Linking geomorphology, weathering and soil cations in the Luquillo Mountains of Puerto Rico

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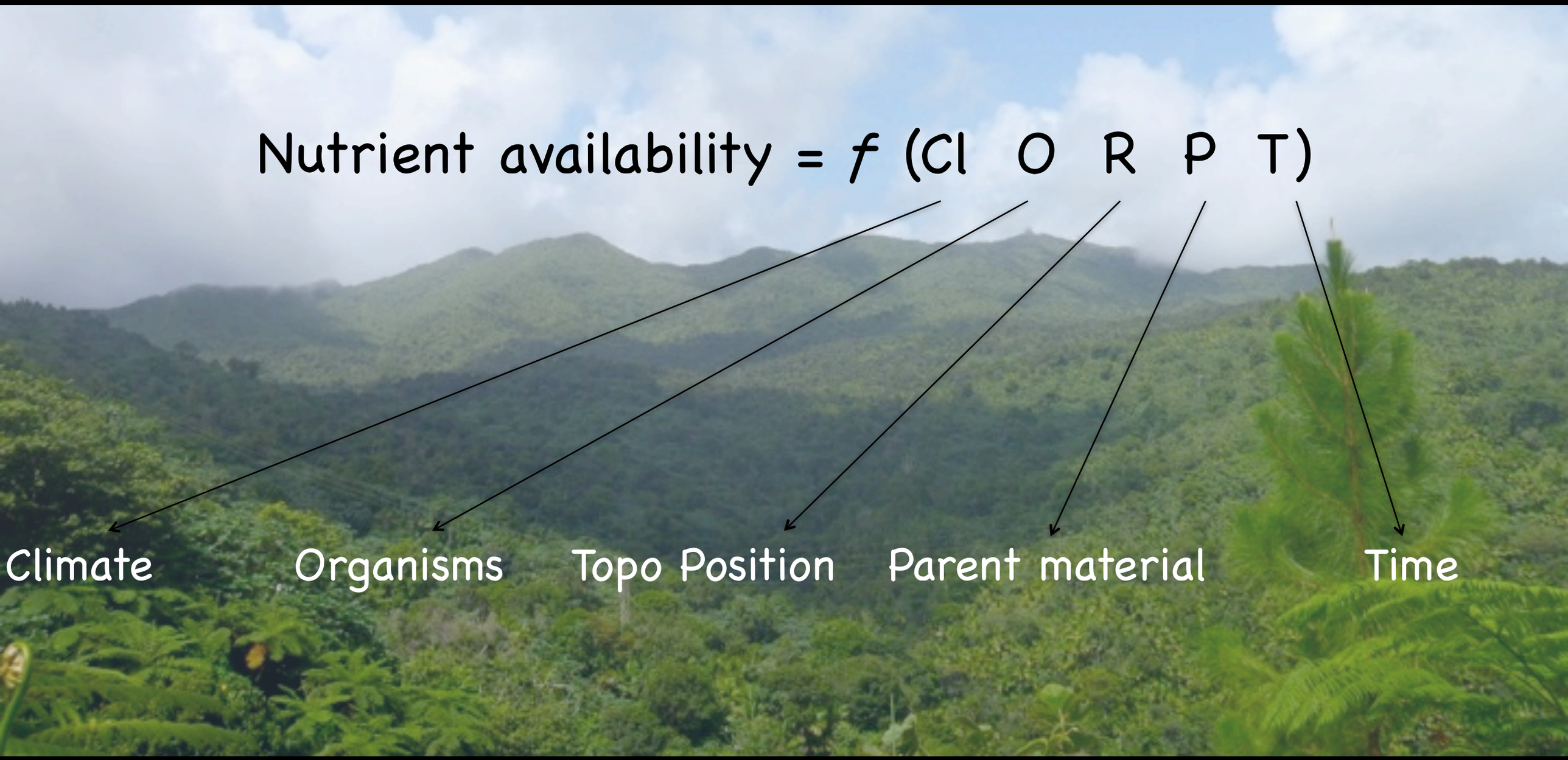
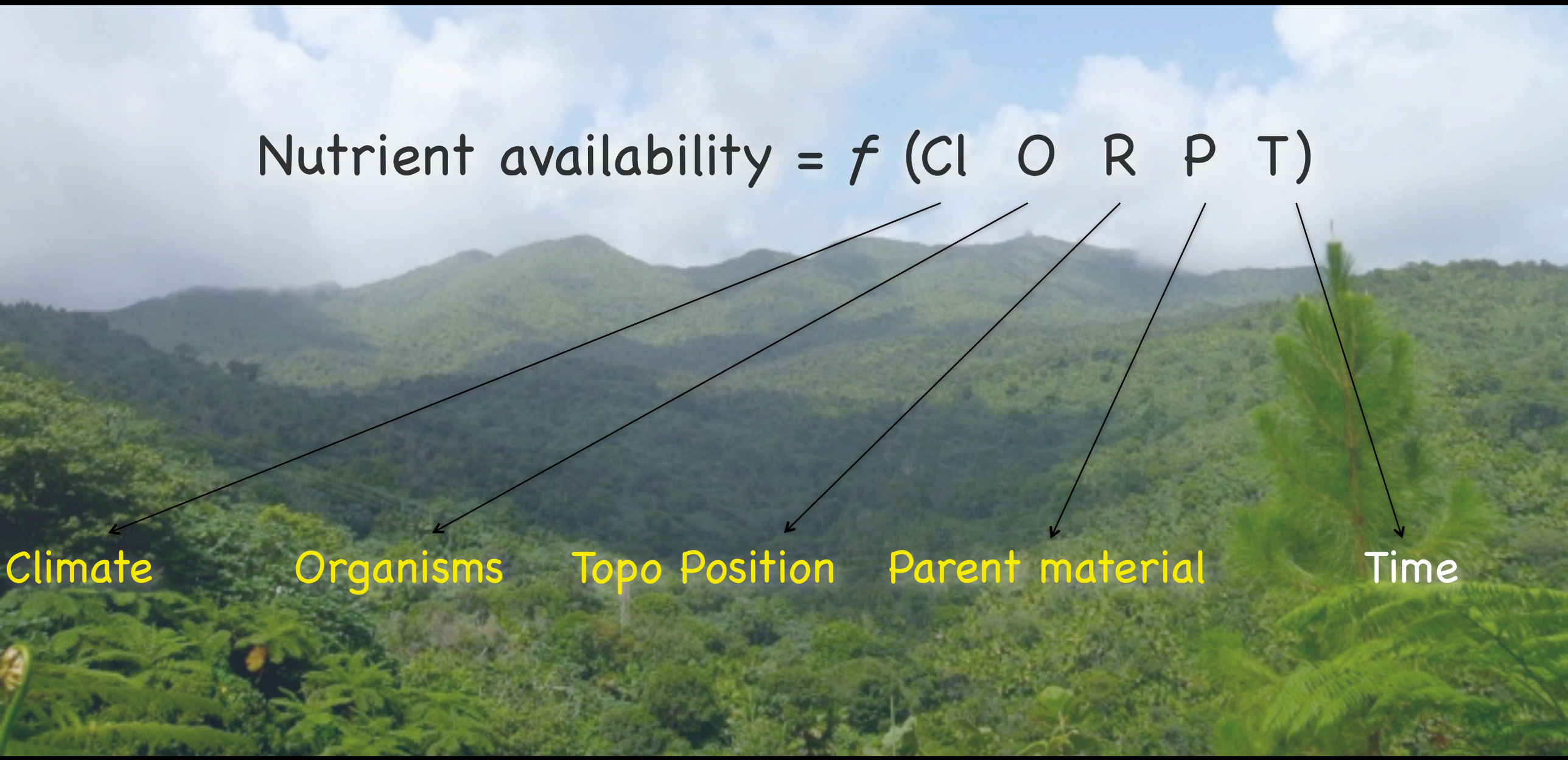
What controls nutrient availability in tropical forests?



Almost always, the approach has been to isolate the effects of one by minimizing variation in the others.

What controls nutrient availability in the tropical forests of the Luquillo Mountains?



We investigated the relative importance of several state factors at once.

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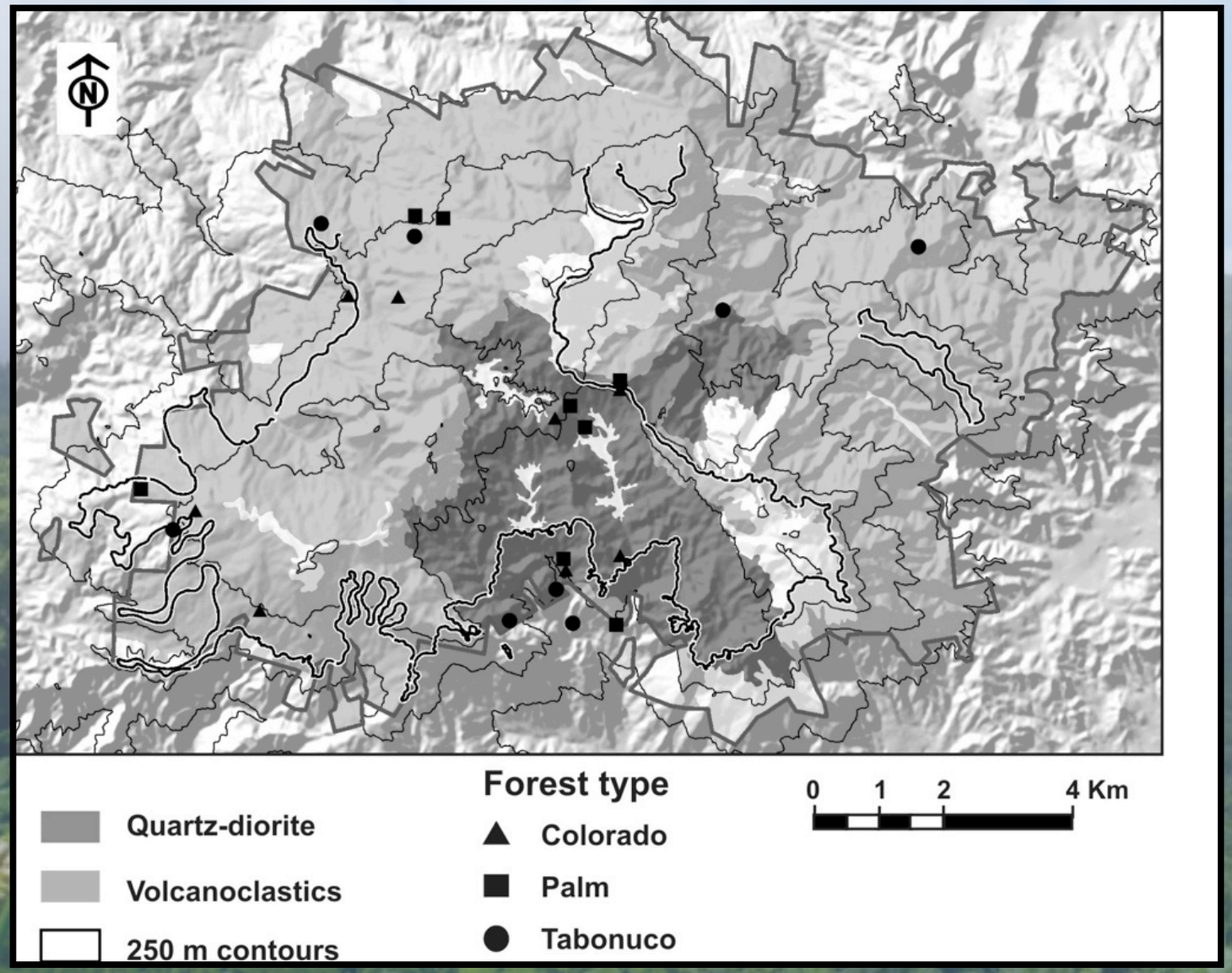


24 Sub-watersheds

- 2 Parent Materials: quartz diorite (QD) and volcaniclastic (VC) (N=8)

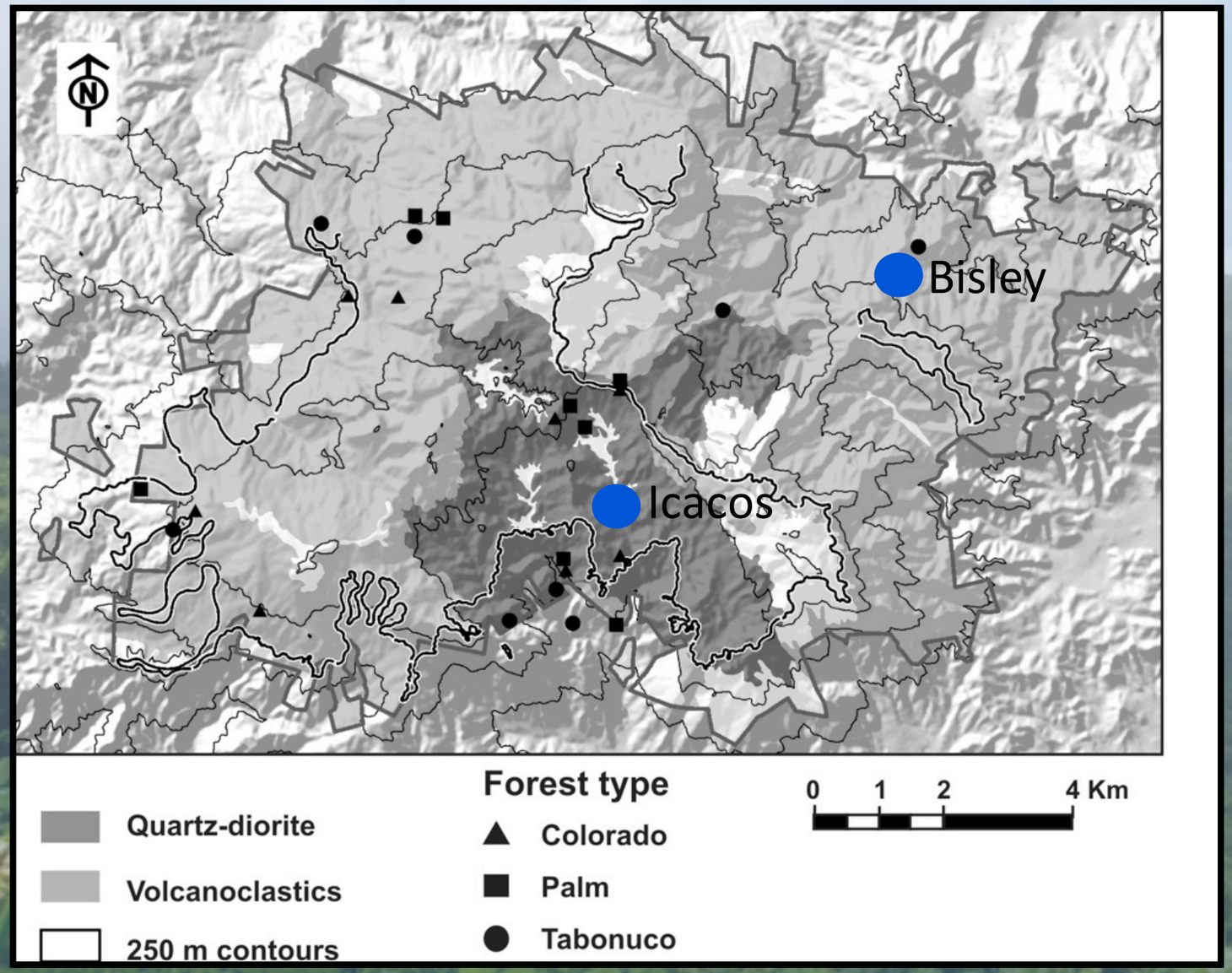
- Three Forest Types : Colorado, Tabonuco, Palm (N = 8)
- Elevation 300-800 m
- 4 of each forest type at 500-700m

- In each sub-watershed - 3 soil pits per ridge, slope and valley positions.

- 216 Soil Pits (3 depths/pit)

Sampling Design

What controls nutrient availability in the tropical forests of the Luquillo Mountains?



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Carbon stocks: Forest Type (even controlled for elevation)

Soil C:N: Elevation (high elevation->higher C:N)

Soil $\delta^{15}N$ - Elevation (lower $\delta^{15}N$ at high elevation)

Labile P - Topographic position (higher down slope)

Total P - Rock type (higher on VC)

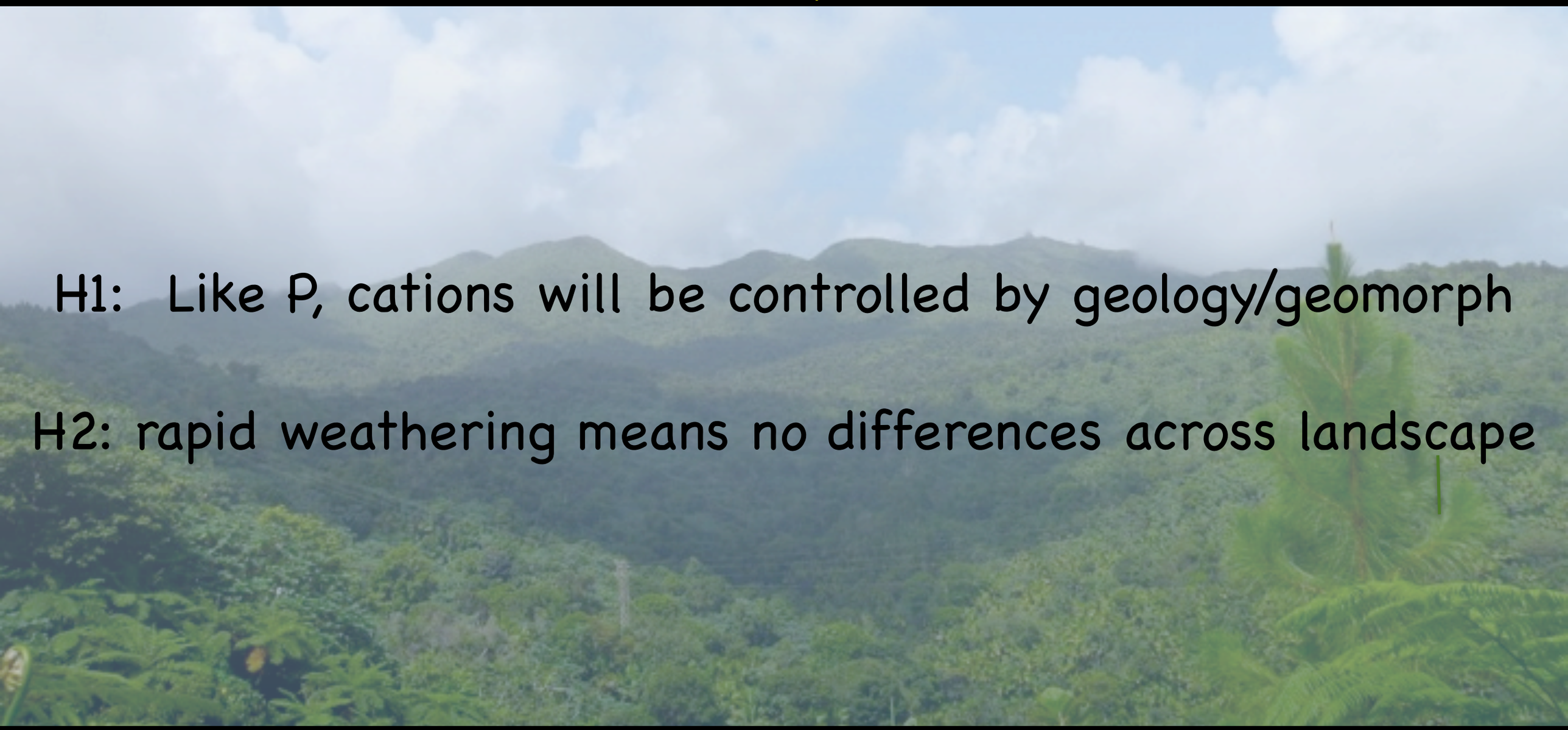
Topo position (higher downslope)

Mage and Porder, 2013, Johnson et al, in prep

C, N are driven by community/climate.

P by geology and geomorpology

What controls soil cation stocks and loss in the tropical forests of the Luquillo Mountains?



A great deal has been done on deep weathering and streams, but little work has been done on cations in soils

What controls soil cation stocks and loss in the tropical forests of the Luquillo Mountains?

Weathering is rapid on QD (White et al, 1995, Brown et al, 1885).

Most weathering on QD occurs at rock/saprolite interface (White 1995, Buss 2013) or around corestones (Fletcher + Brantley, 2010)

Regolith formation 30x faster on VC (Dosseto et 2012)

Solute fluxes from VC watersheds not 30x higher (Stallard, 2012)

Most of the landscape is not in equilibrium (Stallard, 2012)

Does this matter for the cation status of soils?

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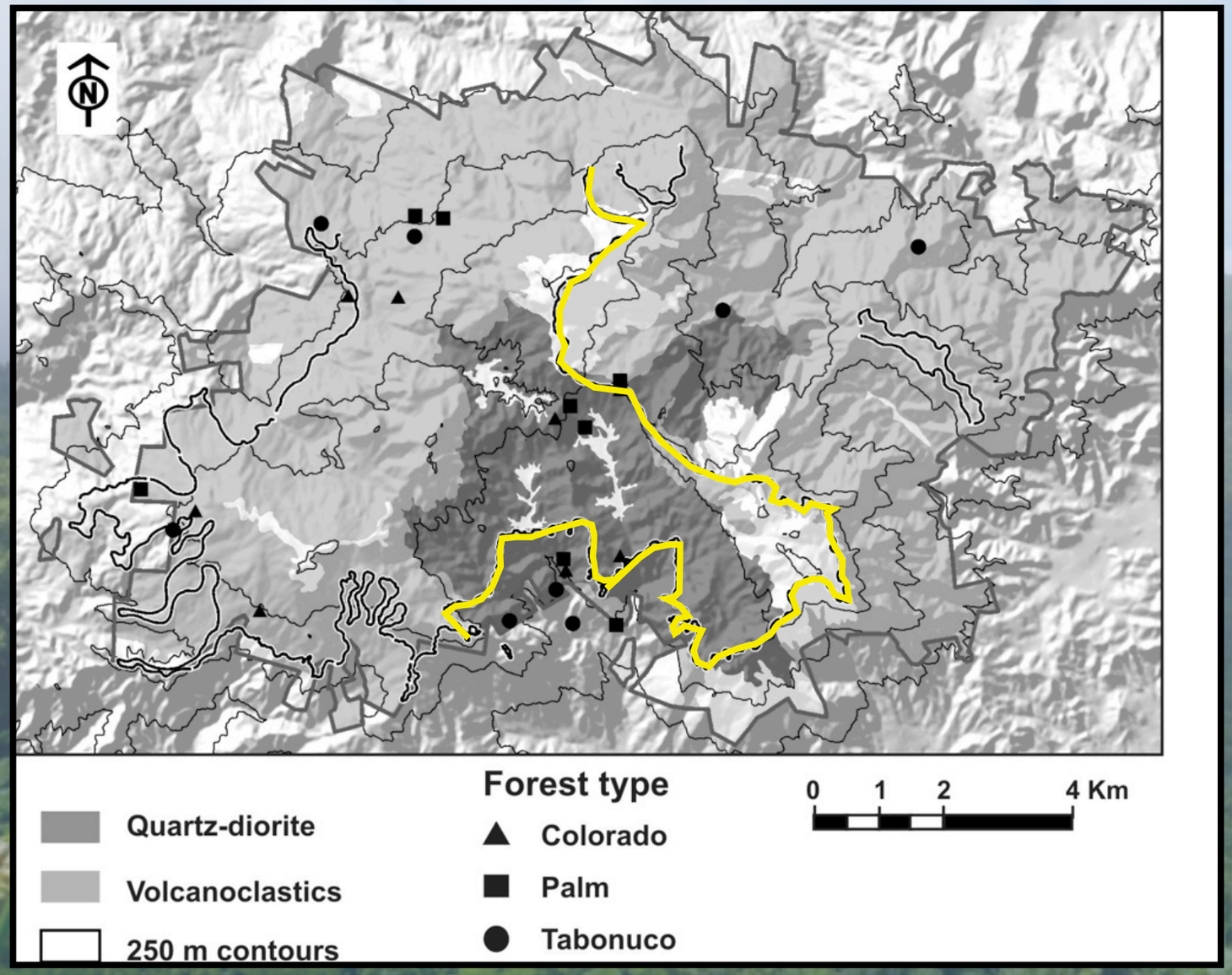

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We missed a key landscape parameter in our sampling design

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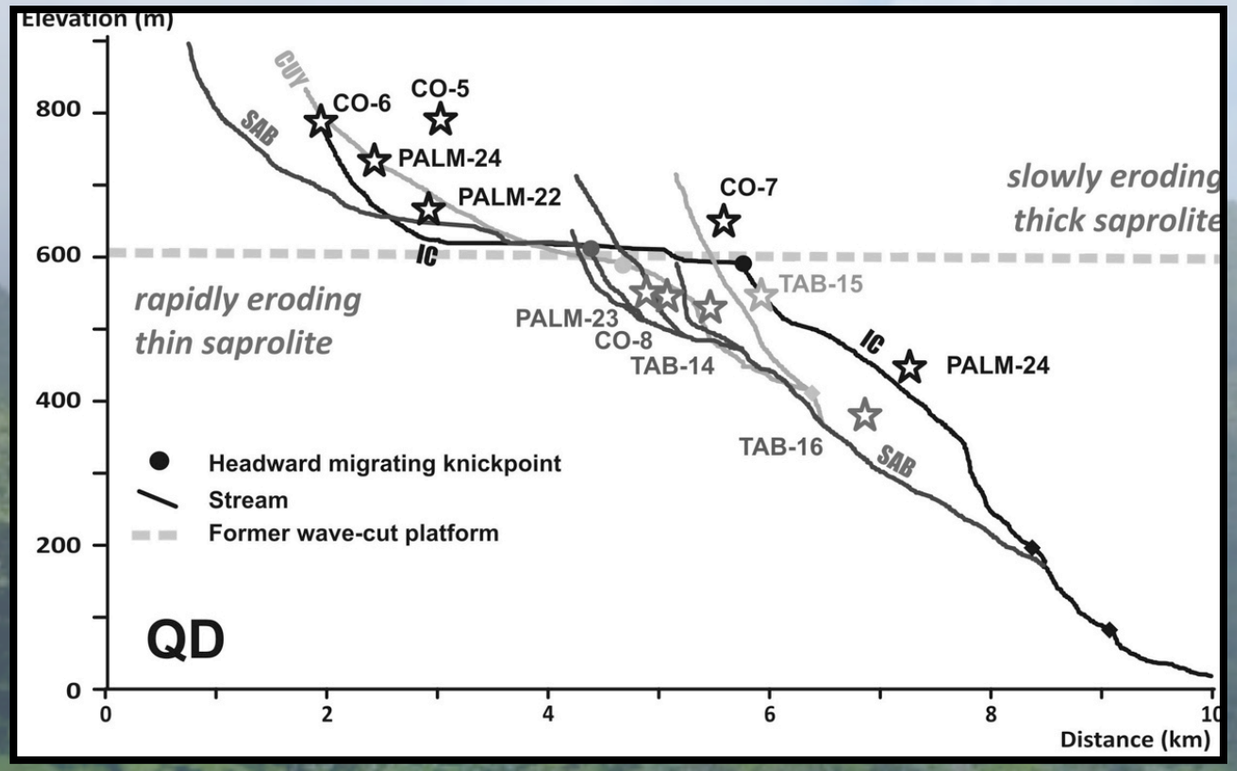

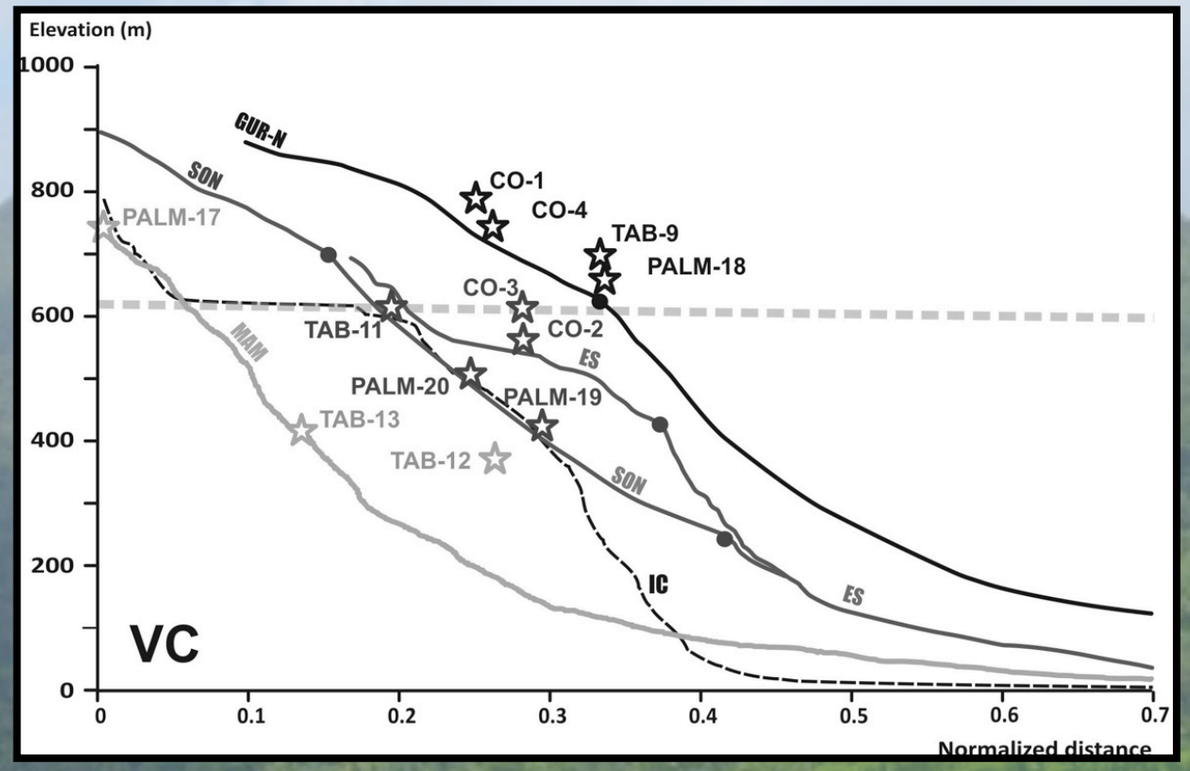

A regional knickpoint drives differences in denudation on QD

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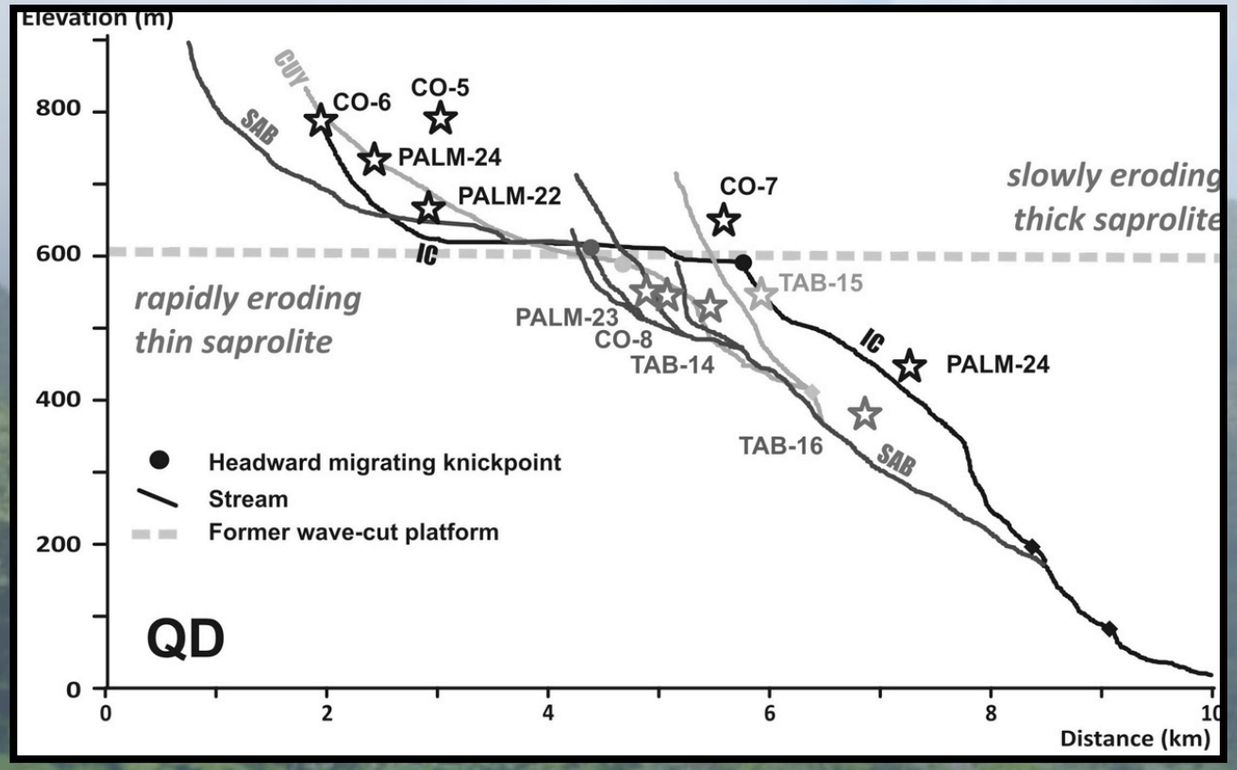

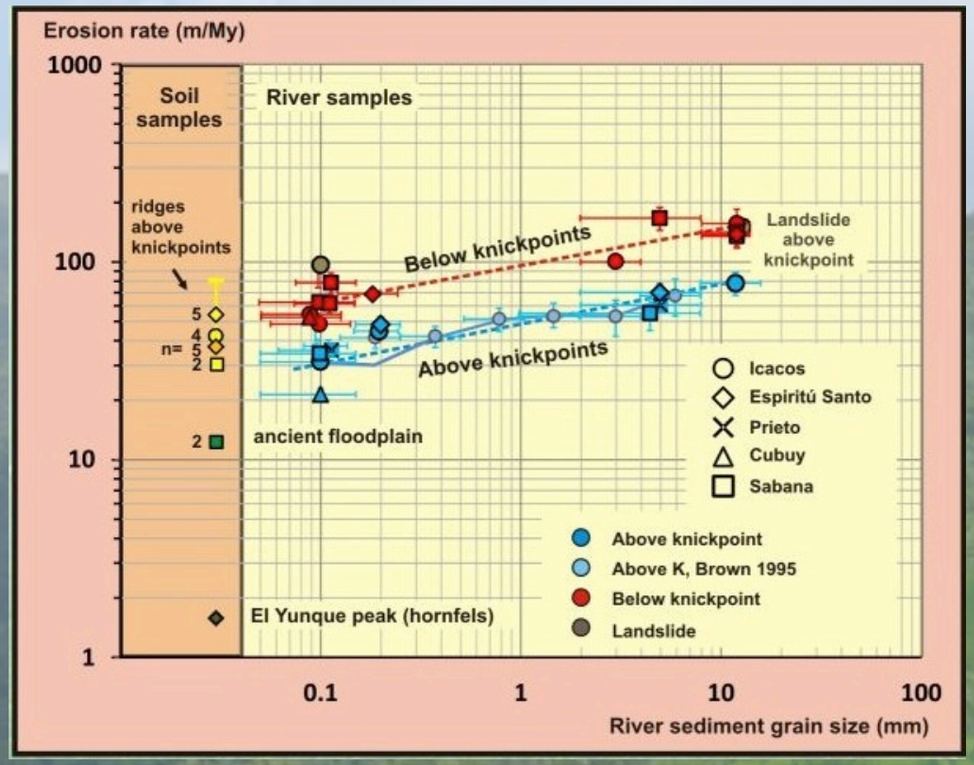

Denudation rates vary by 2-4x across the knickpoint

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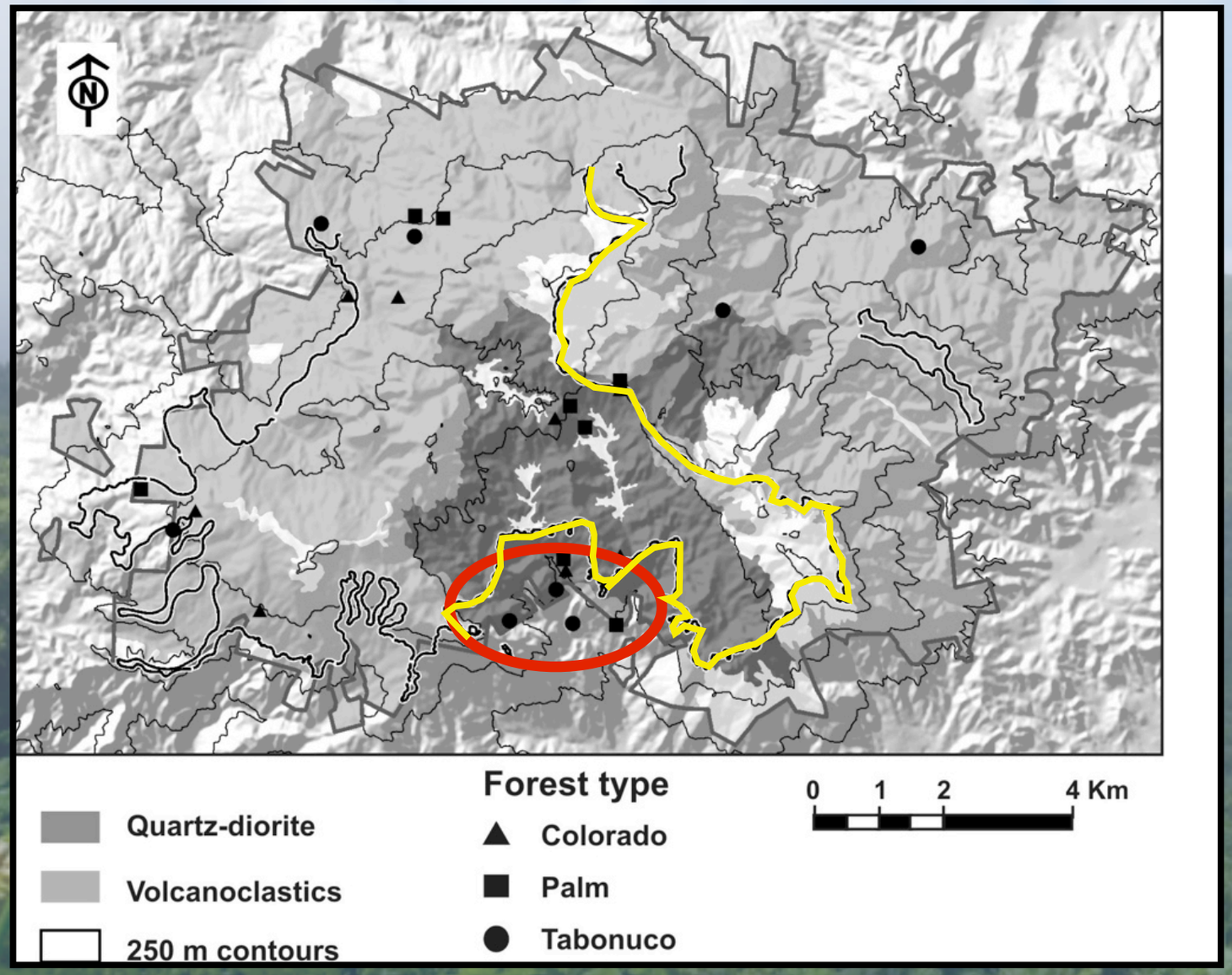

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We only have a few sites below the knickpoint

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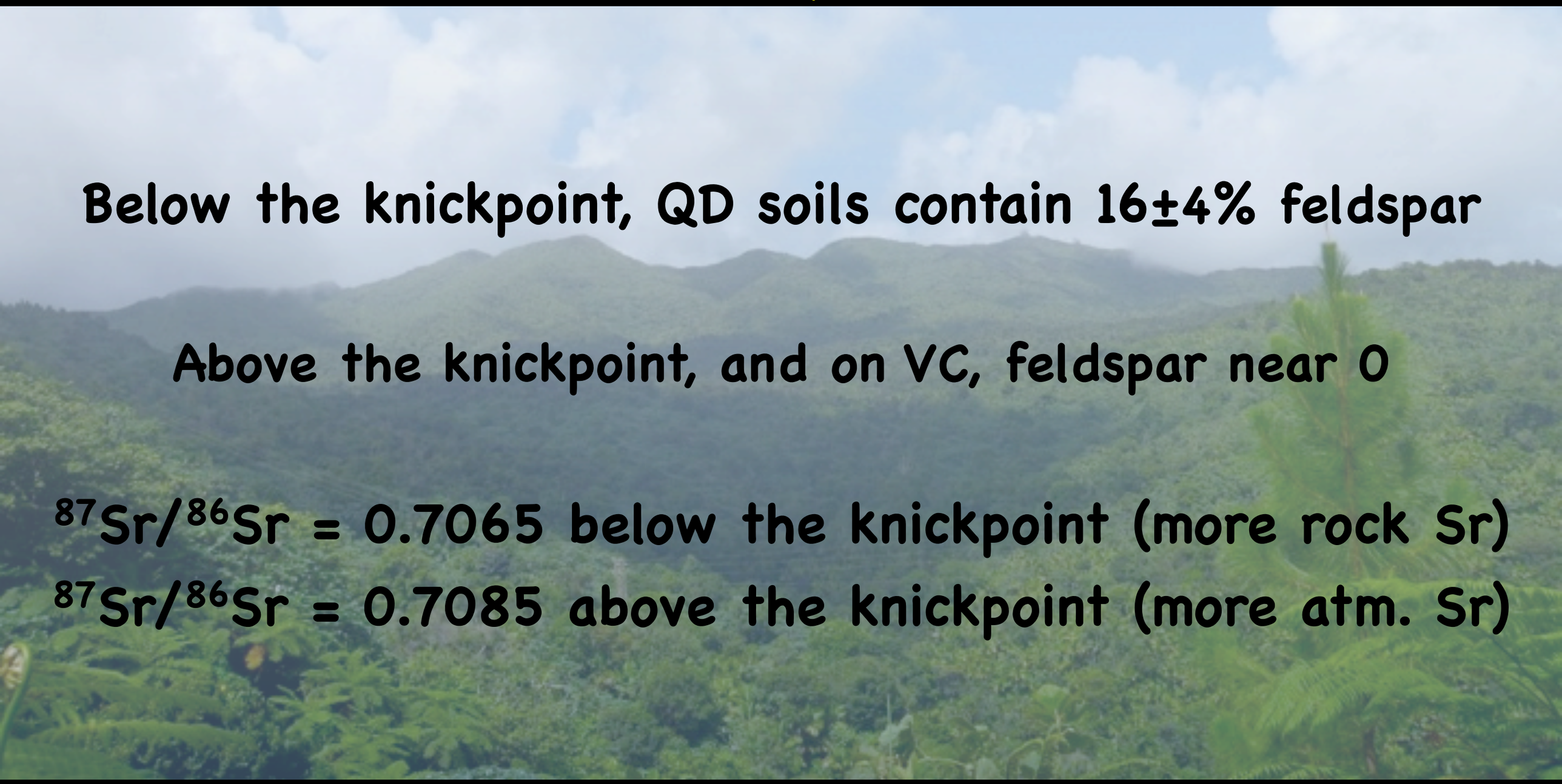


Below the knickpoint, QD soils contain 16±4% feldspar

Above the knickpoint, and on VC, feldspar near 0

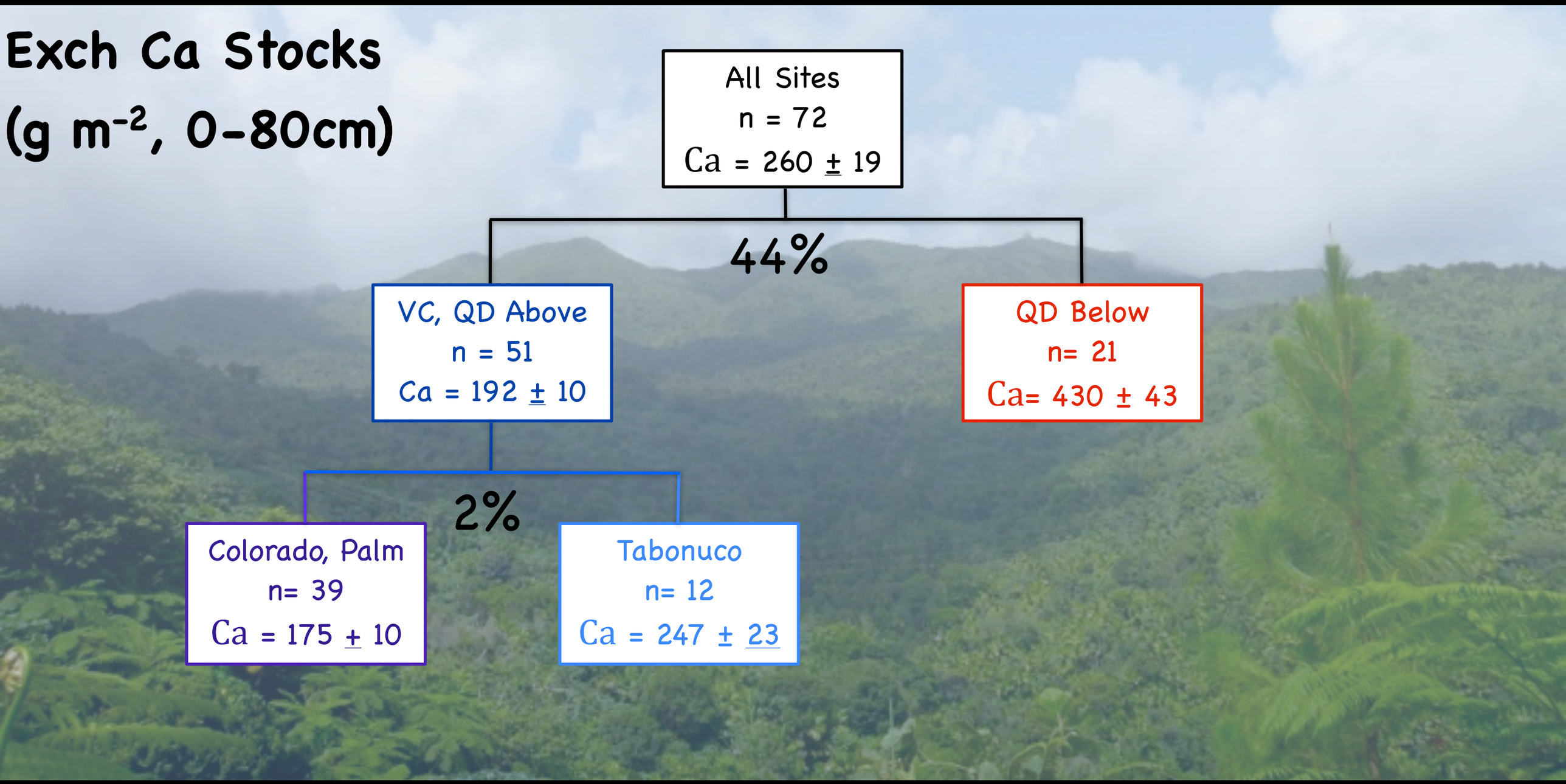
$^{87}Sr/^{86}Sr$ = 0.7065 below the knickpoint (more rock Sr)
$^{87}Sr/^{86}Sr$ = 0.7085 above the knickpoint (more atm. Sr)

Primary minerals are in soils below the knickpoint, not above or on VC

What controls soil **cation stocks** and loss in the tropical forests of the Luquillo Mountains?

Exch Ca Stocks

(g m^{-2}, 0-80cm)

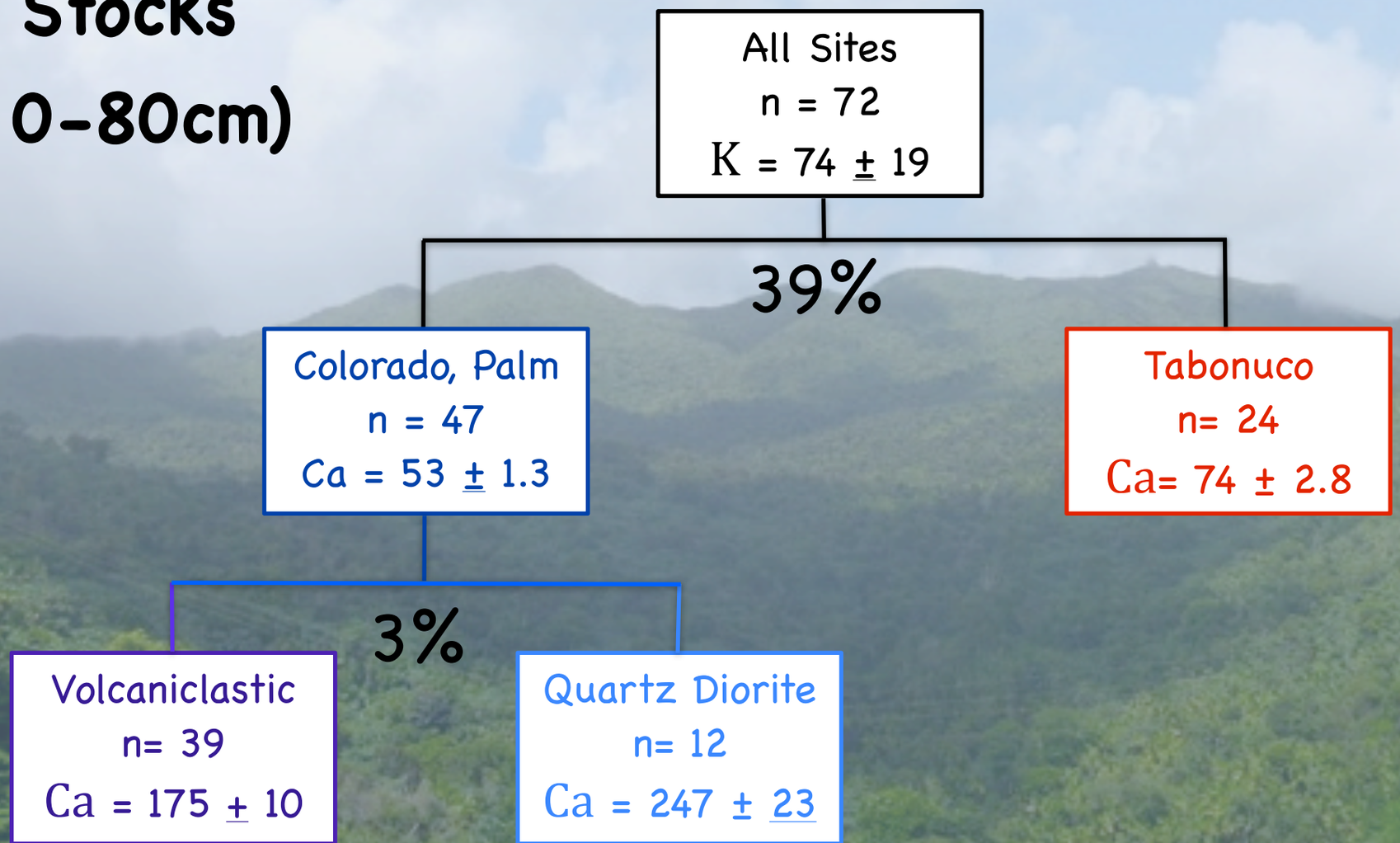


Denudation is the biggest driver of Ca Stocks

What controls soil **cation stocks** and loss in the tropical forests of the Luquillo Mountains?

Exch K Stocks

(g m^{-2}, 0-80cm)



Forest type is the biggest driver of K stocks

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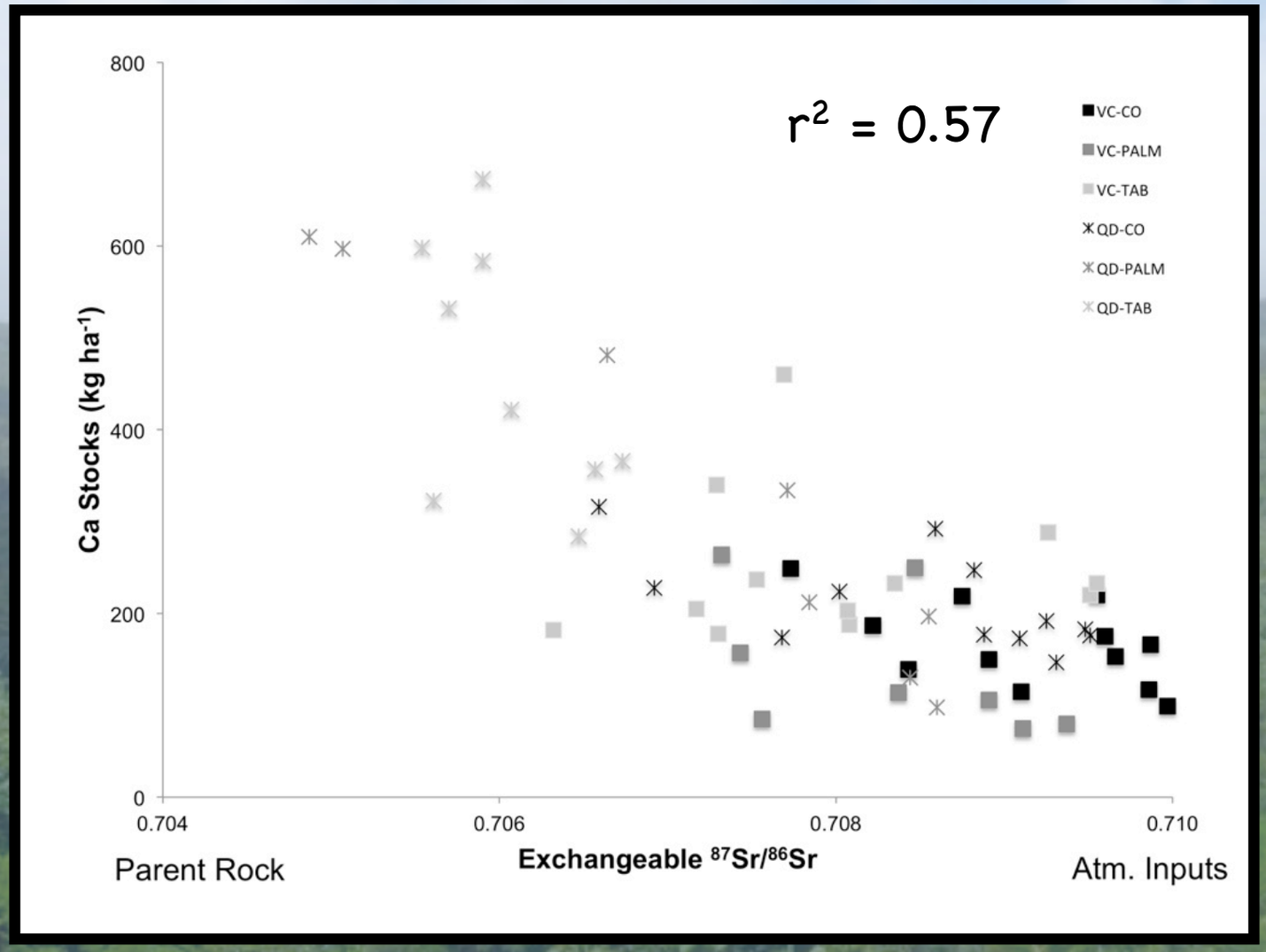

r^2 = 0.32 for K
data not shown

Exch. cation stocks depend on the supply of primary minerals

What controls soil cation stocks and **loss** in the tropical forests of the Luquillo Mountains?

Cation loss relative to parent material (0-80cm)

All Sites
n = 48
$\mathcal{T}_{Ca}, \mathcal{T}_{Mg}, \mathcal{T}_{K}$ = -0.94, -0.86, -0.82
SE = ± 0.12, 0.03, 0.03

33,49,36%

B
VC
n = 27
$\mathcal{T}_{Ca}, \mathcal{T}_{Mg}, \mathcal{T}_{K}$ = -1, -0.97, -0.92
SE = ± 0.00, 0.01, 0.02

QD
n= 21
$\mathcal{T}_{Ca}, \mathcal{T}_{Mg}, \mathcal{T}_{K}$ = -0.86, -0.71, -0.68
SE = ± 0.14, 0.04,

18,10,17%

B
Above Knickpoint
n= 9
$\mathcal{T}_{Ca}, \mathcal{T}_{Mg}, \mathcal{T}_{K}$ = -0.95, -0.81,-0.83
SE = ± 0.02, 0.05, 0.03

A
Below Knickpoint
n= 12
$\mathcal{T}_{Ca}, \mathcal{T}_{Mg}, \mathcal{T}_{K}$ = -0.80, -0.64,-0.56
SE = ± 0.05, 0.06, 0.08

Denudation (and maybe lithology) controls depletion of soil elements relative to parent rock

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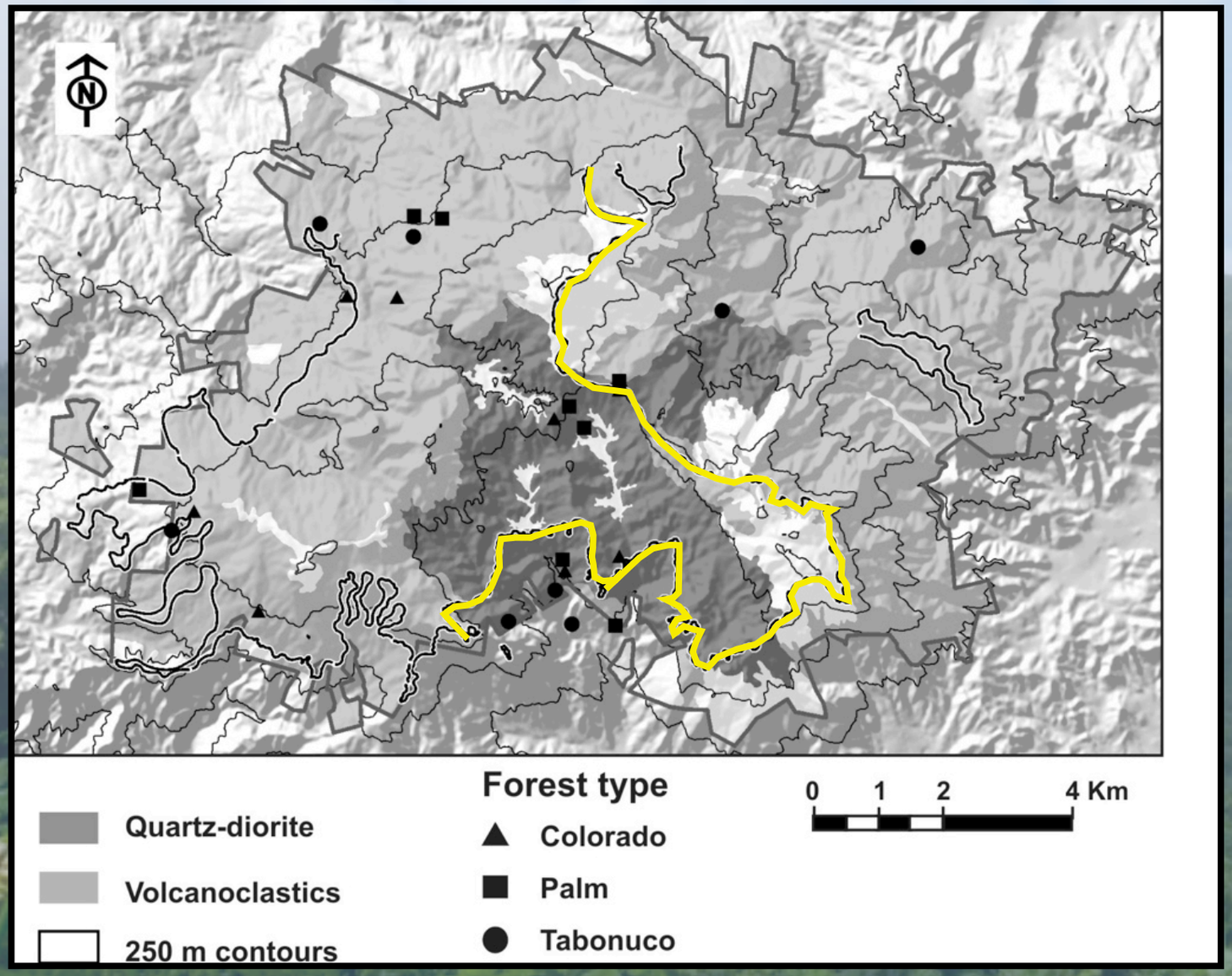

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Our study was not built around differences in denudation…
but maybe it should have been.

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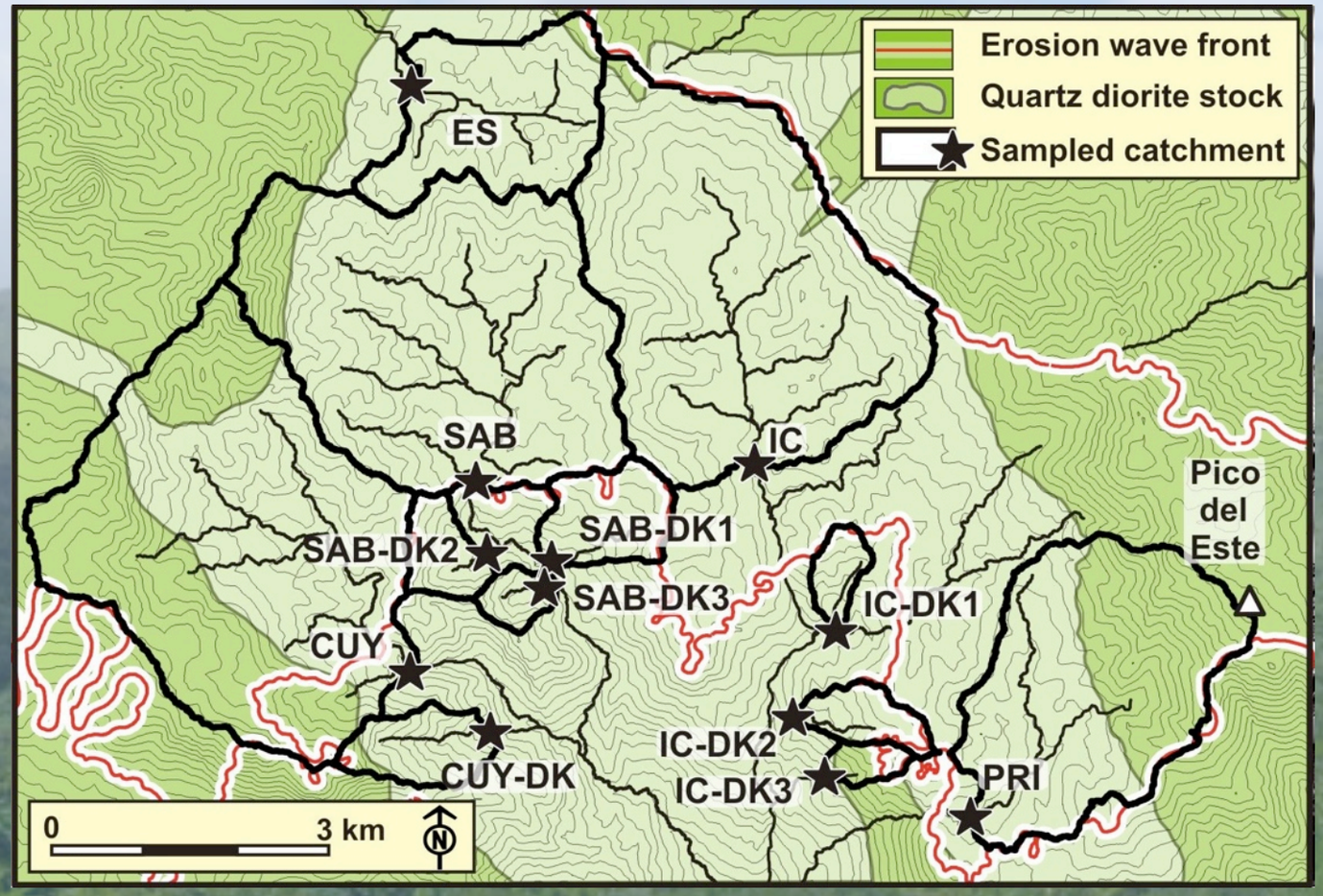

Control for rock type, forest type, elevation.
Vary denudation rate.

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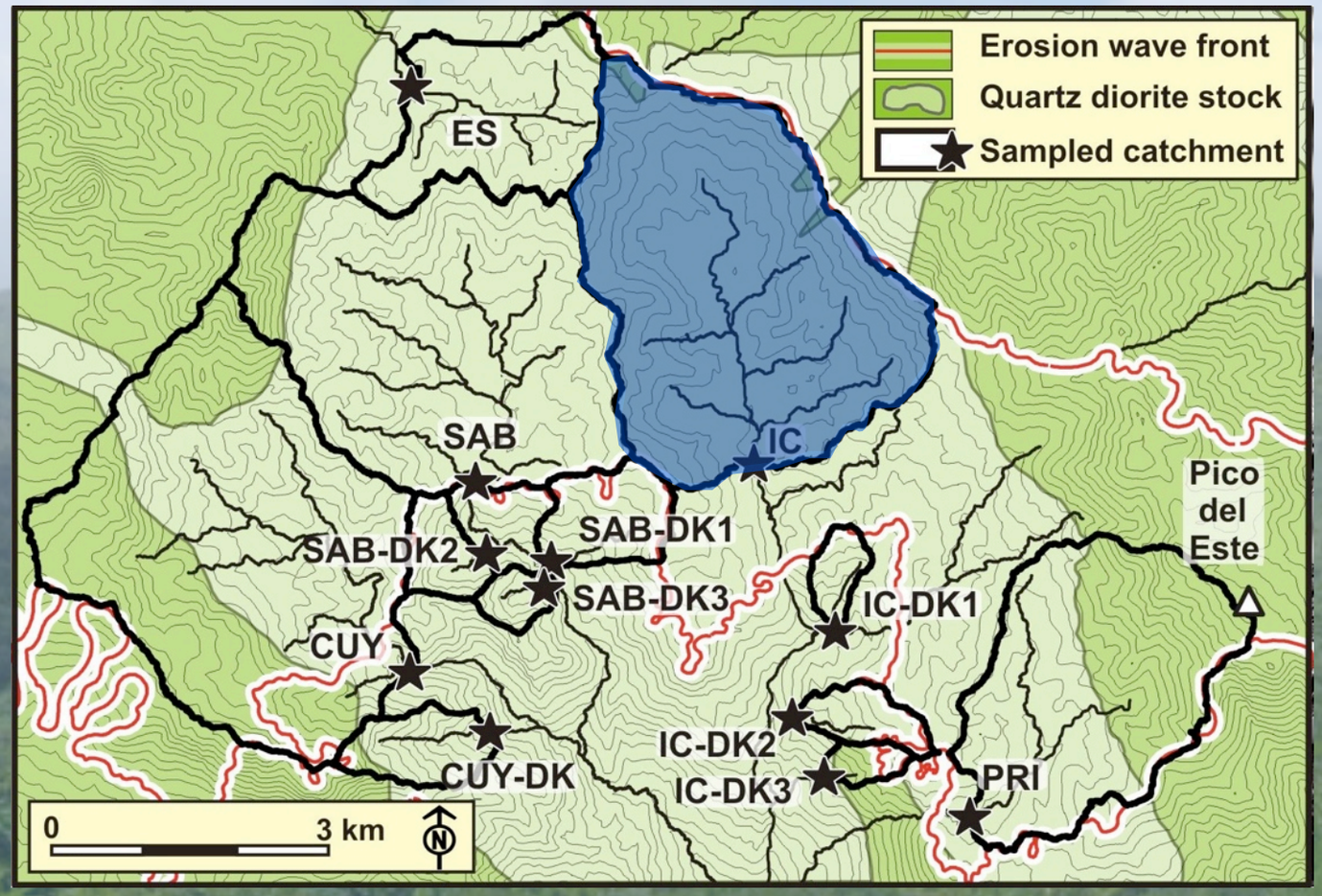

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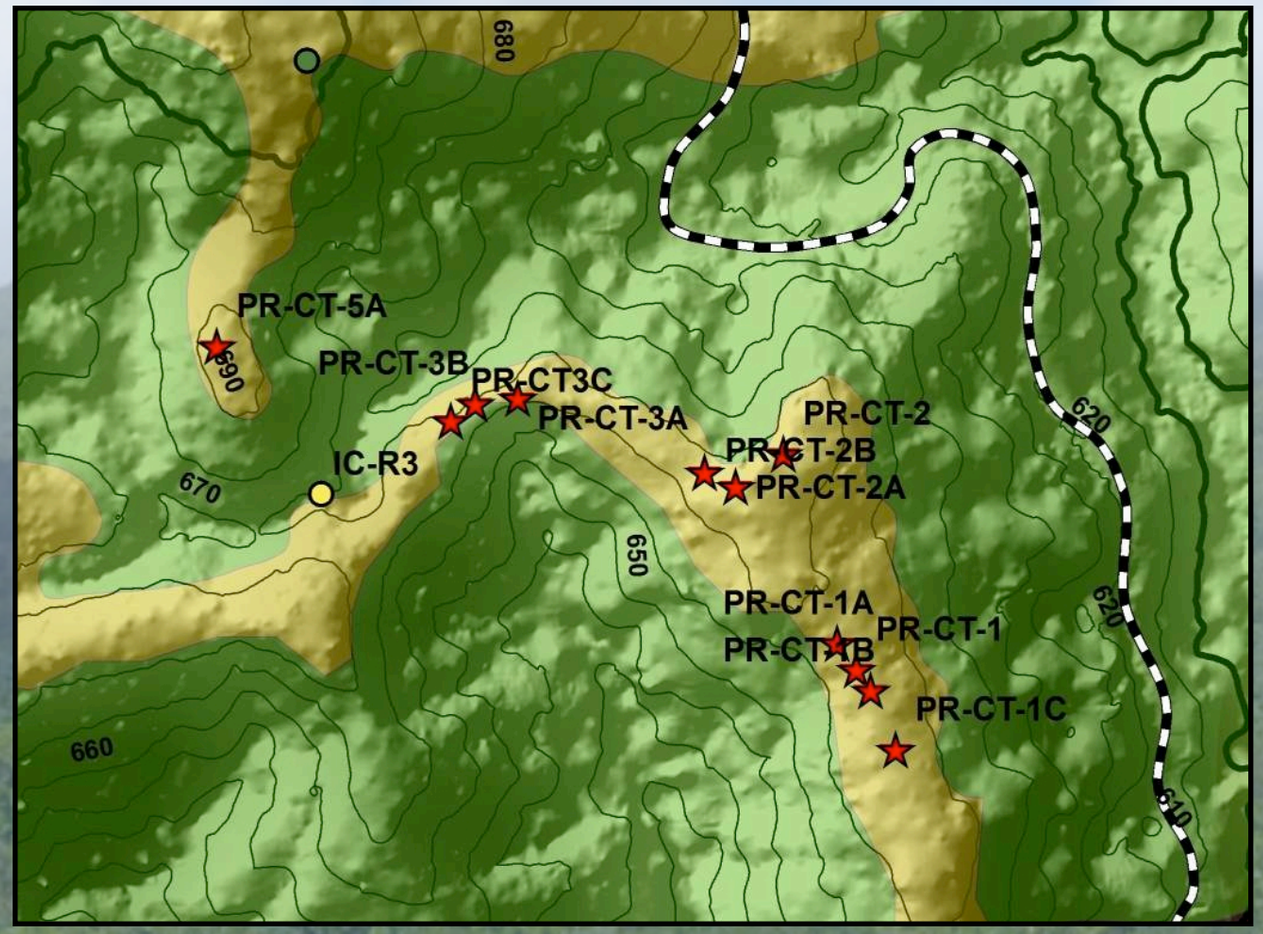

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Vary denudation rate (width for now).

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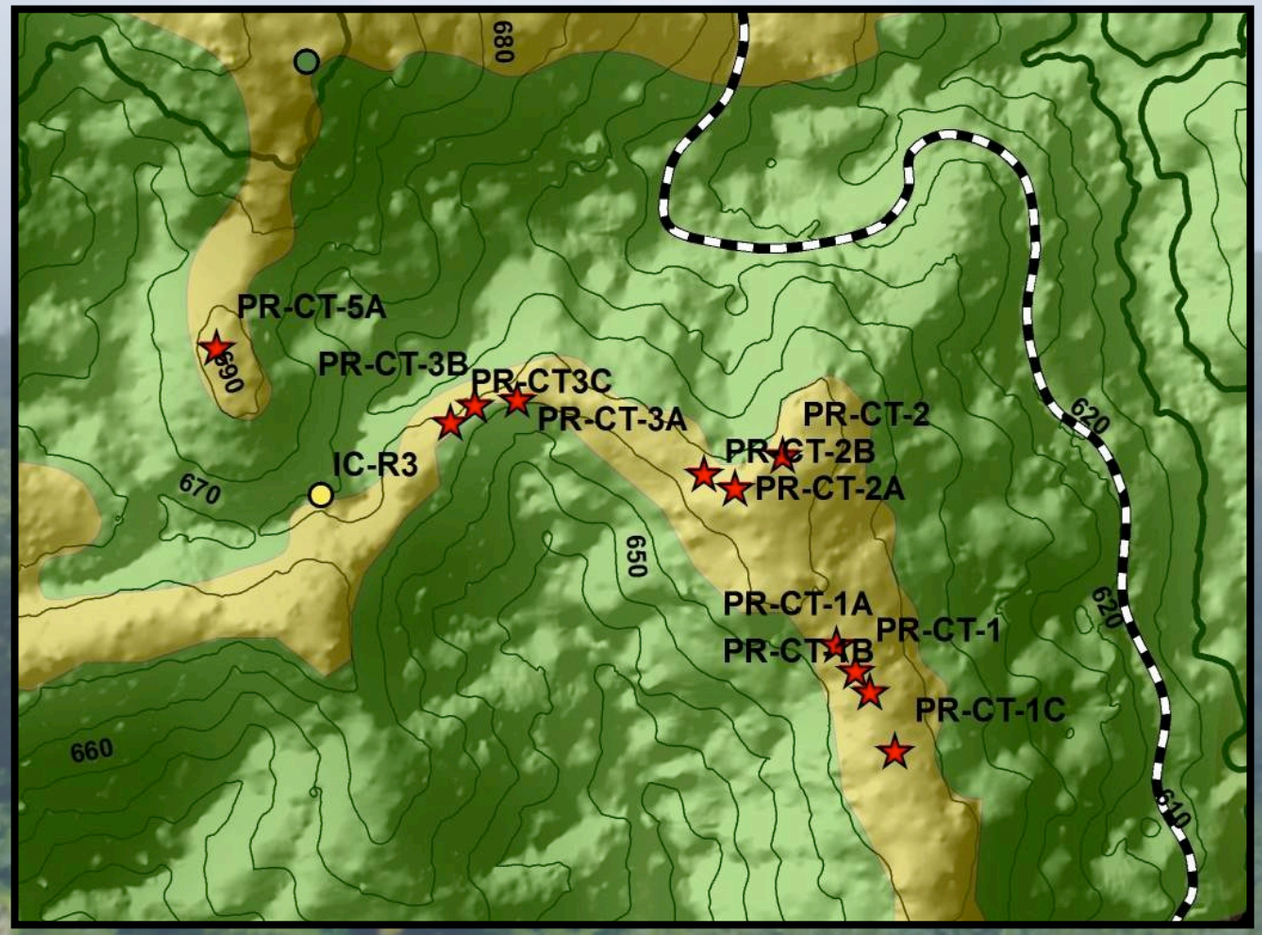

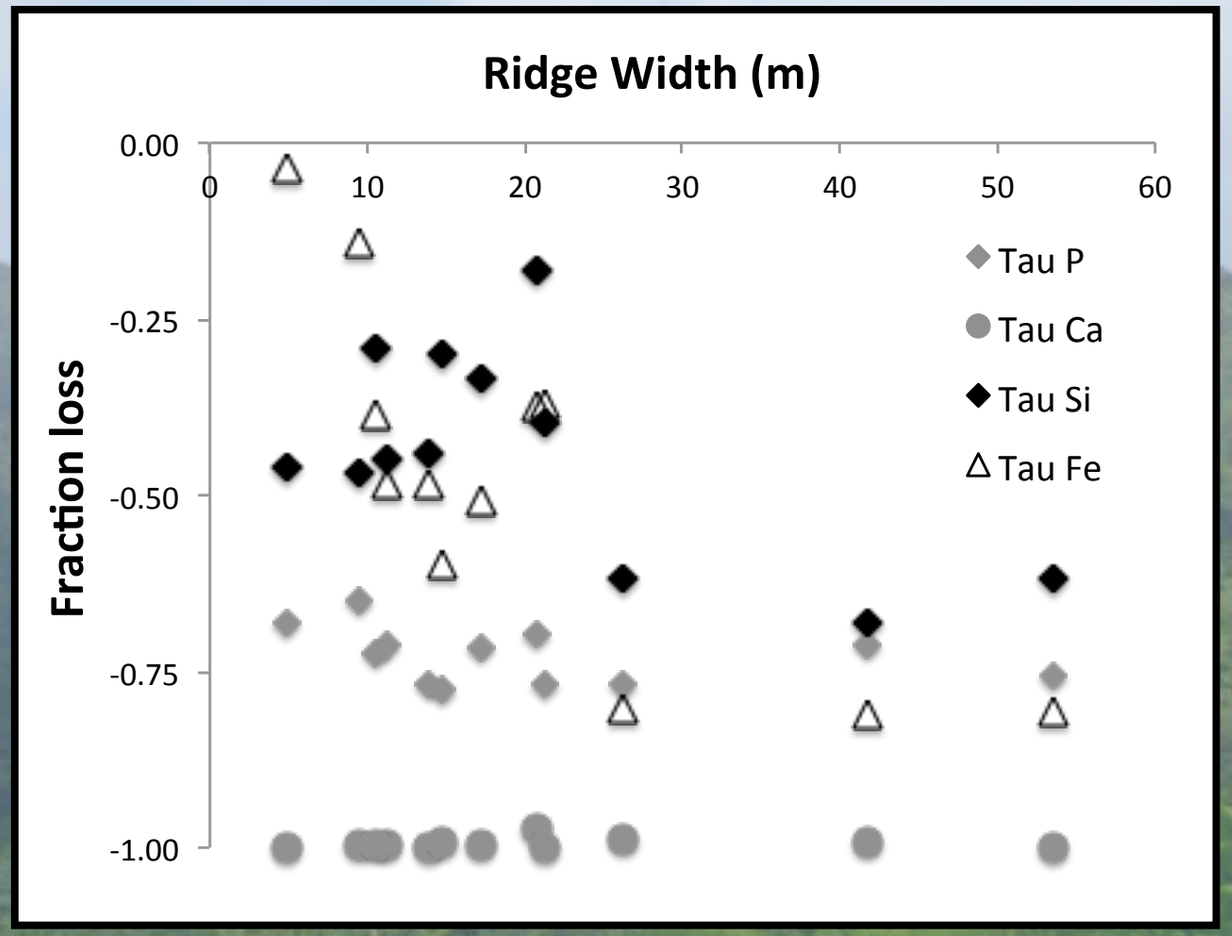

Soil element loss varies with denudation rate

Nutrients do not.

What controls nutrient availability in the tropical forests of the Luquillo Mountains?

Rapid weathering EYNF does not result in universally weathered soils

Geomorphic disequilibrium drives difference in weathering and in nutrients at the landscape scale.

Geomorphic disequilibrium may drive weathering and ecosystem differences in many tropical landscapes.

Conclusions

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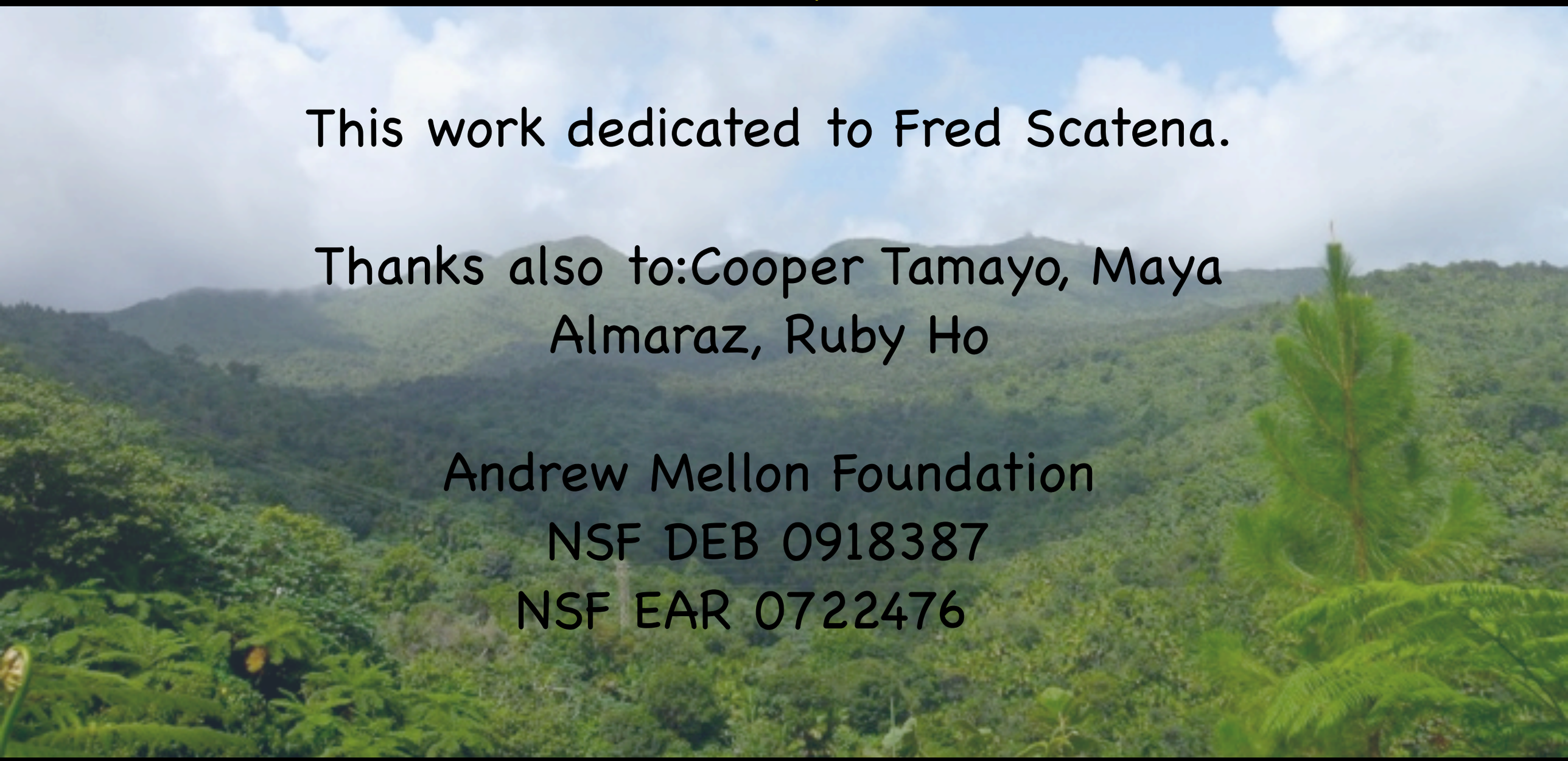

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