The Ecology of Landslides

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P. Scott

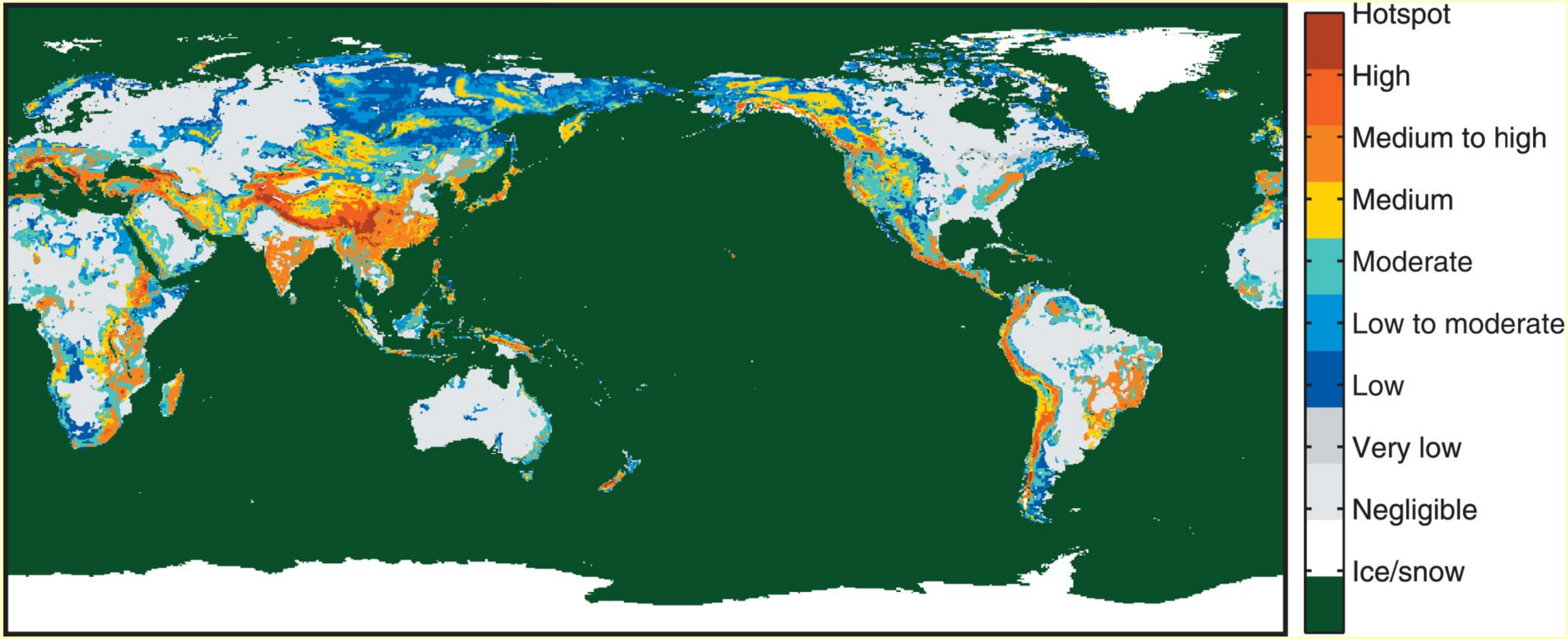
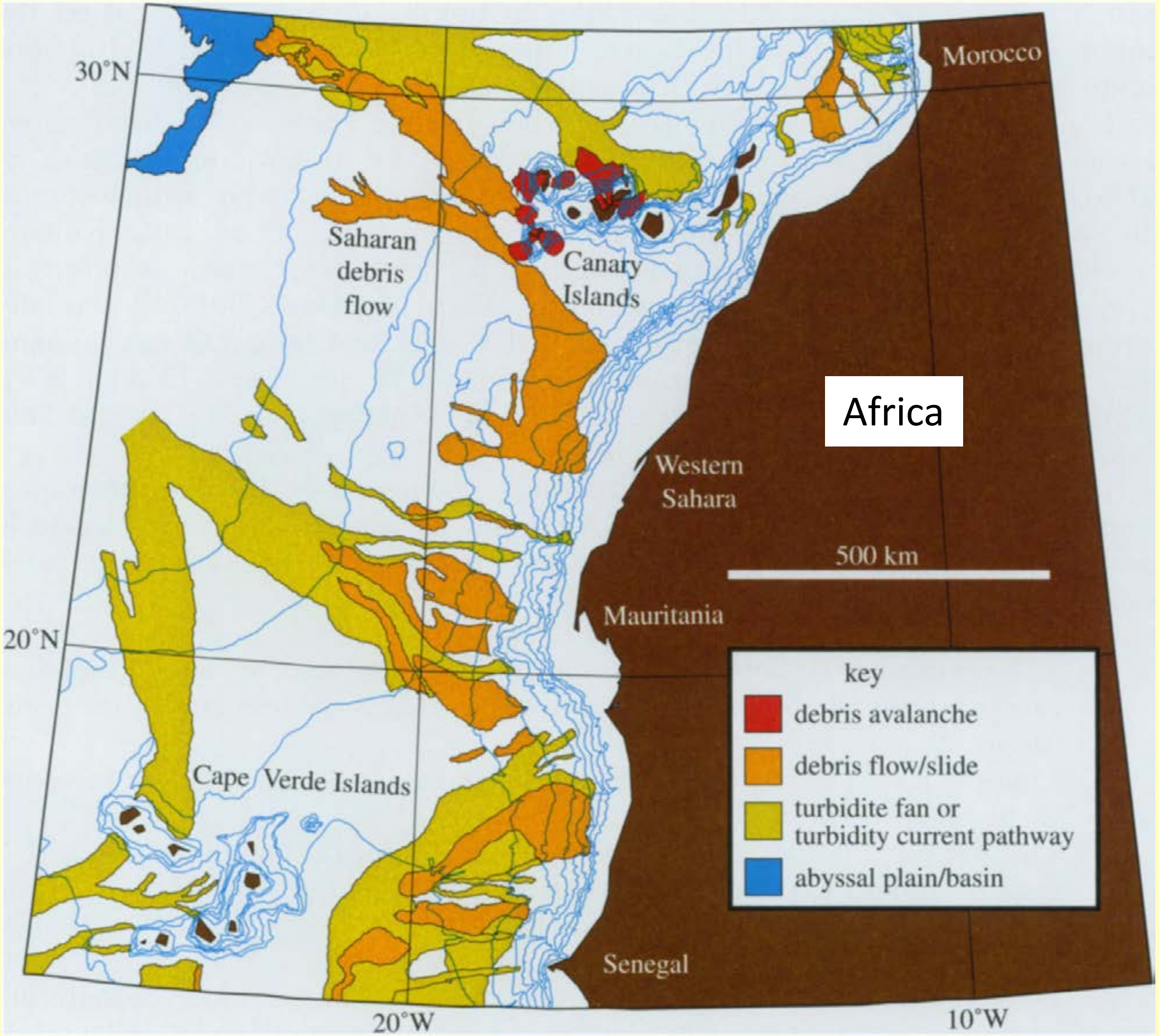


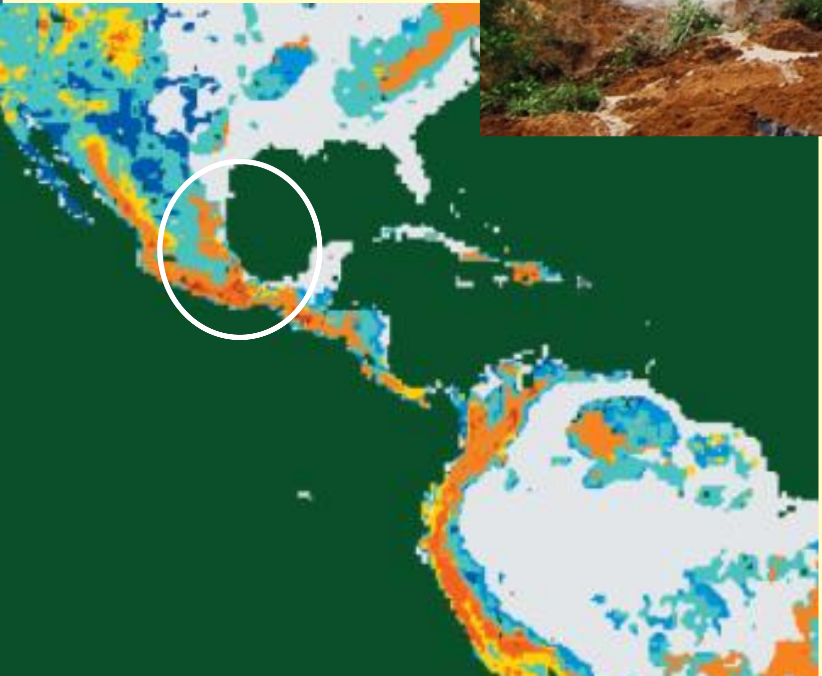
Image by NASA

Landslides: present on 50% of land
abundant on 4%
common in tropical montane regions



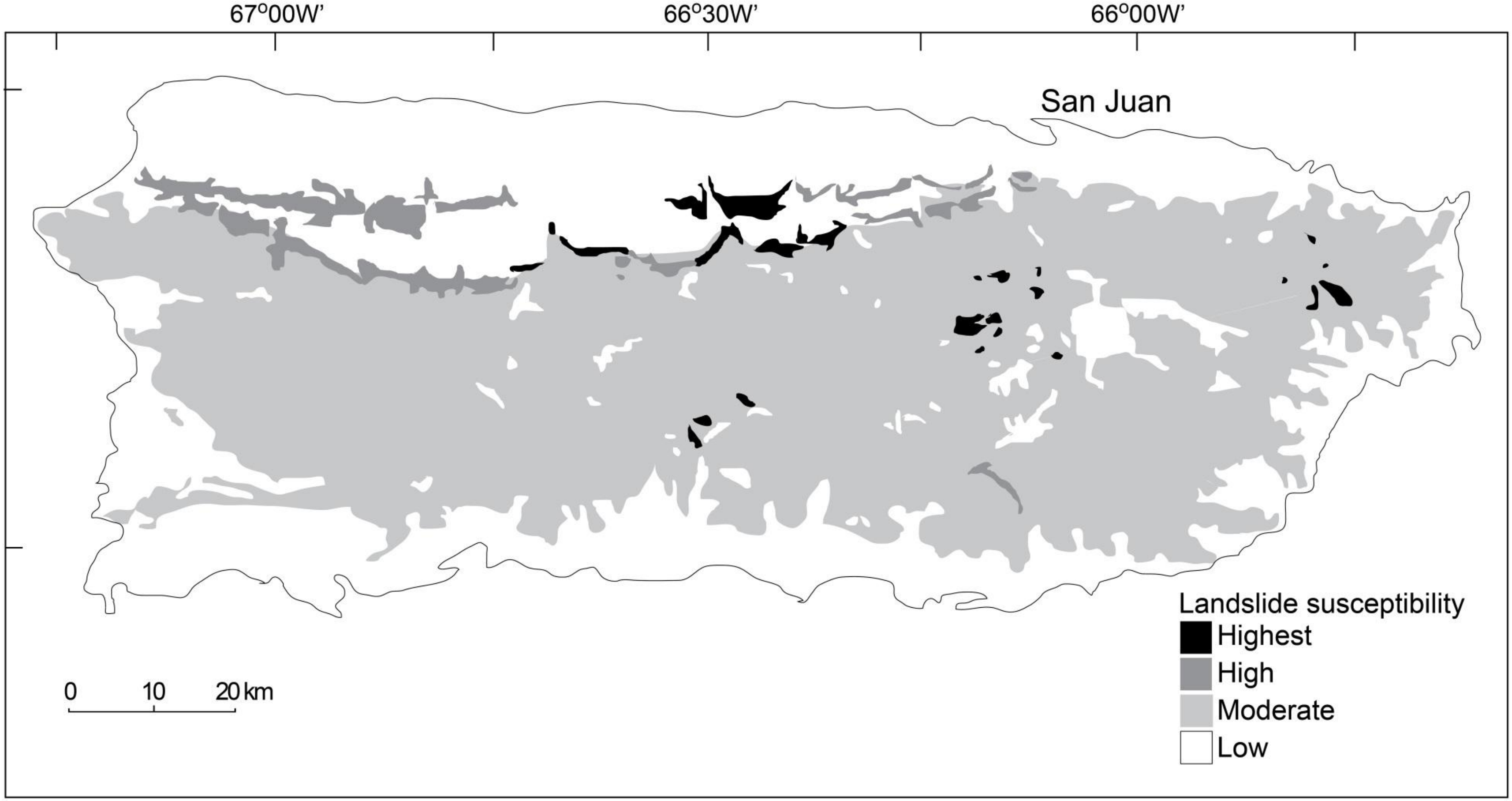
Masson et al. 2006

Submarine landslides are common near continents and around volcanic islands

Veracruz, Mexico landslide
September 2013: Hurricane Manuel

Al Jazeera

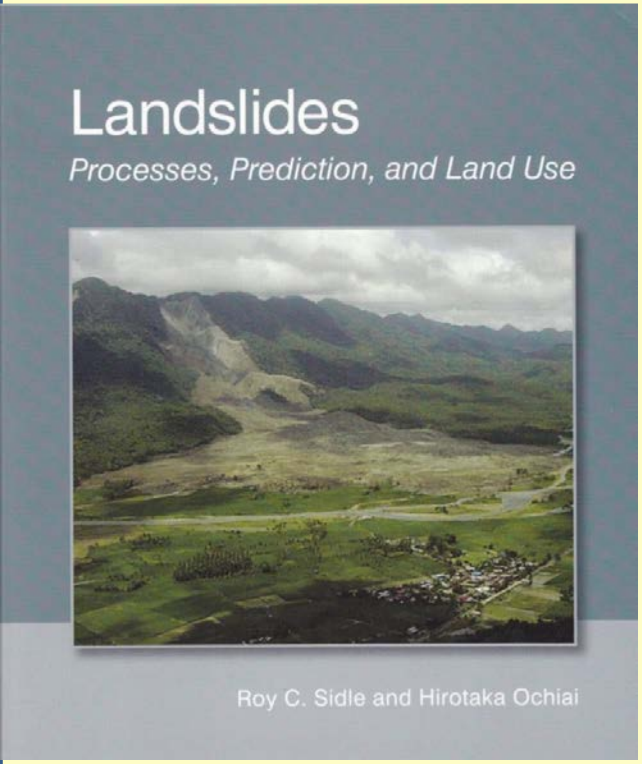


Larsen & Torres-Sánchez 1998

Landslides in Puerto Rico

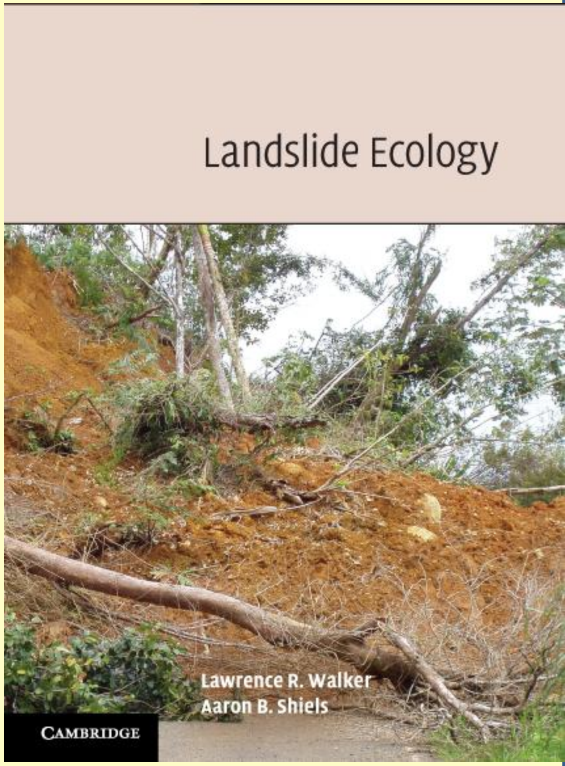
A growing body of literature
is addressing landslide ecology
-unlike the more common geological
or hazard management approaches

MARSCHNER REVIEW
PLANT AND SOIL 377:1-23
Ecological mitigation of hillslope instability: ten key issues facing researchers and practitioners
Stokes et al. 2014



Sidle & Ochiai 2006

Restrepo et al. 2009

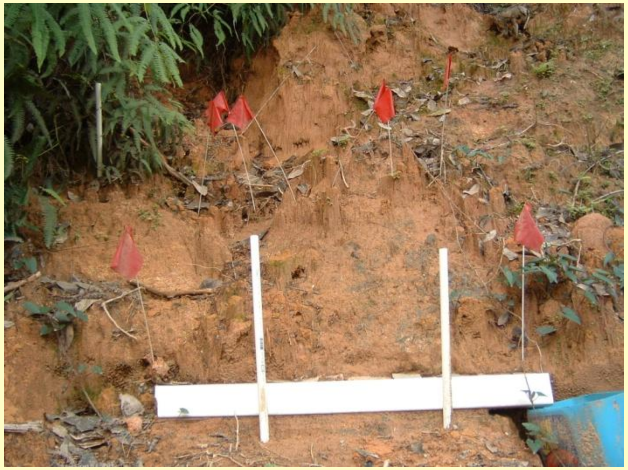


Walker & Shiels 2013

Biogeochemistry
Hydrology
Nutrient cycling

LANDSLIDE ECOLOGY

Spatial heterogeneity
Patch dynamics
Hierarchical scales



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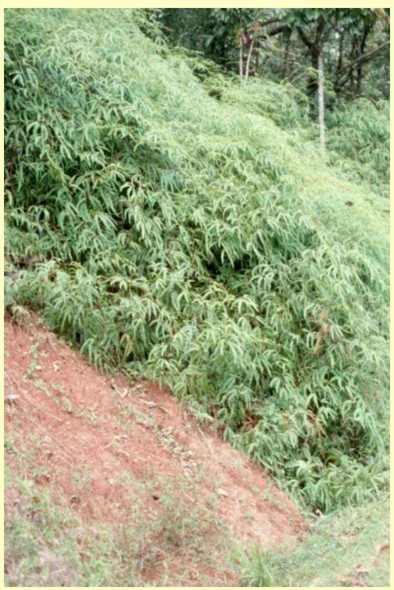
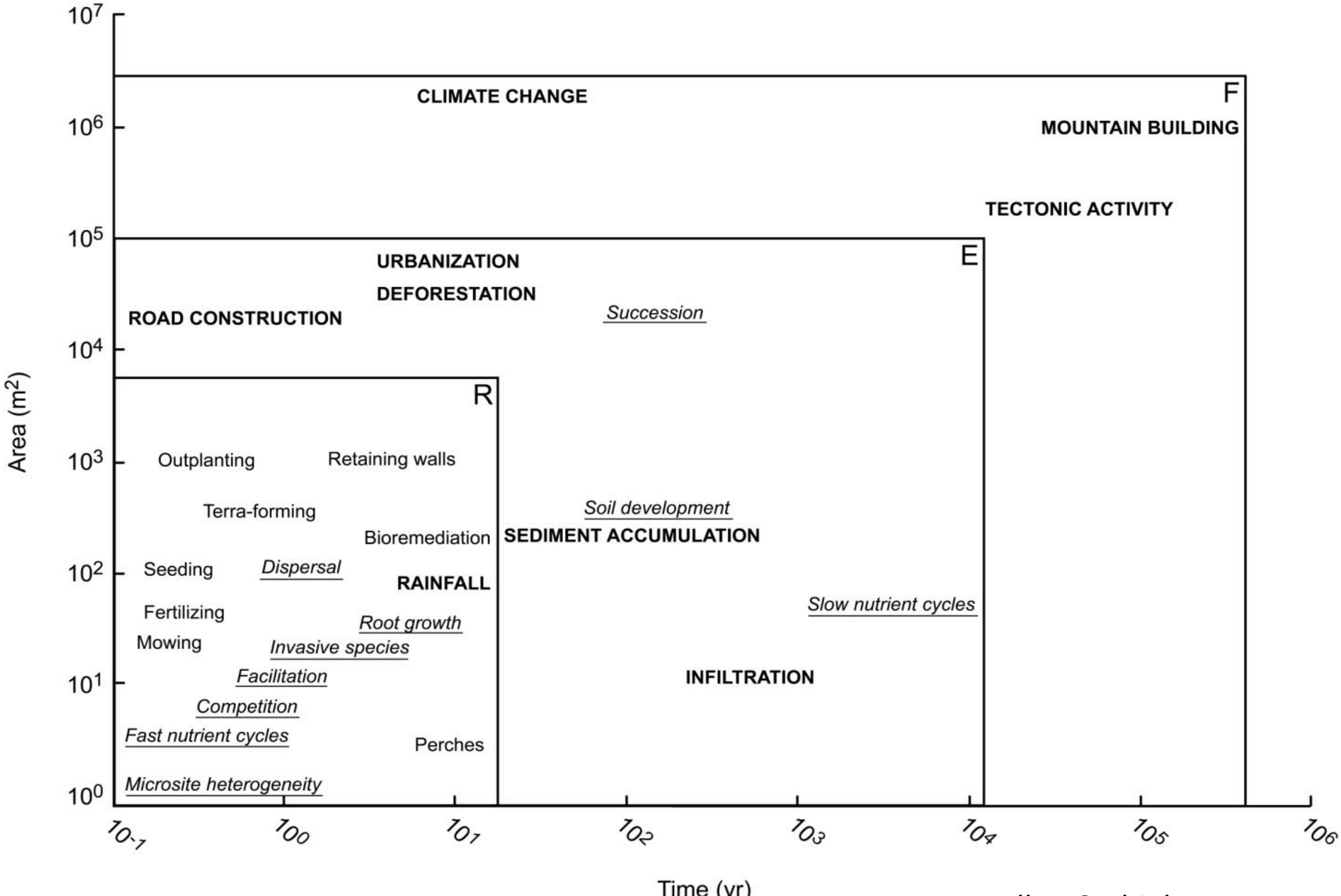


Biodiversity
Succession
Temporal heterogeneity

Prediction
Mitigation
Restoration



Walker & Shiels 2013

Processes in FORMATION (F), *ecology* (E) and restoration (R) of landslides

Why we should care about landslide ecology:

1. To clarify the role of spatial heterogeneity in maintaining biodiversity
2. To understand landscape processes like nutrient cycling
3. To examine land-water linkages of sediments and nutrients
4. To save lives and improve habitat restoration

Some questions for landslide ecology:

1. How do landslides interact with other disturbances?
2. What are the consequences of increasing landslide frequencies?
3. How to better predict and manipulate vegetation to stabilize landslides?

B. Cohen

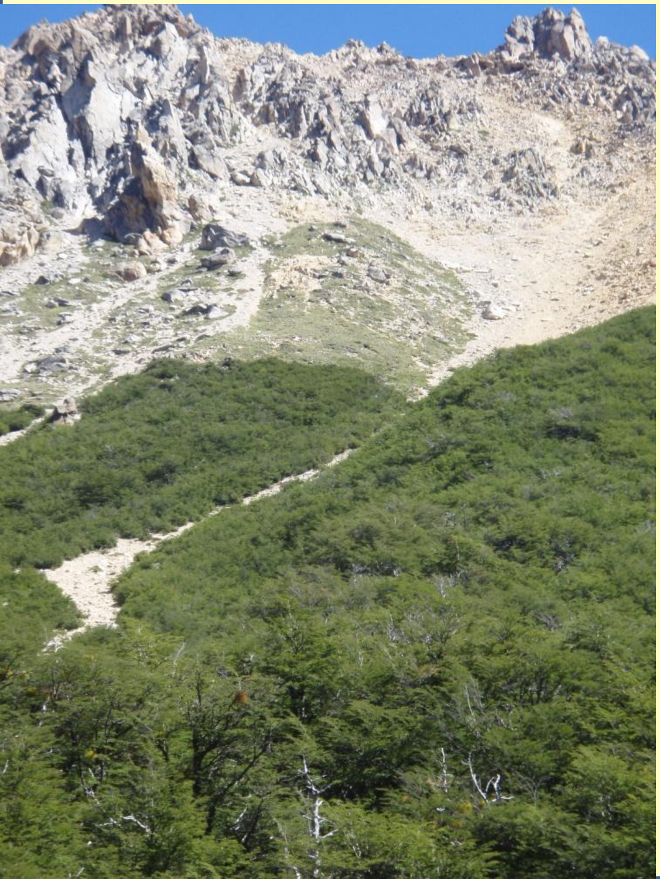
Type of material	Type of movement (increasing speed) →			
	Slide		Flow	Fall
	Rotational	Translational		
Bedrock	Rock slump	Rock slide	Rock avalanche	Rock fall
Regolith	Debris slump	Debris slide	Debris avalanche Debris flow	Debris fall
Sediments	Sediment slump	Slab slide	Earth flow Decreasing sediment size ↓ Sand flow Loess flow Liquefaction flow	Sediment fall

Increasing particle size ↑

Varnes 1958

Generalizations are difficult: landslides are diverse in types of materials and movements

Diversity in shape, size, severity, re-sliding, aquatic linkages



More habitat types

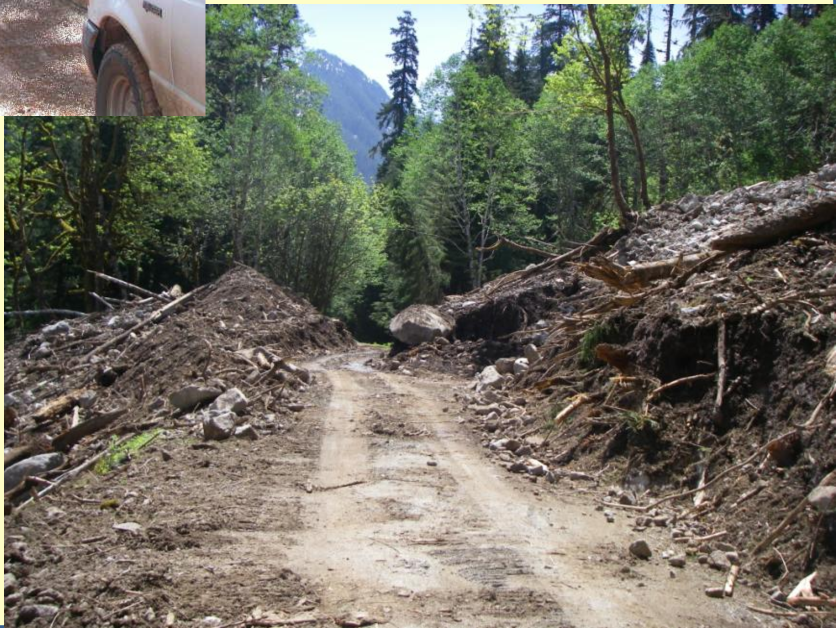
tree
falls

rock
faces

talus

Landslides create high spatial heterogeneity (many habitats)

Roads trigger landslides and create maintenance issues



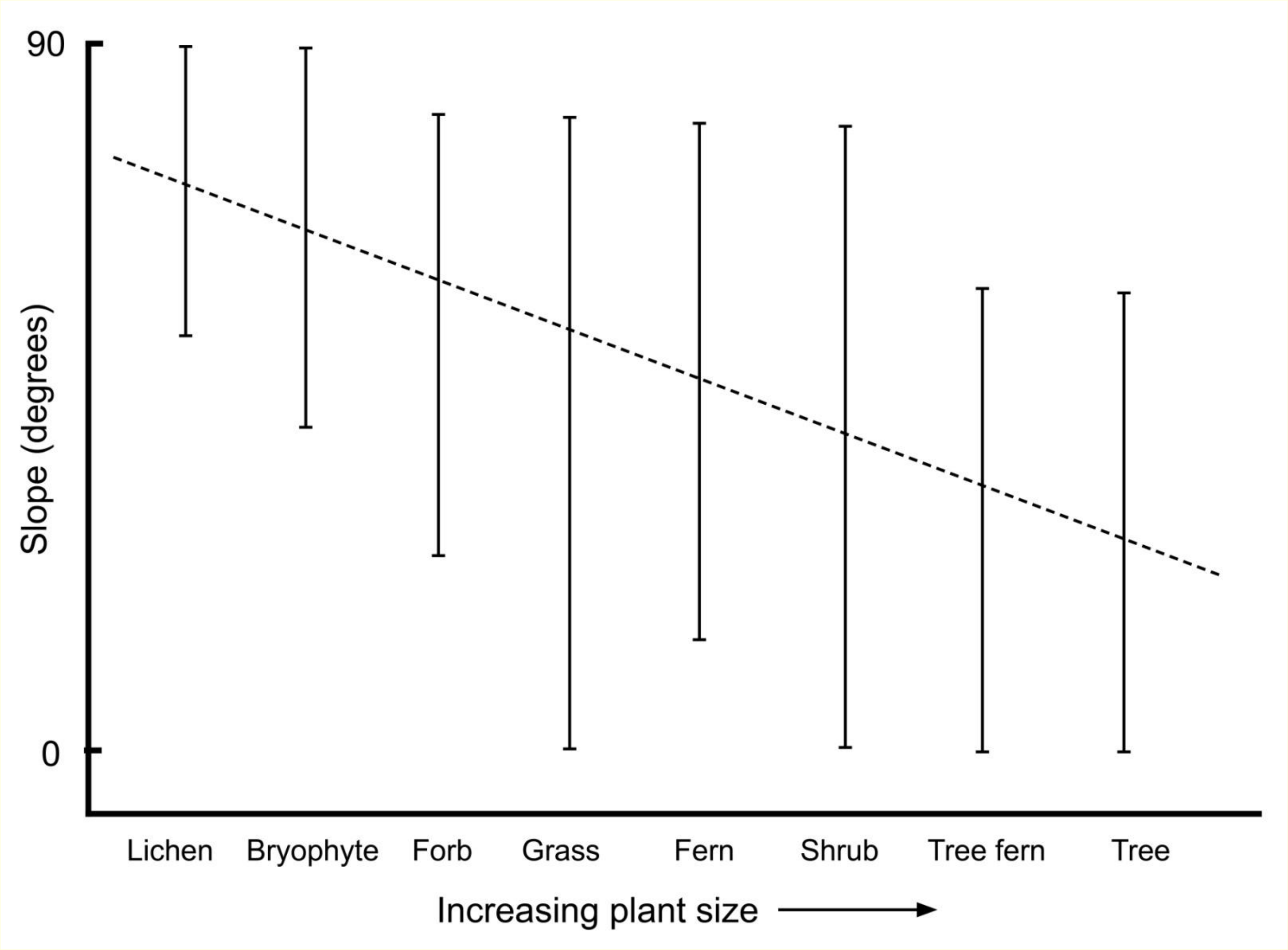
algae

lichen

moss

Non-vascular plant colonizers

Vascular plant colonizers



Walker & Shiels 2013

A hypothesis about landslide plant colonists

E. Velázquez

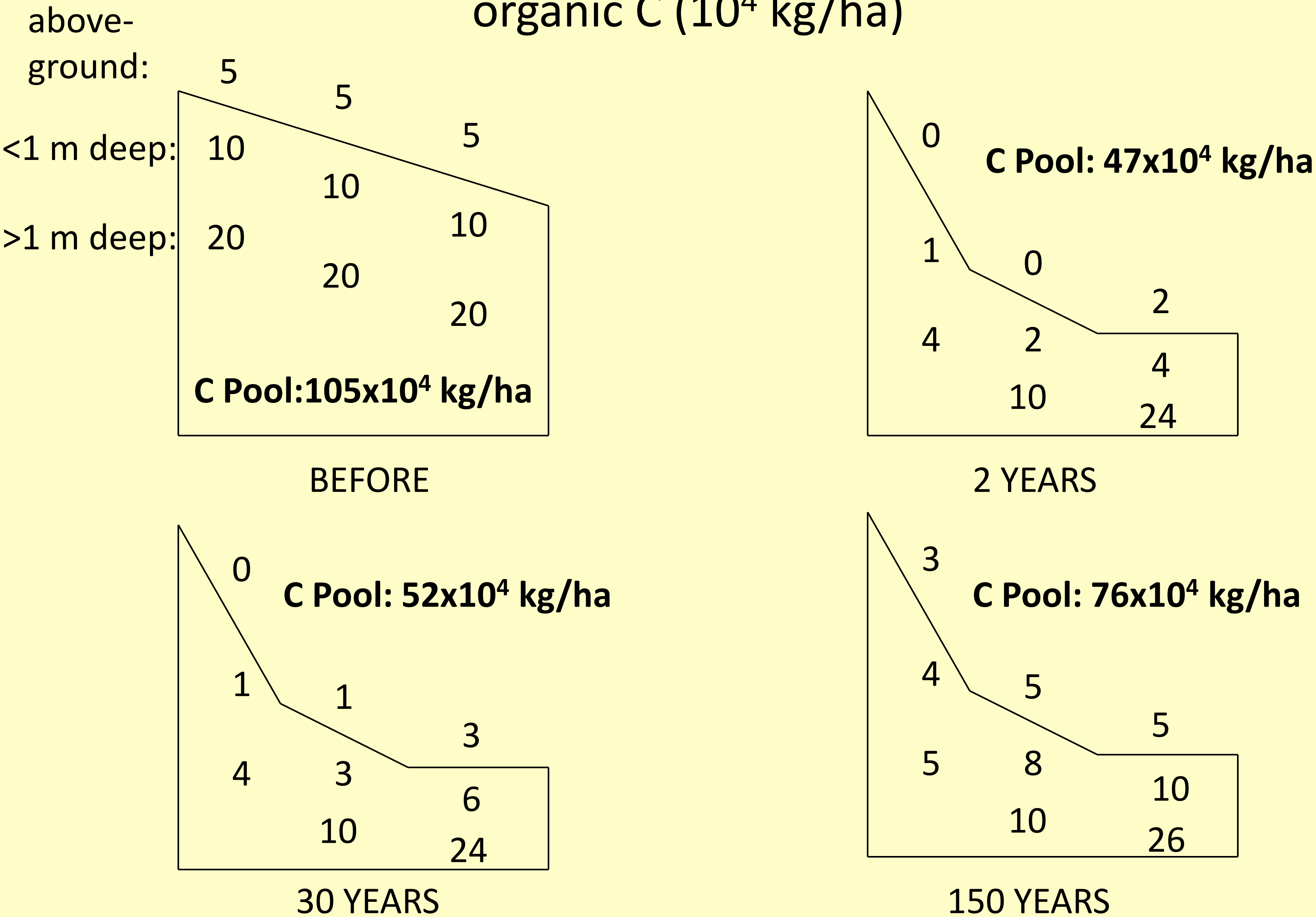
Animal colonizers

A. Shiels

Landslide carbon moves downslope

(net loss despite deposition and successional re-growth)

organic C (10^4 kg/ha)

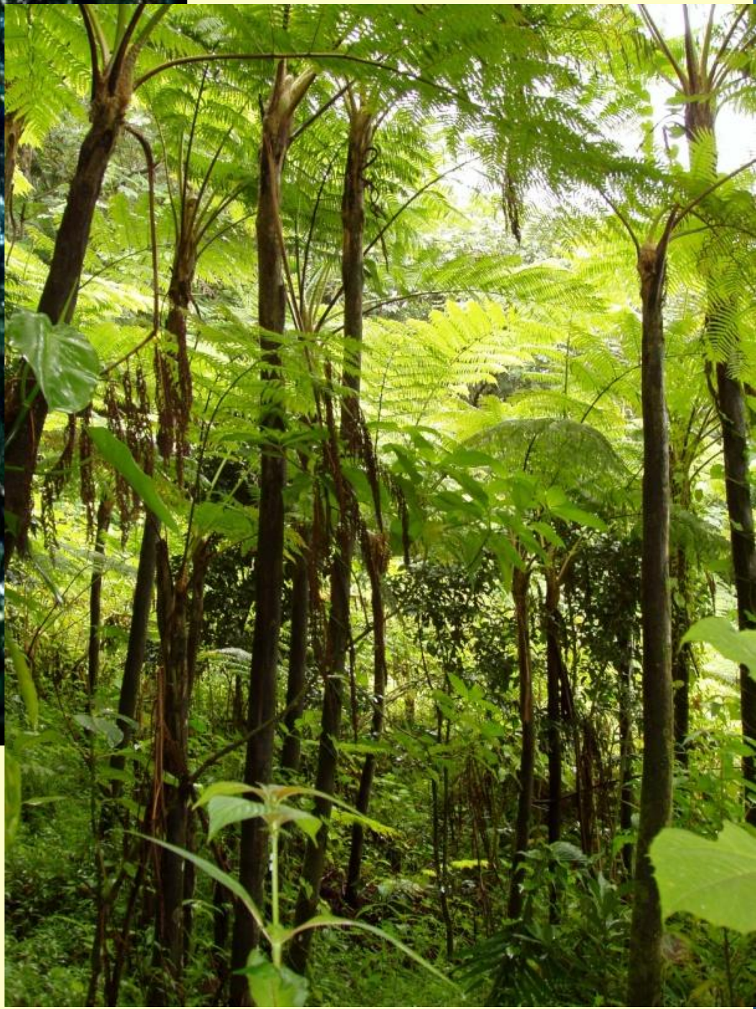


Walker & Shiels 2008



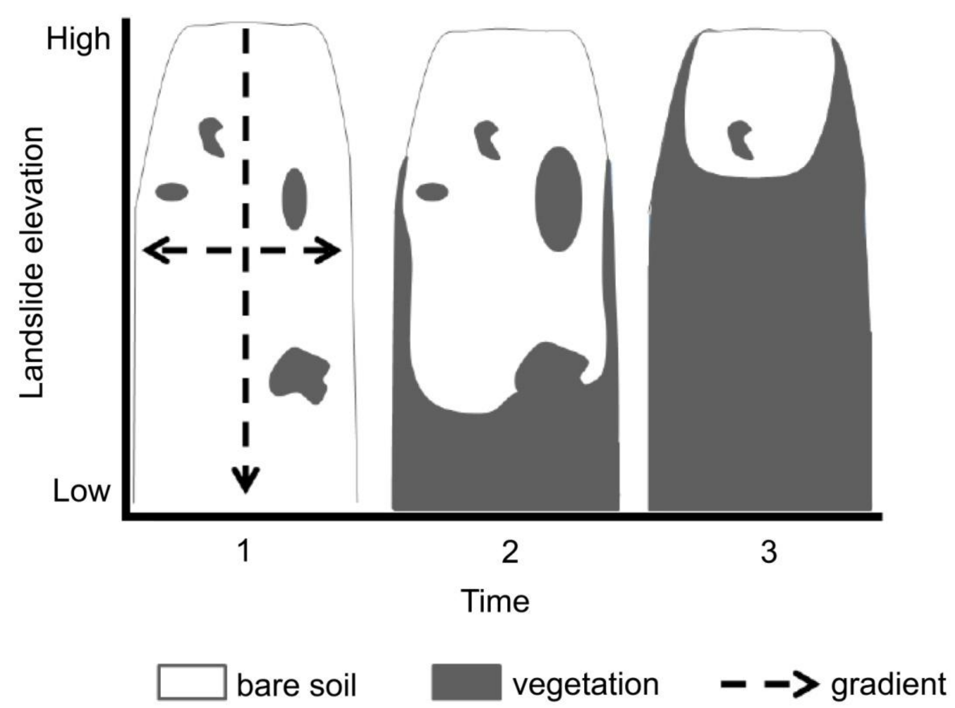



Succession: 6, 18, 22, 34, 55 and 180 months



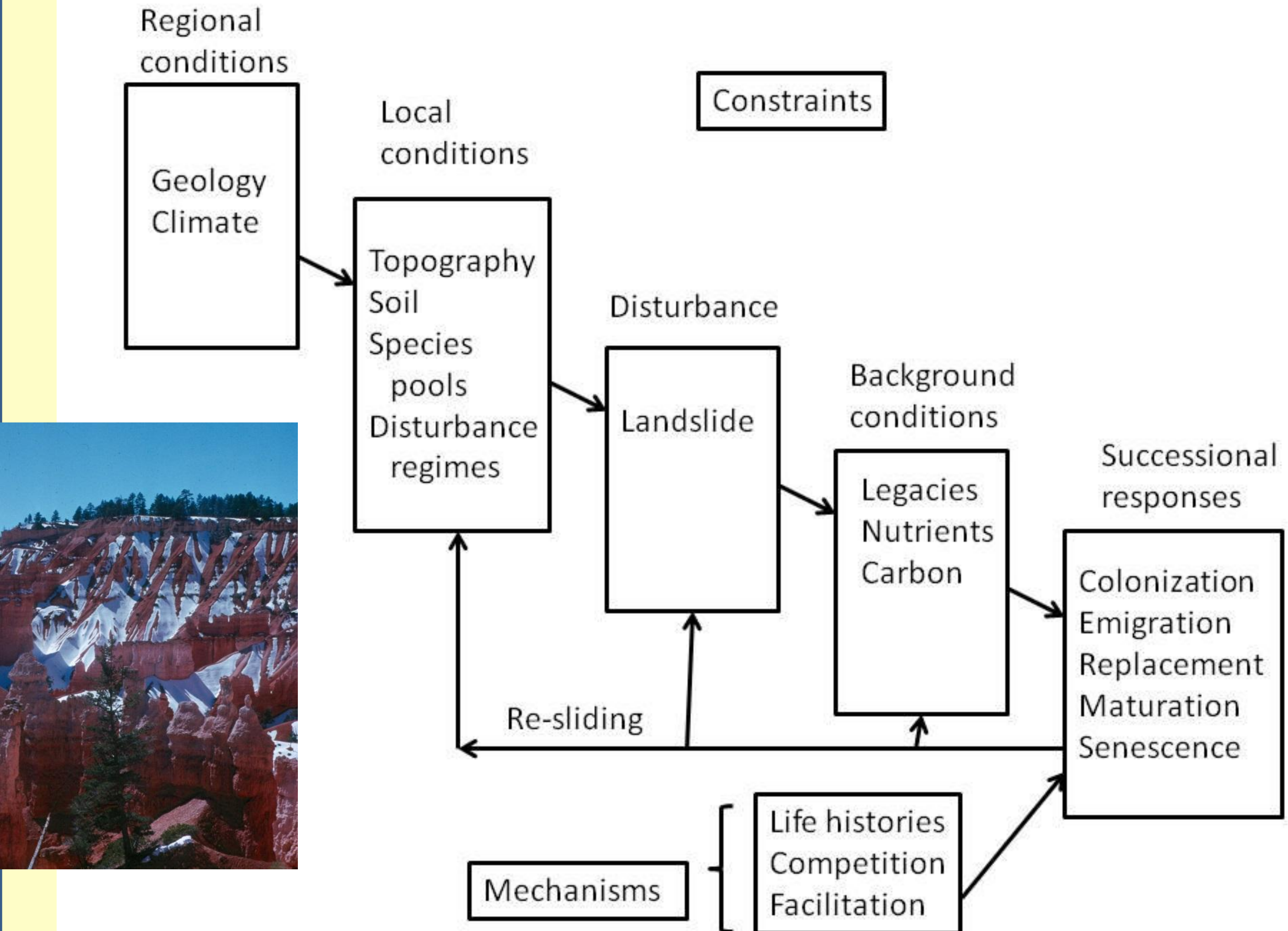
Species interactions:

Thickets of tree ferns can inhibit succession



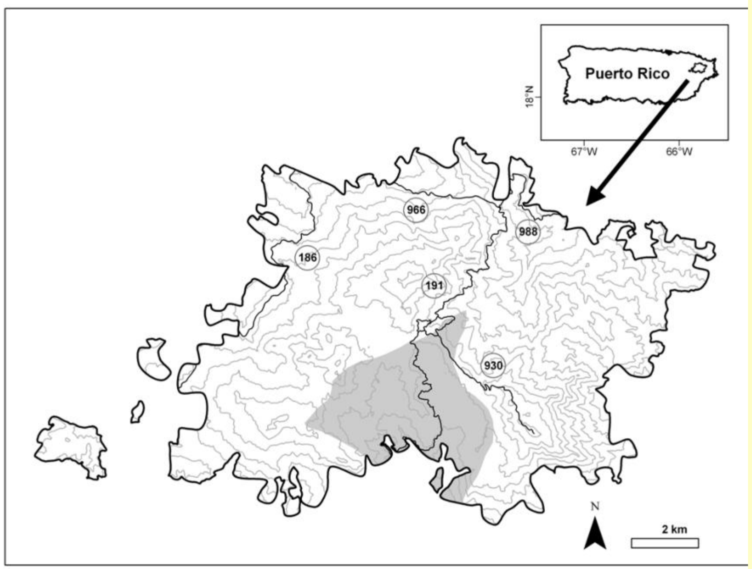
Shiels & Walker 2013

Edges matter for colon- ization



Walker & Shiels 2013

Hierarchical succession model



Evaluation of the role
of abiotic drivers in the Luquillo
Experimental Forest: 6 landslides
and 2 soil types examined for 18 yr

Slip face

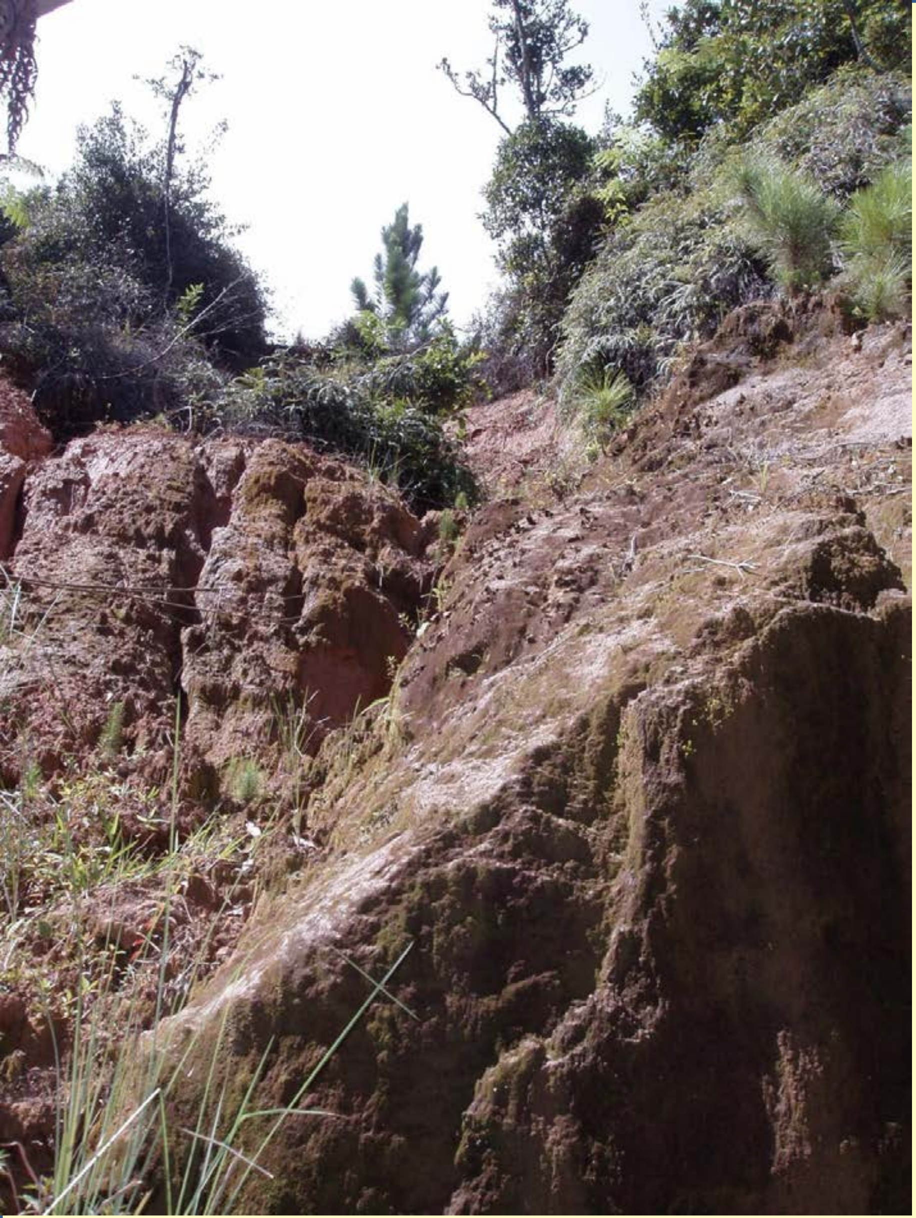
Chute

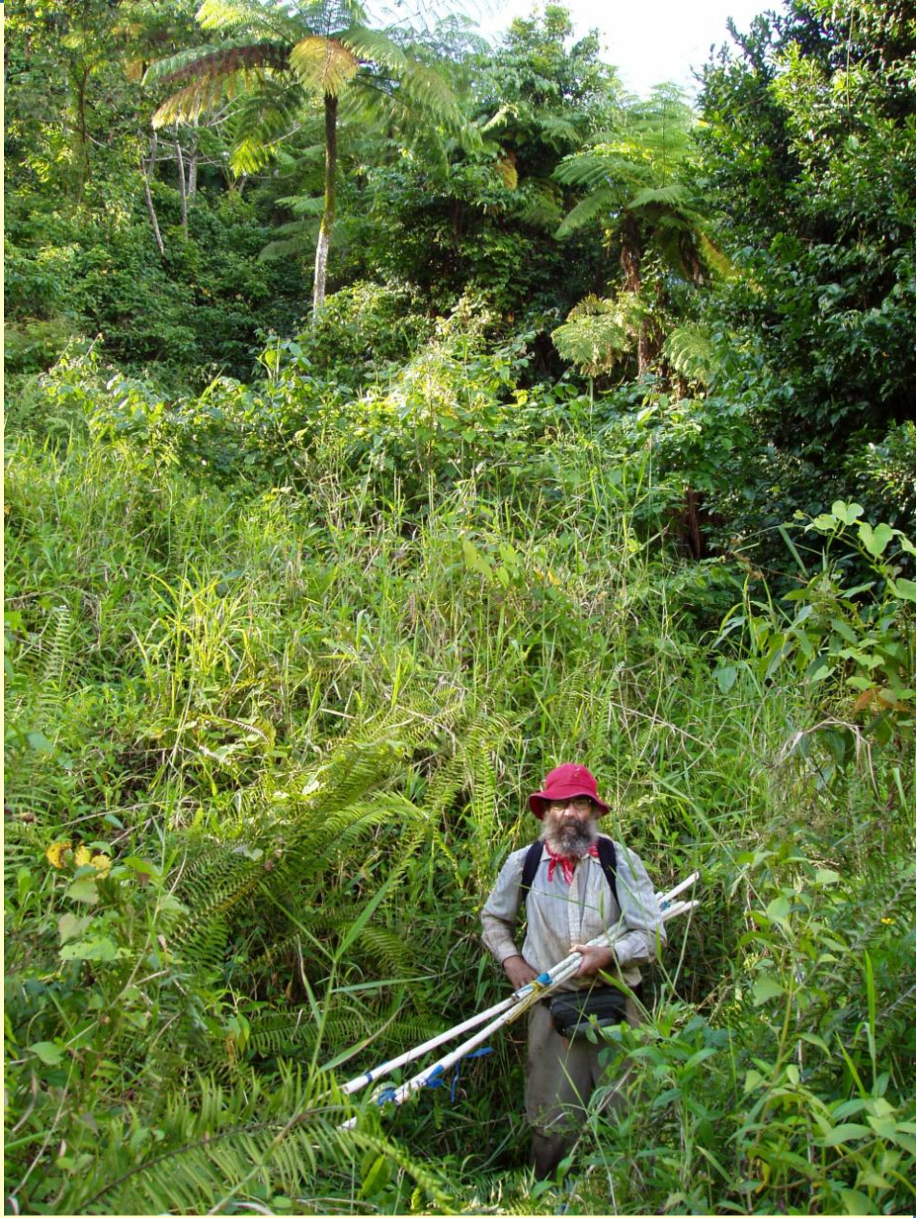
2 X 5 m plots

Catchment size matters

Large

Small





Steep

Not steep

Slope matters

Structural Equation Model Results:
Influence of abiotic factors changes over time

Major drivers (standardized path coefficients > 0.30; $P<0.001$);
bold = > 0.60; caps = positive direction, underline = unexpected direction

	7 years	18 years
Catchment	**SEED PLANTS** tree ferns scrambling ferns	
Slope	**SCRAMBLING FERNS** seed plants	SCRAMBLING FERNS seed plants
Aspect	TREE FERNS	scrambling ferns
Parent material	SEED PLANTS	SCRAMBLING FERNS

Walker et al. 2013

Humans and landslides: intimately intertwined

Humans living with landslides

Vulnerability
- property damage, loss of life

Use
- hunting, gathering food and wood
- fertile soils for agriculture
- objects of study (geologists, ecologists)
- recreation (bird watching, hiking, aesthetics)

Cause
- construction (roads, railroads, mines)
- species removals (forestry, agriculture)
- fire
- tourism (skiing, golfing, resort construction)

How do we predict, mitigate, restore?

Humans managing landslide hazards

Prediction

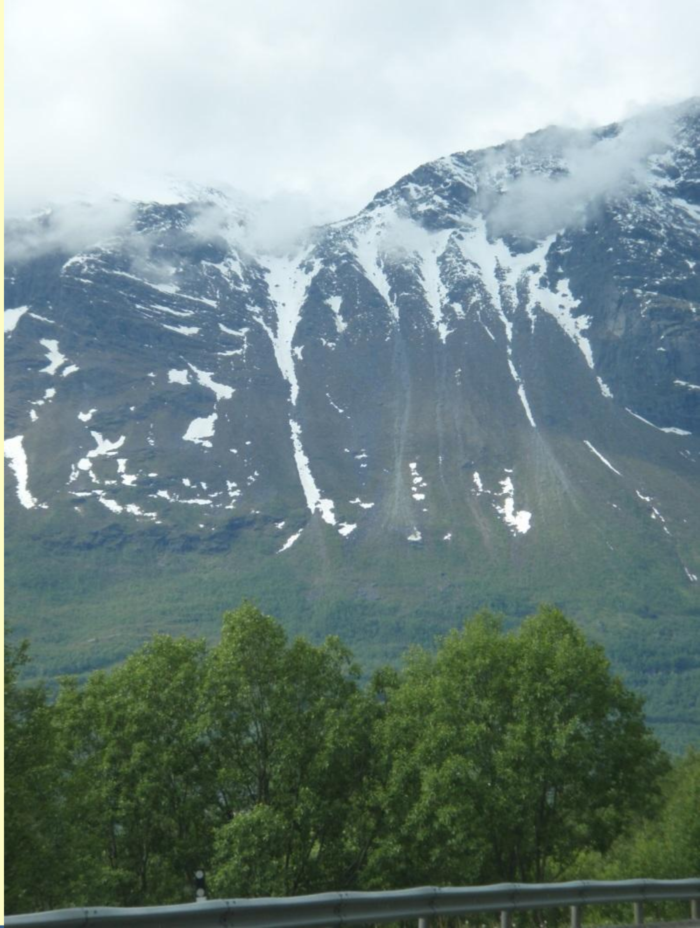
clues from biotic signatures (growth rings, vegetation distribution)

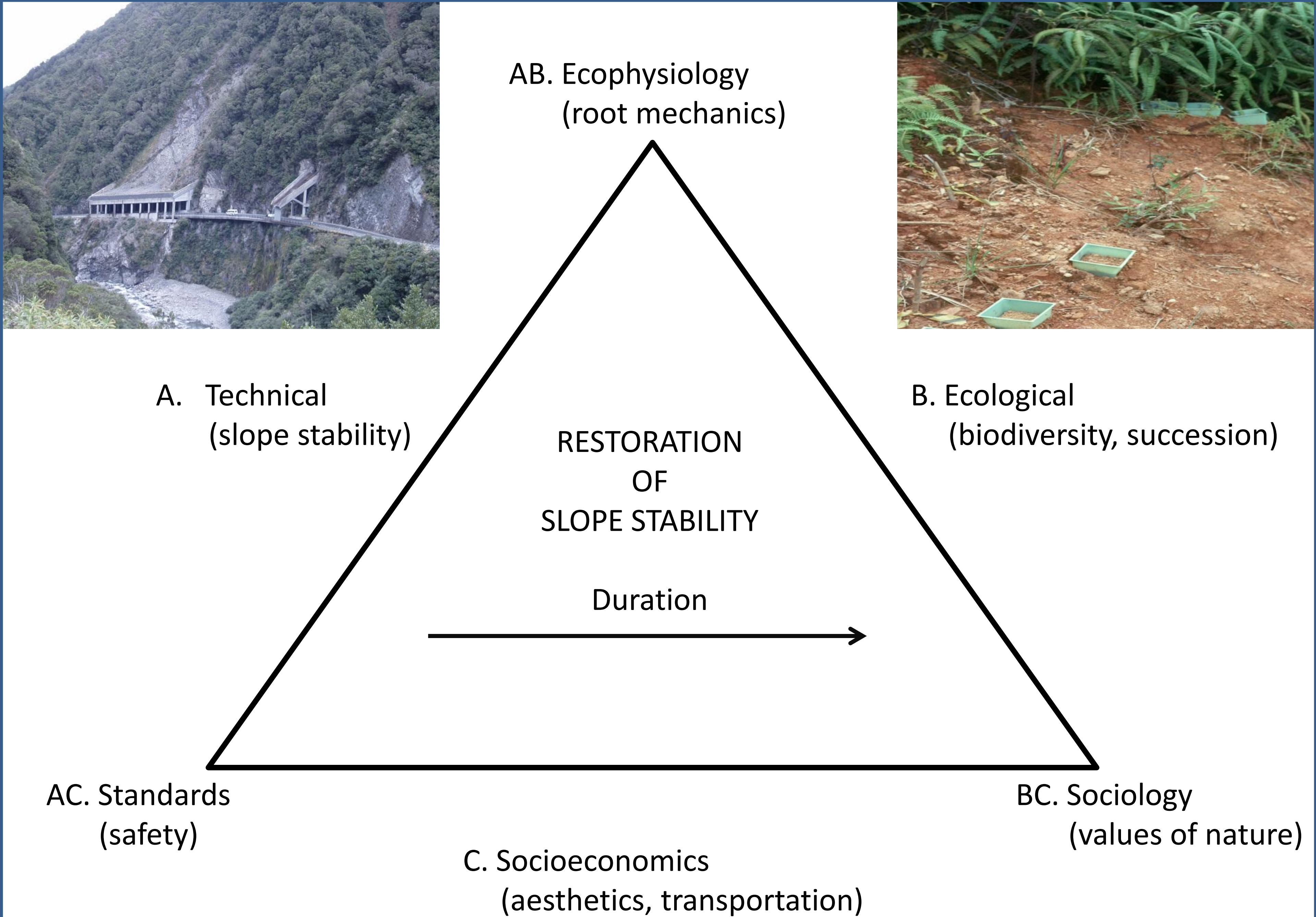
Mitigation

sediment retention or water diversion

Restoration

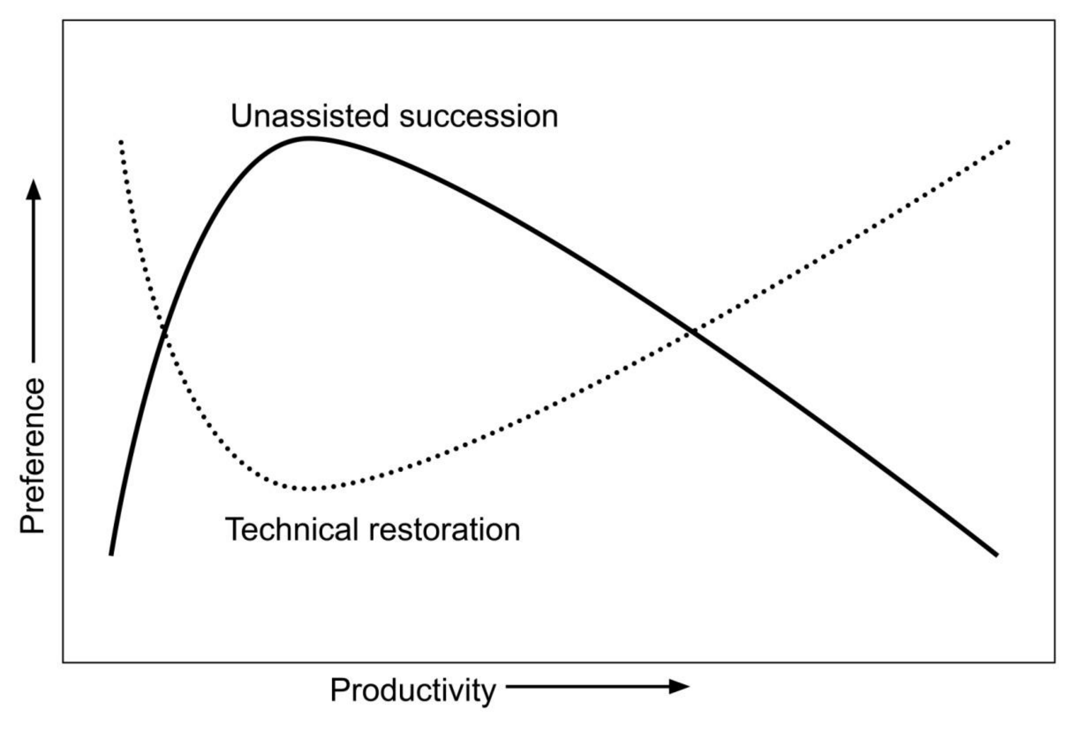
succession: stabilization, soil fertility, plant colonization and species diversity





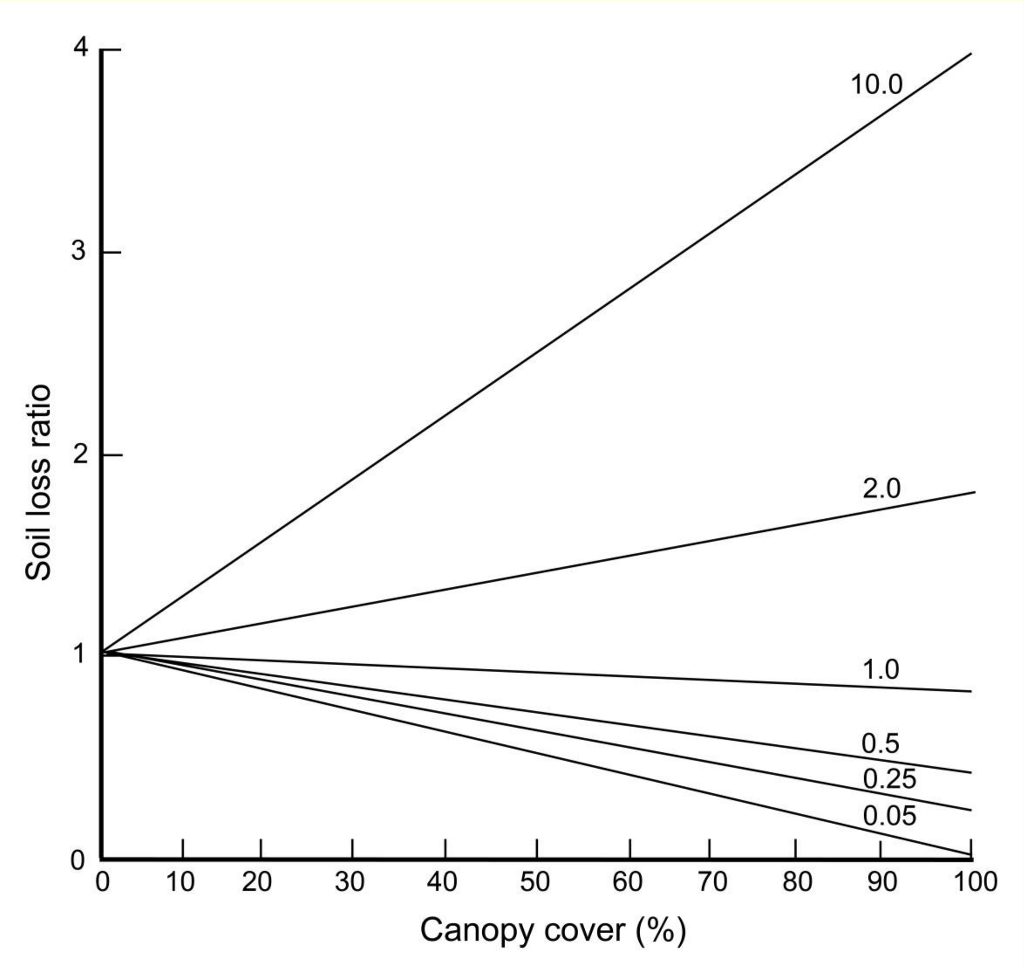
Stokes et al. 2014

Restoration efforts: better if informed by ecology



Prach et al. 2007

Optimal vegetation height in restoration: < 2 m tall



Morgan 2007

Scrambling ferns make good ground cover

Substrate condition	Successional dynamics	Restoration strategies
Infertile, unstable	Very slow	Stabilize with plant cover Increase fertility
Infertile, stable	Slow	Promote stress-tolerant ground cover; fertilize minimally
Fertile, unstable	Moderately fast	Stabilize
Fertile, stable	Fast; trajectory depends on colonizers	Monitor; promote biodiversity

Walker & Shiels 2013

Conclusions

1. Landslides are linked to important landscape features, including ecosystem parameters (e.g., carbon, nutrients) and community parameters (e.g., biodiversity)
2. Landslide succession studies integrate these parameters through insights into soil stability and fertility, plant traits and interactions, land use and repeated disturbances
3. Biotic responses to abiotic conditions change during landslide succession
4. Therefore, landslide ecology provides insights into landscape processes, successional recovery, and restoration techniques

Future of landslide ecology

1. Improving predictive models based on ecological responses
2. Exploring role of novel ecosystems in landslide succession
3. Increasing ecological resiliency to decrease costs of restoration
4. Advising how to better live with landslides in a changing world

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