The Close Links Between the Biological Functioning of Amazonia and Climate

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Amazonia: a unique region, with global impacts on the hydrological cycle, carbon balance, and socioeconomical issues.

Amazonia is a key component of the Earth System.
AMAZON ECOSYSTEMS AT A GLANCE

Maintenance of global carbon cycle
- 15% of global NPP and a key carbon sink for anthropogenic CO₂
- Stores between 100 to 120 billion ton of carbon in the biomass

Powerful hydrology
- 18% of fresh water flow into the global oceans
- Amazon river discharge of 220,000 m³/s

Biodiversity richness
- > 10% of species

Climate stabilization
- Key heat source for the atmosphere
- Annual rainfall = 2400 mm

Helps to maintain cultural and ethnic diversity
- Over 300 indigenous populations, language diversity
There are strong and complex links between the forest biology, and the physics and chemistry of the atmosphere.

**Natural System**

Existing Aerosol and gases

Aerosol formation and growth

Cloud Condensation Nuclei

Water Energy

Primary Organic Aerosol Emissions

Trace Gas Emissions

**The Transition**

Q Precipitation
Q Wet deposition of C, S, N
Q Temperature
Q Radiation
The Amazon basin in transition

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Agricultural expansion

Logging

Global climate change

Decreased water availability for human use, river navigation, and hydroelectric generation

Increased fire risk

Increased aerosols

Decreased regional-scale runoff

Flooding

Decreased agricultural and economic productivity

Increased respiratory disease; air traffic disruption

Reduced water availability for human use, river navigation, and hydroelectric generation
But, the reality of agricultural expansion in the Amazon is one of fire and forest destruction.
Selective logging...
Amazonia as a Complex Nonlinear Interactive System

Illustration from Anke Nölscher
Very significant increase in protected areas 1990-2013

**Protected Areas - Brazilian Amazon**

1990

- # Indigenous Lands: 54
- Area: 11 million ha
- # Protected Areas: 65
- Area: 33 million ha

**Protected Areas - Brazilian Amazon**

Contribuições do NCT-MC

2013

- # Indigenous Lands: 381
- Area: 12 million ha
- # Protected Areas: 311
- Area: 125 million ha
B A Z I
MAPABRASILEIRO DA FOLOREZA
Por munkpio eee I os

% de pessoas em situação de miséria
0 15,8 31,8 47,7 63,5 79,4 95,3

Source: IBGE (2014)
One-third of global protected land is under intense human pressure

Kendall R. Jones, Oscar Venter, Richard A. Fuller, James R. Allan, Sean L. Maxwell, Pablo Jose Negret, James E. M. Watson

Fig. 1. Human pressure within protected areas. (A) Proportion of each protected area that is subject to intense human pressure, spanning from low (blue) to high (orange) levels. (B) Kamianets-Podilskyi, a city within Podolskie Tovtry National Park, Ukraine. (C) Major roads fragment habitat within Mikumi National Park, Tanzania. (D) Agriculture and buildings within Dadohaehaesang National Park, South Korea. [Photo credits: Google Earth]
Photosynthesis: where radiation meets life

During photosynthesis, plants absorb carbon dioxide and sunlight to create fuel, glucose and other sugars for building plant structures. This process forms the foundation of the biological carbon cycle.
Global Net Primary Productivity NPP: South America is key...

Ecosystem Model Data Model Intercomparison (EMDI) project
Carbon cycling: Amazonia stores about 120 Tg C. If only a small fraction goes to or from the atmosphere, large changes in atmospheric CO2 will occur. How tropical forests processes affects carbon, water and energy fluxes?

Net carbon flux:
Today: ZERO

Tree mortality:
significant INCREASE
South American (a) temperature anomalies (°C) and (b) precipitation anomalies.


Aumento médio de temperatura esperado para o Brasil 2071-2099

Mudança na precipitação esperada para o Brasil 2071-2100

Áreas continentais se aquecem mais que áreas oceânicas

Mudanças na chuva (%) em 2071-2100 relativo a 1961-90.

Amazonia e Nordeste do Brasil AE deficiência de chuvas

Sudeste da America do Sul AE aumento nas chuvas

INPE, (RCP 8.5)
Climate models predict increasing temperature variability in poor countries

A) Boreal summer [June, July, and August (JJA)]

B) austral summer [December, January, and February (DJF)],

(C) the whole year

Relative changes of Standard Deviation of monthly temperature anomalies until the end of the 21st century. Averaged over 37 climate models

Bathiany et al., Sci. Adv. 2018;4: May 2018
Projected distribution of natural biomes for RCP 2.4, 4.5 and 8.5. Deforestation scenarios for 20%, 40% and 50% + Fire effect

We believe that the sensible course is not only to strictly curb further deforestation, but also to build back a margin of safety against the Amazon tipping point, by reducing the deforested area to less than 20%, for the commonsense reason that there is no point in discovering the precise tipping point by tipping it.

Nobre et al., PNAS, 2016
Projected reductions of 50% or more of forest cover!
‘TIPPING POINTS’ OF FOREST-CLIMATE EQUILIBRIUM IN THE AMAZON

A) Tropical forest in equilibrium with current climate
   One stable equilibrium state
   Amazon covered mostly by forests

B) Savanna state triggered by climate change and/or deforestation
   Two stable equilibrium states
   - Forests in the West
   - Savannas in the East-Southeast

C) Stability of second equilibrium state
   Savanna enhanced by increased/intensity of droughts and forest fires

Thresholds for tipping from state A to state B by \( \pm 6^\circ C \) Amazon warming or \( \pm 6 \) to \( 6^\circ C \)
- Forest fire frequency (increasing)
- Lengthening of dry season (increasing)
- Increasing climate extremes

\( \text{SGDSWHG IRP & DUGRVR DQG %RUPD, 2010; %RUPD, 1REUH DQG & DUGRVR, 2013, 1 REUH HWWO, 2015, 2016} \)
The complex soil-plant-atmosphere system

Ahmad B. Moradi
Ecological adaptation: Deep rooting in the Eastern Amazon
Hydrological cycle critical for Amazonia

Pyrocumulus clouds
Aerosol and cloud lifecycles
Amazonia is critical for water vapor transport over South America

What processes control these fluxes?
Is the Amazonian hydrological cycle intensifying?

Maximum monthly, annual mean and minimum monthly mean Amazon river discharge at Óbidos and in green maximum and minimum daily mean river \( \delta^{18}O \) in precipitation in Bolivia derived from tree rings (Brienen et al. 2012) and (c) tropical Atlantic sea surface temperature from Extended reconstructed sea surface temperature) (Gloor et al. 2013).
Média: 27,87 ± 1,15 m

Média: 17,66 ± 1,83 m

Média: 10,21 ± 2,04 m

1. $\text{SQRV FDCHQGLRV LQGLFDP RKLQDG} \ H\mu\text{HPDV (129 P), VHF} \ VHLDV (<15 P) HJUDQGHV DPQWMXGHV DQXDLV (13 P), YDORH/P iLPRV HP negrito$
Recent intensification of Amazon flooding extremes driven by strengthened Walker circulation

Jonathan Barichivich1,2,*, Emanuel Gloor3, Philippe Peylin1, Roel J. W. Brienen5, Jochen Schöngart1, Juan Carlos Espinoza7, Kanhu C. Pattanayak

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Adv. 2018;4: eaat8785
The Amazon climate system has been oscillating between two extremes in the last 13 years.

**DROUGHTS**
- 3 events (1/200)
- In the last 13 years

2005
2010
2015/16 (El Niño-related)

**FLOODS**
- 3 events (1/200)
- In the last 13 years

2009
2012
2014 (over SW Amazon)
Freshwater availability is changing worldwide

Dry season length is increasing in Amazonia

Annual time series of dry season length (DSL)

Annual time series of dry season END (DSE)

Dry season length has increased by $6.5\pm2.5$ days/decade;

Fu et al. 2013 (PNAS)
To study the effects of precipitation and how it influences other phenomena, scientists study moisture and precipitation in the atmosphere. Satellite observations cover broad areas and provide more frequent measurements that offer insights into when, where, and how much it rains or snows worldwide. Researchers from NASA's Global Modeling and Assimilation Office ran a 10-kilometer global mesoscale simulation to study the presence of water vapor and precipitation within global weather patterns. In this simulation, from May 2005 to May 2007, rainfall represented with color ranging from 0 to 15 millimeters per hour, total available water vapor, and precipitation were monitored.
Deforestation in Amazonia 1977-2017 in km² per year

Deforested area (km² per year)
Fire spots in Amazonia 1998-2017
Large scale aerosol distribution in Amazonia

- Severe health effects on the Amazonian population (about 20 million people)
- Climatic effects, with strong effects on cloud physics and radiation balance.
- Changes in carbon uptake and ecosystem functioning
Aerosol emissions make the high variability visible – it also applies to aerosol composition and the trace gases!
All non linear processes
Convective clouds: Key for radiation balance and precipitation
Relationship between aerosols and precipitation in the La Plata Basin

AERONET (Aerosols) + TRMM (Precipitation) + BRAMS (simulations)

Reduction in precipitation with increase in aerosols

BRAMS: Simulations with cloud microphysics confirm the measurements

Silva Dias et al., 2014
Regional dry-season climate changes due to three decades of Amazonian deforestation

Emergence of the southeast–northwest cloud and precipitation ‘dipoles’ with increasing deforestation in Rondônia

Jaya Khanna Nature climate change 2017
Conceptual overview of terrestrial carbon cycle - chemistry - climate interactions

Arneth et al., 2011

Kulmala et al., 2013
Fires increase Amazon forest productivity through increases in diffuse radiation

Rap et al., 2015

Modeled 1998–2007 mean percentage changes in (a–c) diffuse radiation, (g–i) GPP, and (j–l) NPP during the wet (defined here as December to May) season, dry (June to November) season, and August due to BBA emissions.
Air quality and human health improvements from reductions in deforestation-related fire in Brazil

C. L. Reddington¹, E. W. Butt¹, D. A. Ridley², P. Artaxo³, W. T. Morgan⁴, H. Coe⁴ and D. V. Spracklen¹* 

Dry season mean AOD retrieved by MODIS

⇒Reduction in PM2.5 may be preventing roughly 1,700 premature adult deaths annually across South America.
ACRIDICON Flights G5-HALO plane dry season 2014
How particles are produced in Amazonia?

T0 site (ATTO) (All data)
\( N: \sim 320 \, \text{cm}^{-3} \)

T0 site (ATTO) (dry season)
\( N: \sim 3100 \, \text{cm}^{-3} \)

It rains a lot. Removal very high. How the particles are formed?
HALO Plane up to 13 Km altitude
Flight AC09 - 11 Sep 2015
Clean air in Northern Amazon Basin

Andi Andreae, 2016
Biogenic organic aerosol formation at low $\text{H}_2\text{SO}_4$ happens in UT!

Condensation to new Particles

Particle Growth

Biogenic Volatiles

Boundary-Layer Aerosols

processing reduces volatility

(semi)volatile compounds

(semi)volatile compounds

Andi Andreae, 2016
Clouds as active aerosol processors in the atmosphere
Atmospheric observations at ATTO
Brazil’s NDC to the Paris Agreement calls for ecosystem restoration of 12.5 million hectares

PLANAVEG Goals (1,000 ha)

- Amazon
- Cerrado
- Pampa
- Atlantic Forest
- Caatinga
- Pantanal

12.5 million hectares
NDC of Brazil

MMA (2017) PLANAVEG, Soares-Filho et al. (2014)
SIX MAJOR TRANSFORMATIONS FOR GLOBAL SUSTAINABILITY

**Energy**
- Decarbonization, efficiency
- Energy access

**Sustainable consumption and production**
- Resource use, circular economy, sufficiency, pollution

**Food, Land Use & biosphere**
- Sustainable intensification, ocean, biodiversity, forests and water, healthy diets, nutrients

**4th Industrial Revolution**
- Artificial intelligence, big data, biotech, nanotech, autonomous systems

**Cities**
- Housing, mobility, sustainable infrastructure, water, pollution

**SDGs: Prosperity**
- Social inclusion
- Sustainability

**Human capacities & demography**
- Education, health, ageing, labor markets, gender, inequalities

**The World in 2050 Project, IASA, 2018**
Amazonia is key to global sustainability

Thanks!!!, Obrigado!!!