This work was funded with the generous support of the American people through the Leader with Associates Cooperative Agreement No.EPP-A-00-06-00014-00 for implementation of the TransLinks project. The contents of this report are the responsibility of the author and do not necessarily reflect the views of the United States government.

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# Tropical Land Use Change and Soil Carbon: Implications for REDD

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**Erika Marín-Spiotta:** University of Wisconsin-Madison

♦♦♦♦♦♦♦♦

Provided by the **Land Tenure Center.** Comments encouraged:

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# TROPICAL LAND USE CHANGE AND SOIL CARBON: IMPLICATIONS FOR REDD

June 16, 2010

USAID Biodiversity & Forestry Seminar Series

Erika Marín-Spiotta

DEPARTMENT OF GEOGRAPHY
University of Wisconsin-Madison

Land Tenure Center

# TROPICAL LAND USE CHANGE AND SOIL CARBON: IMPLICATIONS FOR REDD

Emily Atkinson

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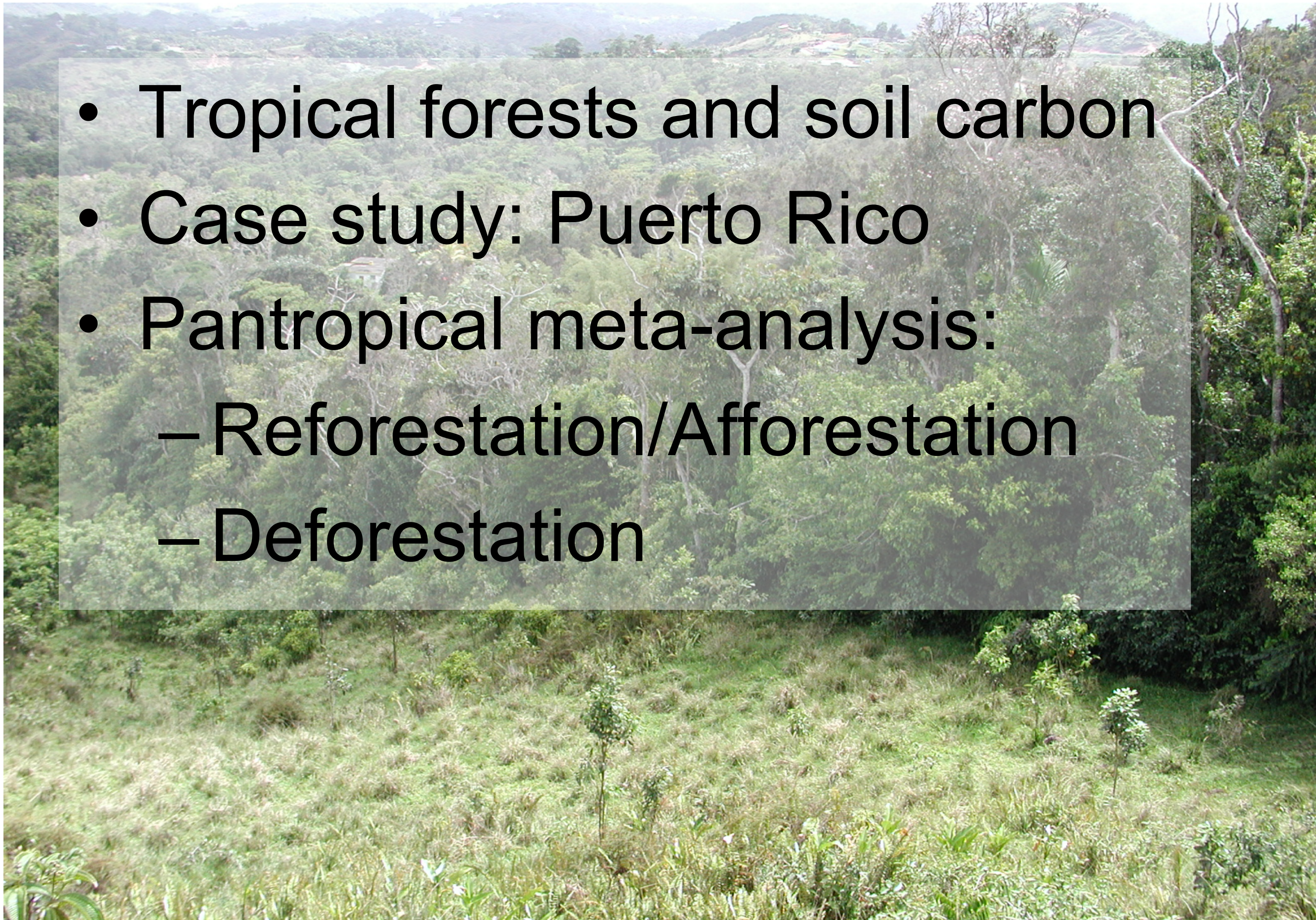
# Today's talk



- Tropical forests and soil carbon
- Case study: Puerto Rico
- Pantropical meta-analysis:
  - Reforestation/Afforestation
  - Deforestation

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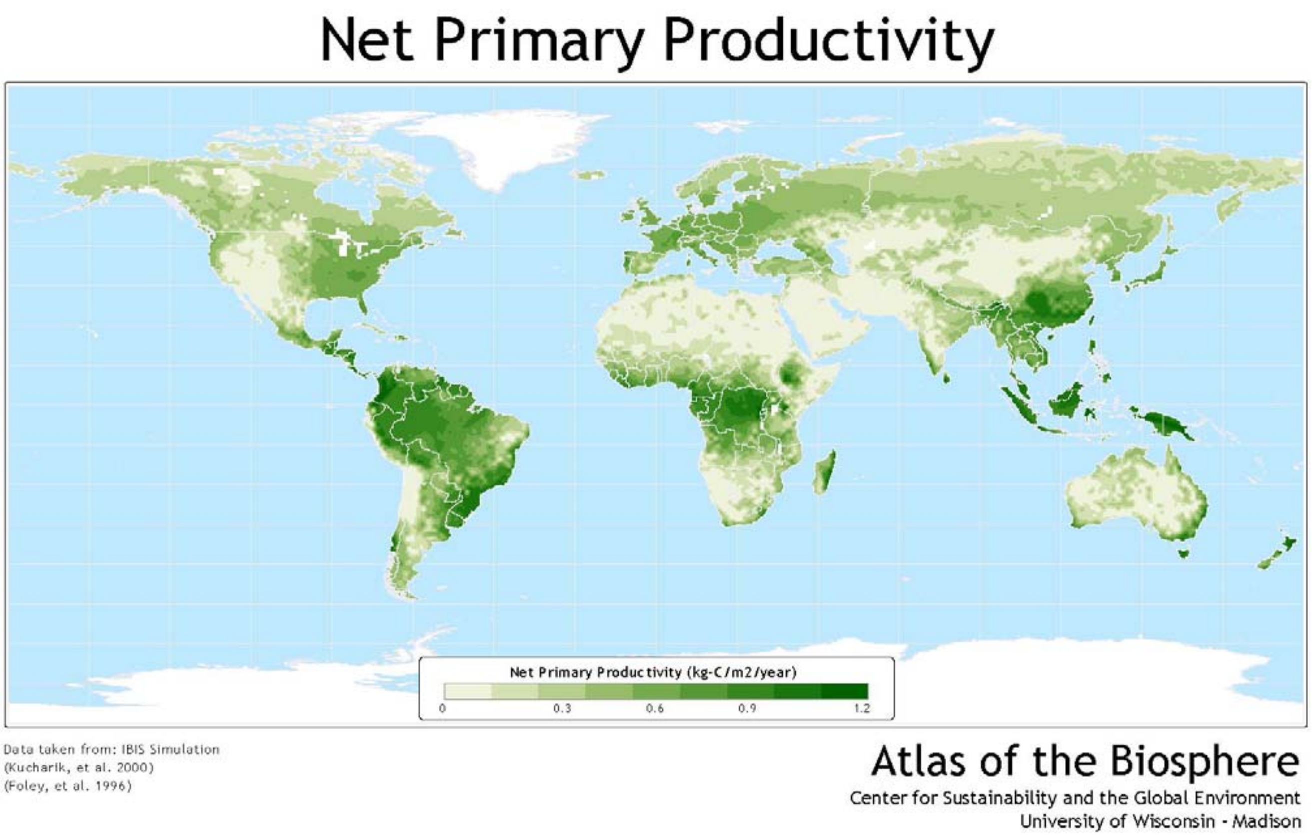
# Tropical forests play major role in global C cycle.

- Tropics: high solar radiation throughout year, high temperature, and high precipitation

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# Tropical forests play major role in global C cycle.

- Highest rates of C fixation
- High C stocks in vegetation and soils
- Dynamic interactions with atmosphere

# Tropical deforestation impacts C cycle.

- Reduction C storage potential in biomass
- Loss soil C during initial disturbance
- Release GHG from fire and decomposition

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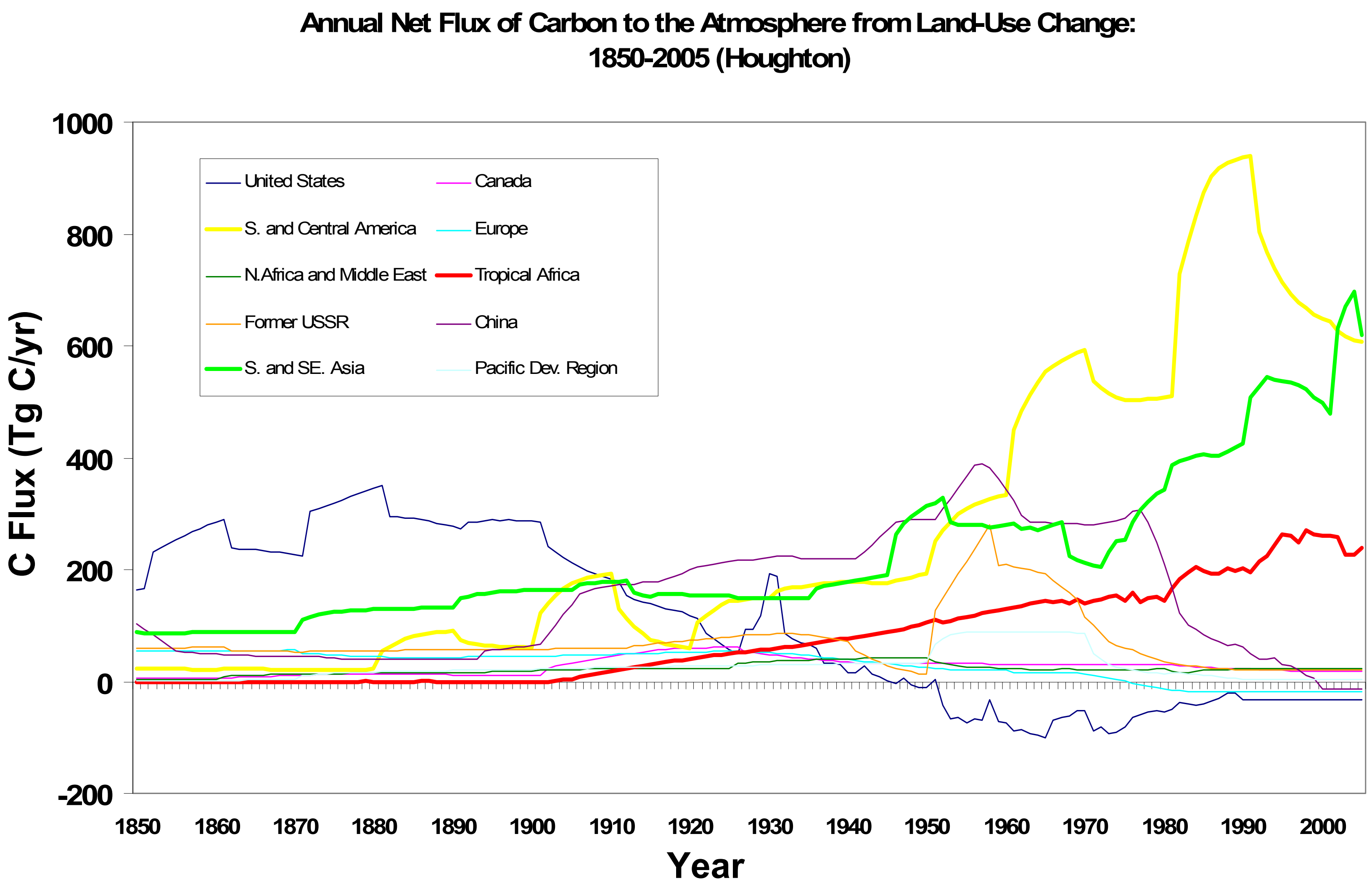
# Tropics are greatest emitters of C due to LUC.

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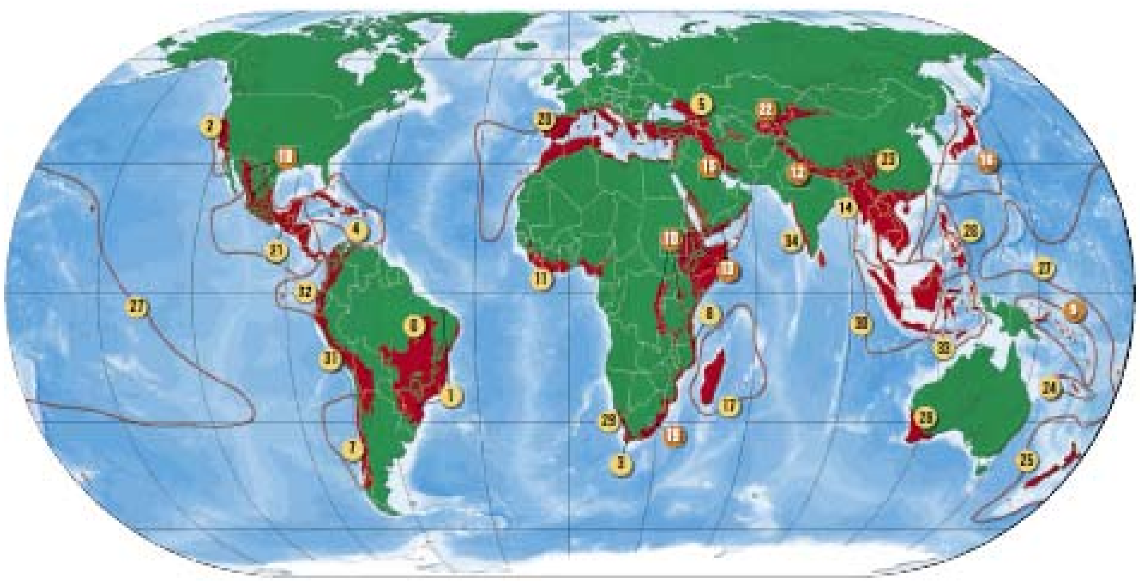
Houghton 2008

# Tropics host high biodiversity.

CI FACTS

## Biodiversity Hotspots

CONSERVATION INTERNATIONAL



**Biodiversity Hotspots**

Earth's biologically richest places, with high numbers of species found nowhere else. Hotspots face extreme threats and have already lost at least 70 percent of their original vegetation.

1. Atlantic Forest
2. California Floristic Province
3. Cape Floristic Region
4. Caribbean Islands
5. Caucasus
6. Cerrado
7. Chilean Winter Rainfall-Valdivian Forests
8. Coastal Forests of Eastern Africa
9. East Melanesian Islands
10. Eastern Afromontane
11. Guinean Forests of West Africa
12. Himalaya
13. Horn of Africa
14. Indo-Burma
15. Irano-Anatolian
16. Japan
17. Madagascar and Indian Ocean Islands
18. Madrean Pine-Oak Woodlands
19. Maputaland-Pondoland-Albany
20. Mediterranean Basin
21. Mesoamerica
22. Mountains of Central Asia
23. Mountains of Southwest China
24. New Caledonia
25. New Zealand
26. Philippines
27. Polynesia-Micronesia
28. Southwest Australia
29. Succulent Karoo
30. Sundaland
31. Tropical Andes
32. Tumbes-Chocó-Magdalena
33. Wallacea
34. Western Ghats and Sri Lanka

● New hotspots

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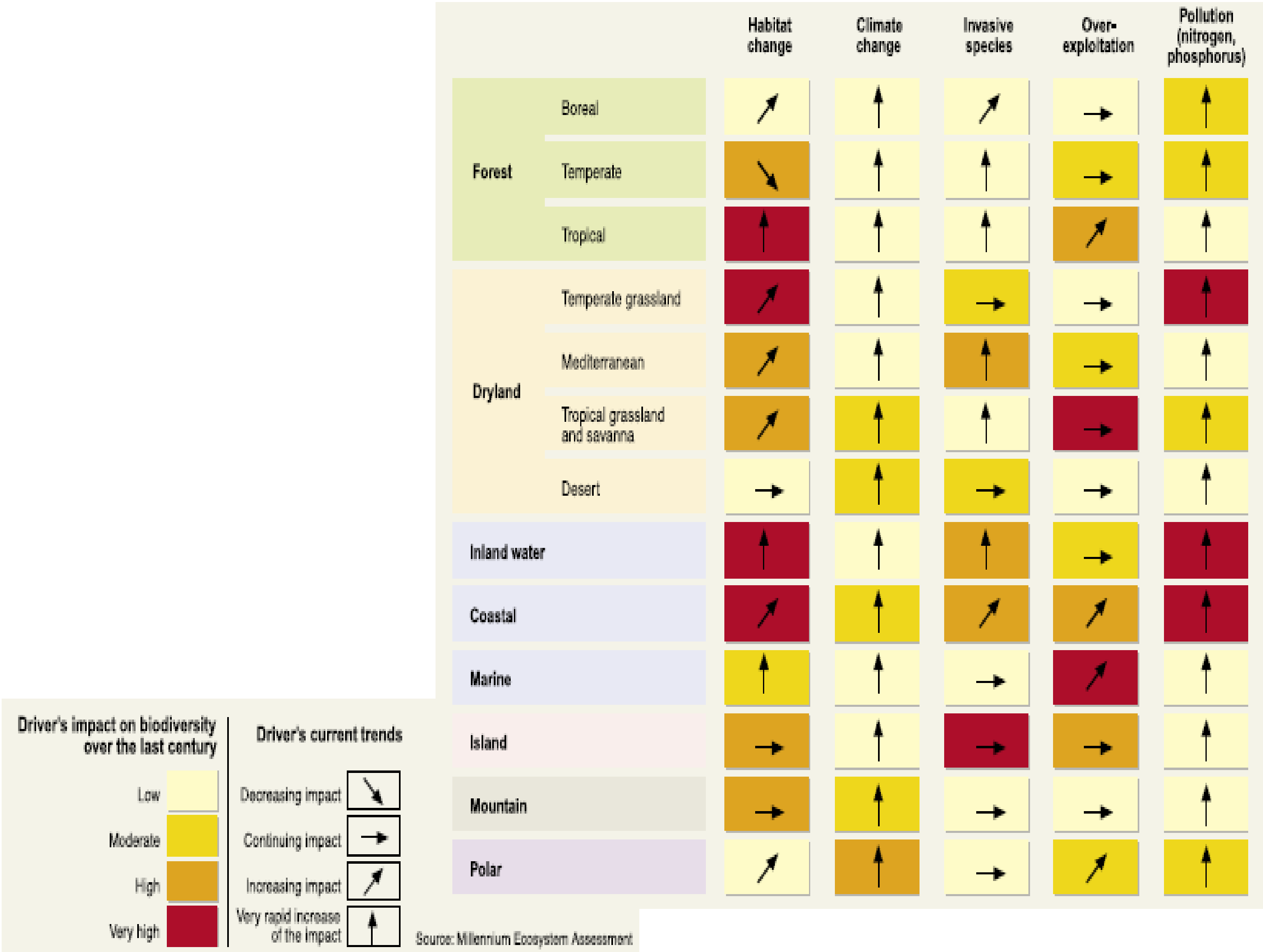
# Habitat loss main driver biodiversity loss.

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# Reforestation : Opportunities for C & Biodiversity

- C sequestration
- Biodiversity habitat
- Recovery forest ecosystem goods and services

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# What about soil carbon?


- Soil organic matter
- Important source of soil fertility:
  - Stores nutrients and water
  - Improves soil structure and permeability
- Store 2-3 times more C than aboveground biomass and atmosphere

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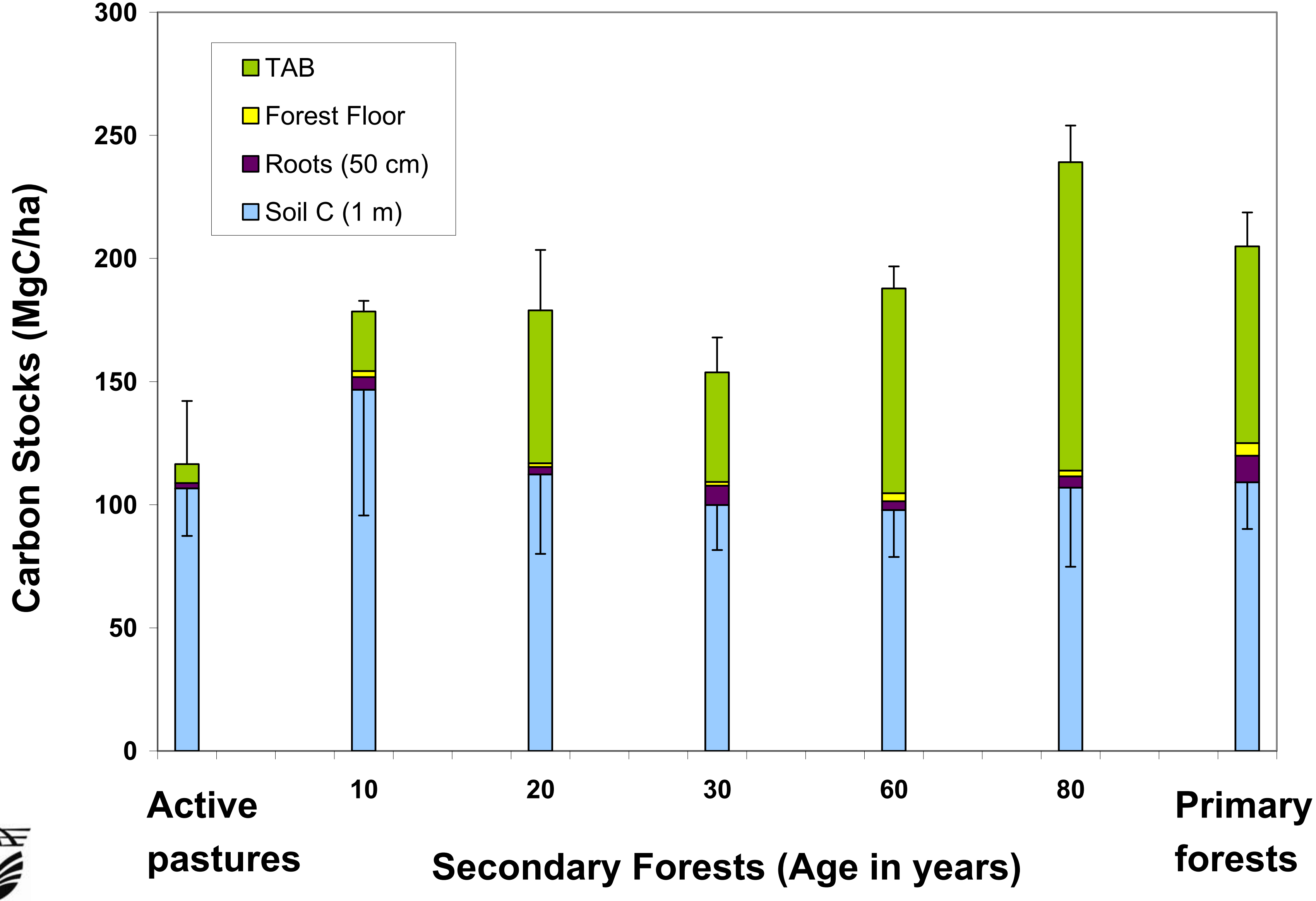
# What about soil carbon?

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# Measuring C stocks: Aboveground

- Plant biomass C
  - 50% C x amount biomass (t/ha)
- Methods:
  1. Direct harvest of all biomass (destructive sampling)
  2. Dimensional analysis (allometry)

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# Measuring C stocks: Belowground

- Root biomass C
  - 50% C x amount biomass (t/ha)
- Soil C:
  1. Direct measurement, excavations (combustion)
  2. Dimensional analysis (allometry)

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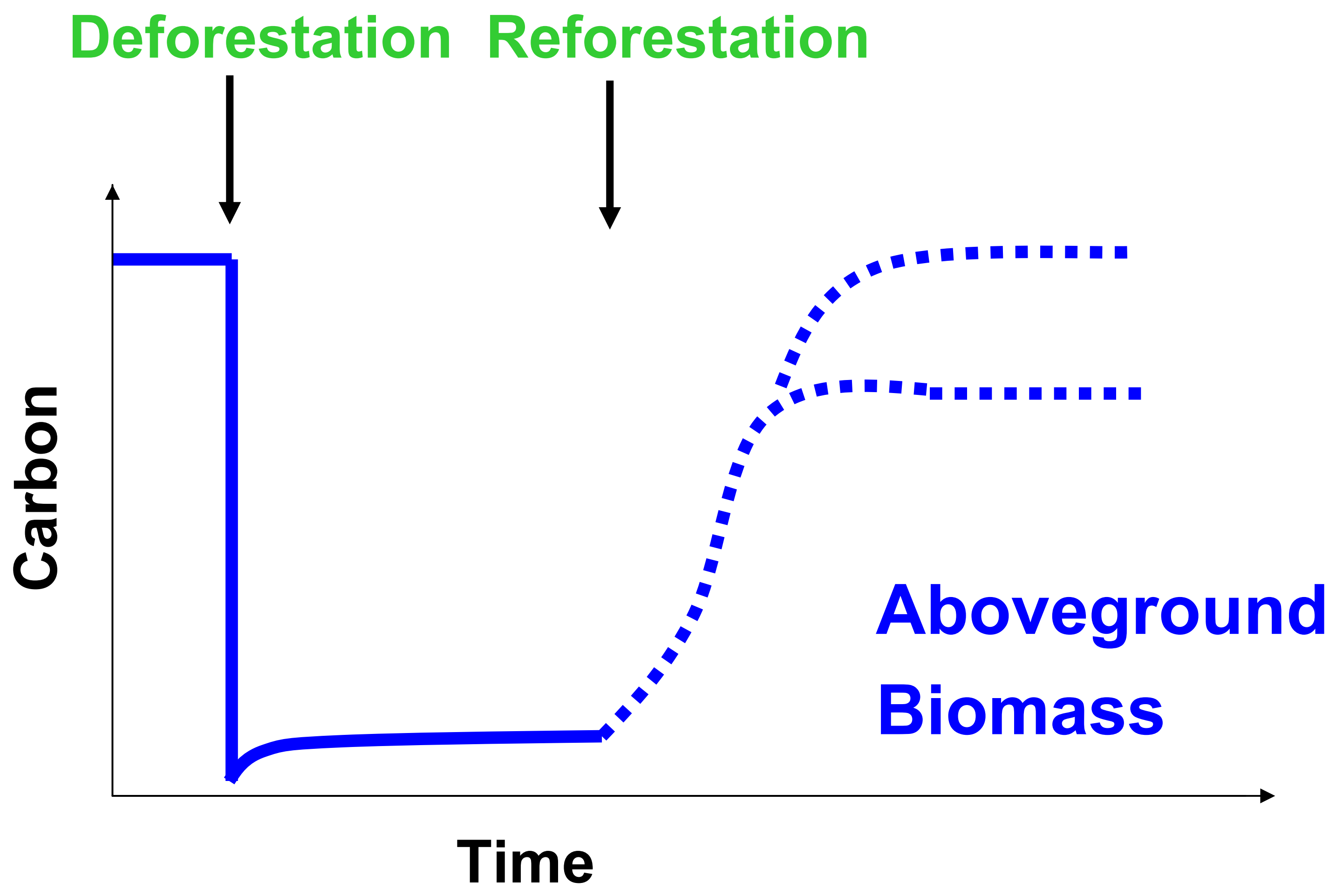
# What is the fate of C during reforestation?

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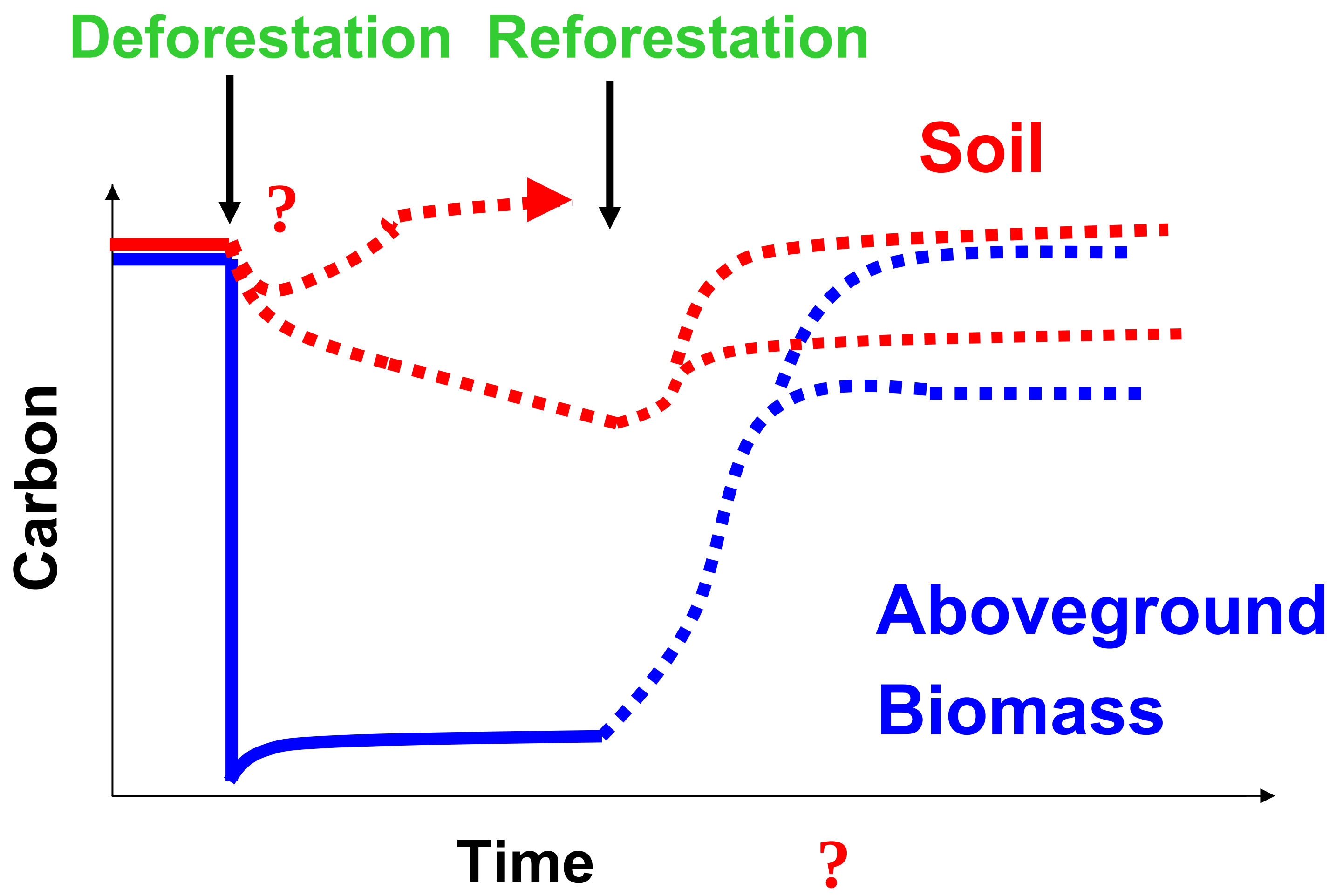
# What is the fate of C during reforestation?



# Case Study: Puerto Rico

| Year | Forest Cover (%) Island-wide | Cayey region |
|---|---|---|
| mid 1940s | 13 | 20 |
| mid 1990s | 42 | 62 |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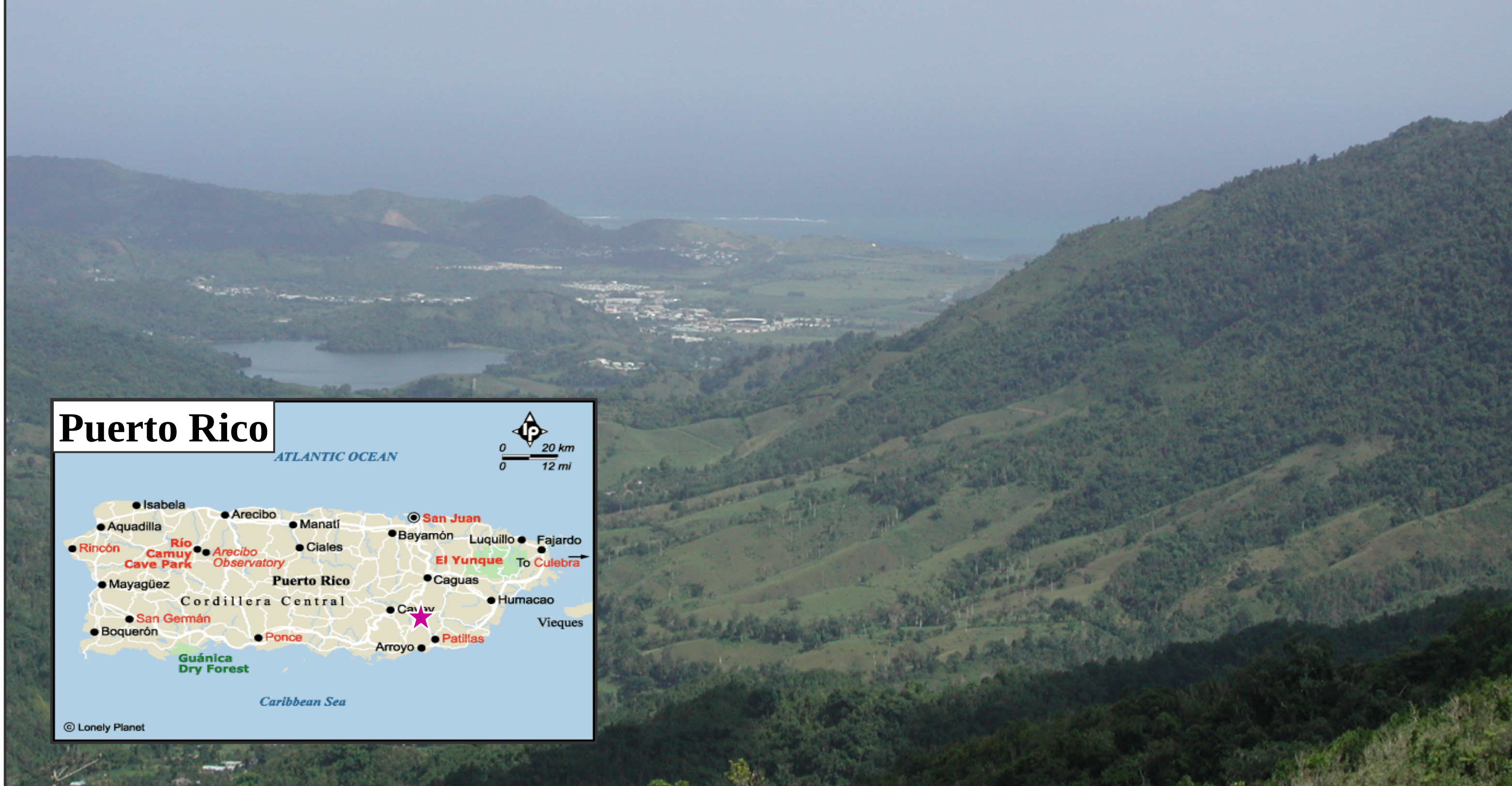
# Case Study: Puerto Rico

- C benefits and costs of industrialization
- New LU/LCC driver: urbanization

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# Chronosequence Approach

ACTIVE PASTURES | 10 | 20 | 30 | 60 | 80 | PRIMARY FORESTS

SECONDARY FORESTS
(years since pasture abandonment)

# Reforestation of pastures: Aboveground

- Can secondary forests recover characteristics of undisturbed forests?

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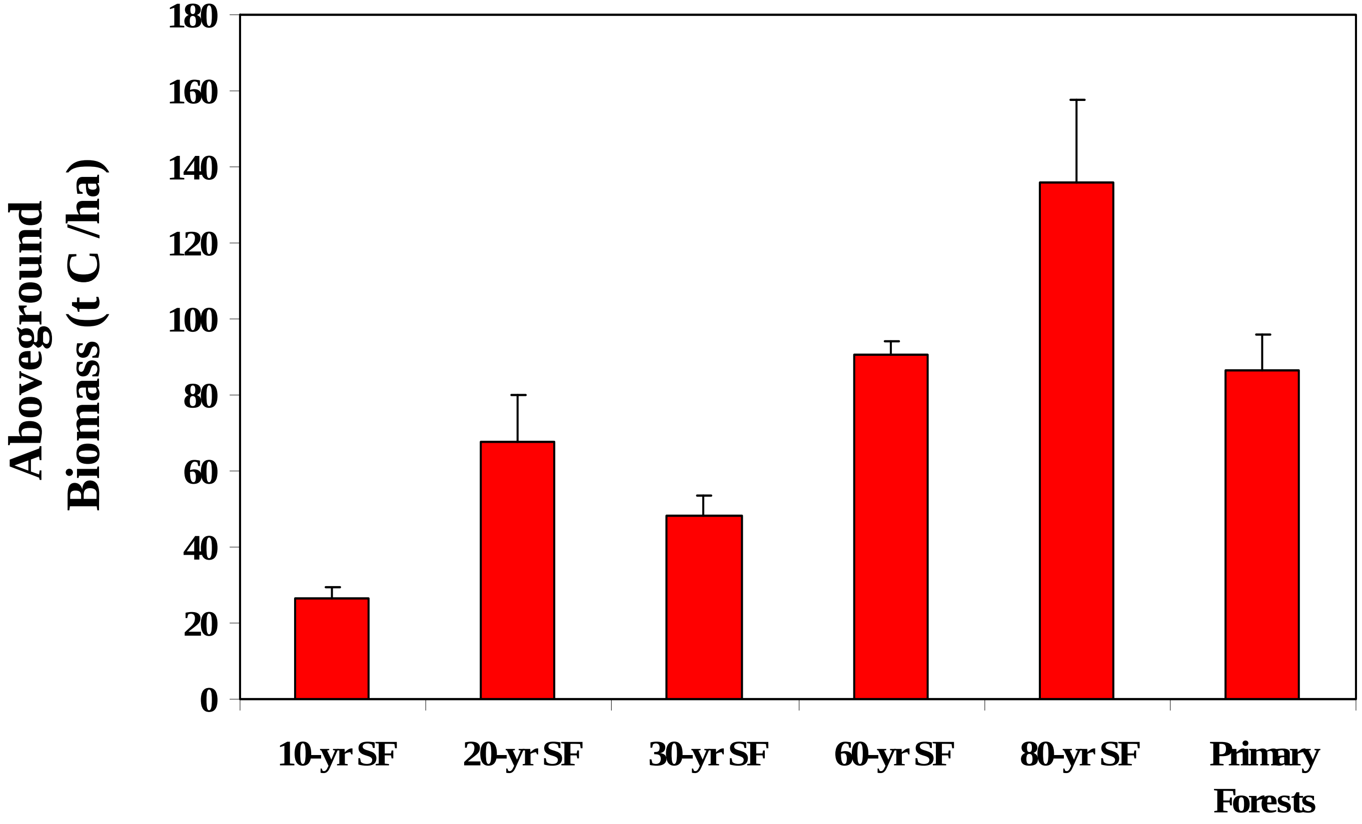
# Secondary forests accumulate more biomass C.

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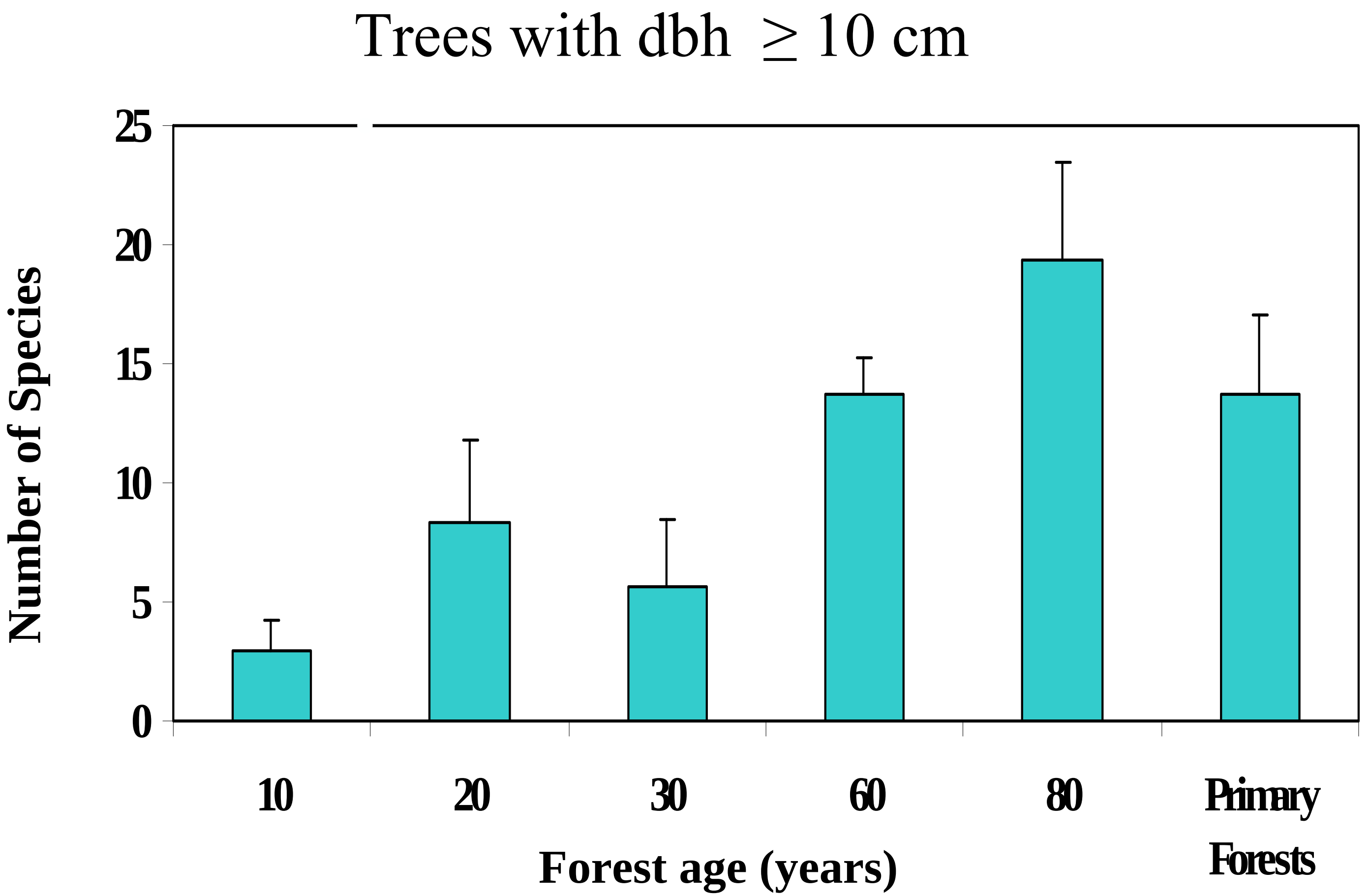
Marín-Spiotta et al. 2007. *Ecological Applications*

# Old secondary forests recover species richness.




Marín-Spiotta et al. 2007. *Ecological Applications*

# Reforestation of pastures: Belowground

- Do secondary forests regrowing on pastures sequester C in soils?

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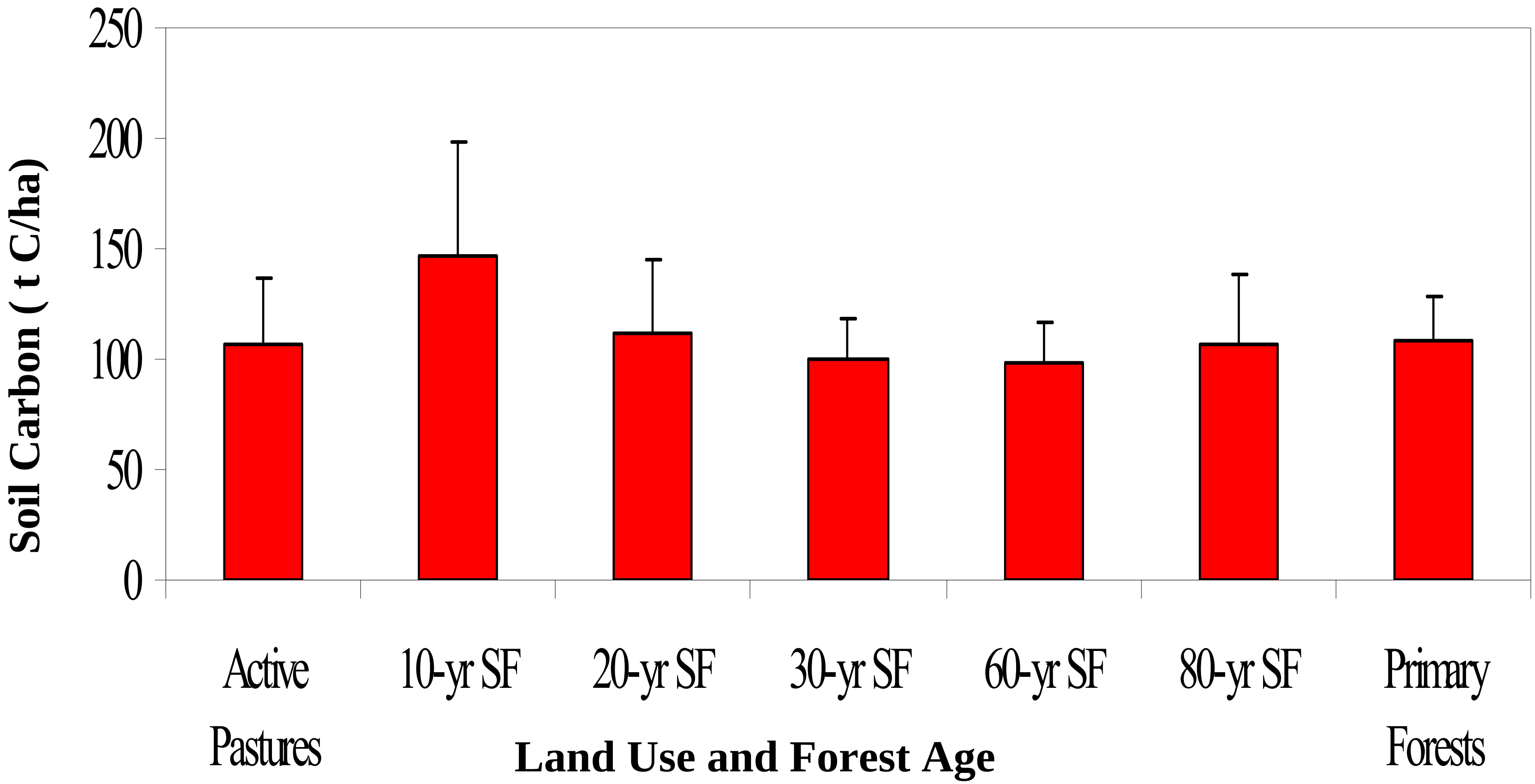
# Soil carbon stocks (1 m) do not change.

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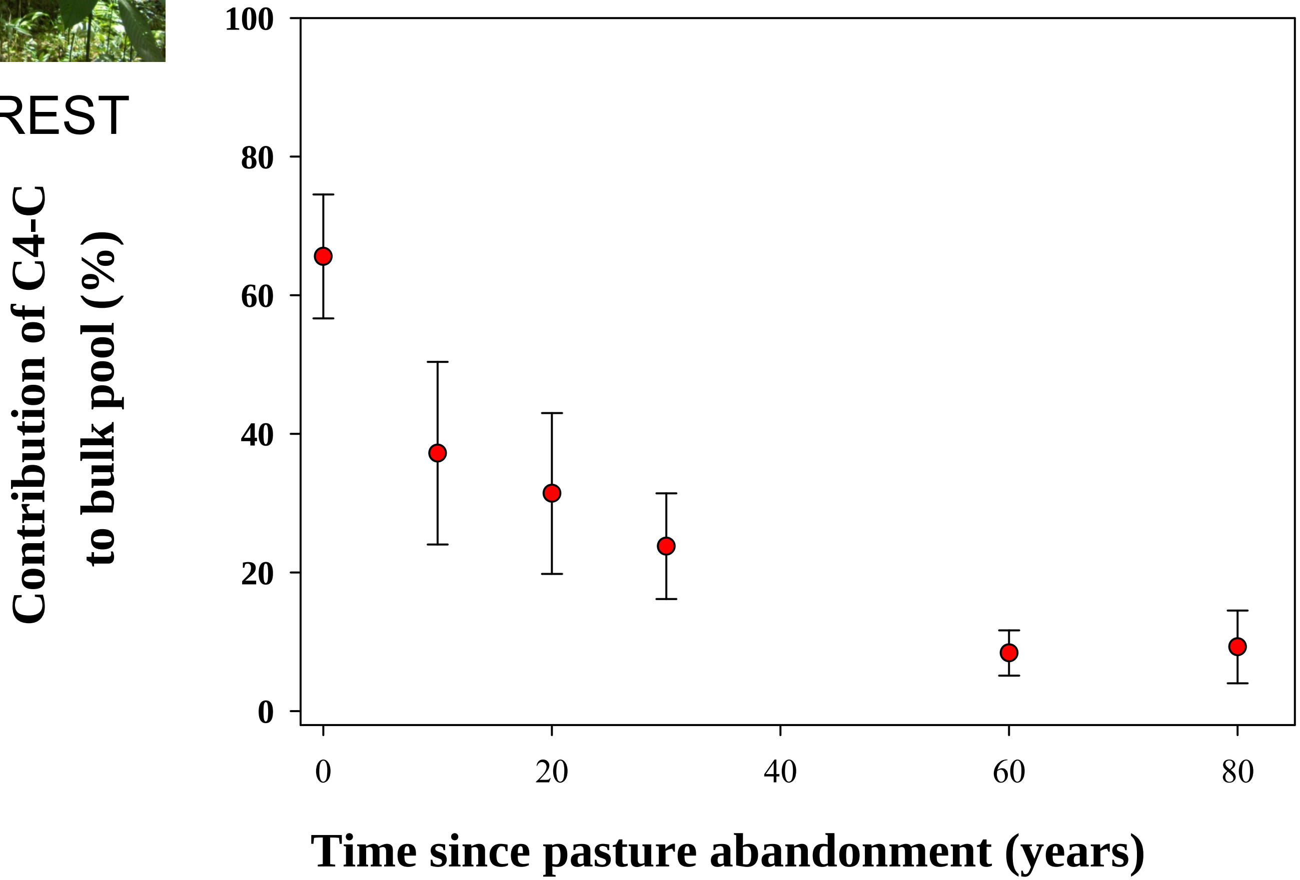
Marín-Spiotta et al. 2009. *Global Change Biology*.

# New forest C compensated by loss old pasture C.

FOREST

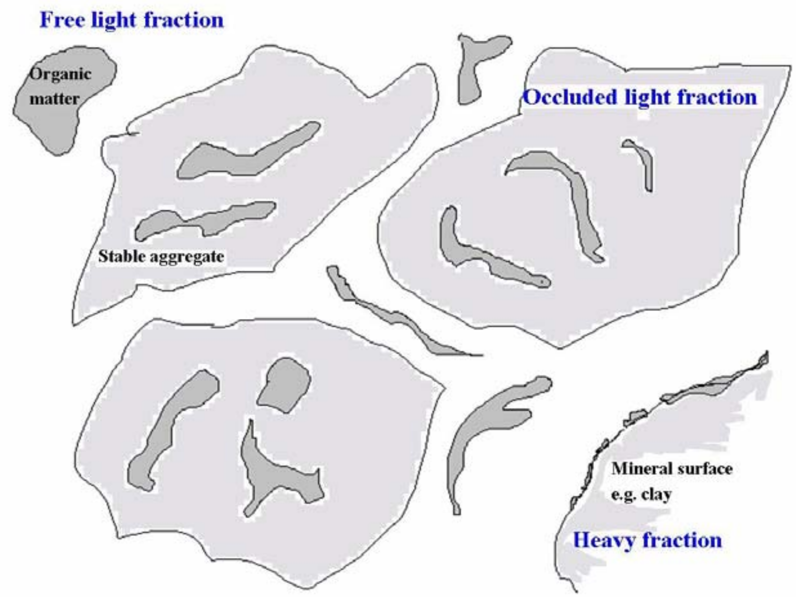
PASTURE




Marín-Spiotta et al. 2009. *Global Change Biology*.

# Soil C fractions have different residence times.

- Longer mean residence time of physically protected C in disturbed soils
  - Active pastures ~ 100 yr
  - 10-yr secondary forests ~ 90 yr
  - Other forests ~ 60 yr




Marín-Spiotta et al. 2008. *Geoderma*

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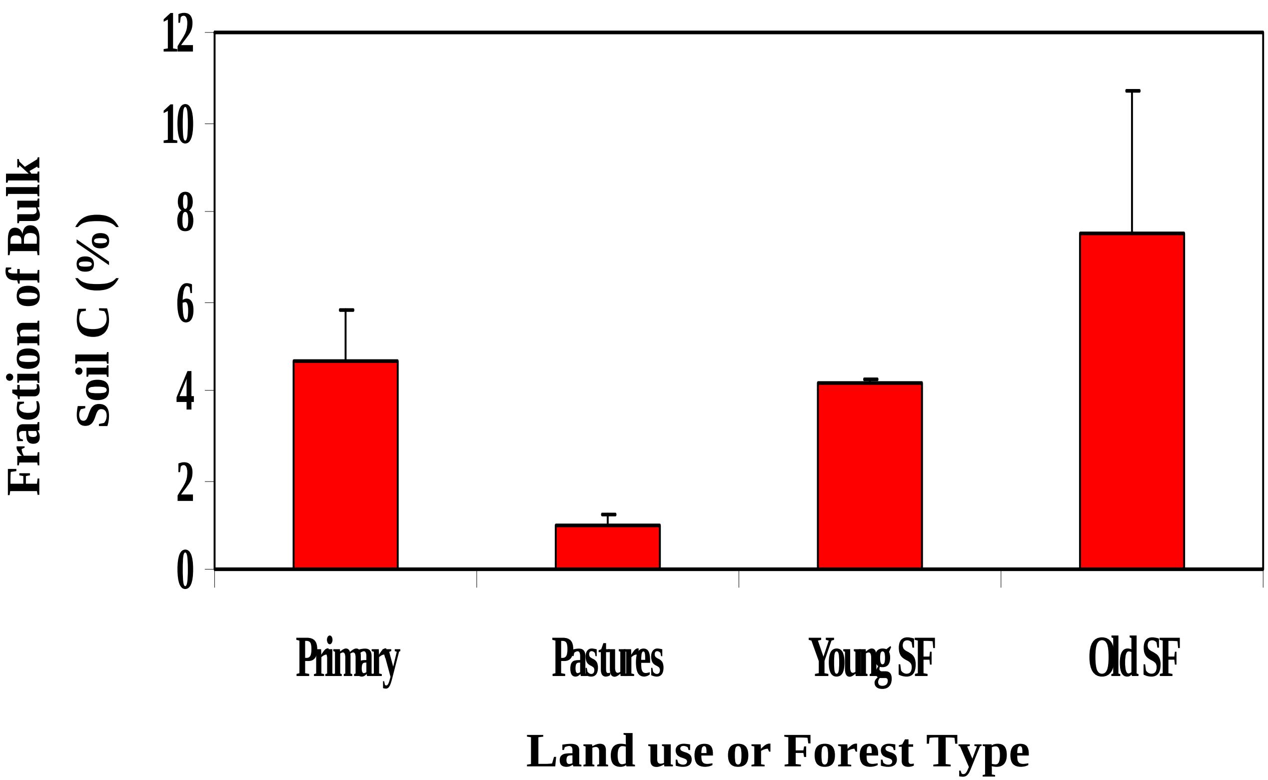
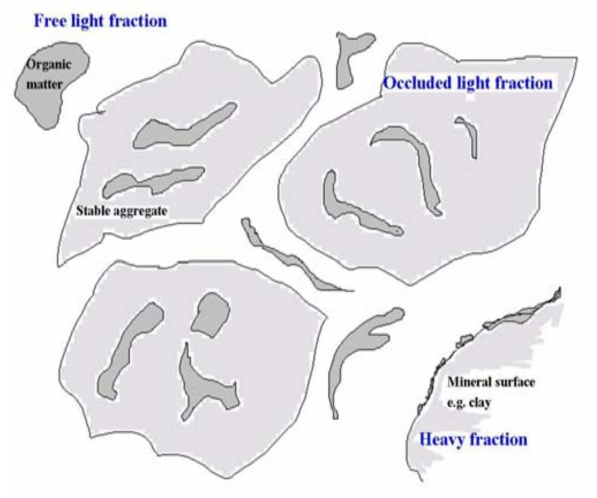
# Soil C fractions differ in their sensitivity.

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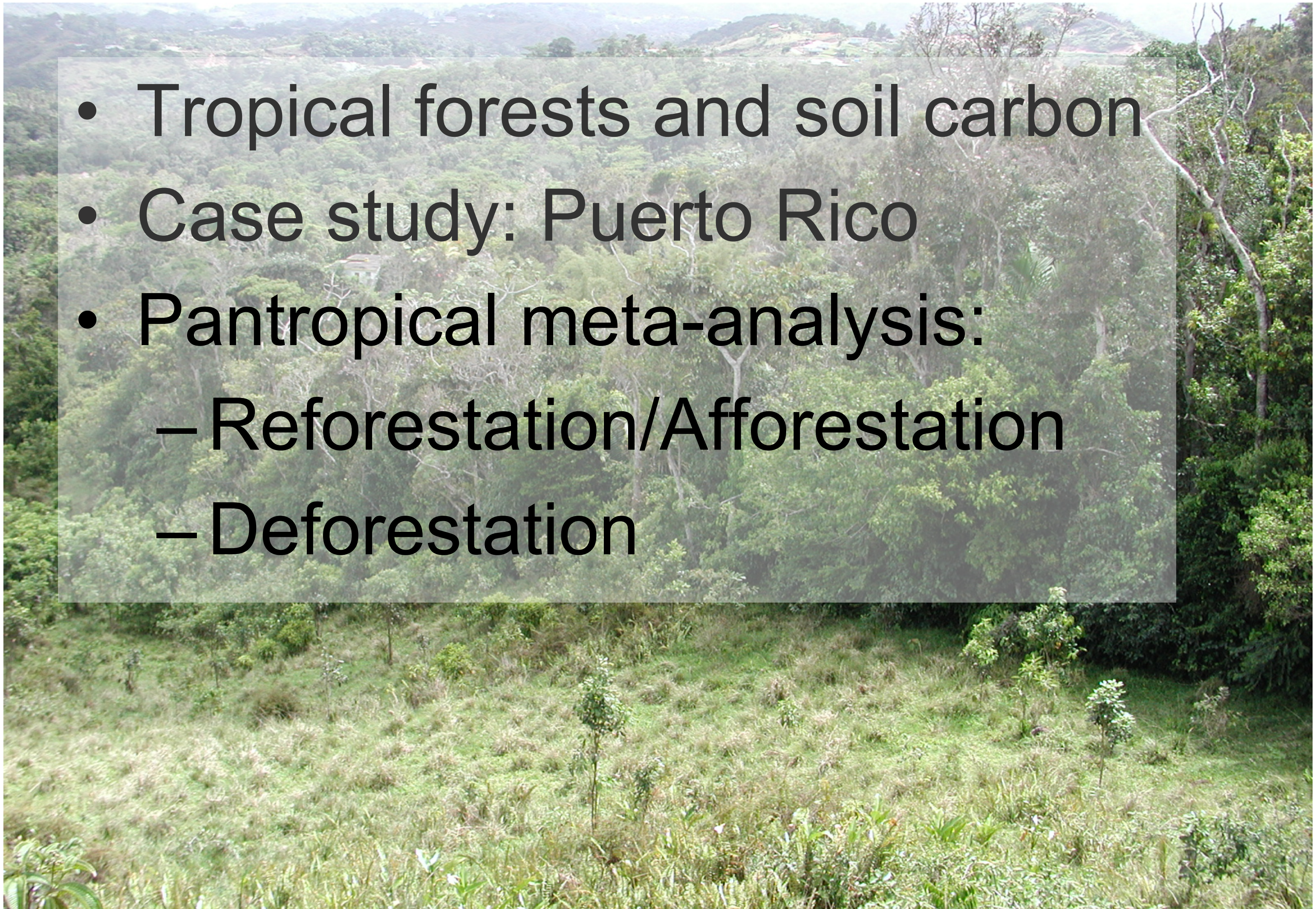
Marín-Spiotta et al. 2009. *Global Change Biology*.

# Today's talk



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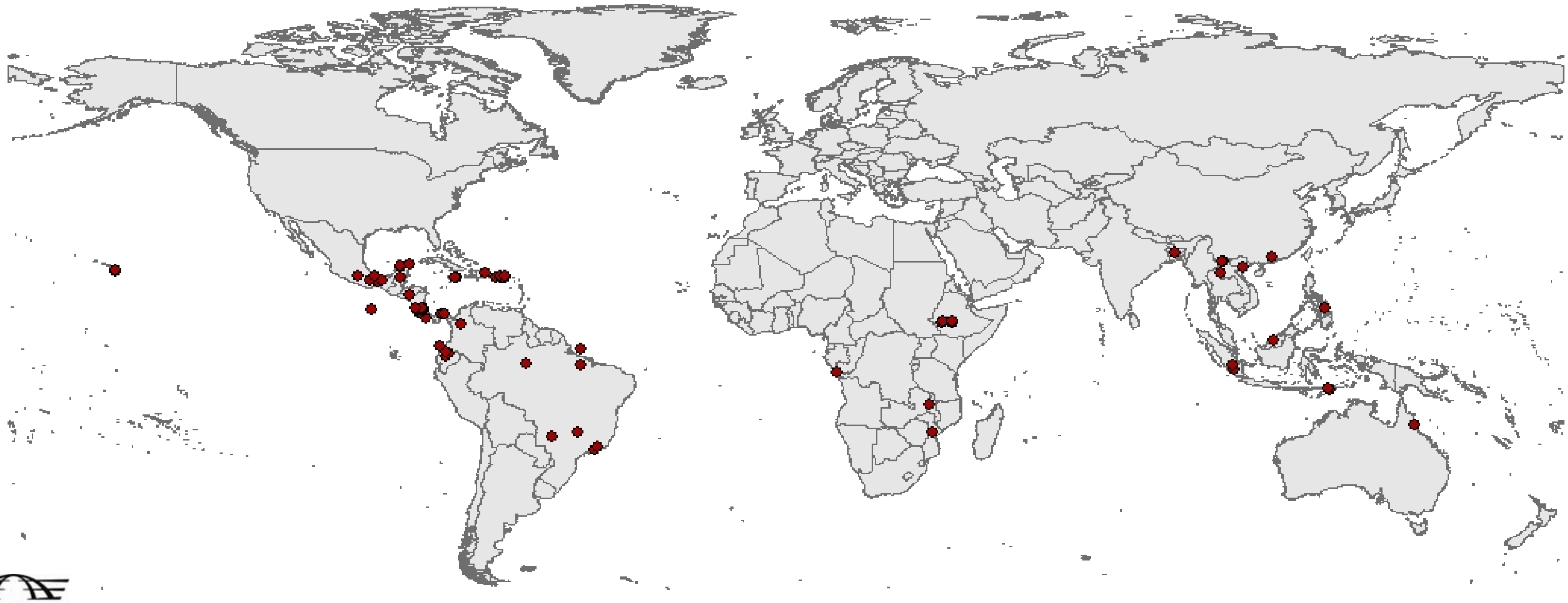
# Meta-analysis: Pantropical Affo/Reforestation

- Soil C stocks (MgC/ha) from **439** plots from **71** chronosequence and paired-site studies in **27** countries, representing **10** USDA soil orders



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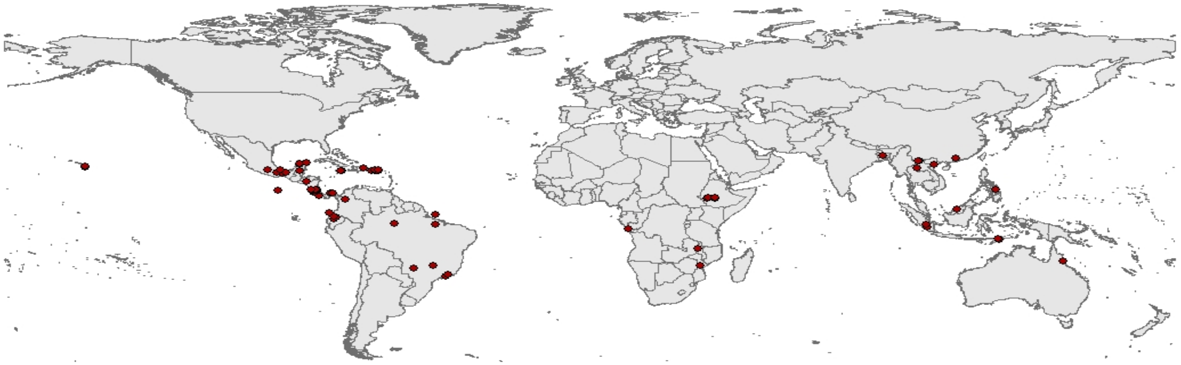
# Meta-analysis: Pantropical Reforestation

- Data biased towards young sites: mean and median age was **20.0 ± 0.6** and **16 years**.
- Shallow depths
- Mean **soil C stock** to 30 cm was **77.9 ± 2.1 MgC/ha**.



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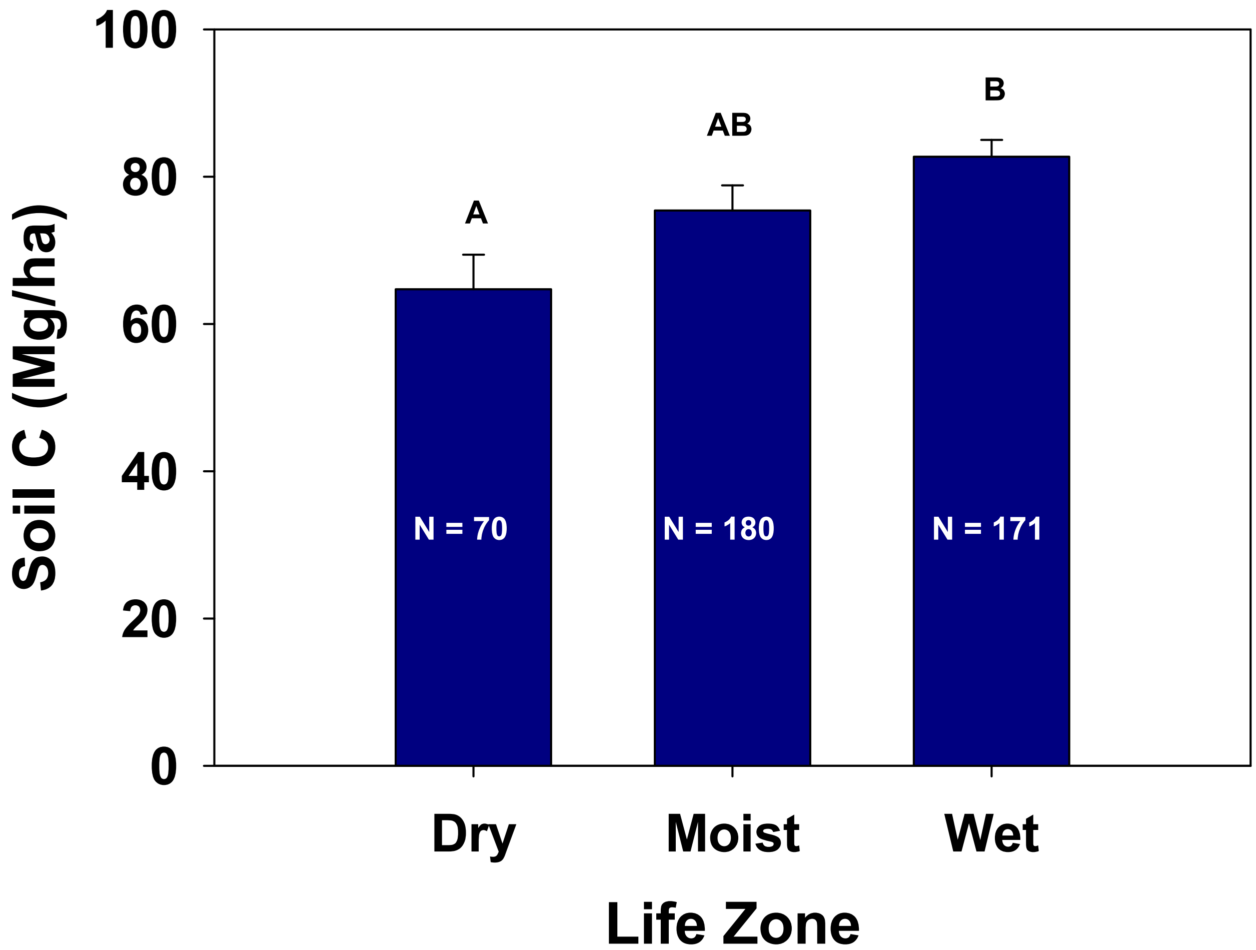
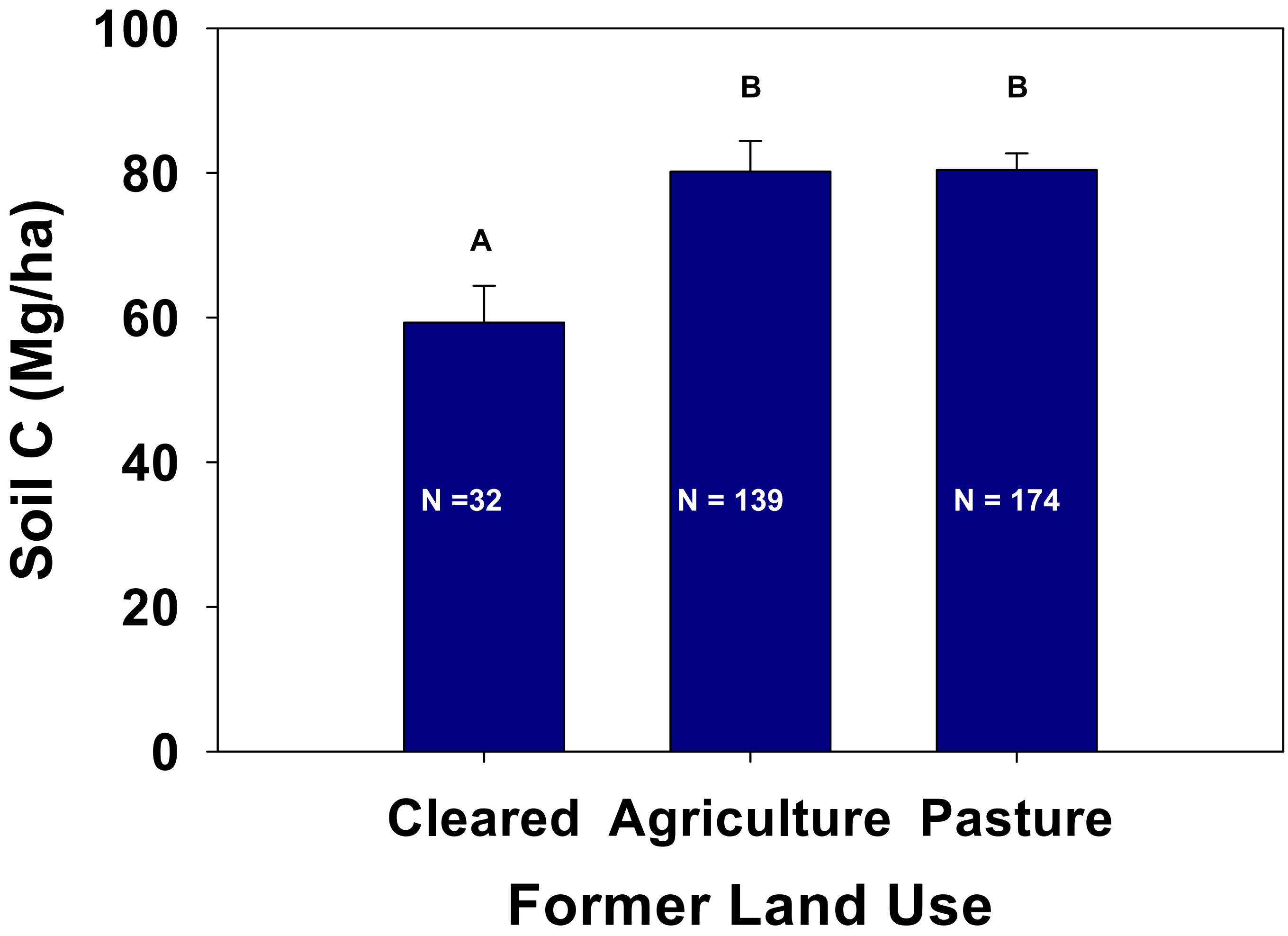
# Dry forests averaged lower soil C than wet forests.

- Dry forests (MAP < 1000 mm) underrepresented.



# Former pastures and crops had same soil C.

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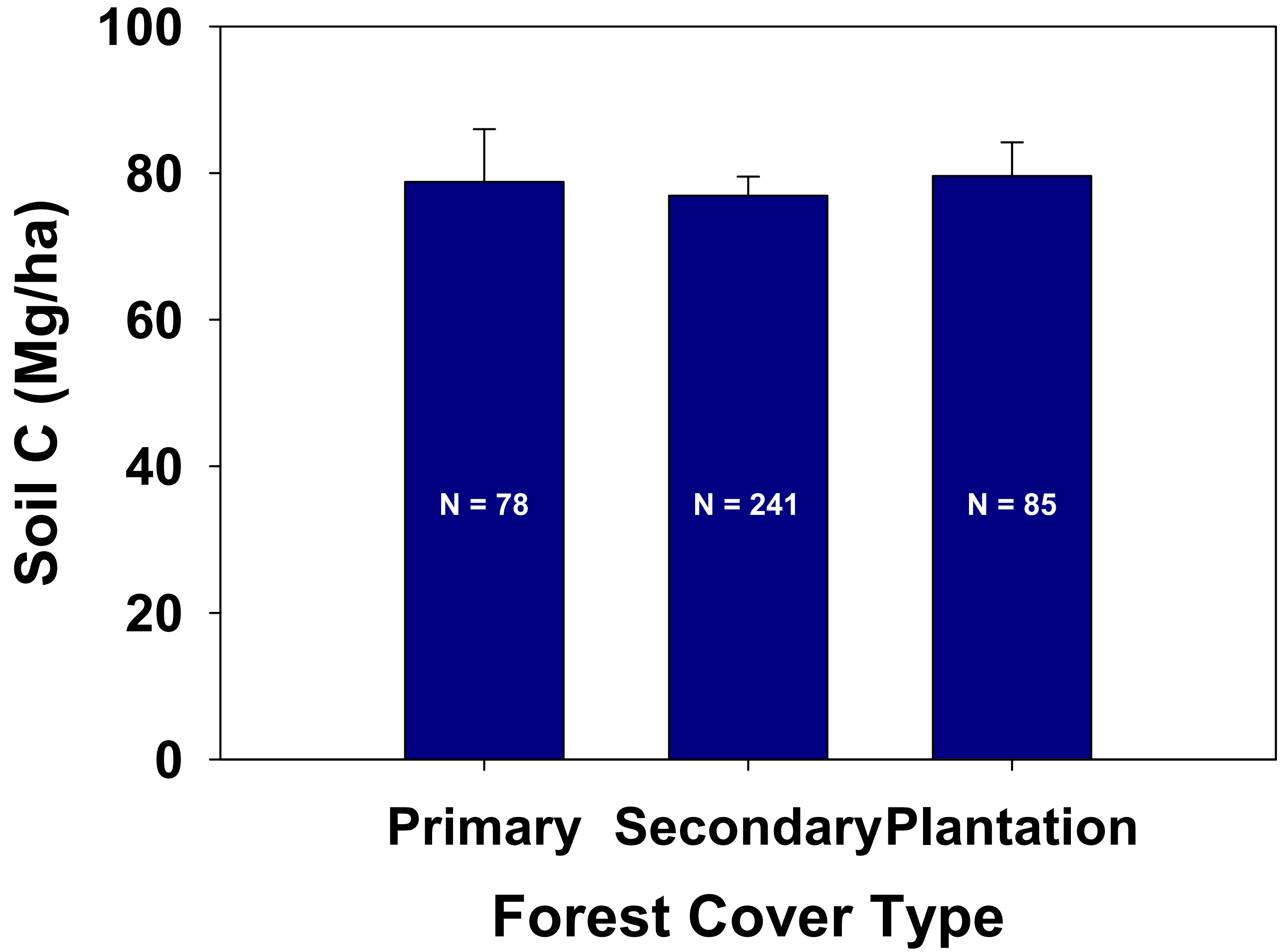
# No difference among current forest cover type.

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# Forest age is not a good predictor of soil C.

Best fit regression equations for soil carbon (Mg/ha) (in the top 30 cm) with time following tropical reforestation.

| *Parameter* | *Equation* | r2 | n |
|---|---|---|---|
| All ages | | | |
| All data | SOIL C = 47.3 + 11.2*(ln AGE) | 0.05 | 371 |
| Life zone | | | |
| Dry forests | n.s. | | 44 |
| Moist forests | SOIL C = 27.1 + 17.4*(ln AGE) | 0.12 | 147 |
| Wet forests | n.s. | | 155 |
| Past land use | | | |
| Agriculture | SOIL C = 30.0 + 18.5*(ln AGE) | 0.08 | 139 |
| Pasture | n.s. | | 174 |
| Cleared | n.s. | | 32 |
| Cover type | | | |
| Plantations | n.s. | | 85 |
| Secondary forests | SOIL C = 47.7 + 10.5*(ln AGE) | 0.04 | 241 |

*Note* : n.s., not significant

All p-values < 0.01

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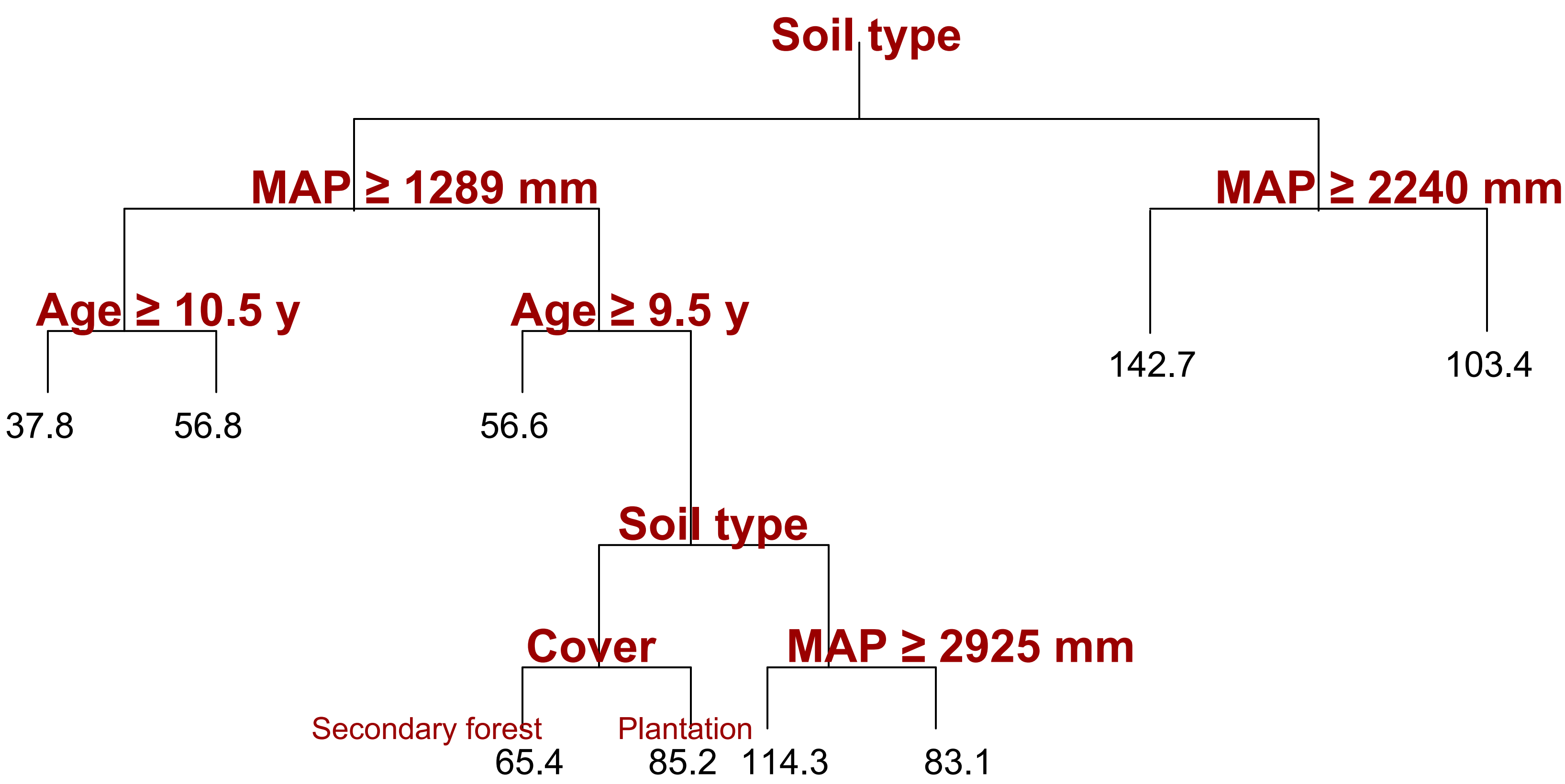
# Soil type & rainfall had greatest effects on soil C.



# Site-specific factors matter

- Fate of soil C during affo/reforestation depends on:
  - Soil type (Andisols vs Inceptisols: López-Ulloa et al. 2002)
  - Depth and stage of succession (Bautista-Cruz and del Castillo 2005)
  - Intensity former land use (de Koning et al. 2003)
  - Species planted

| Species type | Soil C | |
|---|---|---|
| *Eucalyptus* | - | Lemenih et al. 2004, Bagali et al. 1993 |
| Pine | - | Farley et al. 2004, Kirschbaum et al. 2008 |
| Nitrogen-fixers | + | Lemenih et al. 2004, Resh et al. 2002 |
| *Cupressus* | + | Lemma et al. 2006 |
| Hardwoods | + | Paul et al. 2002 |

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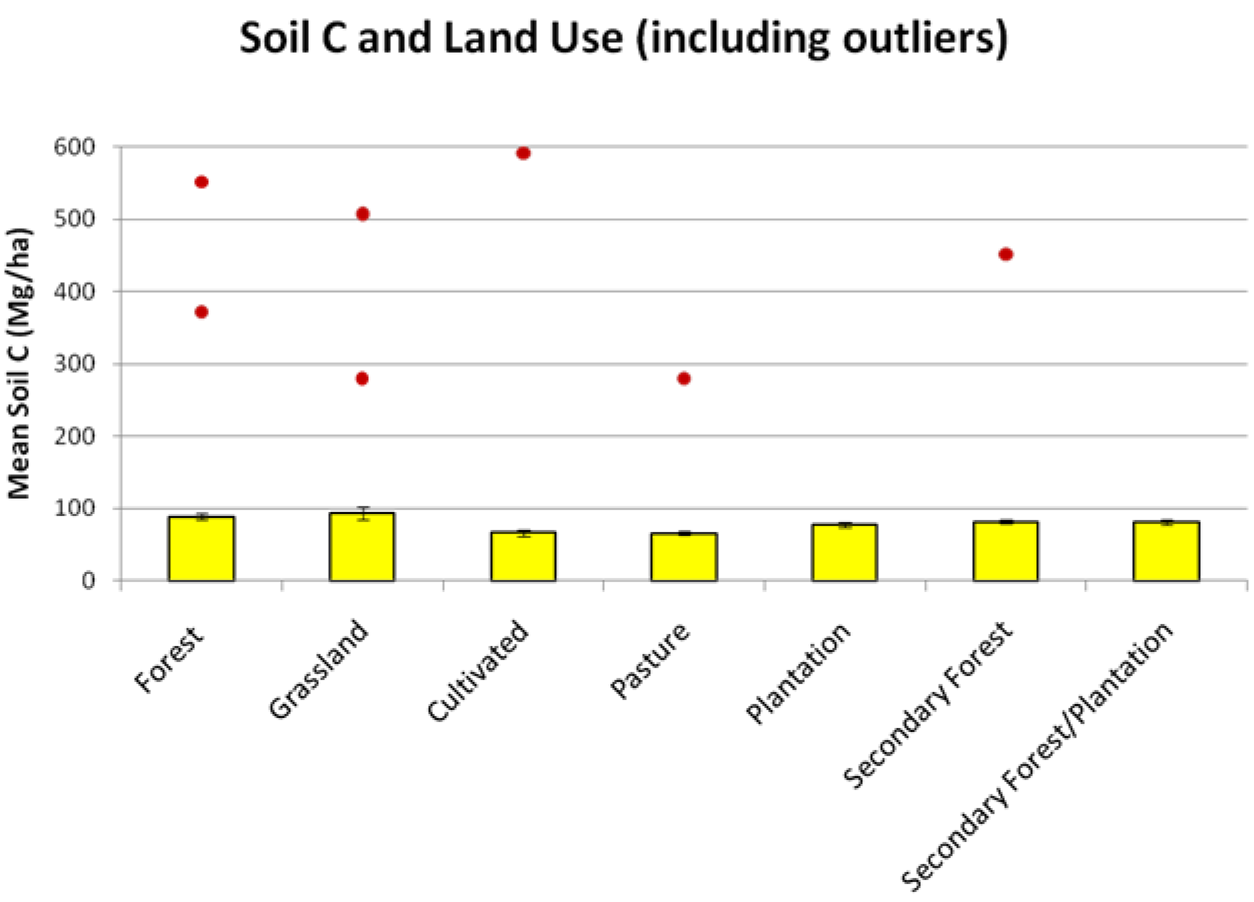
# Soil type matters.

- Outliers: Histosols (organic soils, peatlands)



# Limitations of Available Data

- Under-representation sites in drier climates
- Shallow depths (20 cm)
- Unknown heterogeneity
- Soil C concentration (%) vs content (Mg/ha); need to measure bulk density!
- Bias towards young ≤ 20 years : long-term trends?
- Little mechanistic understanding soil C incorporated into affo/reforestation studies
- Unknown land use and management history



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# Lessons from case studies

- Importance of physical protection mechanisms
- Site-specific factors matter
- Small-scale, low intensity land use
- How can we best select sites for C sequestration?
- How can we best manage our agricultural and grazing lands to conserve soil organic matter reserves?

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# Carbon storage: an end or a means to an end?

- Global warming
- Biodiversity and human livelihoods
- Plantations versus secondary forests
- Forest value

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