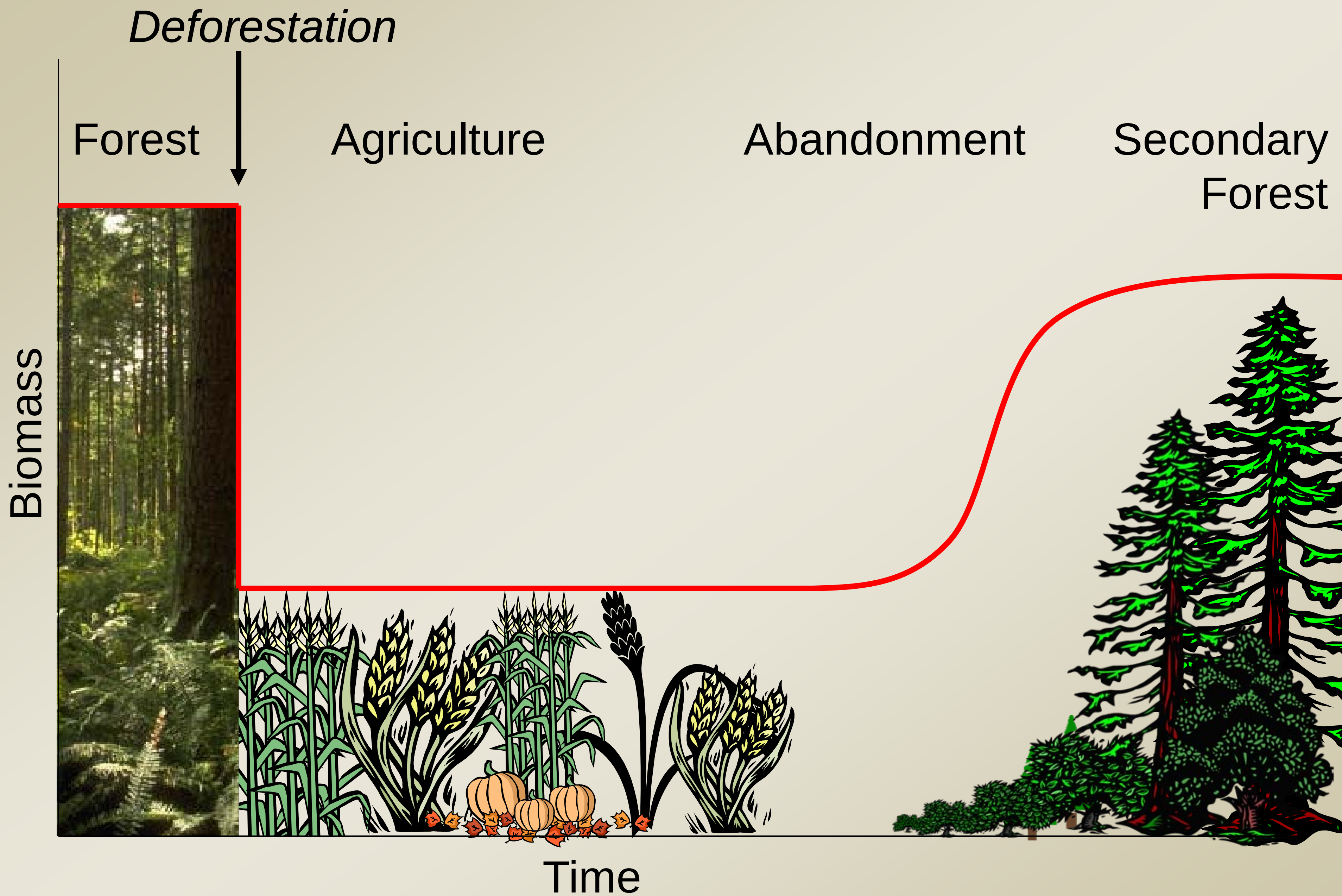
Deforestation

Forest

Agriculture


Deforestation
Forest
Agriculture
Biomass
Time


Deforestation
Forest
Agriculture
Abandonment
Secondary Forest


Deforestation
Forest
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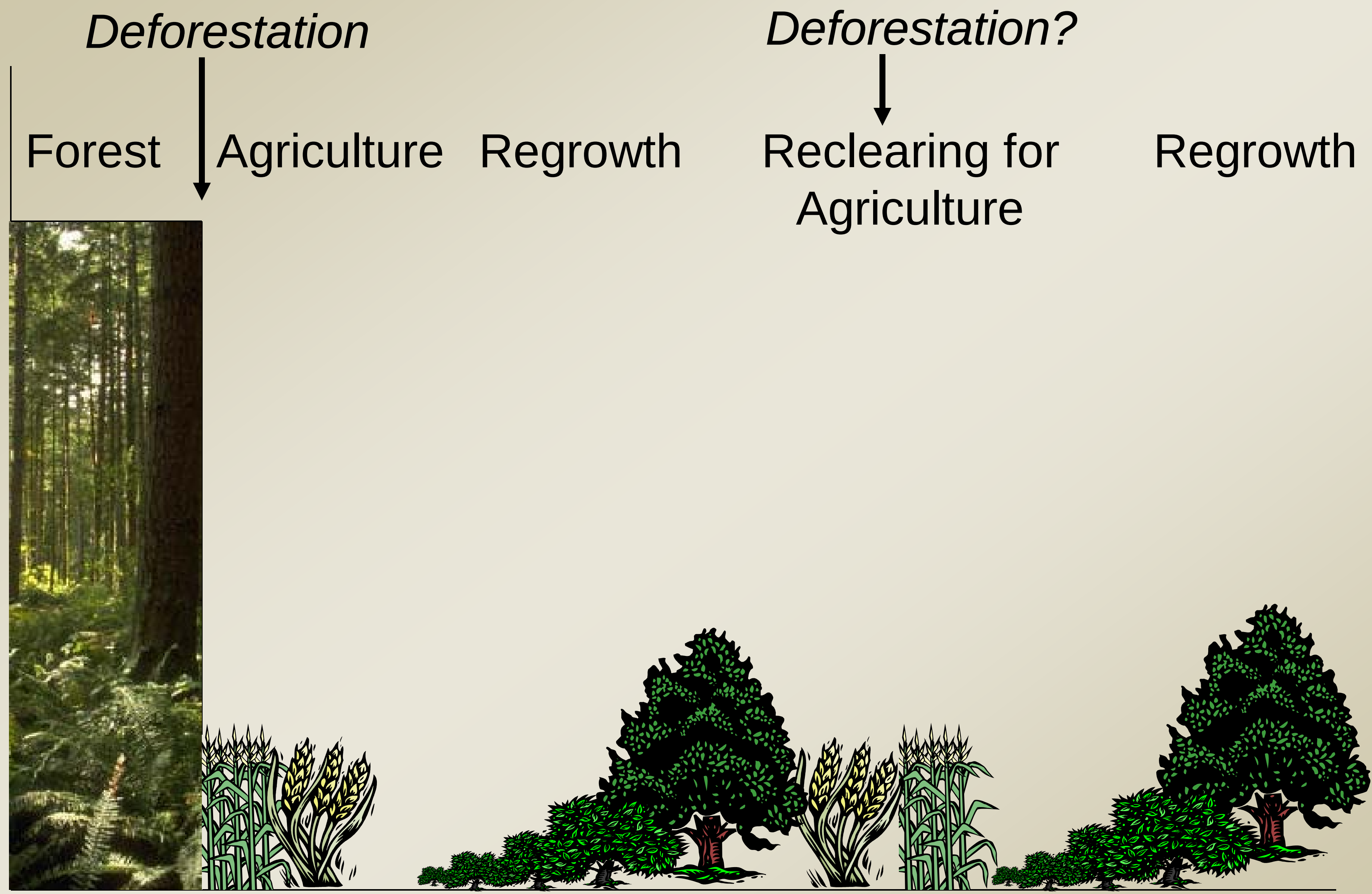
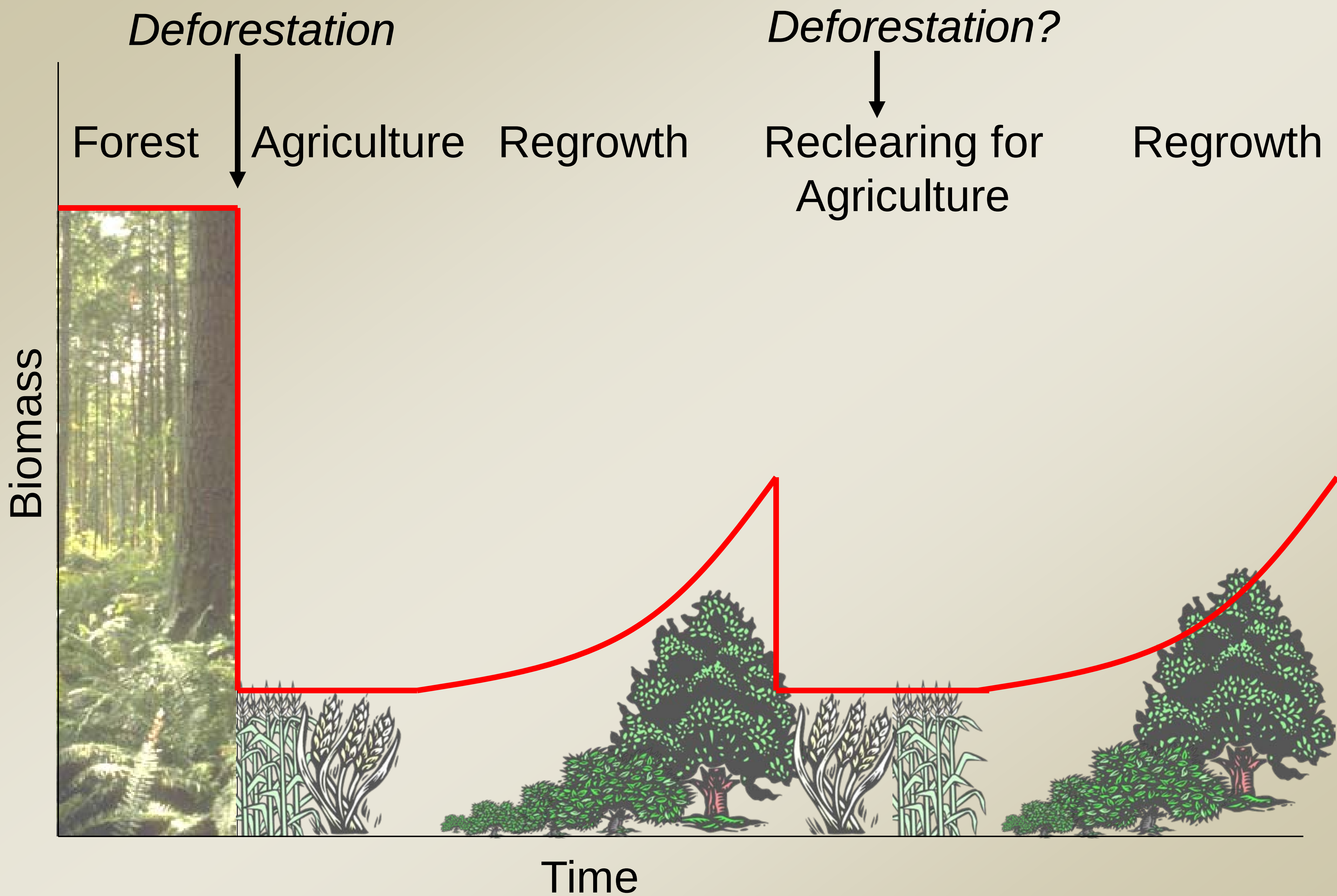
Secondary Forest
Biomass
Time


Deforestation
Deforestation?
Forest
Agriculture
Regrowth
Reclearing for Agriculture
Regrowth


Deforestation
Deforestation?
Forest
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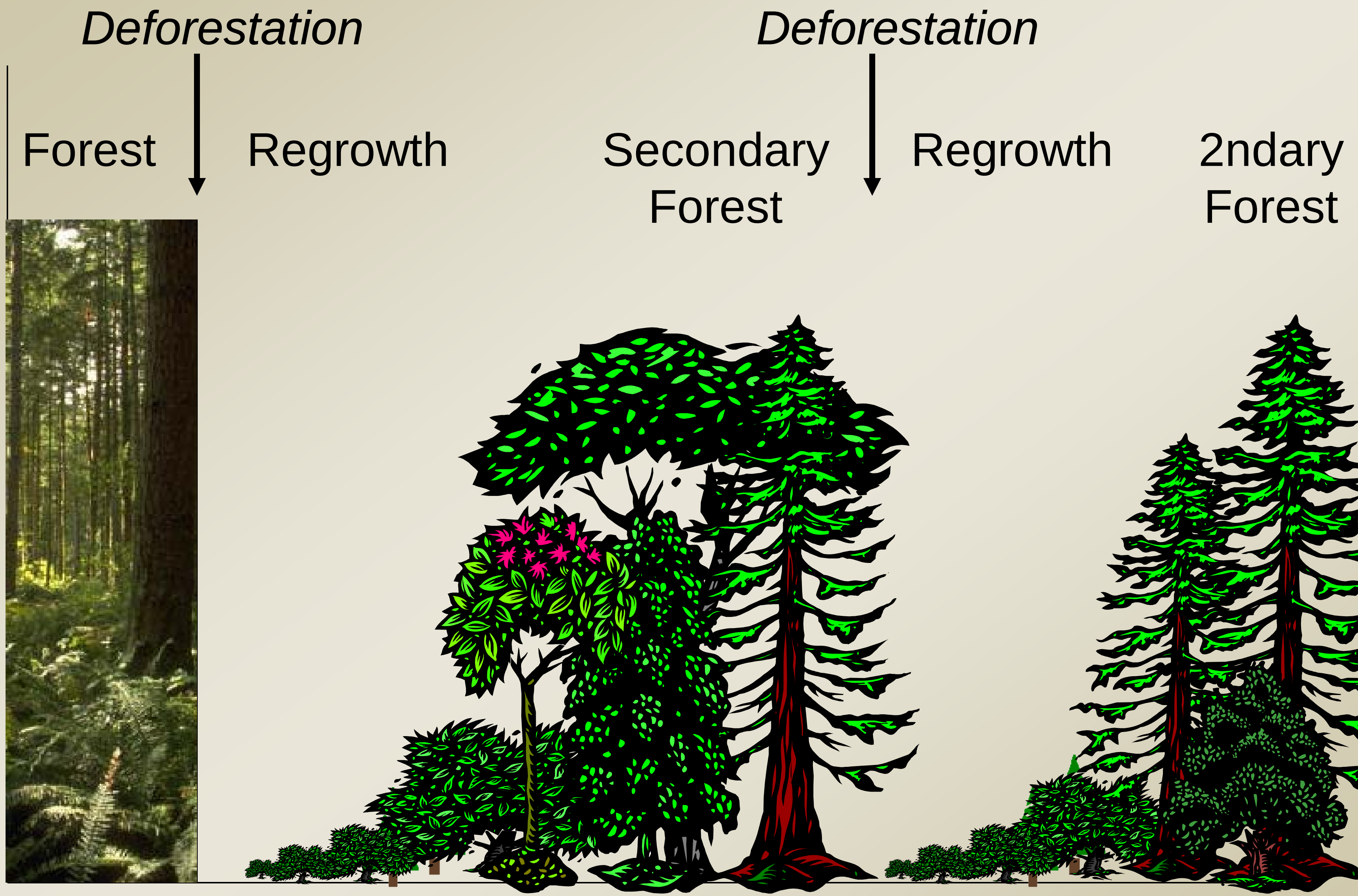
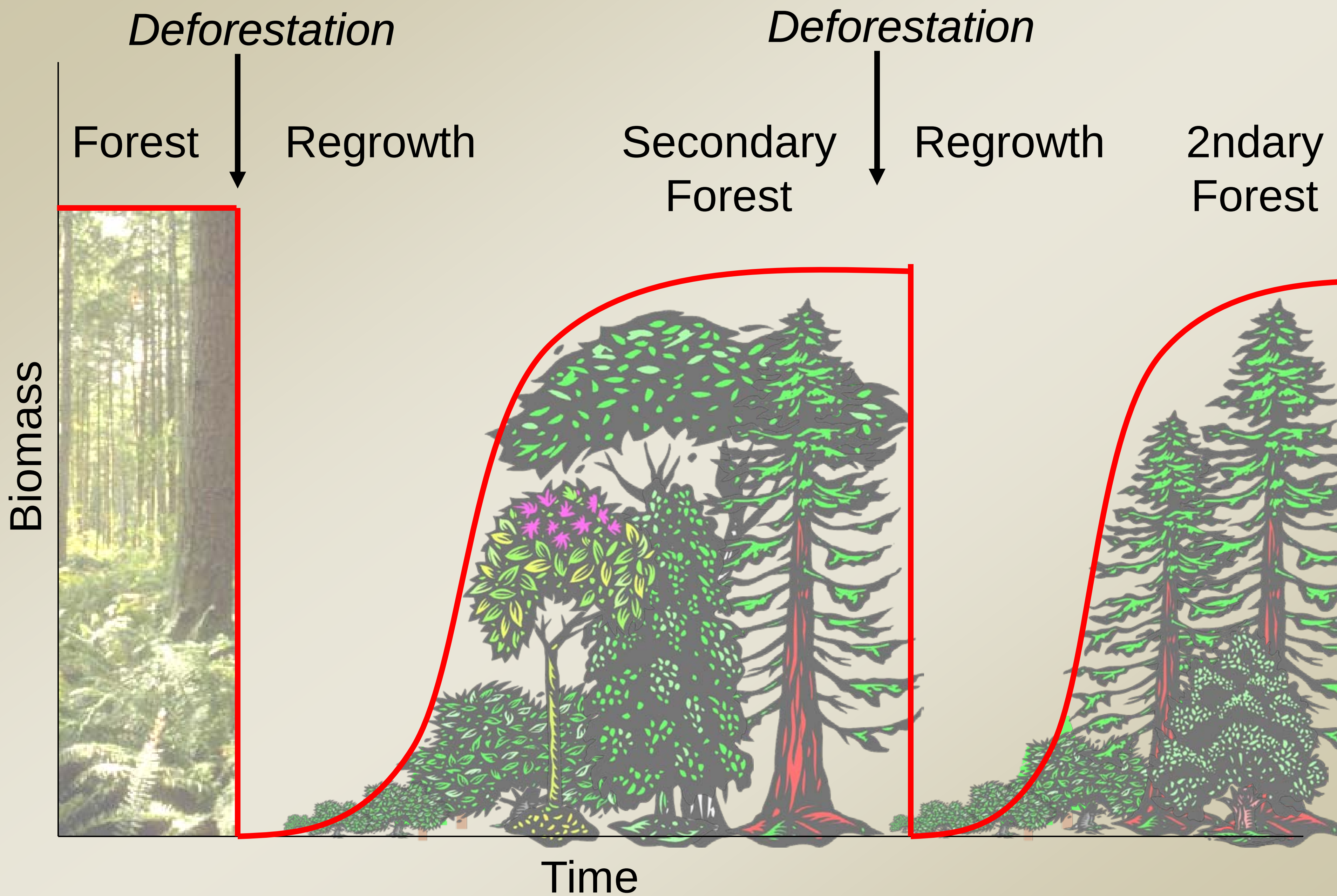
Regrowth
Reclearing for Agriculture
Regrowth
Biomass
Time



Deforestation
Deforestation
Forest
Regrowth
Secondary
Forest
Regrowth
2ndary
Forest


Deforestation
Deforestation
Forest
Regrowth
Secondary Forest
Regrowth
2ndary Forest
Biomass
Time

Need to track fate of cleared land

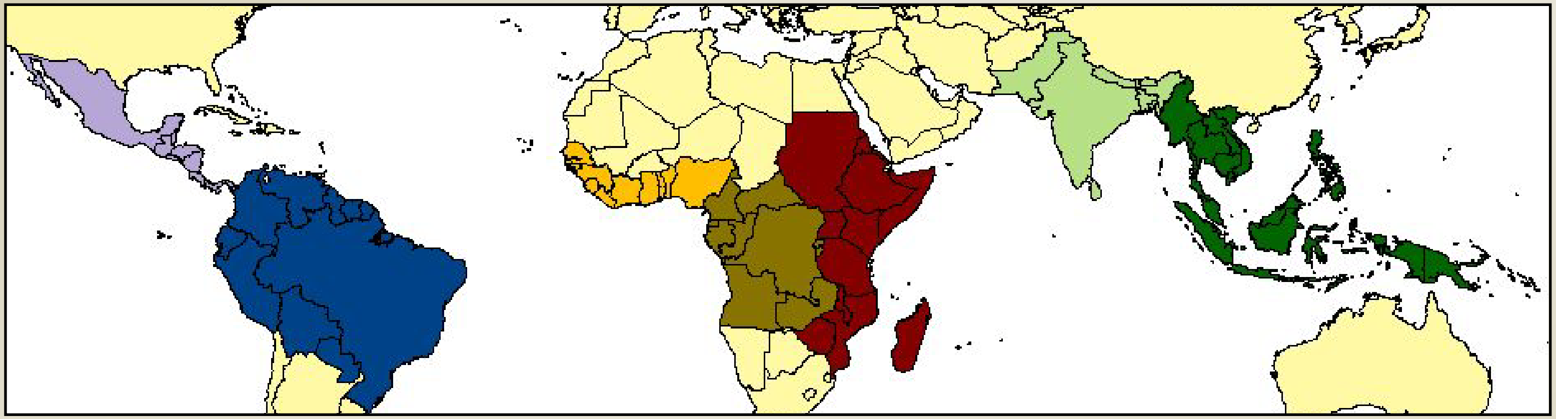
A Way forward?

- **Triangulated estimate** of deforestation rates, with **error bars**
- **Locations of change** from AVHRR – snapshots
- land cover **dynamics** from:
  - high-temporal resolution remote sensing data
  - completed meta-analyses (Lambin and Geist, Rudel)
  - household surveys, local census data, etc.

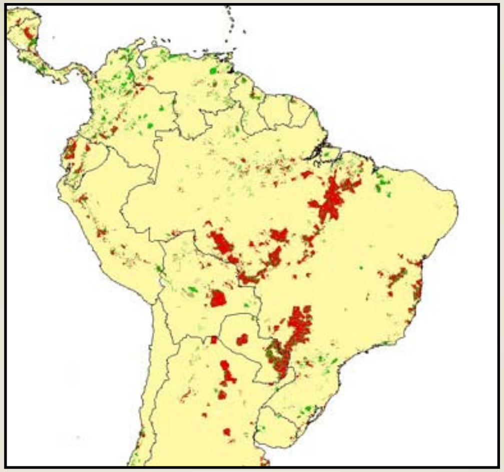
Integrate with “regional” land-use transition models

Regional Land-use Transition Models

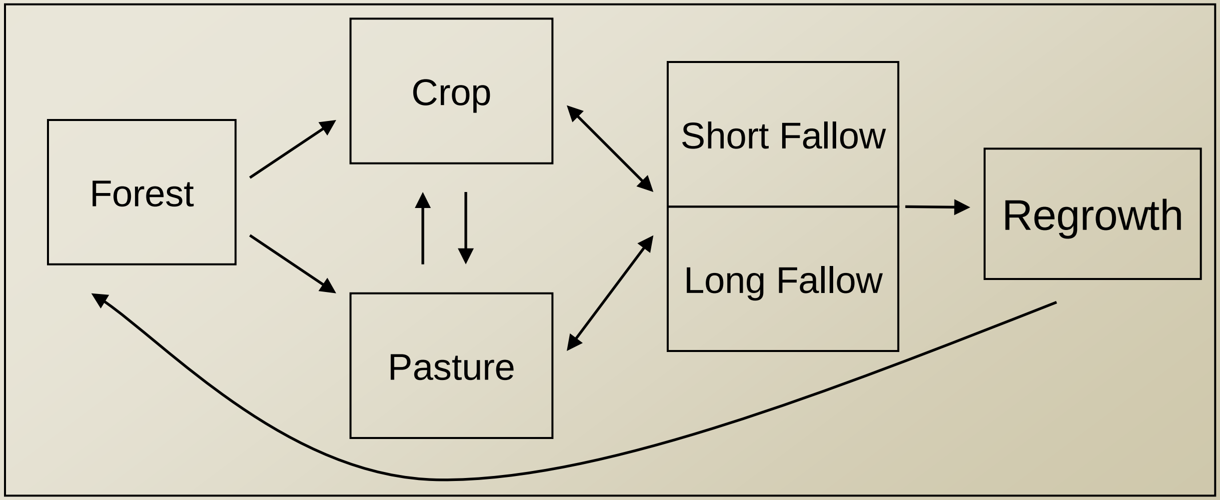
Land-use regions identified by meta-analysis (Tom Rudel, Rutgers)



Consensus Estimate



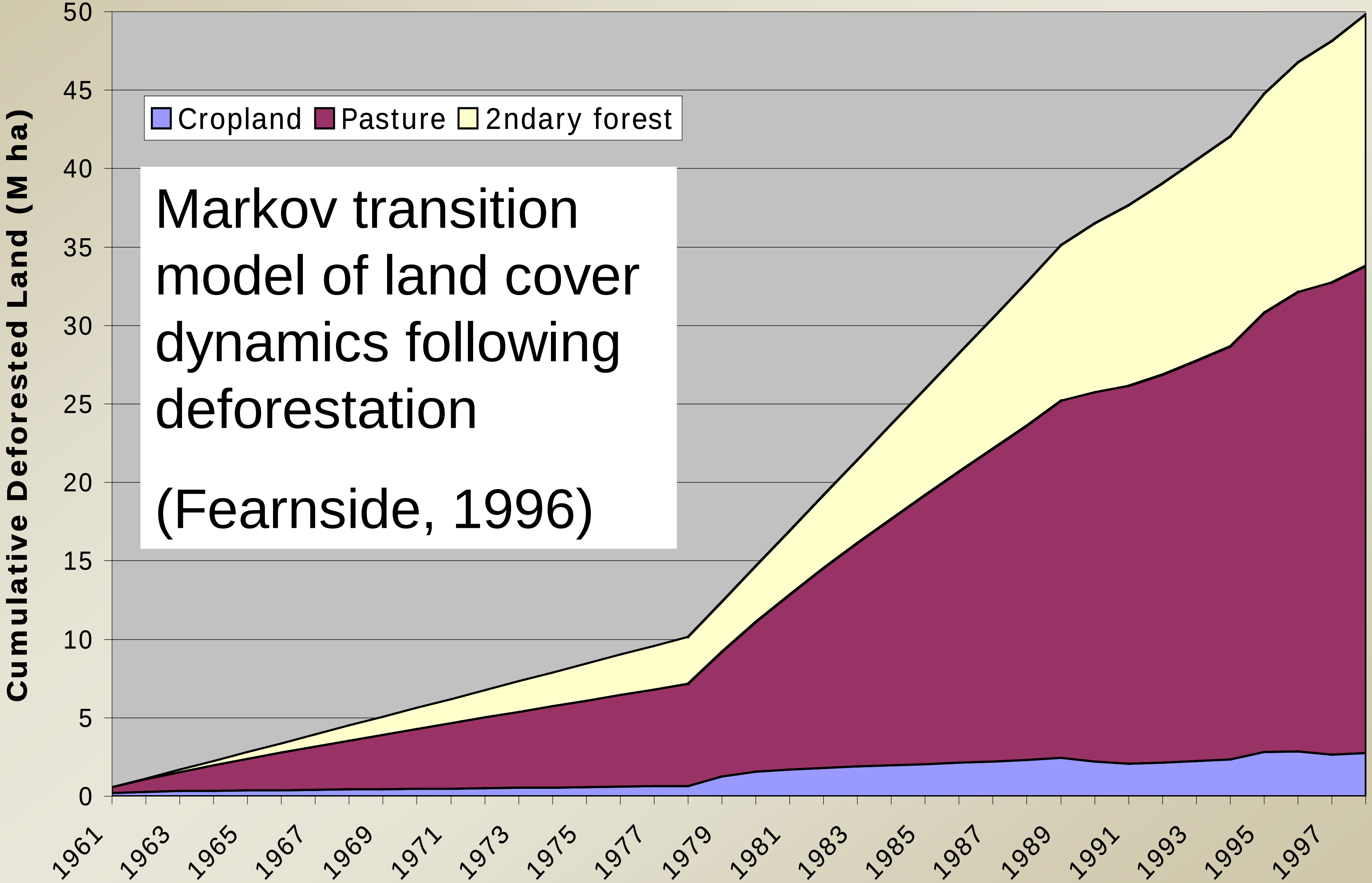
Land-use Transition Models



Implications for C emissions

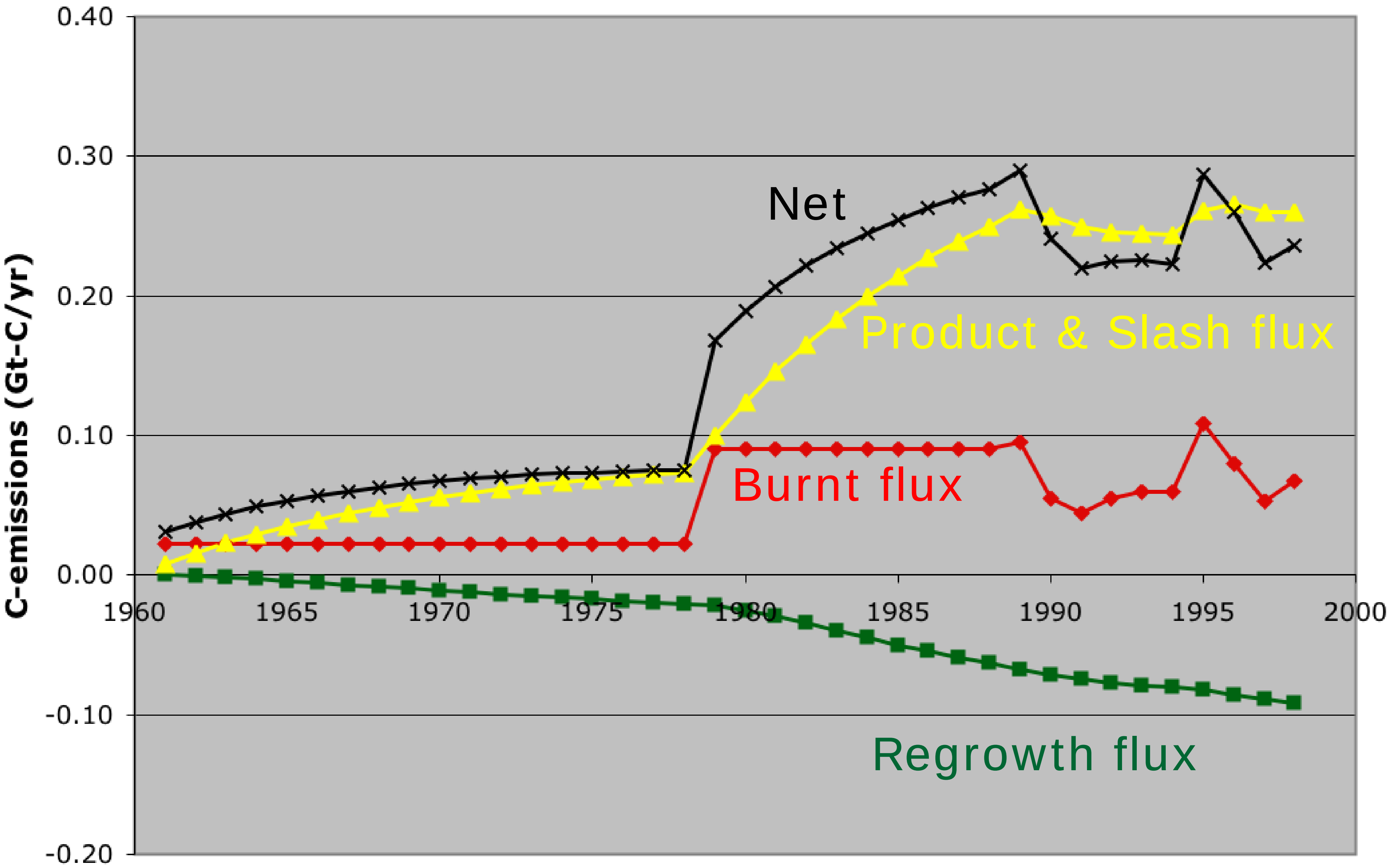
- Gross deforestation will overestimate emissions
  - Regrowth & uptake of carbon is important
- Net deforestation will underestimate emissions
  - Will overestimate uptake from regrowth

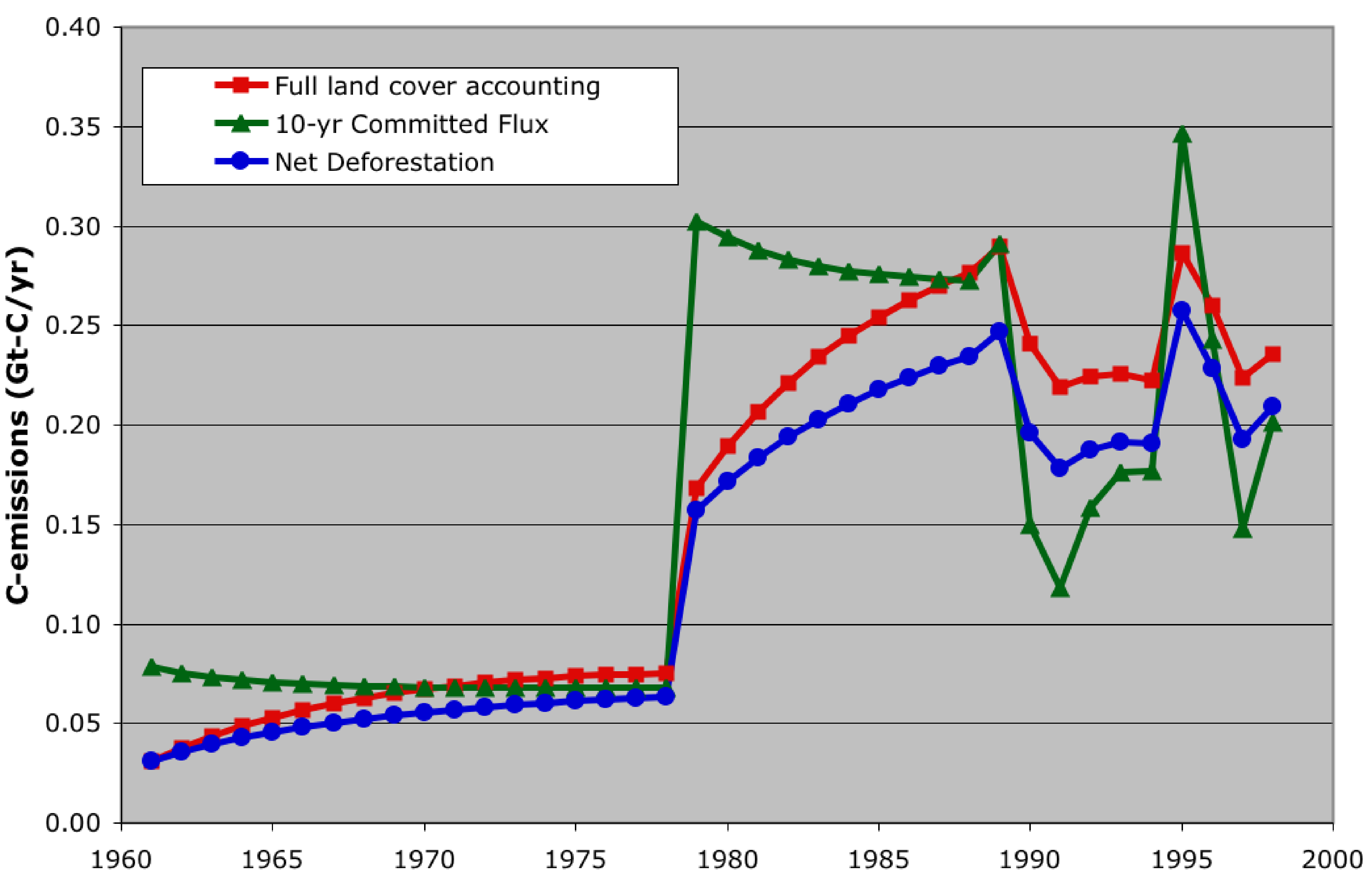
An example: Amazon Basin



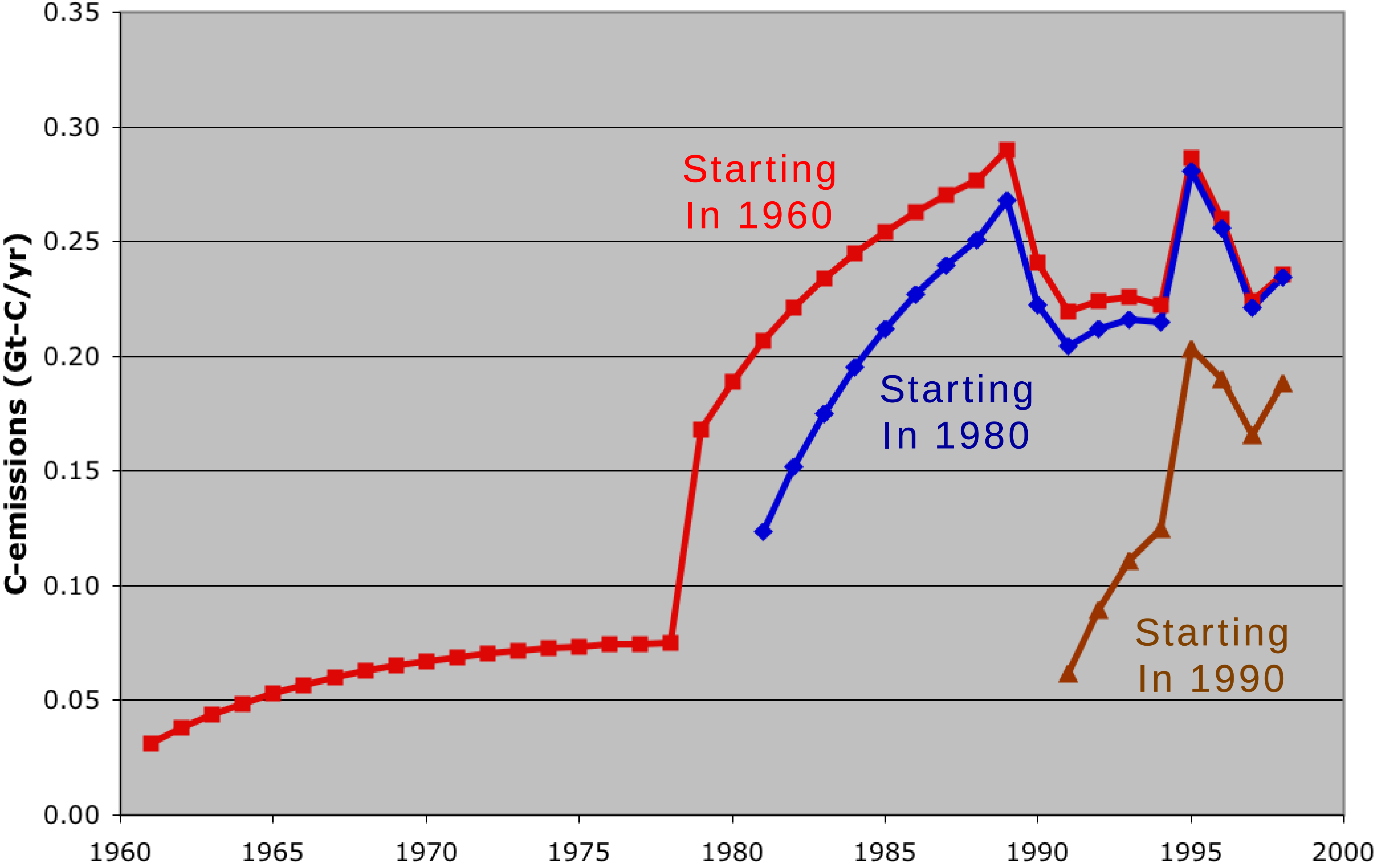
Markov transition model of land cover dynamics following deforestation

(Fearnside, 1996)


C-emissions (Gt-C/yr)
0.40
0.30
0.20
0.10
0.00
-0.10
-0.20
1960
1965
1970
1975
1980
1985
1990
1995
2000
Net
Product & Slash flux
Burnt flux
Regrowth flux



Full land cover accounting
10-yr Committed Flux
Net Deforestation
C-emissions (Gt-C/yr)
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
1960
1965
1970
1975
1980
1985
1990
1995
2000



C-emissions (Gt-C/yr)
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
1960
1965
1970
1975
1980
1985
1990
1995
2000
Starting In 1960
Starting In 1980
Starting In 1990

Conclusions

- It is important to consider the full suite of land cover transformations to evaluate carbon emissions.
  - Need to integrate remotely-sensed with ground-based case study information.

- History of land use is important!
  - e.g., consider *at least* previous 20 yrs in Amazon

- ~~Net~~ or ~~Gross~~ Deforestation, ~~Committed~~ Flux