Water resources and ecosystem services

examples from Panamá, Puerto Rico, and Venezuela

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Ecosystem services from forested watersheds

mainly product and goods

- water resources
- wood products
- biodiversity, genetic resources, enhanced resilience to wildfire, pathogens, invasive species
- recreation, ecotourism
- reduced peak river flow during storms
- increased availability of groundwater and base flow in streams during dry annual dry season & droughts
- reduced soil erosion and landslide probability
- buffer to storm surge and tsunamis [forested coastlines]

Ecosystem service challenges

Land use and governance

- deforestation
- forest fragmentation
- increased wildfire frequency
- urban encroachment on forest margins

Climate-change

- temperature & precipitation, both averages & extremes
- intensity, frequency, duration of storms & droughts
- sea level rise
- rising atmospheric carbon dioxide concentration

Climate change:
What have we already observed?

- **1983 to 2012**: warmest 30-year period of last 1400 years northern hemisphere

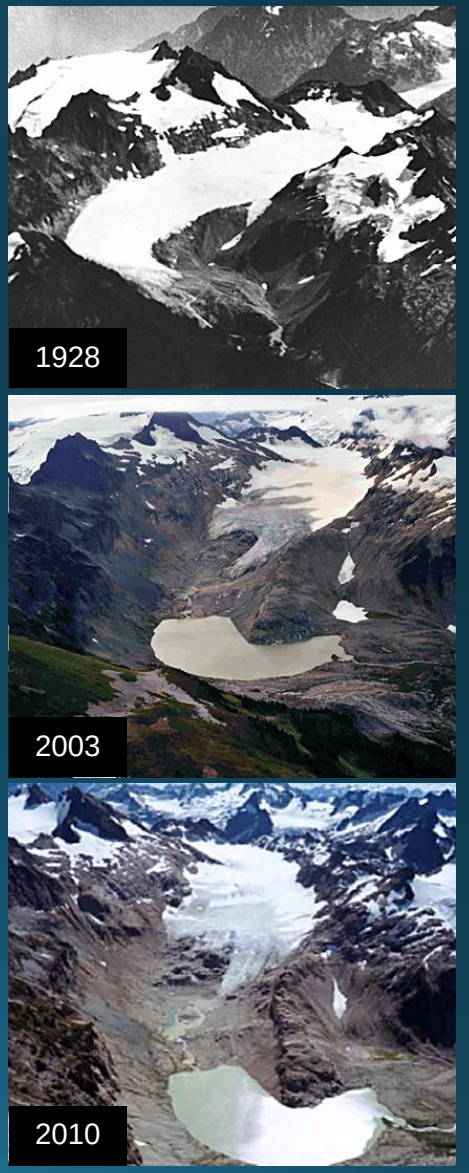
- **1880 to 2012**: globally averaged air temps over land & ocean show warming of 0.85 °C

- **since 1901**: increase in average mid-latitude northern hemisphere land area precipitation

- **1979 to 2012**: annual mean Arctic sea-ice extent decreased 3.5 to 4.1% per decade

- **1901 to 2010**: global mean sea level rose 0.19 m

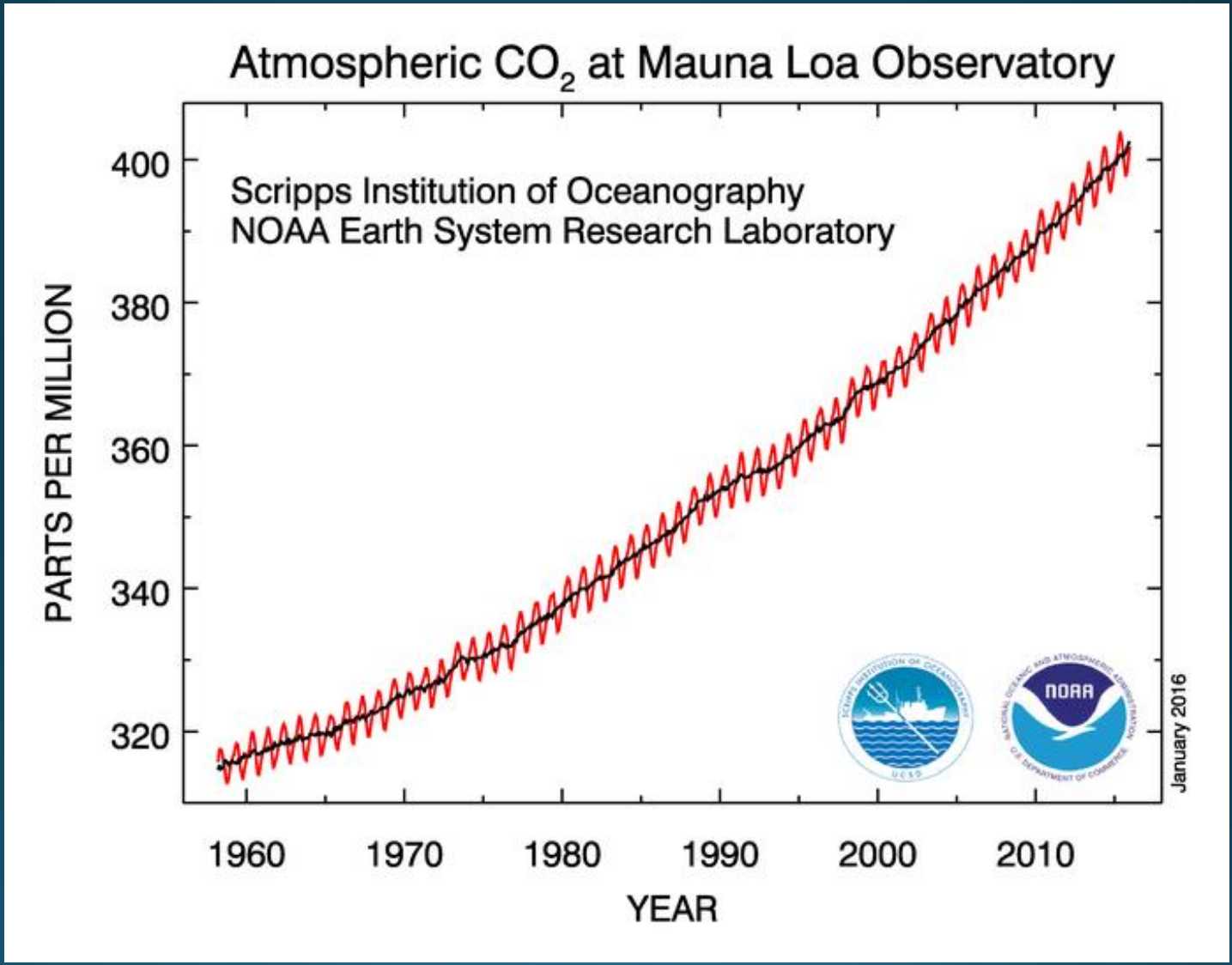
- **since mid-19th century**: rate of sea level rise has been larger than mean rate during previous 2000 years



South Cascade Glacier, U.S

Source: IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.

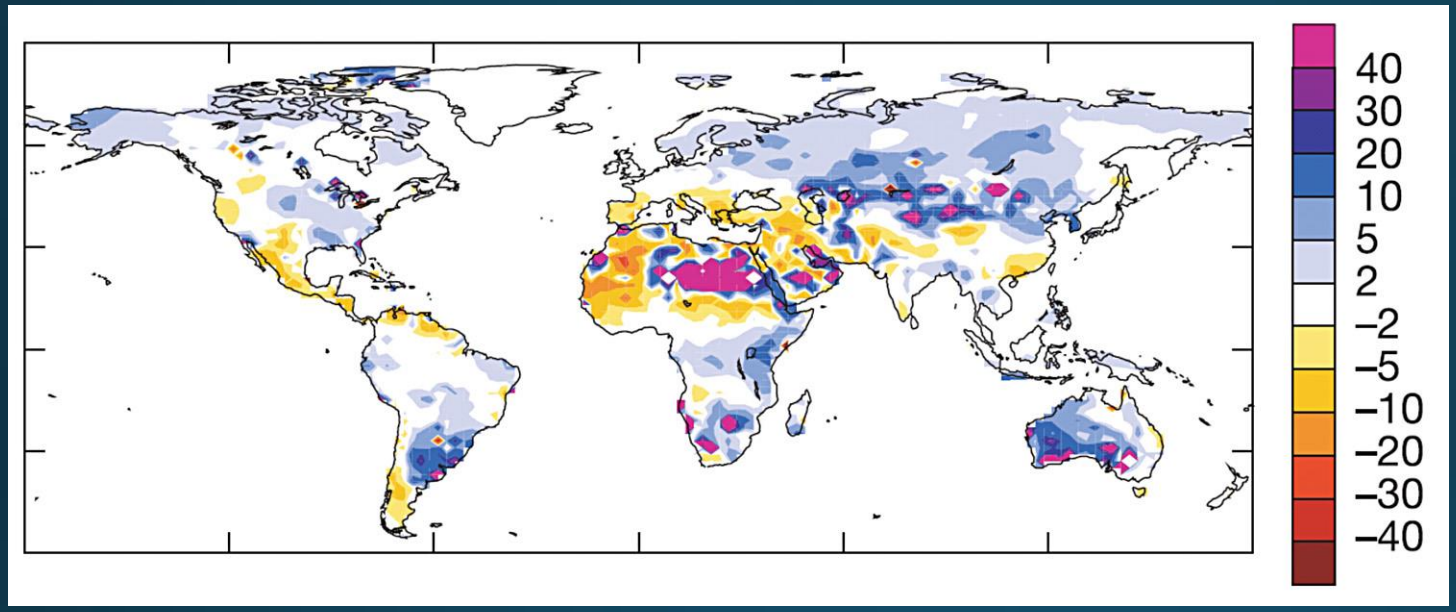
Keeling curve: CO_2 rise & importance of monitoring



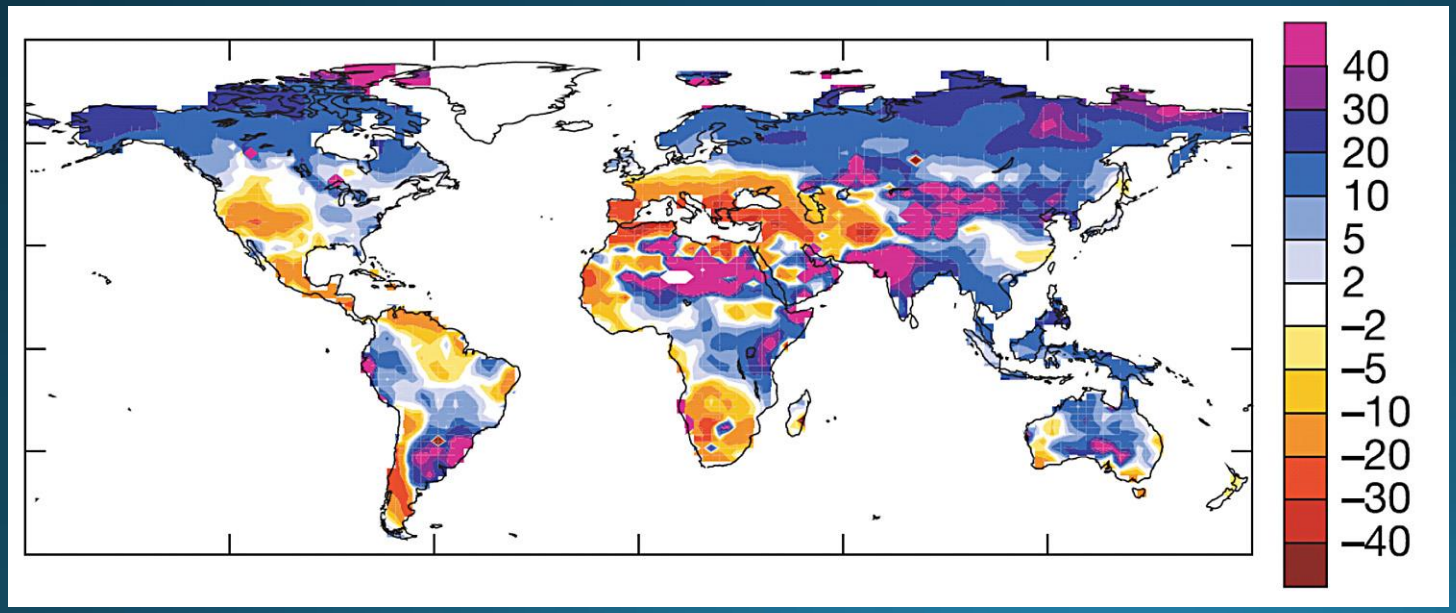
http://www.esrl.noaa.gov/gmd/ccgg/trends/

C.D. Keeling, R.B. Bacastow, A.E. Bainbridge, C.A. Ekdahl, P.R. Guenther, and L.S. Waterman, Atmospheric carbon dioxide variations at Mauna Loa Observatory, Hawaii, Tellus, vol. 28, 538-551, 1976

Relative change in surface runoff (%)



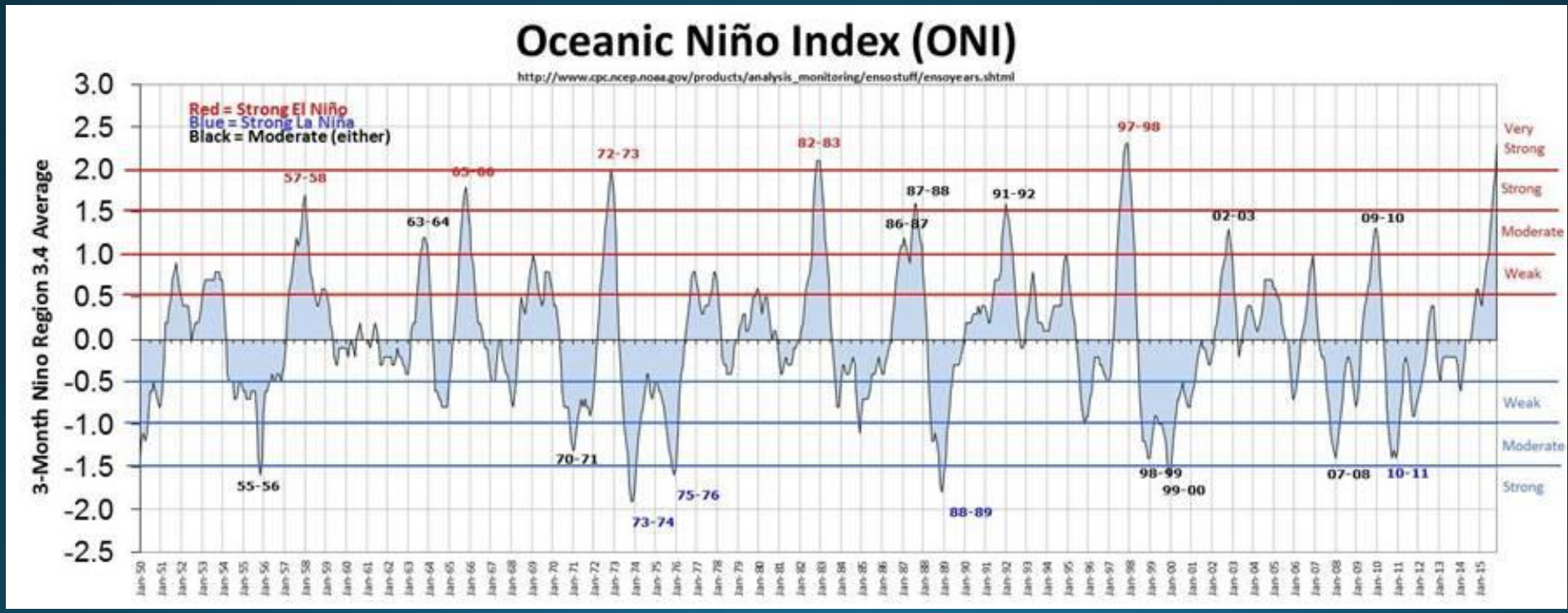
20th Century



21st Century

(Milly, Dunne, and Vecchia, *Nature,* 2005)

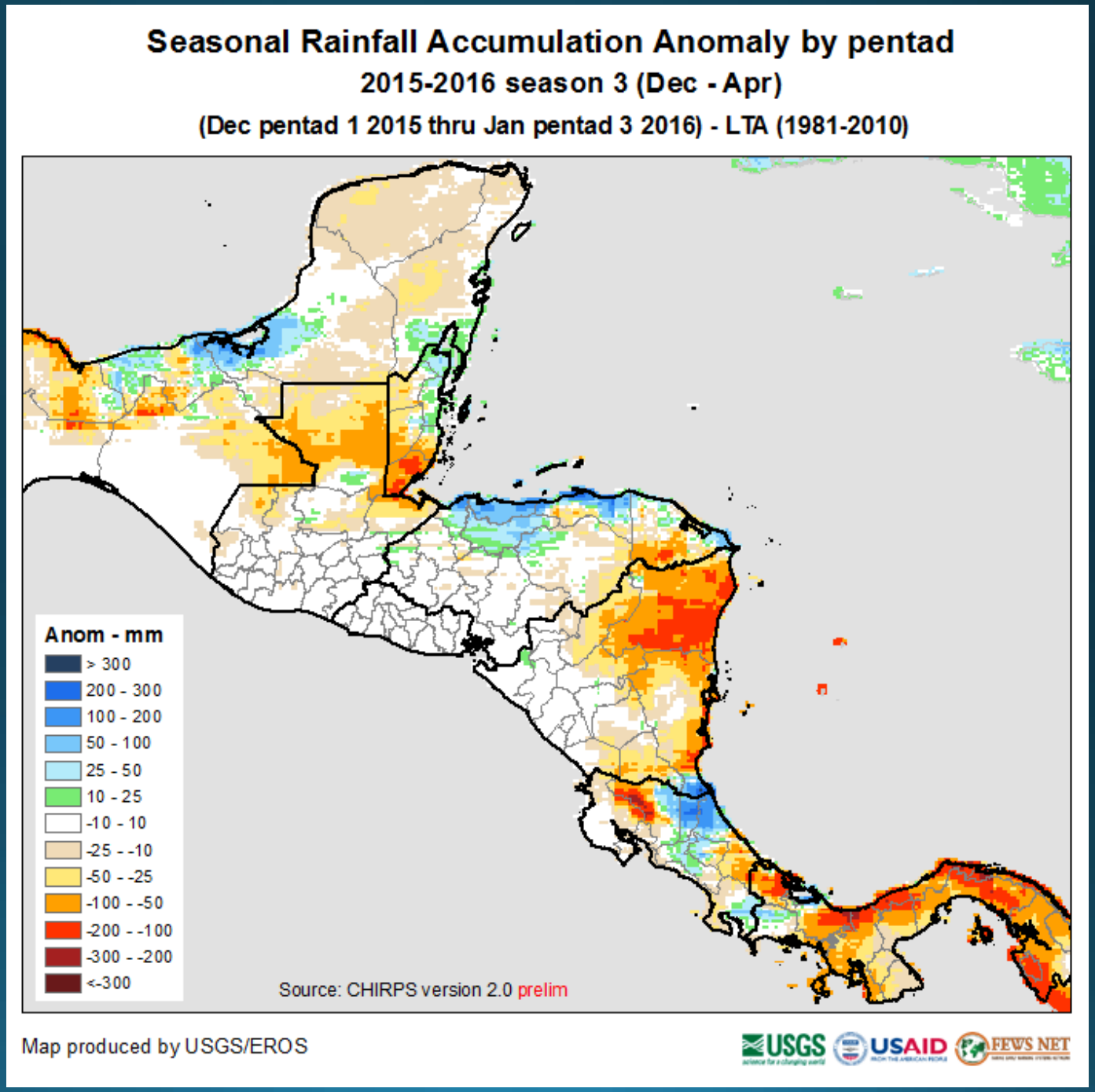
Climatic uncertainty and synoptic systems impact water resources and temperature



Rainfall

Central America

December 2015 to January 2016



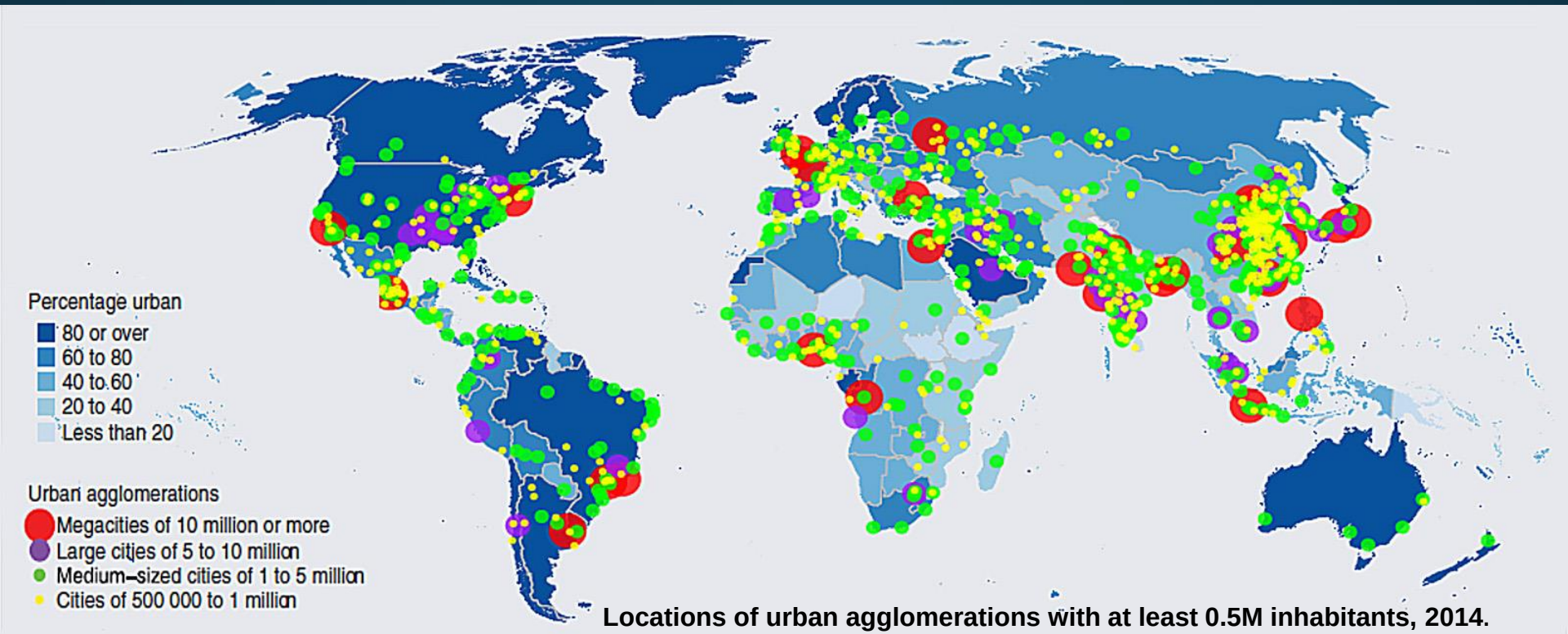
Global population expansion and urbanization

- > 50% of world population lives in urban areas

- urban areas expected to absorb all population growth in next 40 years

- 23 megacities with 10+ M inhabitants; all but six in developing world

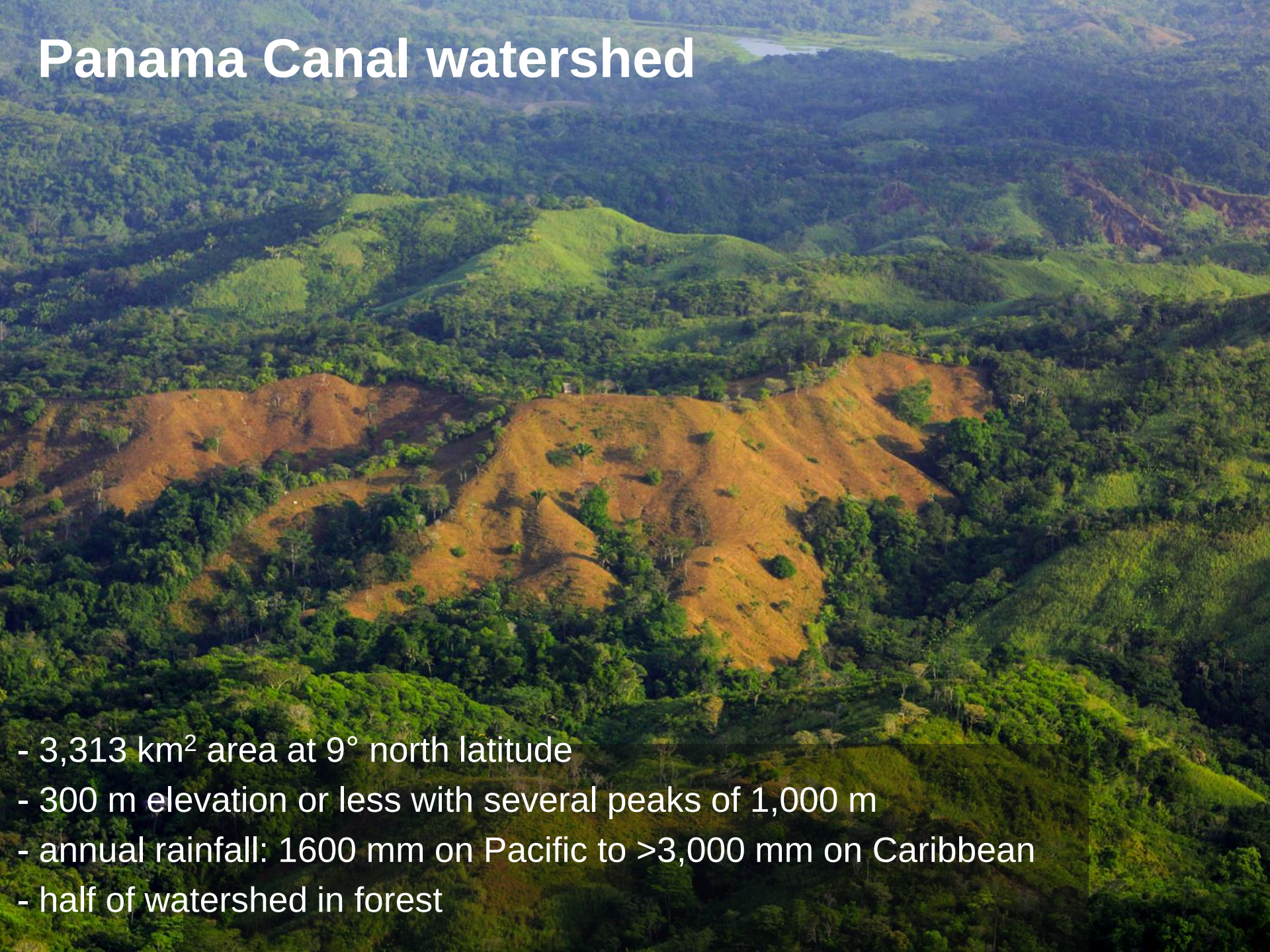
- more people now at risk as megacities encroach on riparian corridors, floodplains, mountain fronts, and coastlines



Locations of urban agglomerations with at least 0.5M inhabitants, 2014.

Source: United Nations, 2014.

Panama Canal watershed



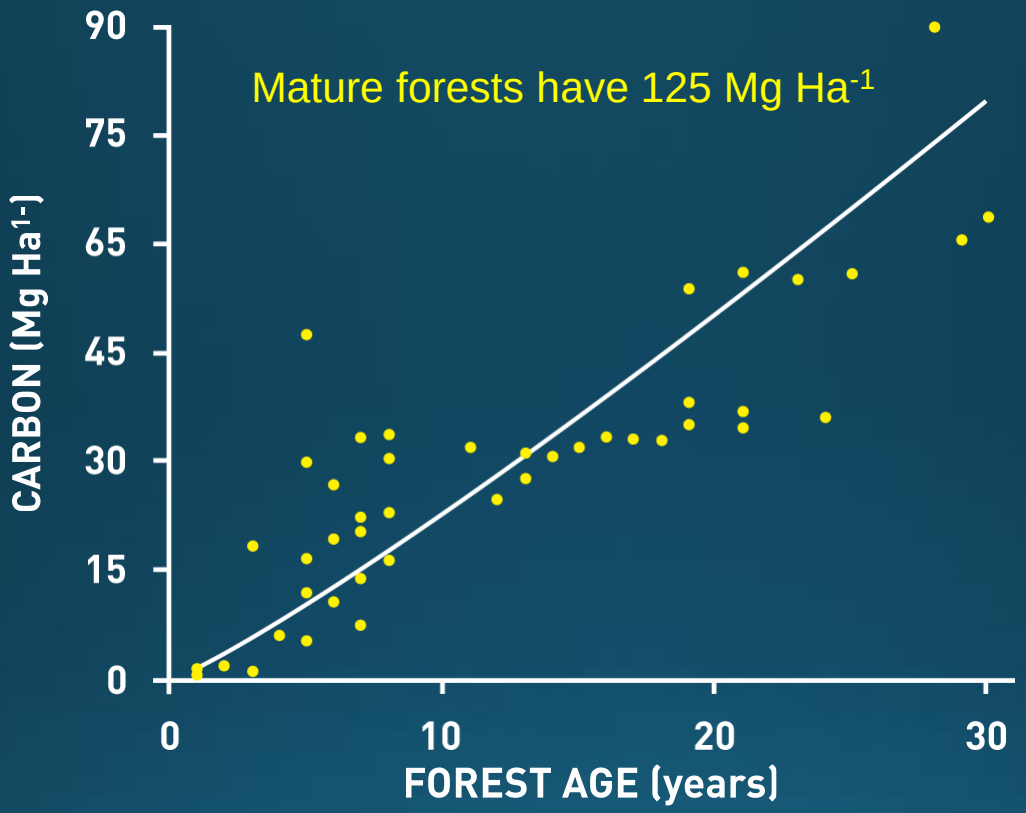
- 3,313 km^2 area at 9° north latitude
- 300 m elevation or less with several peaks of 1,000 m
- annual rainfall: 1600 mm on Pacific to >3,000 mm on Caribbean
- half of watershed in forest

Panama Canal watershed: ecosystem services

- multiple high-value services with national, regional, and global significance
- shipping
- recreation, biodiversity, carbon sequestration
- water most important control

- streamflow: 4.4 km^3, with 2.6 km^3 lockages of vessels (59%) $2B/y
- hydroelectric power: 1.2 km^3 (27%) $246M/y
- drinking water supply 0.27 km^3 (6%) $29M/y
- balance, 7%, lost to evaporation & groundwater infiltration

Carbon sequestration, secondary forests, Panamá

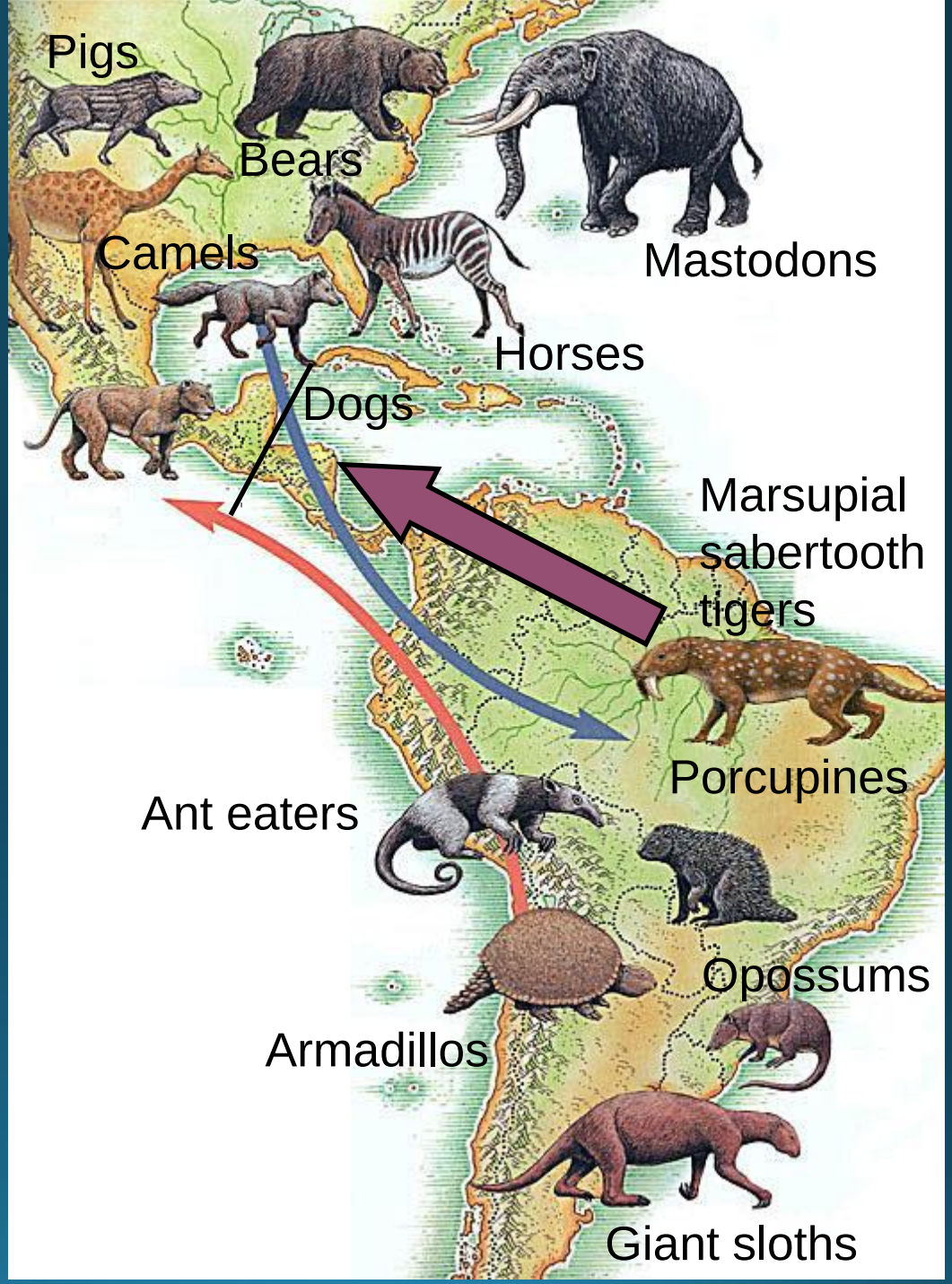


Biotic Interchange

- joining of two continents

- began as isthmus closed, starting as long ago as ~10M y ago

- full closure of isthmus at ~3.5M y ago



Mammals at present

but, wait, there's more:
other interchanges in progress

- Coyotes (*Canis latrans)* moving southward from Mexico

- Crab-eating Fox, (*Cerdocyon thous*) moving northward from Colombia & Venezuela

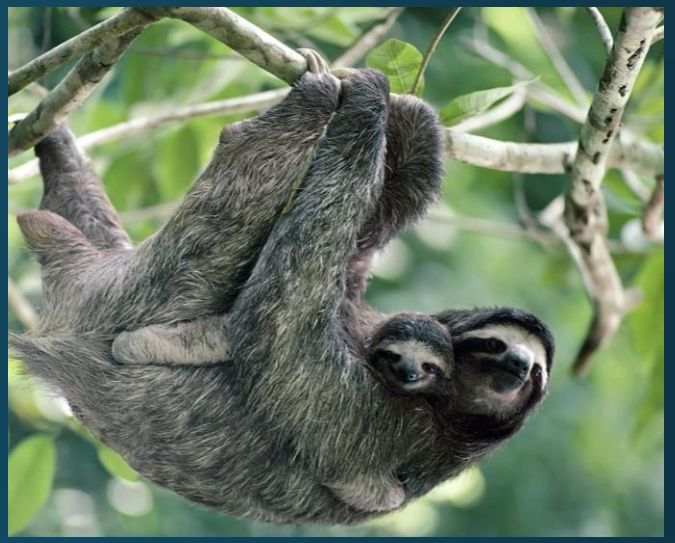
Three species survive from South

Porcupine
Possum
Armadillo

60% of mammals are from North

Forests in Panamá: rich in biodiversity

Known unknowns and importance of maintaining biodiversity



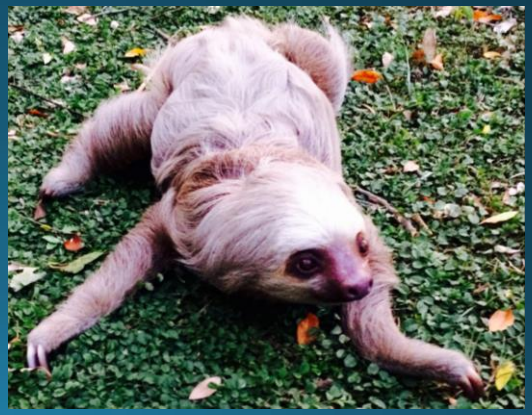
- Sloths carry wide variety of micro- and macro-organisms on their coarse outer hair

- 84 fungi isolates obtained in culture from surface of hair collected from living three-toed sloths (*Bradypus variegatus*)

- broad range of activities against strains of parasites that cause malaria (*Plasmodium falciparum*) and Chagas disease (*Trypanosoma cruzi*), and against the human breast cancer cell line MCF-7

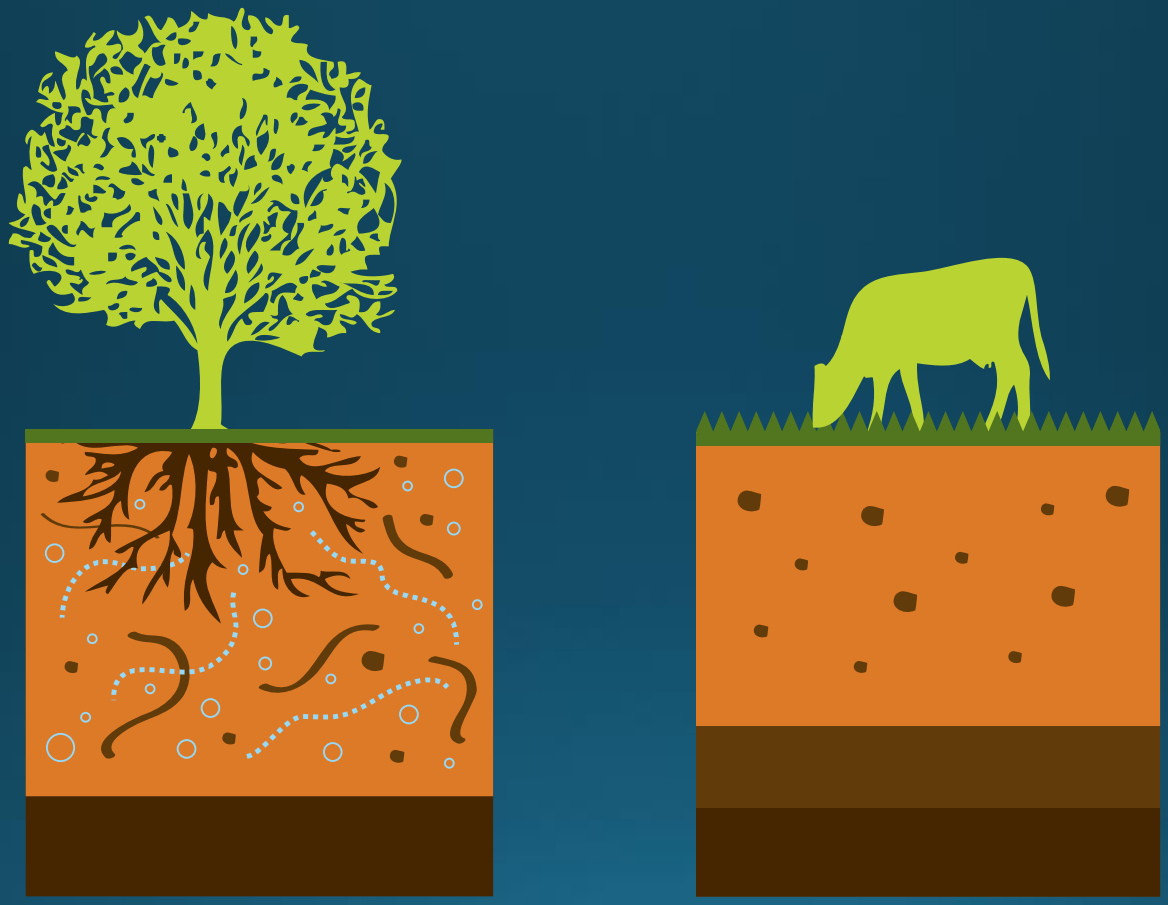
- one fungal extract had unusual pattern of bioactivity against Gram-negative bacteria--suggests a potentially new mode of action

- results reveal the importance of exploring novel environments for bioactive fungi



citation: Sloth Hair as a Novel Source of Fungi with Potent Anti-Parasitic, Anti-Cancer and Anti-Bacterial Bioactivity Sarah Higginbotham et al., PLoS One, 2014

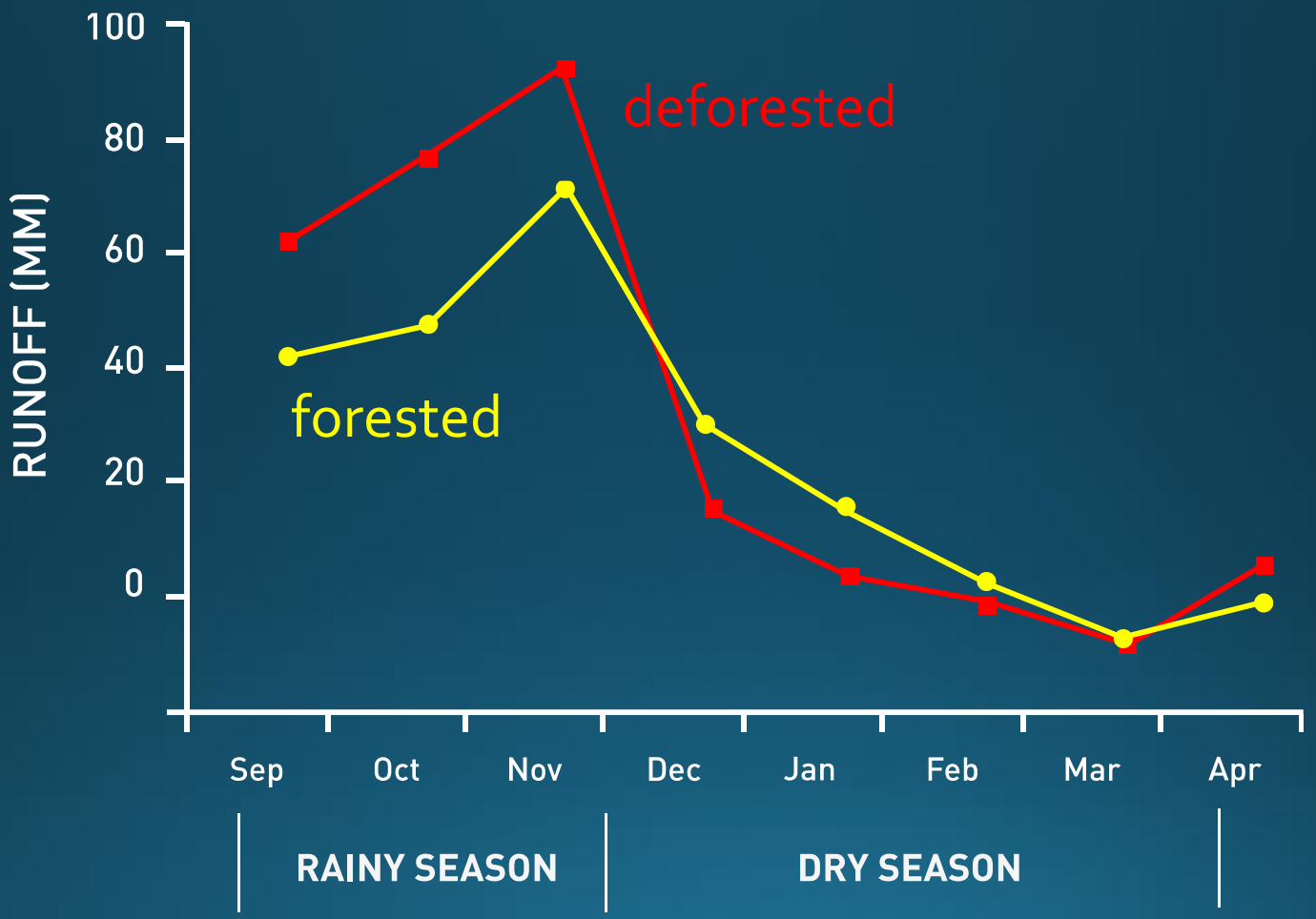
Ecosystem service and hydrology: forest soils act like a sponge



FOREST

PASTURE

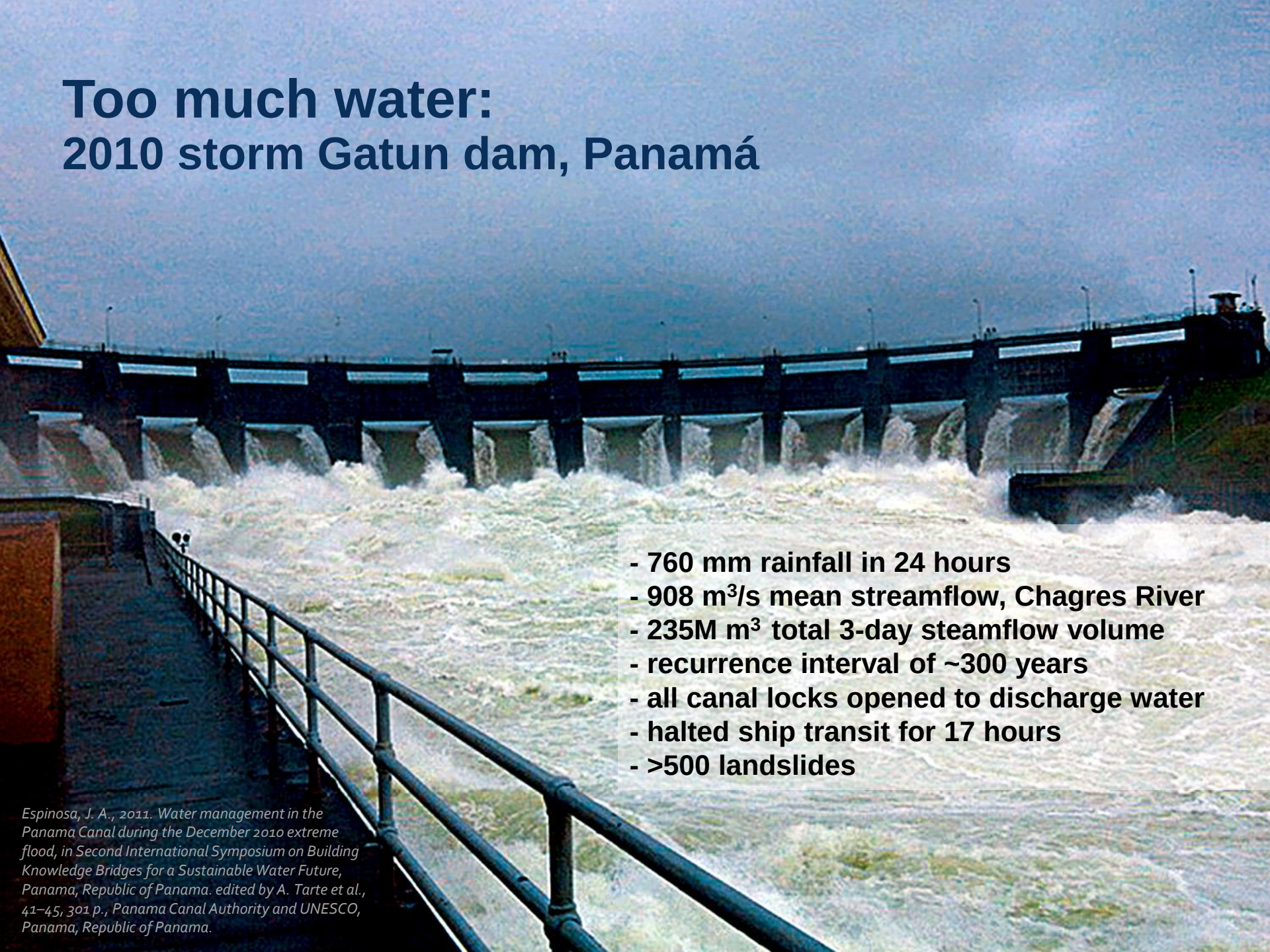
Services provided by the sponge effect:



Ogden, Crouch, Stallard, and Hall, 2013. Effect of land cover and use on dry season river runoff, runoff efficiency and peak storm runoff in the seasonal tropics of central Panama. Water Resources Research.

Too little water:
2013 drought, Lake Bayano, Panamá

Too much water:
2010 storm Gatun dam, Panamá

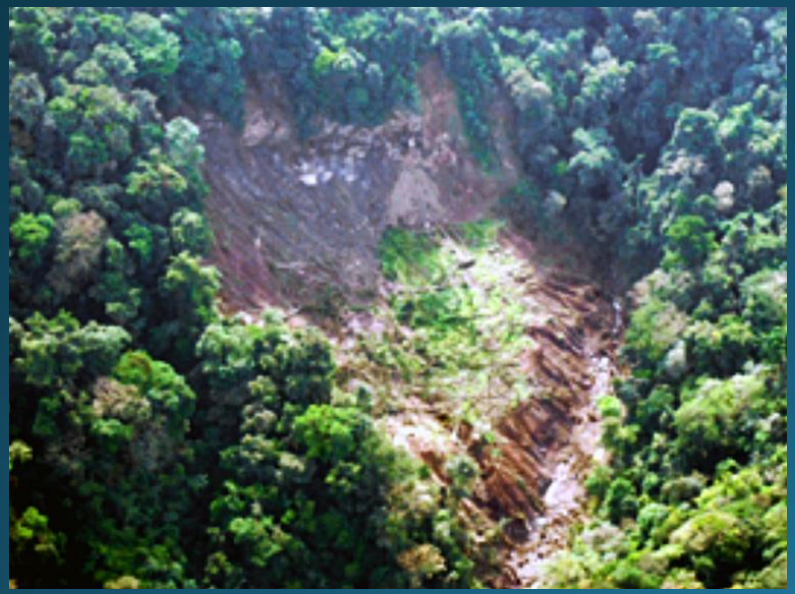


- 760 mm rainfall in 24 hours
- 908 m^3/s mean streamflow, Chagres River
- 235M m^3 total 3-day steamflow volume
- recurrence interval of ~300 years
- all canal locks opened to discharge water
- halted ship transit for 17 hours
- >500 landslides

Espinosa, J. A., 2011. Water management in the Panama Canal during the December 2010 extreme flood, in Second International Symposium on Building Knowledge Bridges for a Sustainable Water Future, Panama, Republic of Panama. edited by A. Tarte et al., 41–45, 301 p., Panama Canal Authority and UNESCO, Panama, Republic of Panama.

Panama Canal watershed:
ecosystem services and 2010 storm

- 50% of watershed is forested
- if less forest had been present, peak flows and total runoff volume would likely have exceeded maximum capacities of lock and dam designs



Landslide scars, Chagres watershed, 2010 | Photo by R.F. Stallard, USGS

Puerto Rico

- Rainfall: 1,600 mm
- Runoff: 910 mm
- >30% of island in forest (mainly broadleaf evergreen)

Puerto Rico, 1989,
after Hurricane Hugo

Puerto Rico:
Luquillo mountains & ecosystem services

19th century

- wood products and charcoal

20th & 21st century

- water
- recreation
- carbon sequestration
- biodiversity

Luquillo mountains

Rio Mameyes

Puerto Rico:
Luquillo mountains & ecosystem services

- public-supply water drawn from 34 locations along nine rivers
- 70% of streamflow diverted before reaching ocean
- most from two intakes:
  Río Mameyes 18,940 m^3/day
  Río Fajardo 45,460 m^3/day
- total of 0.252M m^3/day of water withdrawn from streams
- at $1.06 per m^3 for residential customers, value is ~$270,000/d
- $32,000/d in hydroelectric energy
- recreational use: >1M visitors/y, generates $3.2M/y

Puerto Rico

Ecosystem services are enhanced with good governance:

Forest cover enhances water supply & reduces hazard but not if structures are poorly located

Debris flows, Peñuelas

Debris flow deposit, Peñuelas

Barrio Mameyes, Ponce

Puerto Rico

Forest cover reduces flood hazard but rare high-magnitude storms can exceed mitigation benefit

Peak streamflow, Rio Grande de Loiza, Hurricane Hortense

Peak streamflow over Loiza Dam, Hurricane Hortense

Flood damage & sediment transport, Rio Grande de Arecibo, after Hurricane Georges

Flood damage & coastal sediment plume, Rio Grande de Arecibo, after Hurricane Georges

Sierra de Ávila, Vargas, Venezuela:

- 10º 36’ north latitude on Caribbean coast

- 2,000 m high east-west trending mountain range; peak at 2,765 m above sea level

- forested preserve established in 1958

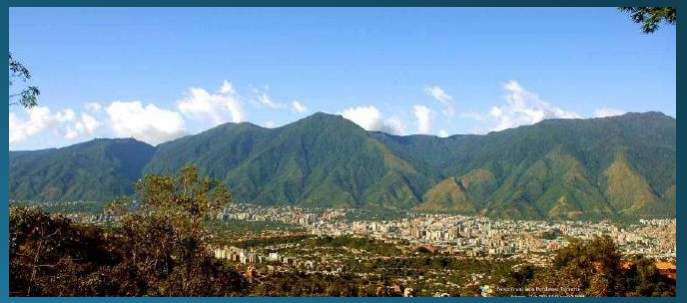
- rivers and streams mostly drain to the north; emerge from steep canyons onto alluvial fans

- rainy season May to October, 750 to 1,000 mm/y

- multiple forest types:
    - mainly evergreen forest
    - xeric and dry tropical forest in the low elevations
    - montane wet forest and sub-páramo forest at upper elevations
    - cloud forest near the mountains crests

Vargas state


Sierra de Avila, view to east


Sierra de Avila, view to north, Caracas in foreground

Sierra de Ávila, Vargas, Venezuela:
ecosystem services

- potable freshwater withdrawal limited:
  steep gradients & narrow canyons,
  few locations for water storage

- water extraction: local, low-volume
  run-of-river intakes & small impoundments

- strong seasonal rainfall variation:
  water supply unreliable

- no hydropower: streams too short

- recreation is greatest economic value:
  serves visitors & residents of Caracas, pop. 5.2M

- carbon sequestration

- maintenance of biodiversity

Stream channel with debris flow barriers, Sierra de Ávila

Sierra de Ávila, Vargas, Venezuela

Ecosystem services are enhanced with good governance:

Forest cover reduces flood & landslide hazard but not if structures are poorly located

Alluvial fans are one of the highest risk settings on earth

High density urbanization on alluvial fan

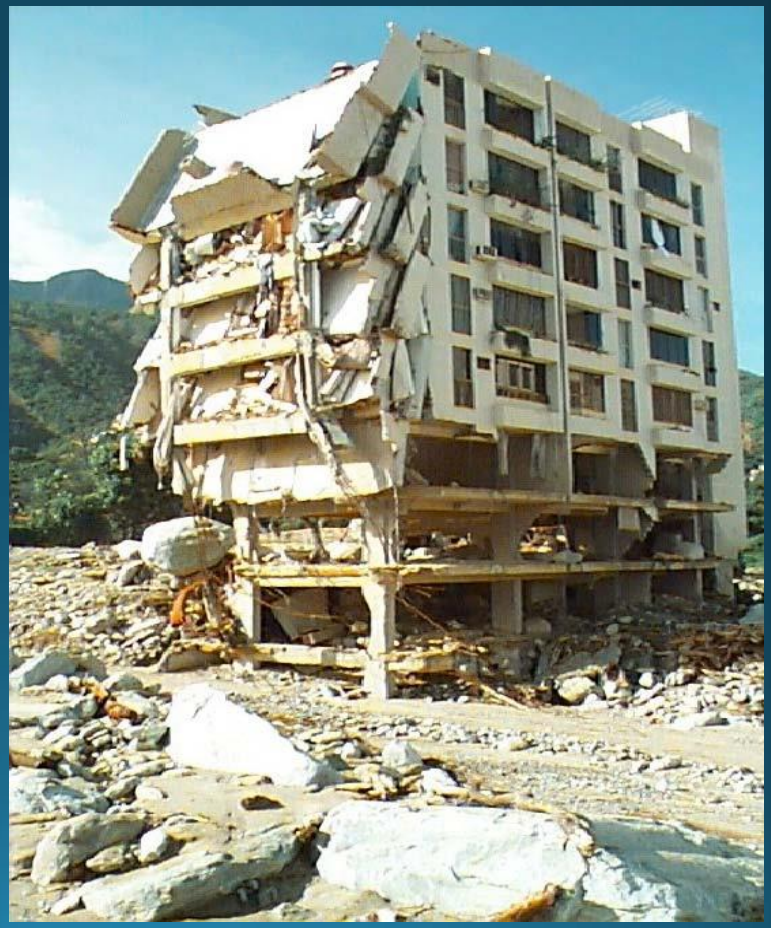
Larsen, M.C., and Wieczorek, G.F., 2006. Geomorphic effects of large debris flows and flash floods, northern Venezuela, 1999. Tropical Geomorphology with Special Reference to South America, Latrubesse, Edgardo, ed., Zeitschrift für Geomorphologie Suppl. 145, p. 147-175.

Sierra de Ávila, Vargas, Venezuela

Ecosystem services are enhanced with good governance:

Forest cover reduces hazard but not if structures are poorly located

Damaged high cost structures in path of large debris flows



Sierra de Ávila, Vargas, Venezuela

View to west, 100’s of landslide scars, extensive urbanization in vulnerable locations

Discussion: challenges to ecosystem services

Governance:

Mountains and rivers are transboundary, crossing political and cultural divisions

Management of ecosystem services is dependent on local stakeholders & strong governance, regional and national institutions, and international institutions

Zoning, planning, and enforcement assure that maximum benefits available

Climate change:

The IPCC Fifth Assessment Report (2014): climate change has begun to affect the frequency, intensity, and length of extreme events, thus increasing the need for adaptation

Weather and climate are highly stochastic: timing and amount of precipitation needed for water resources is increasingly uncertain

What can be done?

Combination of mitigation & adaptation

Will we effectively adapt to and mitigate the human-induced management and climate-change challenges we face?

Do we have the political will and social cohesion to make the necessary costly investment? in:

- Modifying our management of water, energy, and other systems

- Making water, land, & environmental resources, and agricultural production sustainable and resilient

- Helping vulnerable communities adapt

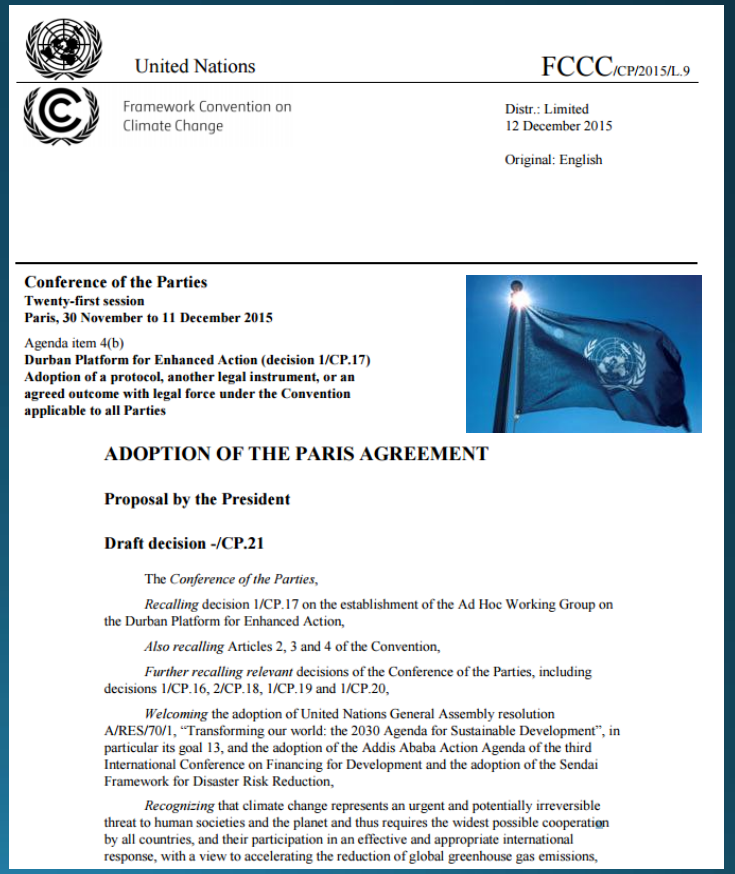
2015, the end of denial?

The New York Times

Pope Francis, in Sweeping Encyclical, Calls for Swift Action on Climate Change

By JIM YARDLEY and LAURIE GOODSTEIN JUNE 18, 2015

ENCYCLICAL LETTER
LAUDATO SI'
OF THE HOLY FATHER
FRANCIS
ON CARE FOR OUR COMMON HOME



United Nations

Framework Convention on Climate Change

FCCC/CP/2015/L.9

Distr.: Limited
12 December 2015

Original: English

Conference of the Parties
Twenty-first session
Paris, 30 November to 11 December 2015

Agenda item 4(b)
Durban Platform for Enhanced Action (decision 1/CP.17)
Adoption of a protocol, another legal instrument, or an agreed outcome with legal force under the Convention applicable to all Parties

ADOPTION OF THE PARIS AGREEMENT

Proposal by the President

Draft decision -/CP.21

The *Conference of the Parties*,

Recalling decision 1/CP.17 on the establishment of the Ad Hoc Working Group on the Durban Platform for Enhanced Action,

Also recalling Articles 2, 3 and 4 of the Convention,

Further recalling relevant decisions of the Conference of the Parties, including decisions 1/CP.16, 2/CP.18, 1/CP.19 and 1/CP.20,

Welcoming the adoption of United Nations General Assembly resolution A/RES/70/1, "Transforming our world: the 2030 Agenda for Sustainable Development", in particular its goal 13, and the adoption of the Addis Ababa Action Agenda of the third International Conference on Financing for Development and the adoption of the Sendai Framework for Disaster Risk Reduction,

Recognizing that climate change represents an urgent and potentially irreversible threat to human societies and the planet and thus requires the widest possible cooperation by all countries, and their participation in an effective and appropriate international response, with a view to accelerating the reduction of global greenhouse gas emissions,

At the Paris climate conference (COP21), December 2015, 195 countries adopted the first-ever universal, legally binding global climate deal.

Agreement sets out a global action plan to put the world on track to avoid dangerous climate change by limiting global warming to well below 2°C.

The agreement is due to enter into force in 2020.

Thank you

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