Overview on Deforestation and Forest Degradation in the Amazon

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INPE
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2001 2005 2008 2013 2014 2016 2018

- **2001 – B.Sc.** FAPESP — ufscar
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- **2016 – Marie Curie Advanced Research Fellow** MARIE CURIE ACTIONS — UNIVERSITY OF LEICESTER
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Fieldwork

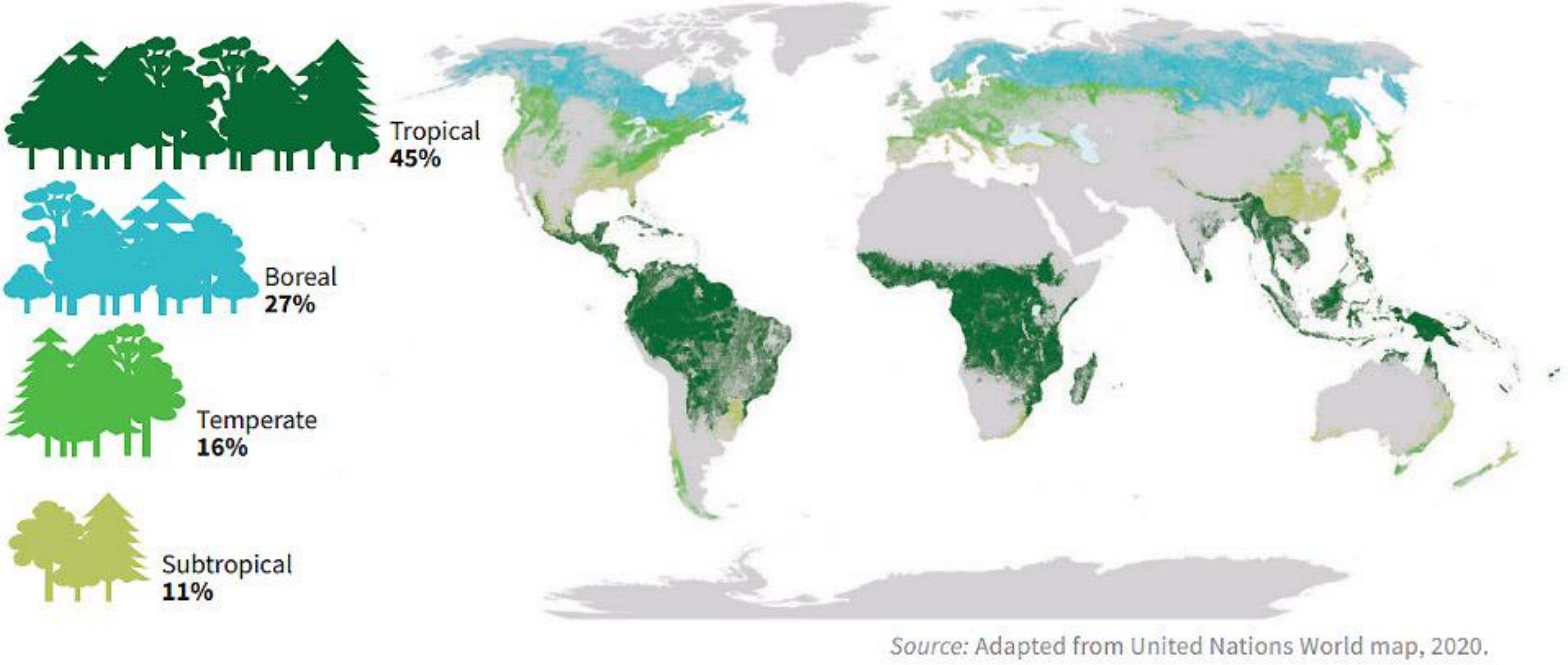
Earth Observation

Data Analyses
Machine Learning
Deep Learning

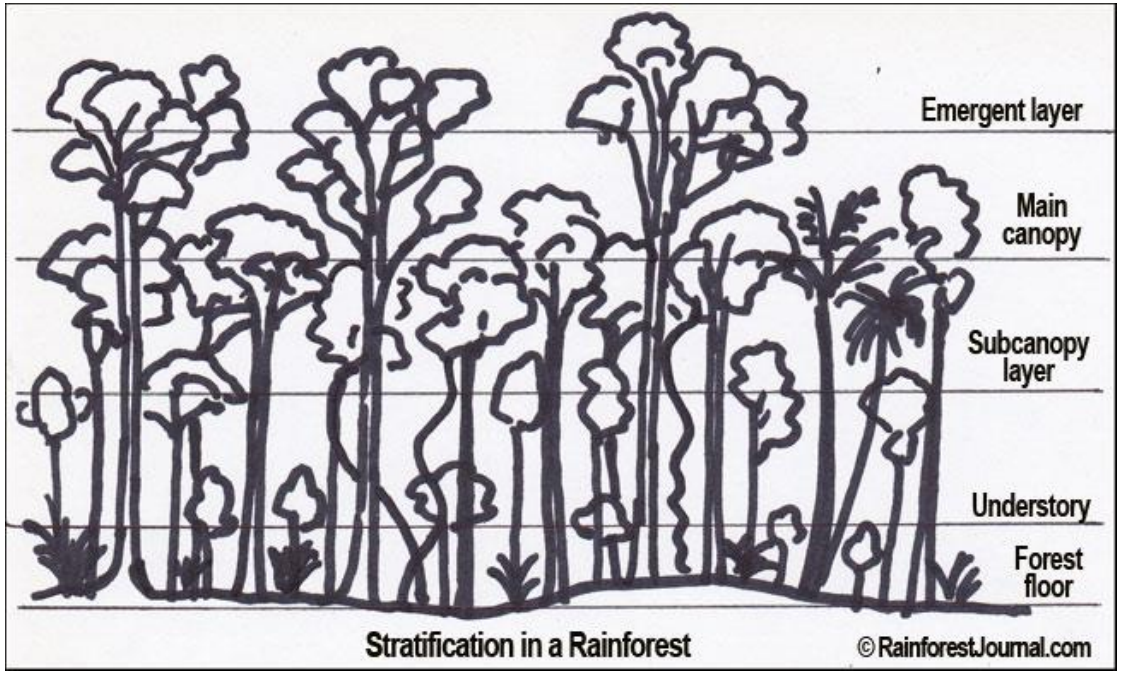
01 Biodiversity

02 Forest Structure

03 Carbon



The world has total forest cover of 4.06 billion hectares, of which 1.8 billion hectares (or 45%) is tropical forest (FAO, 2020, pp. 1)



Estimation: 1,053 species account for half of the planet's 800 billion tropical forest trees. The other half are comprised of 46,000 tree species. The number of rare species is extreme, with the rarest 39,500 species accounting for just 10% of trees (Slik et al 2015).

Earth Observation for Tropical Forest Structure Analysis and Disturbance Monitoring

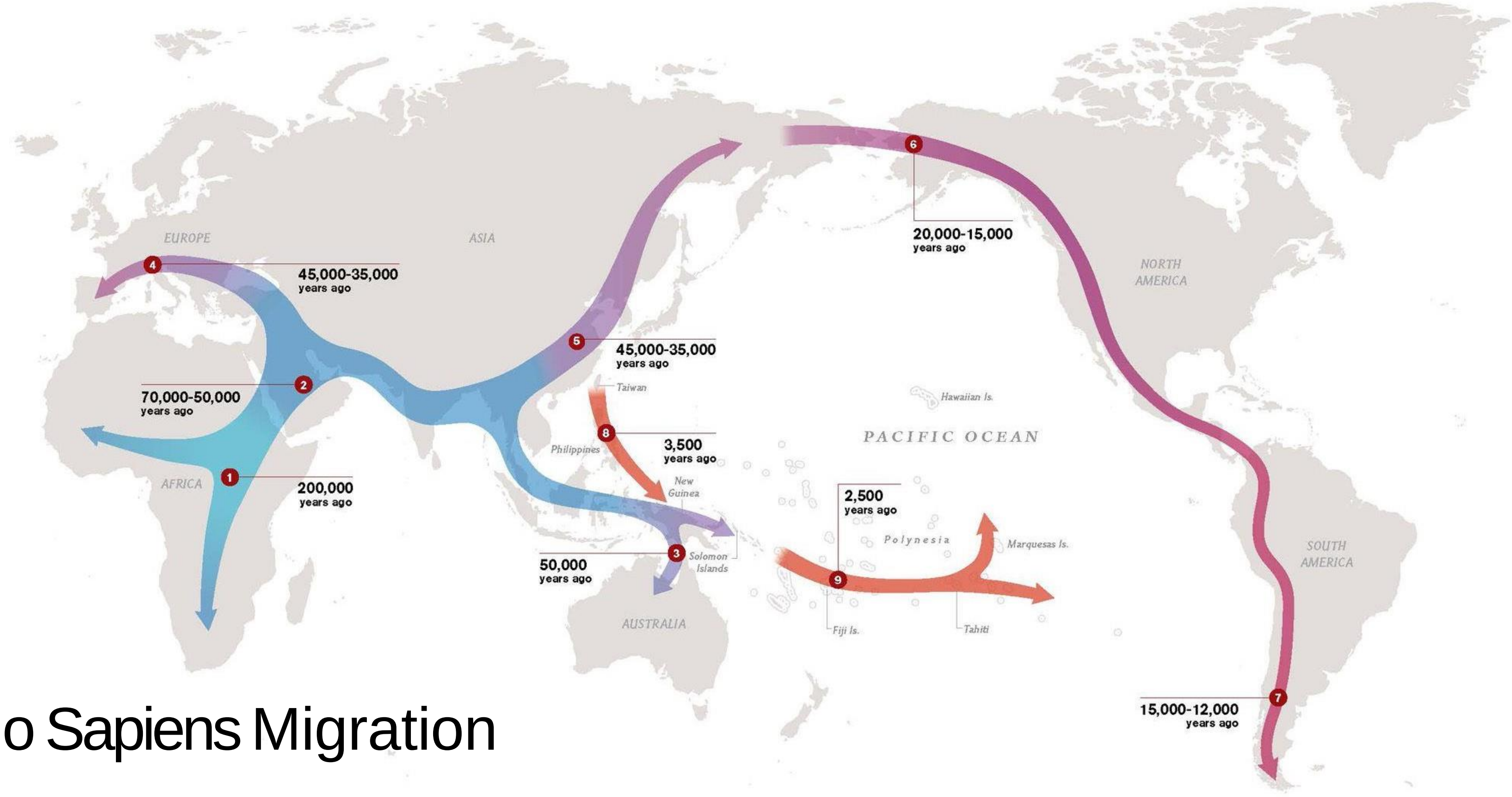
Southern frontlines: Latin America and the Caribbean

‘The Earth is crying out for help’: as fires decimate South America, smoke shrouds its skies

Members of a fire brigade work to extinguish a fire rising in Amazon rainforest in Brazil, on 8 August 2024. Photograph: Adriano Machado/ Reuters

https://www.theguardian.com/global-development/2024/oct/02/south-america-wildfire-smoke-deforestation-drought

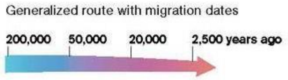
When the antropogenic disturbance start?

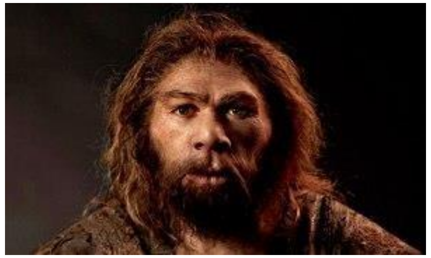


Homo Sapiens Migration

GLOBAL JOURNEY

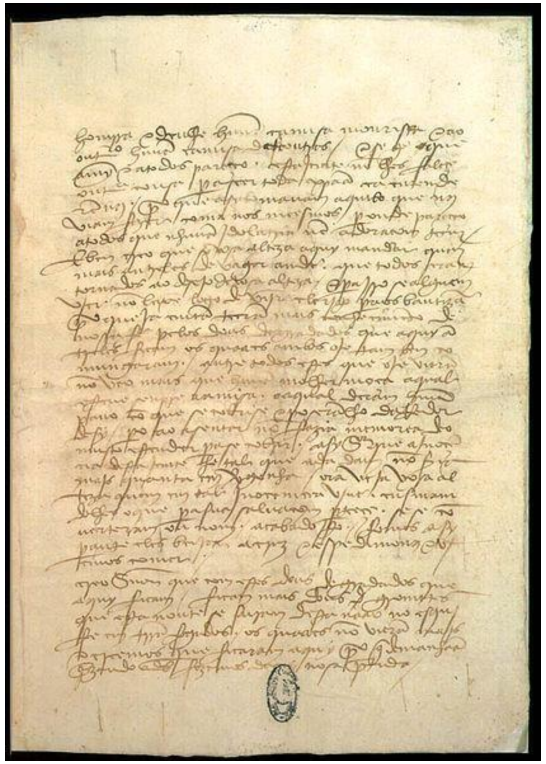
Once modern humans began their migration out of Africa some 60,000 years ago, they kept going until they had spread to all corners of the Earth. How far and fast they went depended on climate, the pressures of population, and the invention of boats and other technologies. Less tangible qualities also sped their footsteps: imagination, adaptability, and an innate curiosity about what lay over the next hill.

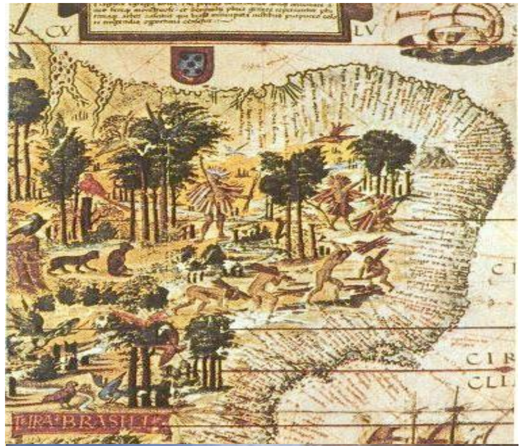


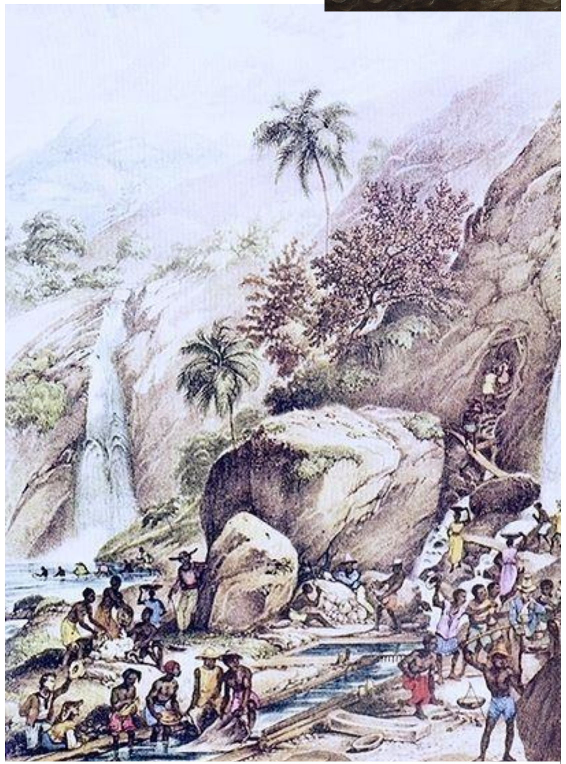


Source: https://education.nationalgeographic.org/resource/global-human-journey/

Since The Age of the Discovery the tropical forests have been explored intensely





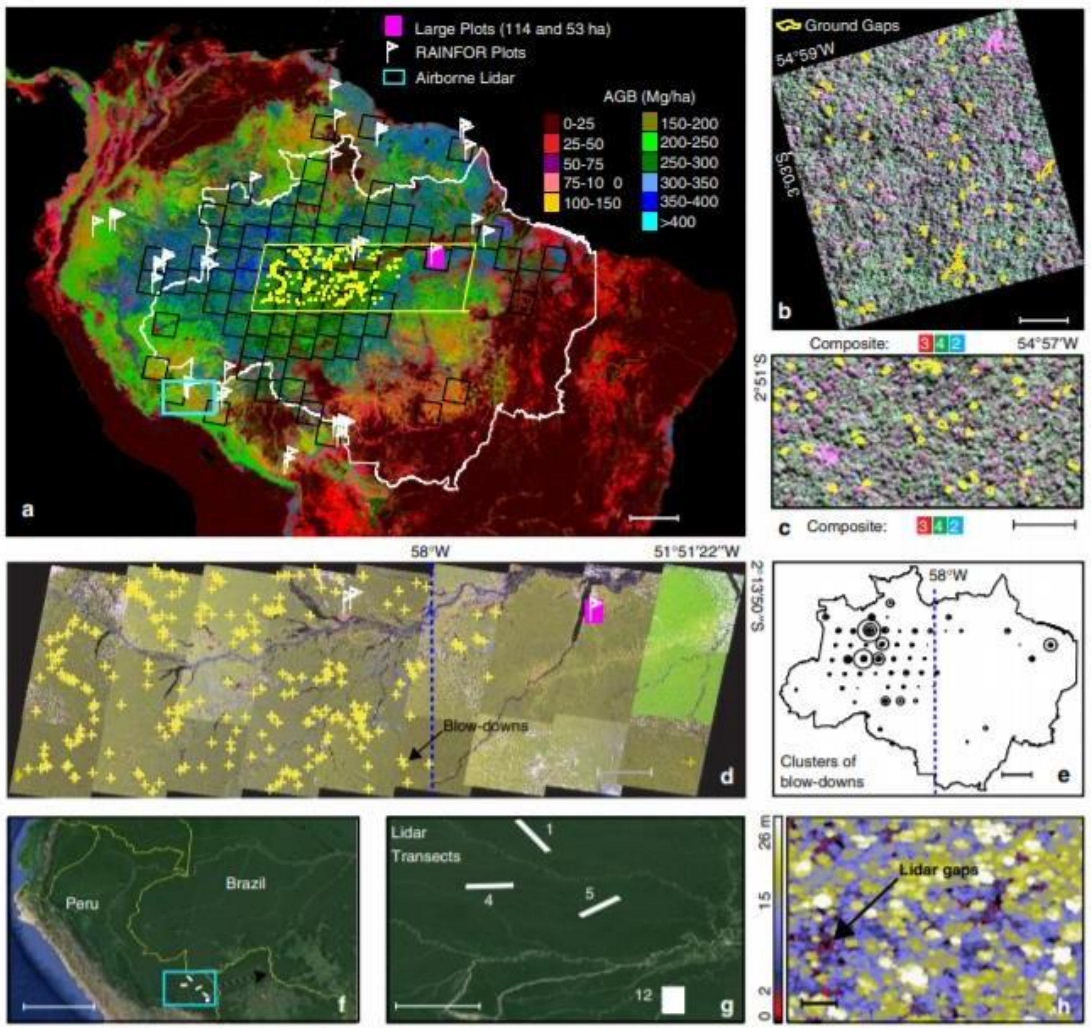


“While we were walking in this forest to cut wood, some parrots passed through these trees, green and brown, large and small, so that it seems to me that there will be many in this land.” (Pero Vaz de Caminha)

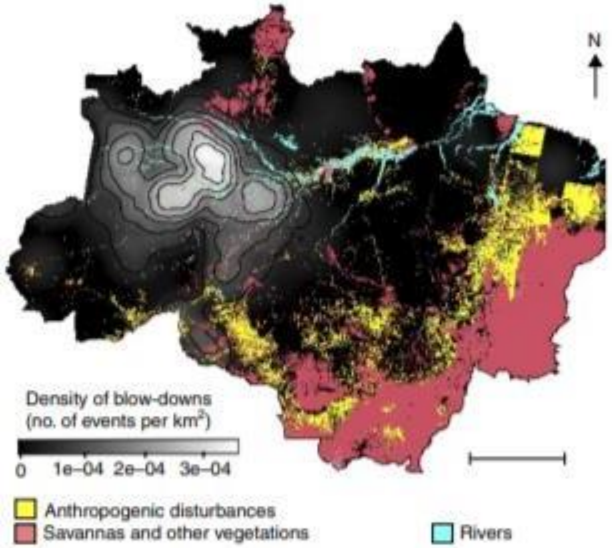

VERA TOTIVS EXPEDITIONIS NAVTICÆ

Tropical Forest: Natural and Antropogenic Disturbances

Tropical Forest Natural Disturbances



Amazon Basin-wide data of natural forest disturbances. (**a**) Spatial distribution of RAINFOR forest census plots[10] ($n = 135$), inspected Landsat images ($n = 137$) with occurrences of large blow-down disturbances ≥30 ha (ref. 26) (black boxes, $n = 330$ blow-downs) and ≥5 ha (ref. 25) (yellow dots, $n = 279$ blow-downs) underlain by an ABG map of the Amazon. White, yellow and turquoise in (**a**) indicate the Brazilian border, the mosaic of Landsat images in the Central Amazon[25] (as shown in (**d**)), and the lidar airborne campaigns in Peru[24], respectively. (**b**) Large forest inventory plot of 114 ha (ref. 23) with ground gaps (yellow polygons, $n = 55$) overlain on a high-resolution IKONOS-2 image acquired in 2008 in the Eastern Amazon. (**c**) Large plot of 53 ha (ref. 23) with ground gaps ($n = 51$) over a second high-resolution IKONOS-2 image acquired in 2009. (**d**) Digitally classified blow-downs in an East-West mosaic of Landsat images from the Central Amazon. (**e**) Representation of disturbance size areas found in all Landsat images—blow-downs disturbances ≥30 ha areas are proportional to the size of the circles. (**f**) Location of the lidar airborne campaigns in the Southern Peruvian Amazon[24] (turquoise box). (**g**) Lidar data collections in four large transects of tropical forest (48,374 ha, $n = 30,130$ gaps $\geq 20\,m^2$ in erosional *terra firme* and depositional forests). (**h**) Details of the detection of gaps in lidar canopy height model (CHM)—a 2 m height threshold was used to detect tree-fall gaps in CHM (**h**). Composite in (**b**) and (**c**) means colour compositions of IKONOS-2 image at full-width wavelength for three bands: (2) green 0.51–0.60 μm, (3) red 0.63–0.70 μm and (4) NIR 0.76–0.85 μm. Dashed blue lines in Landsat images (**d**) and central Brazilian Amazon (**e**) divides the areas with high frequency of blow-downs (≥5 ha) between 58°00′W and 66°49′W (western Amazon) and where blow-downs are infrequent in the eastern basin (51°51′W to 58°00′W). Legends of scale-bar for all areas (**a**-**h**) are 500km, 0.2km, 0.2km, 90km, 500km, 572km, 45km and 0.5 km, respectively.



Spatial distribution of large disturbances in the Brazilian Amazon.

Espírito-Santo et al. "**Size and frequency of natural forest disturbances and the Amazon forest carbon balance**." *Nature communications* 5, no. 1 (2014): 1-6.

That study investigates the role of natural forest disturbances in the Amazon on carbon balance. Key findings include:

- **Small-scale disturbances** dominate biomass loss in the Amazon, contributing about 1.28 Pg C per year, primarily from mortality events smaller than 0.1 ha, while larger blow-down events account for a much smaller portion (0.003 Pg C per year).

- **Intermediate disturbances** also contribute to carbon loss but are outweighed by biomass accumulation through tree growth, suggesting that the Amazon forest remains a carbon sink
- (**this study is from 2014**).

- Using a combination of forest inventory, airborne lidar, and satellite remote sensing, the study reveals that even when accounting for disturbances of all scales, the Amazon's carbon sink potential persists, as net biomass gain surpasses carbon losses from natural disturbances.

- This analysis supports the conclusion that large-scale disturbances are infrequent and that the Amazon's carbon balance remains positive, reaffirming its role as a significant carbon sink in the global climate system (**in 2024 Amazon is considering carbon source**)

Rainforest Recovery after Natural Disturbances

Old-growth Atlantic Rain Forest in background, with second-growth in foreground in Bahai, Brazil. (Wayt Thomas Photo)

Ecological Sucession

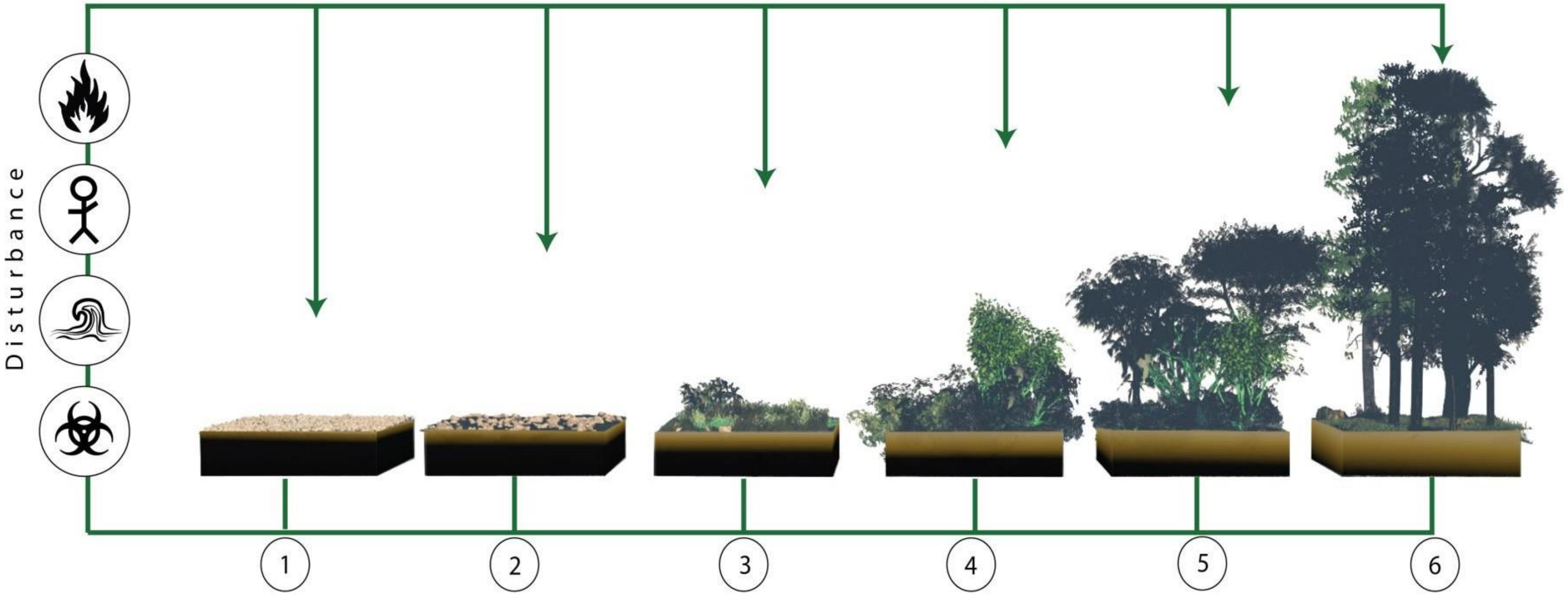
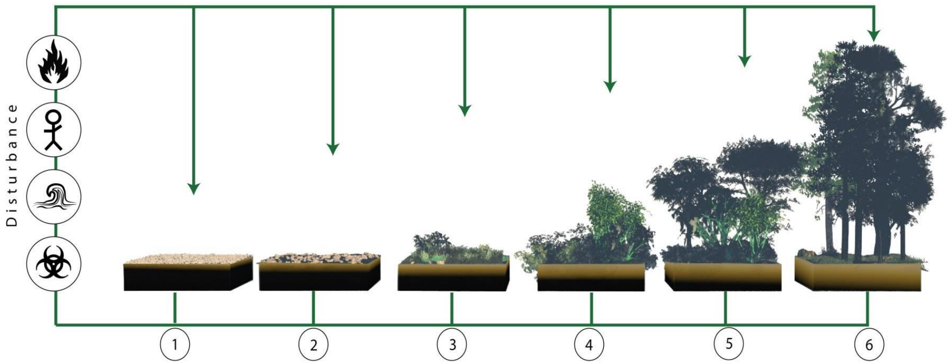
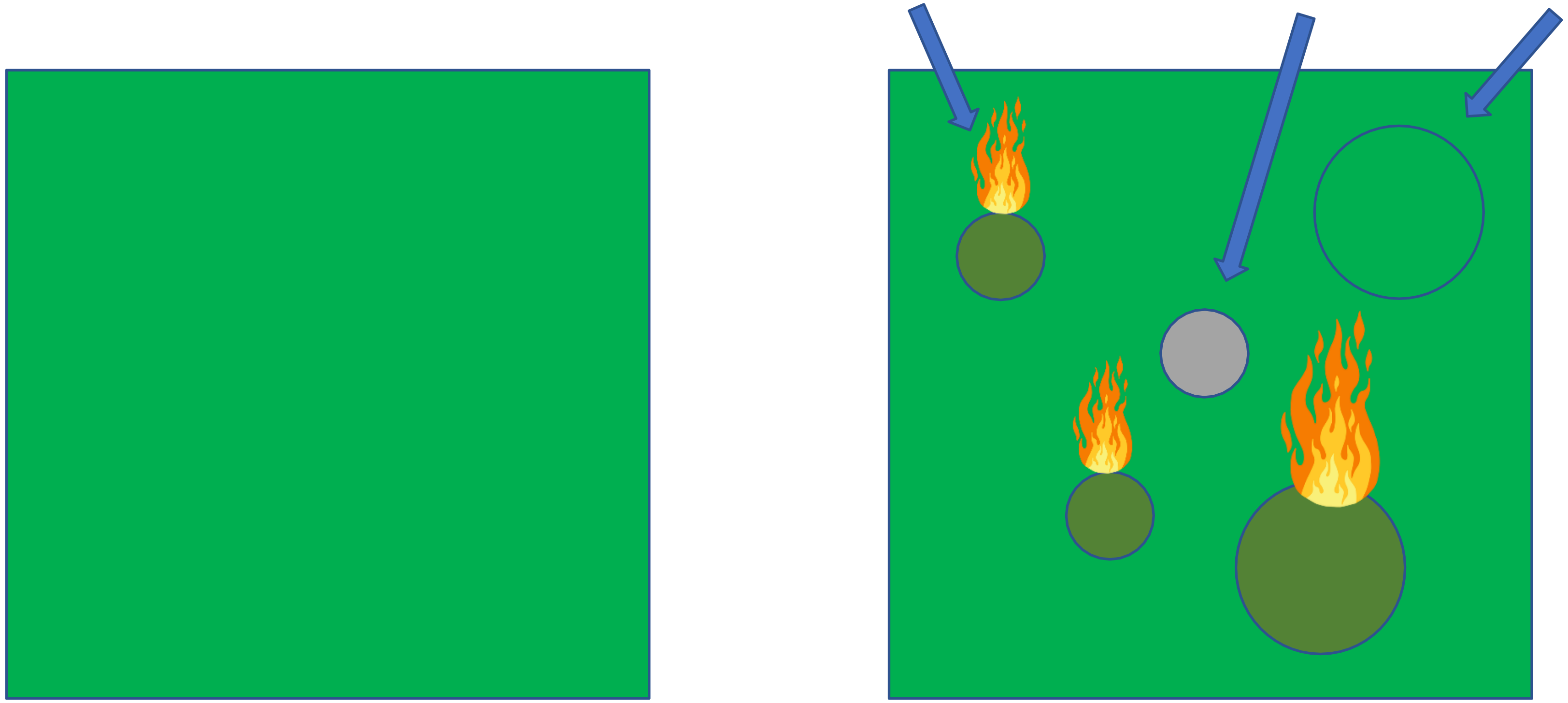


Image credit: modified from *Forest succession* by Lucas Martin Frey,

Disturbance: spatial/temporal variability

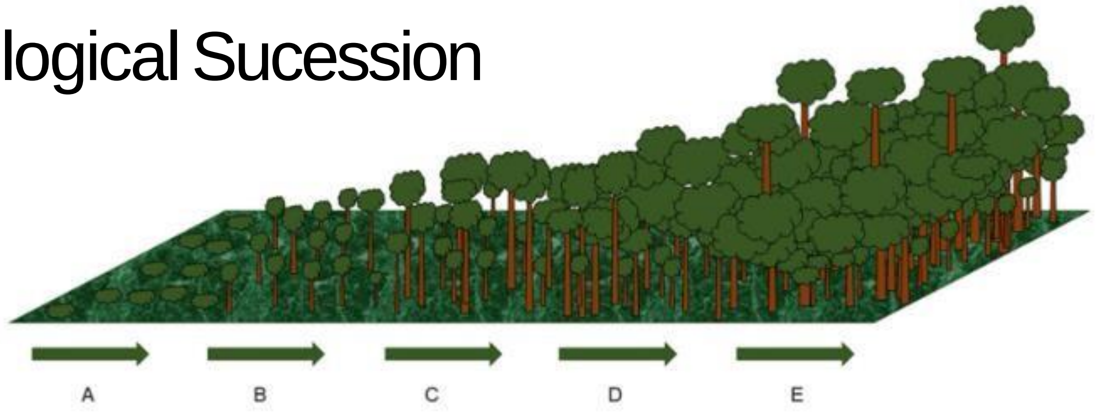




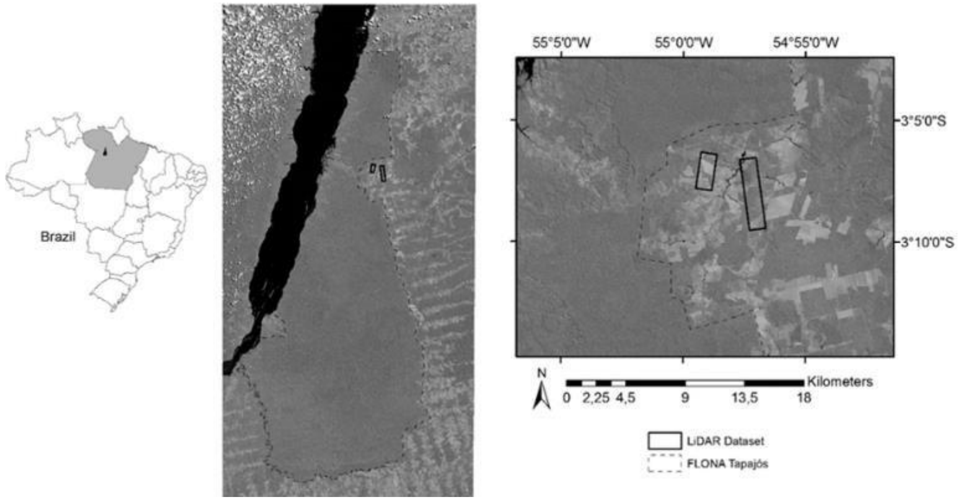
Time 1

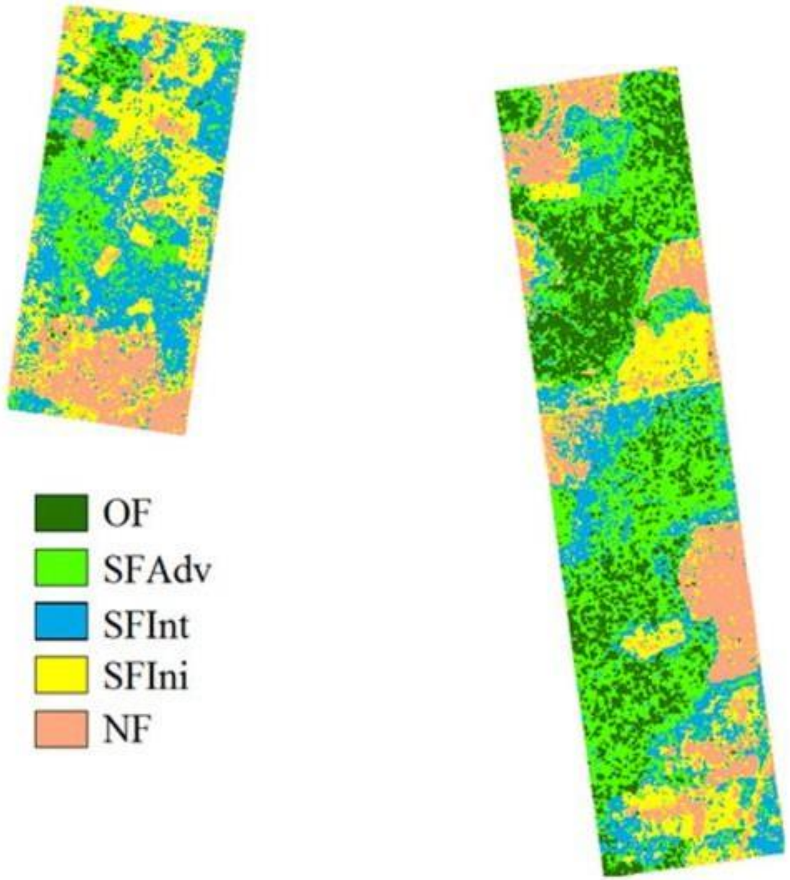
Time 2

Tropical Forest Ecological Sucession



Schematic representation of a tropical forest with different successional stages: A (non-forest); B (secondary forest in initial stage - SFIni); C (secondary forest in intermediated stage - SFInt); D (secondary forest in advanced stage - SFAdv): E (old growth forest or primary forest - OF).





Bispo et al. "**Mapping forest successional stages in the Brazilian Amazon using forest heights derived from TanDEM-X SAR interferometry**." Remote Sensing of Environment 232 (2019): 111194.

Tropical Forest Antropogenic Disturbances

Trans-Amazonian Highway, BR 230 (1972)

Tractors conduct earthwork on a stretch of the Trans-Amazonian Highway still under construction. (Photo: Folhapress) Folhapress

Tree cover loss in South America 2001-2019

Source: Global Forest Watch

BBC

Article

Amazonia as a carbon source linked to deforestation and climate change

https://doi.org/10.1038/s41586-021-03629-6

Received: 11 September 2020

Accepted: 10 May 2021

Published online: 14 July 2021

Check for updates

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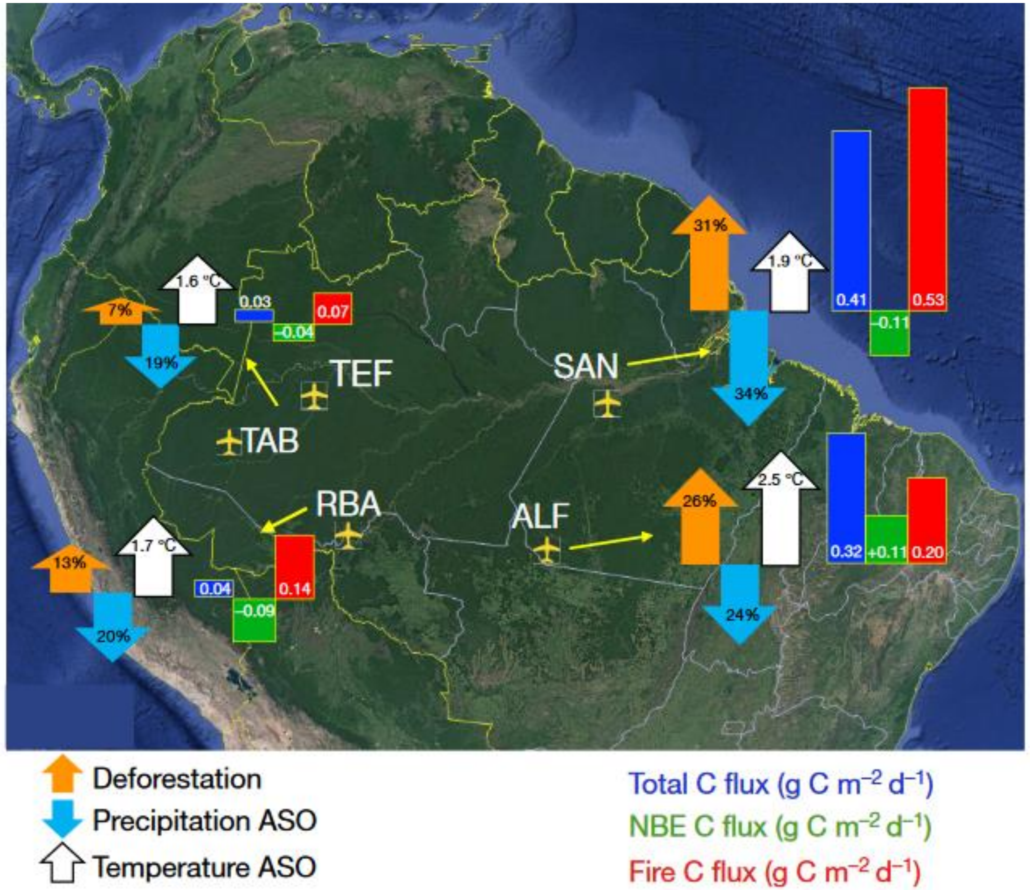


Fig. 5 | Spatial results overview. Summary of historical trends and fluxes for the regions upwind of each site: historical deforestation (orange arrows), reduction in precipitation during ASO (light blue arrows), increase in temperature in ASO (white arrows) and carbon fluxes (total, dark blue bars; NBE, green bars; fire, red bars). Base map from Google Earth (Image Landsat/Copernicus/USDSG; accessed 2020).

- This study reveals that Amazonia, particularly the eastern region, is shifting from a carbon sink to a carbon source due to intensified deforestation, increased dry-season intensity, and higher fire occurrences.

- Aircraft-based measurements from 2010 to 2018 show that southeastern Amazonia has the highest carbon emissions, exacerbated by human activities and climate trends.

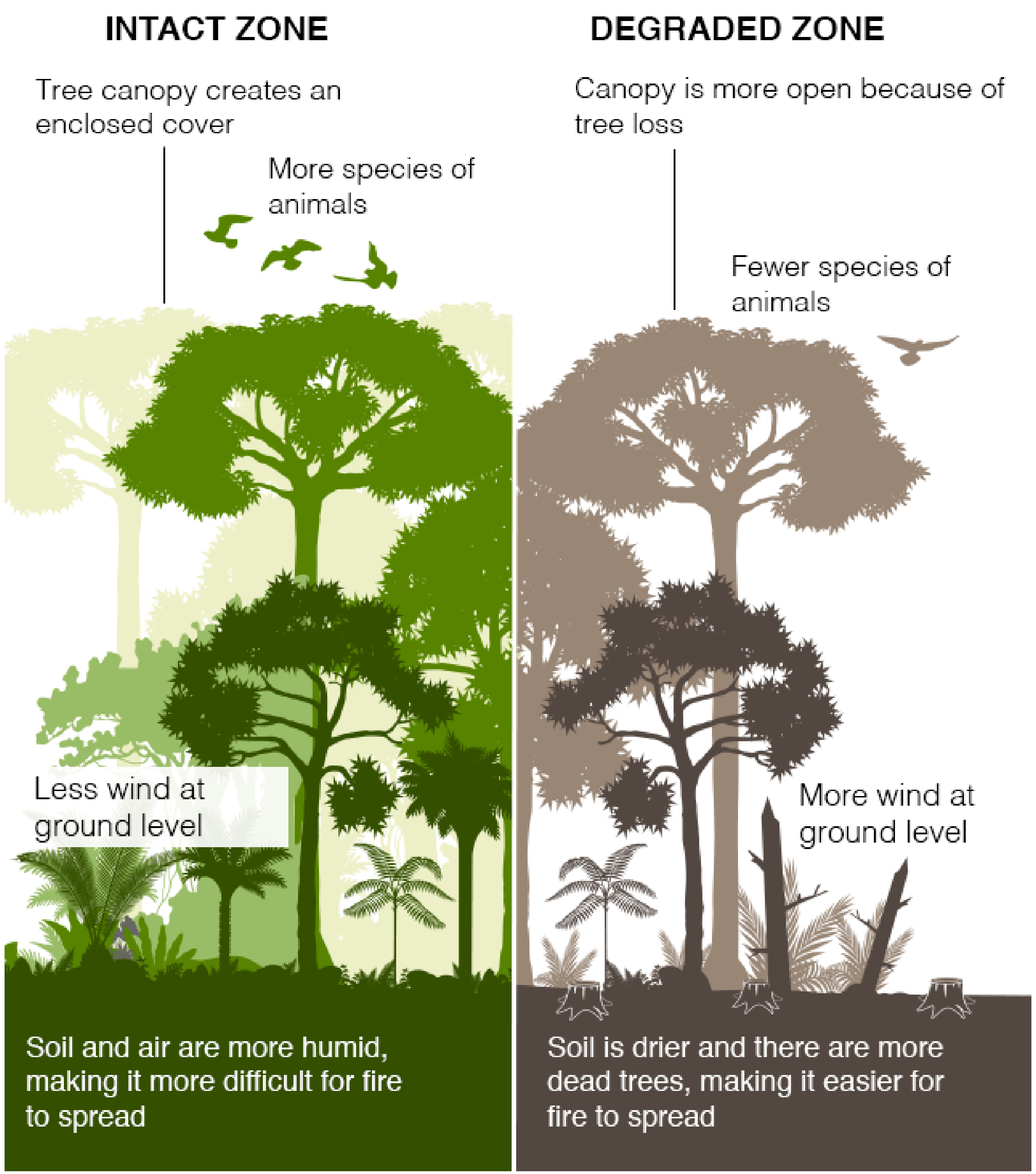
- The east, which has experienced substantial warming and moisture stress, is more prone to carbon losses, while the western Amazon remains closer to a carbon-neutral or sink state.

- These findings highlight the impact of deforestation and climate change on Amazonia’s carbon budget, indicating potential long-term implications for global climate stability.

Deforestation/ Clear Cut

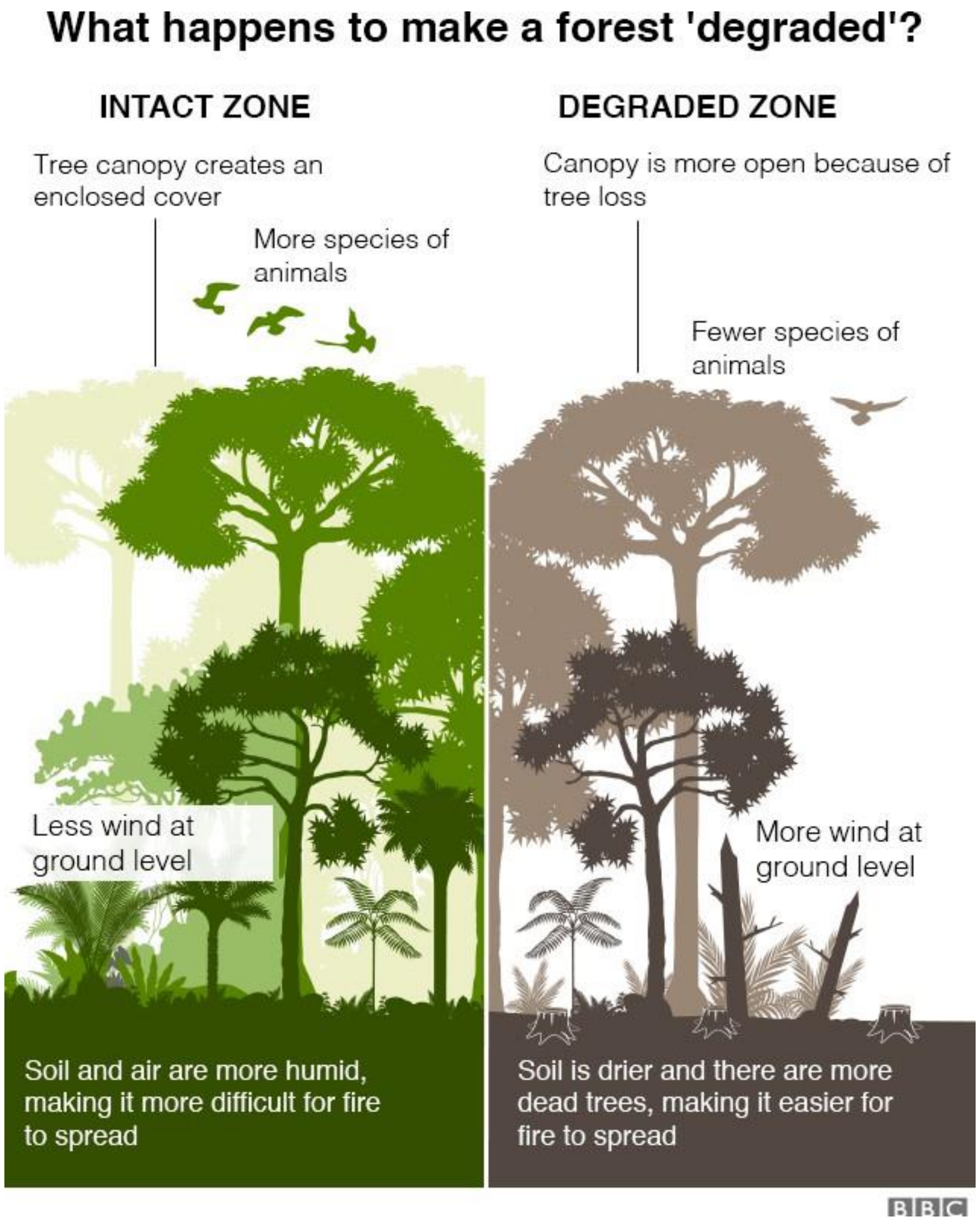
A degraded forest is the result of a process of degradation which negatively affects the structural and functional characteristics of that forest

What happens to make a forest 'degraded'?

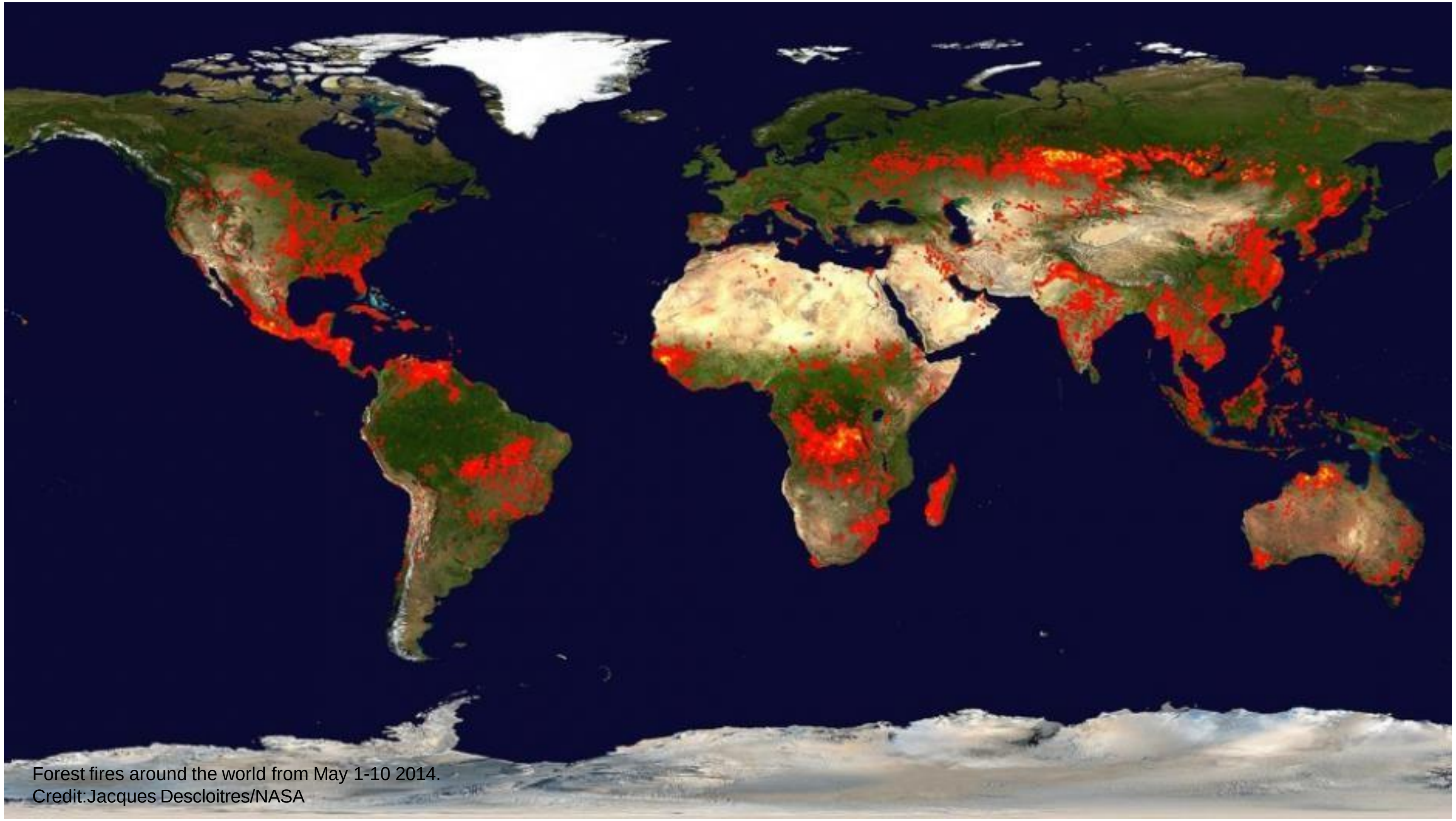


https://www.bbc.co.uk/news/science-environment-51300515 BBC

Degradation

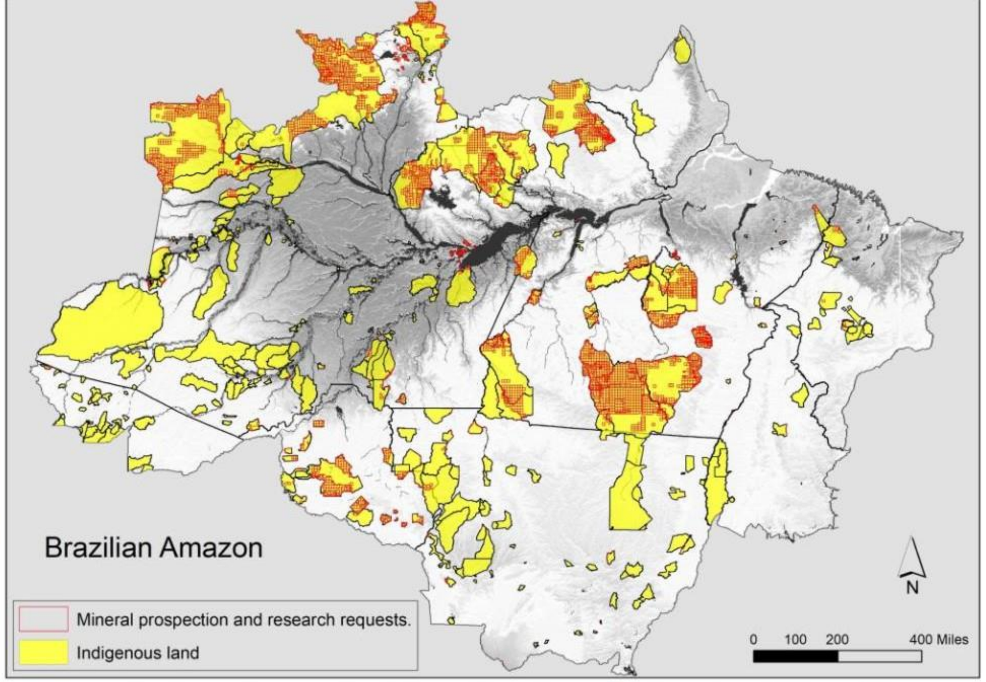




Forest fires around the world from May 1-10 2014.
Credit:Jacques Descloitres/NASA

Illegal mining in the Yanomami Indigenous Territory, in the state of Roraima. Image by Rogério Assis/ISA.



Map showing overlap of mineral concessions and indigenous lands in the Brazilian Legal Amazon. Data from the Brazilian Ministry of Environment, Funai and the Ministry of Mines and Energy.

Illegal mining in the Munduruku Indigenous Territory in the state of Pará. Image by Christian Braga/Greenpeace.

Davi Kopenawa, Yanomami leader and shaman surrounded by children, Demini, Brazil. © Fiona Watson/Survival


© Ricardo Funari / Lineair / Greenpeace

© Greenpeace / Daniel Beltrá

MONGABAY.COM

Deforestation

On a plantation in West Kalimantan in Indonesia, oil palms have replaced all but small patches of forest. ARROWHEAD FILMS

Analysis

Critical transitions in the Amazon forest system

https://doi.org/10.1038/s41586-023-06970-0

Received: 29 August 2022

Accepted: 13 December 2023

Published online: 14 February 2024

Open access

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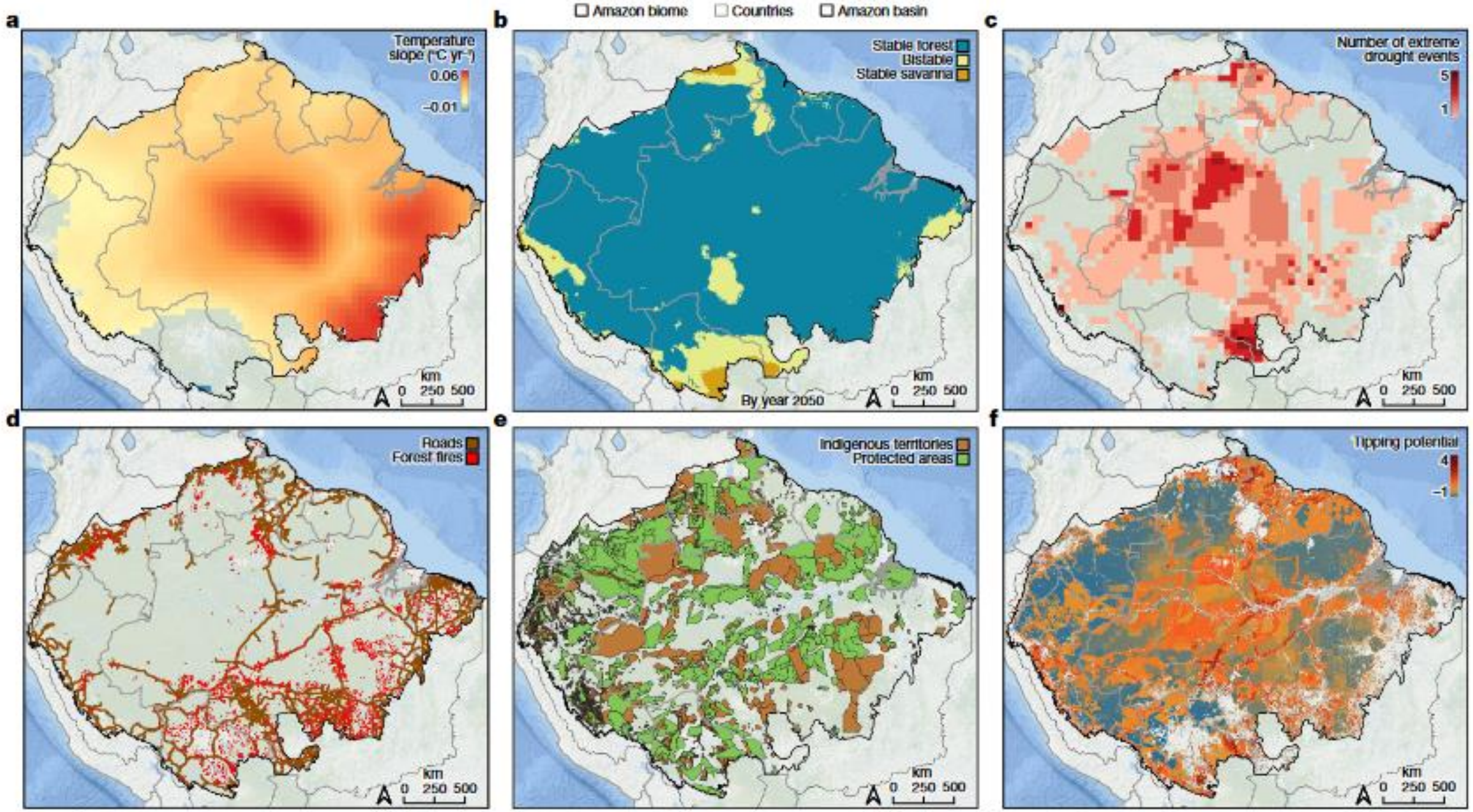


Fig. 1 | Exploring ecosystem transition potential across the Amazon forest biome as a result of compounding disturbances. a, Changes in the dry season (July–October) mean temperature reveal widespread warming, estimated using simple regressions between time and temperature observed between 1981 and 2020 (with $P < 0.1$). **b**, Potential ecosystem stability classes estimated for year 2050, adapted from current stability classes (Extended Data Fig. 1b) by considering only areas with significant regression slopes between time and annual rainfall observed from 1981 through 2020 (with $P < 0.1$) (see Extended Data Fig. 3 for areas with significant changes). **c**, Repeated extreme drought events between 2001–2018 (adapted from ref. 39). **d**, Road network from where illegal deforestation and degradation may spread. **e**, Protected areas and Indigenous territories reduce deforestation and fire disturbances. **f**, Ecosystem transition potential (the possibility of forest shifting into an alternative structural or compositional state) across the Amazon biome by year 2050 inferred from compounding disturbances (**a**–**d**) and high-governance areas (**e**). We excluded accumulated deforestation until 2020 and savannas. Transition potential rises with compounding disturbances and varies as follows: less than 0 (in blue) as low; between 1 and 2 as moderate (in yellow); more than 2 as high (orange–red). Transition potential represents the sum of: (1) slopes of dry season mean temperature (as in **a**, multiplied by 10); (2) ecosystem stability classes estimated for year 2050 (as in **b**), with 0 for stable forest, 1 for bistable and 2 for stable savanna; (3) accumulated impacts from extreme drought events, with 0.2 for each event; (4) road proximity as proxy for degrading activities, with 1 for pixels within 10 km from a road; (5) areas with higher governance within protected areas and Indigenous territories, with −1 for pixels inside these areas. For more details, see Methods.

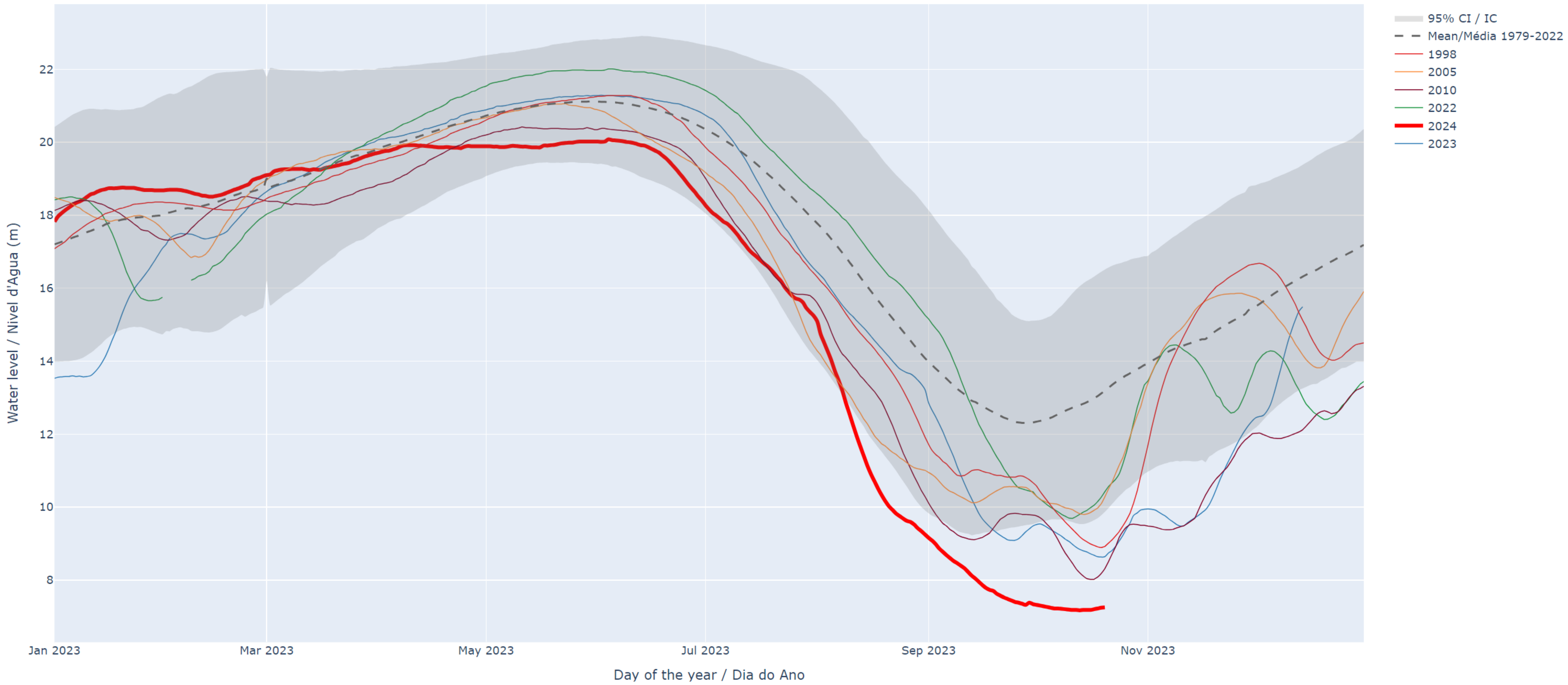
- The study underscores the Amazon's vulnerability to a tipping point, risking large-scale collapse due to compounded stressors like climate warming, deforestation, droughts, and fires.

- Key findings indicate that by 2050, 10-47% of the Amazon could face disturbances severe enough to trigger ecosystem transitions.

- Three possible future trajectories for the forest—degraded, open-canopy, or white-sand savanna ecosystems—highlight distinct feedbacks that exacerbate ecosystem degradation.

- To prevent collapse, the study emphasizes reducing deforestation, expanding restoration, and curbing global greenhouse emissions, which are essential for maintaining the Amazon's resilience and mitigating regional climate impacts.

Drought



https://enso-monitor.onrender.com/ : The data are from the Fonte Boa, AM, gauging station. The site updates daily with data from ANA (National Water and Basic Sanitation Agency).

Castanheirinha
Alvarães
Capucho
Manixi
Caburinim de Baixo
Santa Rosa do Repartimento
Bom Jardim
Campo do Edmundo
São Jose
Fazendinha
Sao Joaquim do Içe
Porto Natal
São Francisco
Bau
Nogueira
São Luis do Macari
São Luis do Macari
Itapiranema
Tefé
Boara de Cima
Missão
TFF
Bacuri
Oct 28th 2020 – 11.83m
08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
©2018 Planet Labs PBC ©Mapbox ©OpenStreetMap 3.26300° S, 64.77743° W
3.30115° S, 64.81363° W
12.33
30.33 m/px
2 km


Castanheirinha
Alvarães
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Caburinim de Baixo
Santa Rosa do Repartimento
Bom Jardim
Campo do Edmundo
Fazendinha
Sao Joaquim do Içe
Porto Natal
São Jose
São Francisco
Bau
Nogueira
São Luis do Macari
Itapiranema
Tefé
Boara de Cima
São Luis do Macari
Missão
TFF
Bacuri
Oct 31st 2021 – 14.06m
01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Nov 2021
©2018 Planet Labs PBC ©Mapbox ©OpenStreetMap
3.28835° S, 64.81927° W
12.35
29.84 m/px
2 km


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São Jose
São Francisco
Bau
Nogueira
São Luis do Macari
Itapiranema
Tefé
Boara de Cima
São Luis do Macari
Missão
TFF
Bacuri
Oct 22nd 2022 – 10.66m
22 23 24 25 26 27 28 29 30 31 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26
Nov 2022
©2018 Planet Labs PBC ©Mapbox ©OpenStreetMap
3.20007° S, 64.84898° W
12.35
29.84 m/px
2 km

Oct 29th 2023 – 9.84m


Castanheirinha
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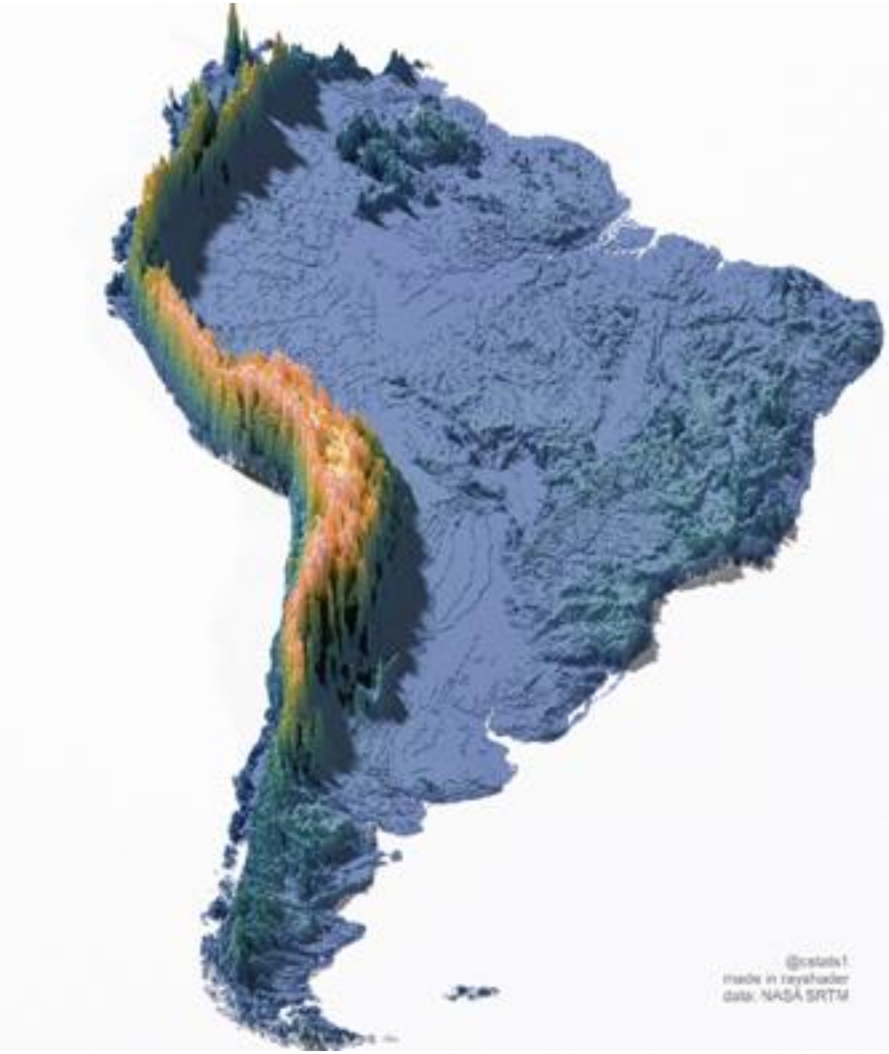
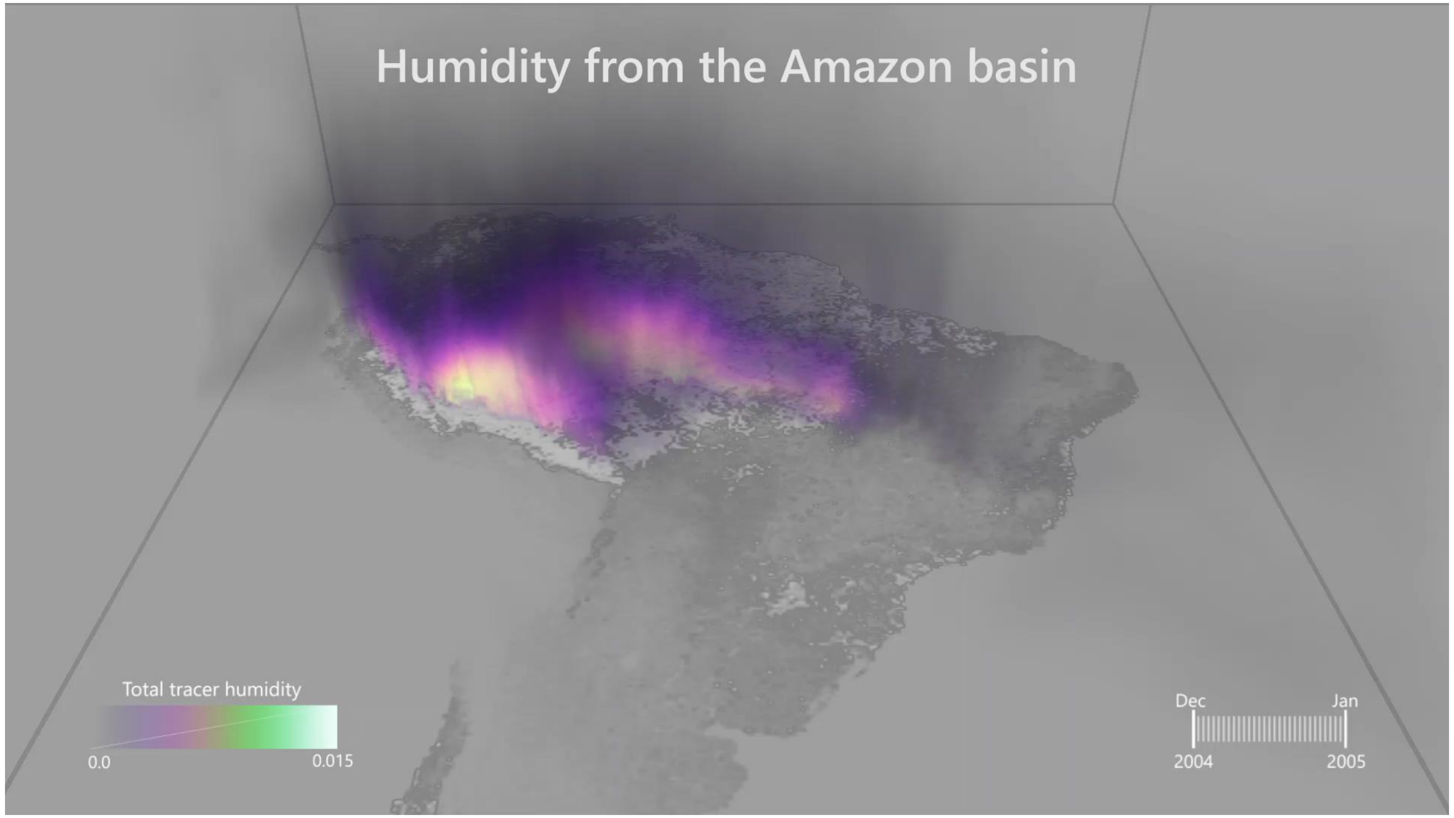
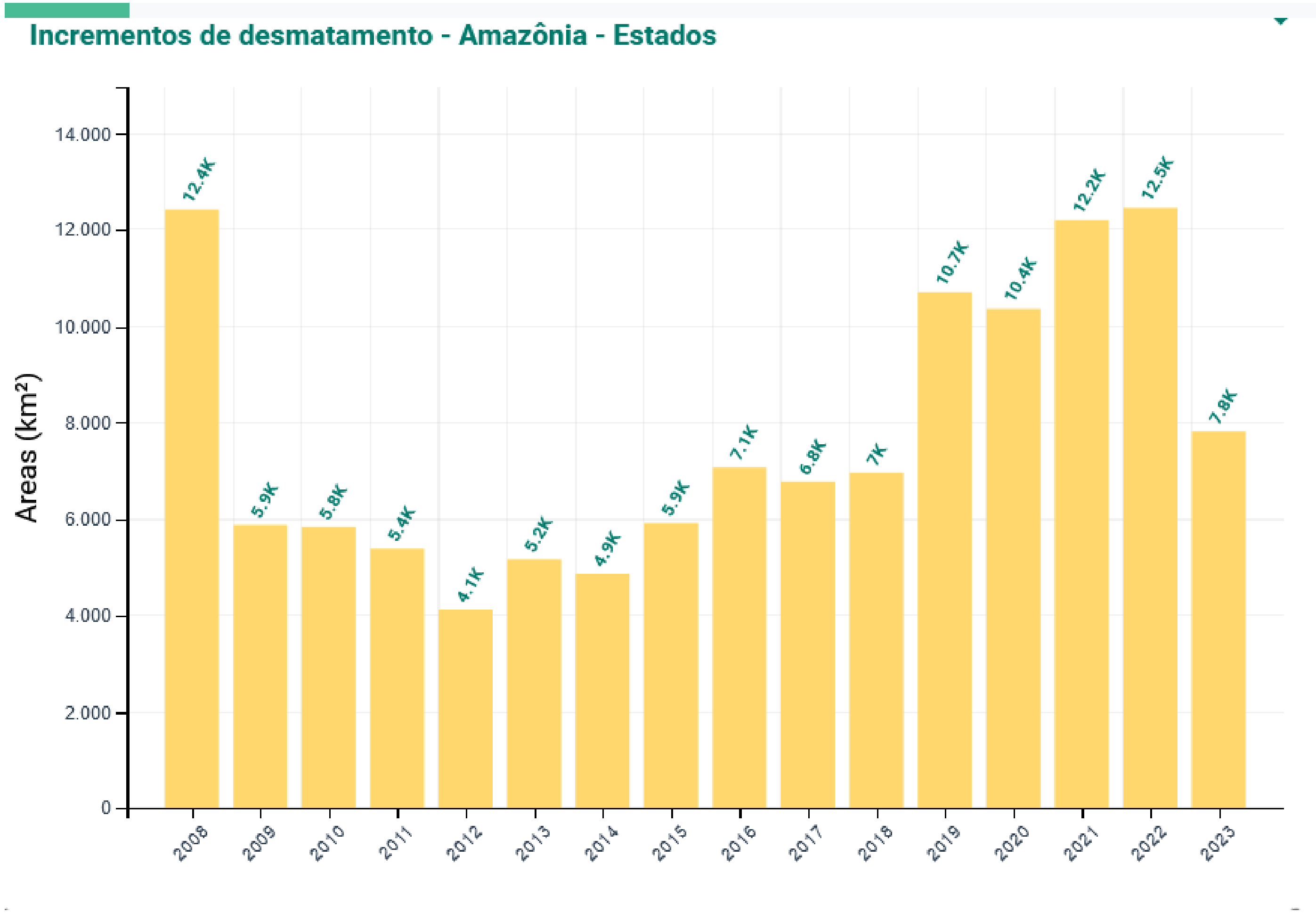
Sao Joaquim do Içe
Porto Natal
São Jose
São Francisco
Bau
Nogueira
São Luis do Macari
Itapiranema
Tefé
Boara de Cima
São Luis do Macari
Missão
TFF
Bacuri
Oct 18th 2024 – 7.22m
01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19
©2018 Planet Labs PBC ©Mapbox ©OpenStreetMap
3.29747° S, 64.82016° W
12.35
29.84 m/px
2 km

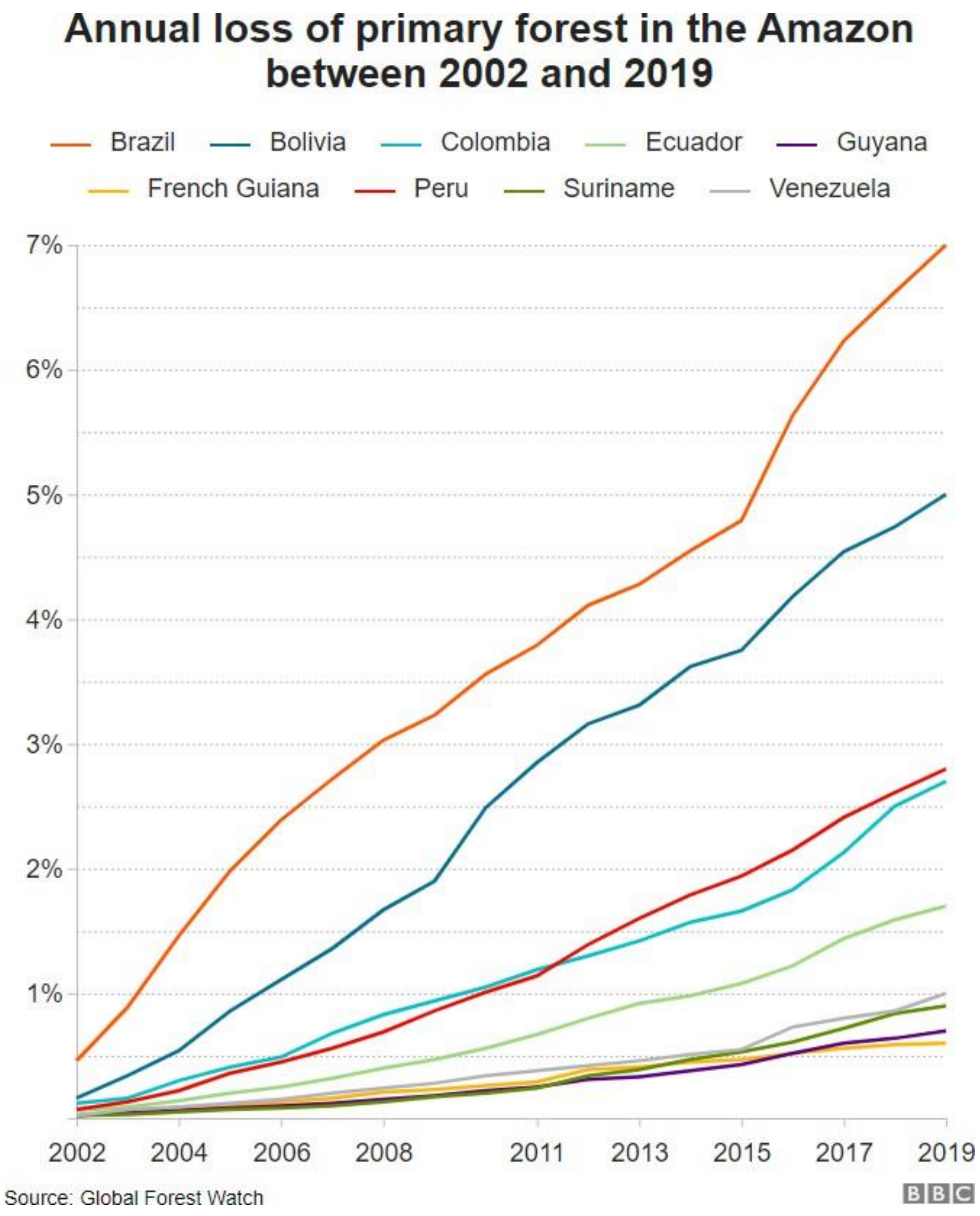


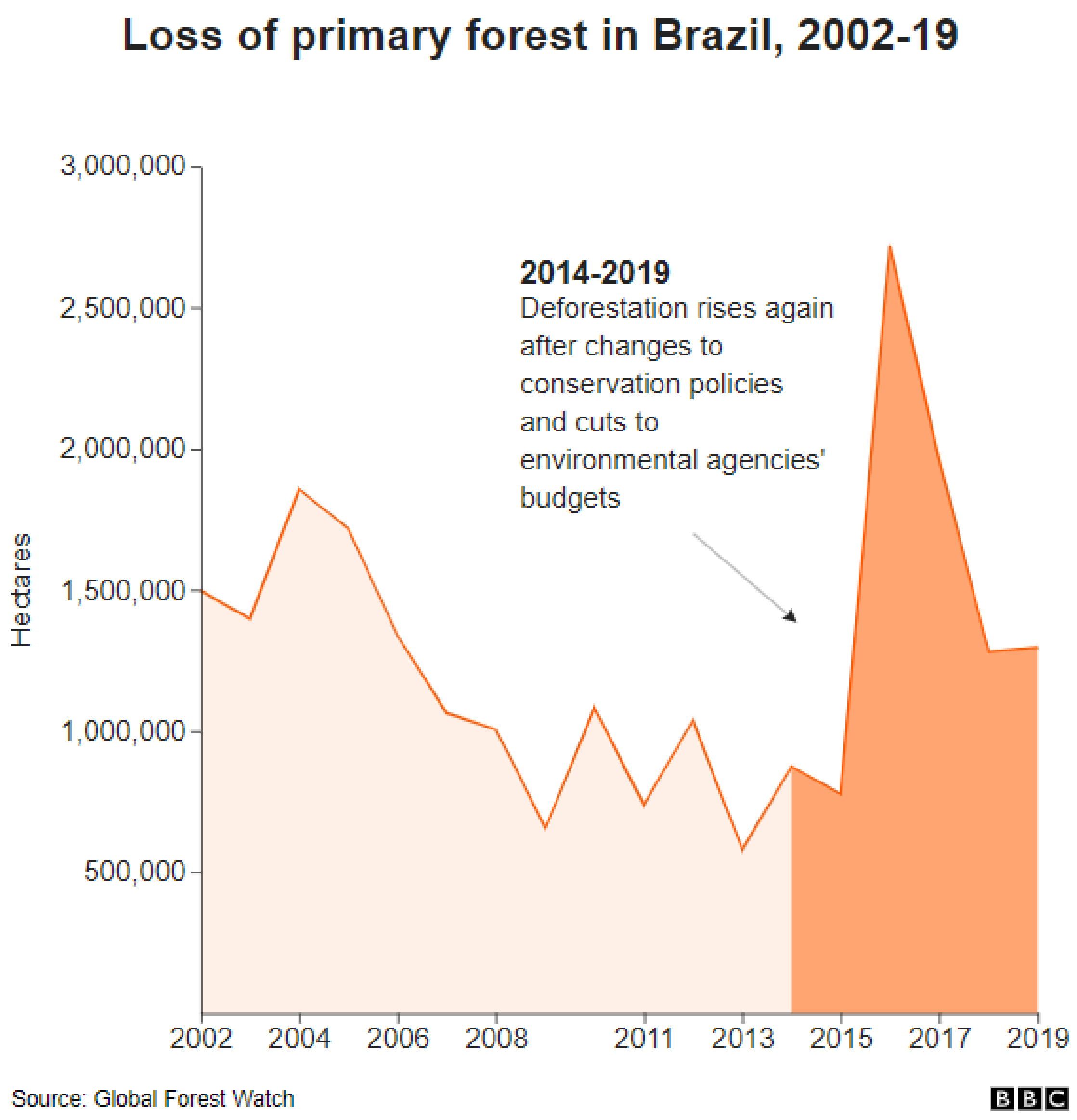


Yang, Z., and F. Dominguez, 2019: Investigating Land Surface Effects on the Moisture Transport over South America with a Moisture Tagging Model. *J. Climate*.

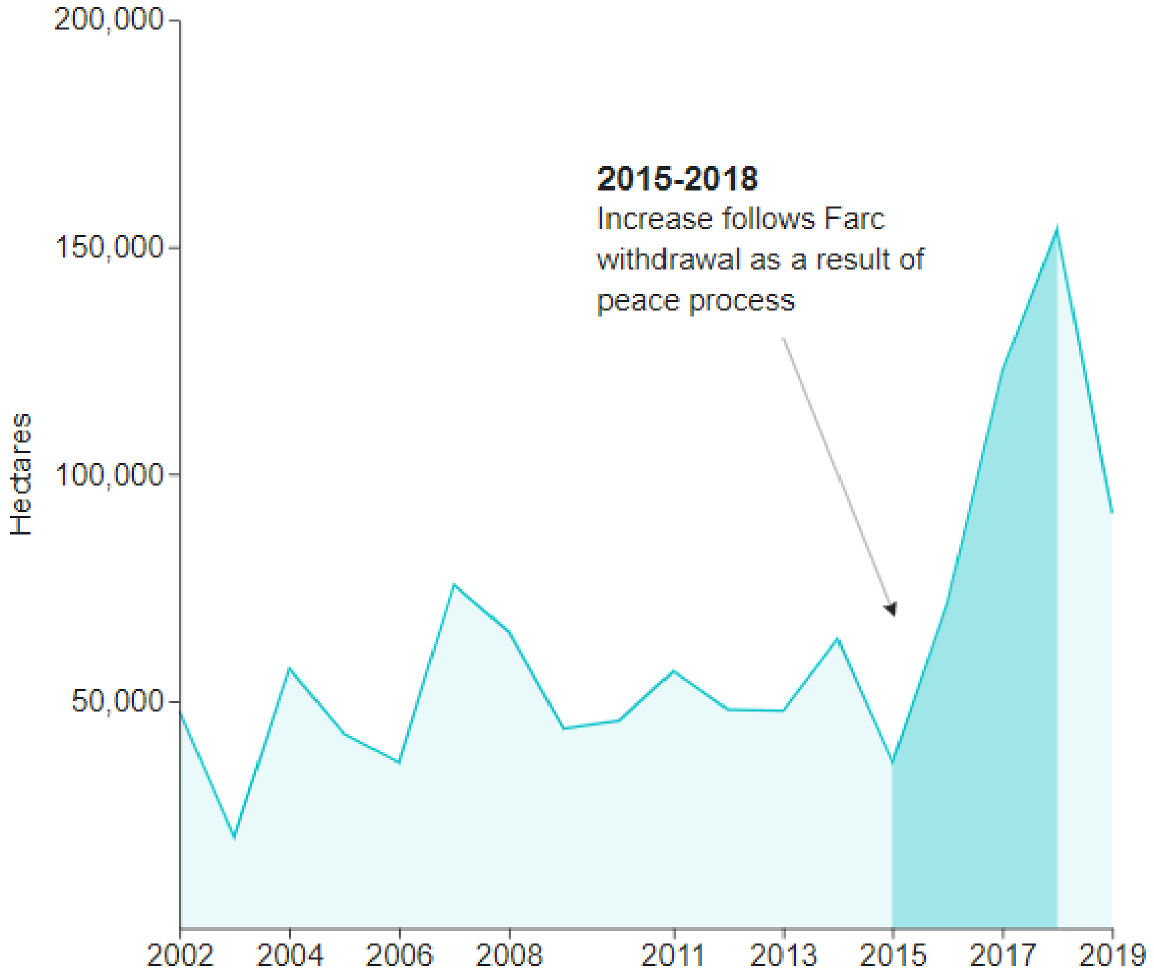


https://terrabrasilis.dpi.inpe.br/app/dashboard/deforestation/biomes/amazon/increments

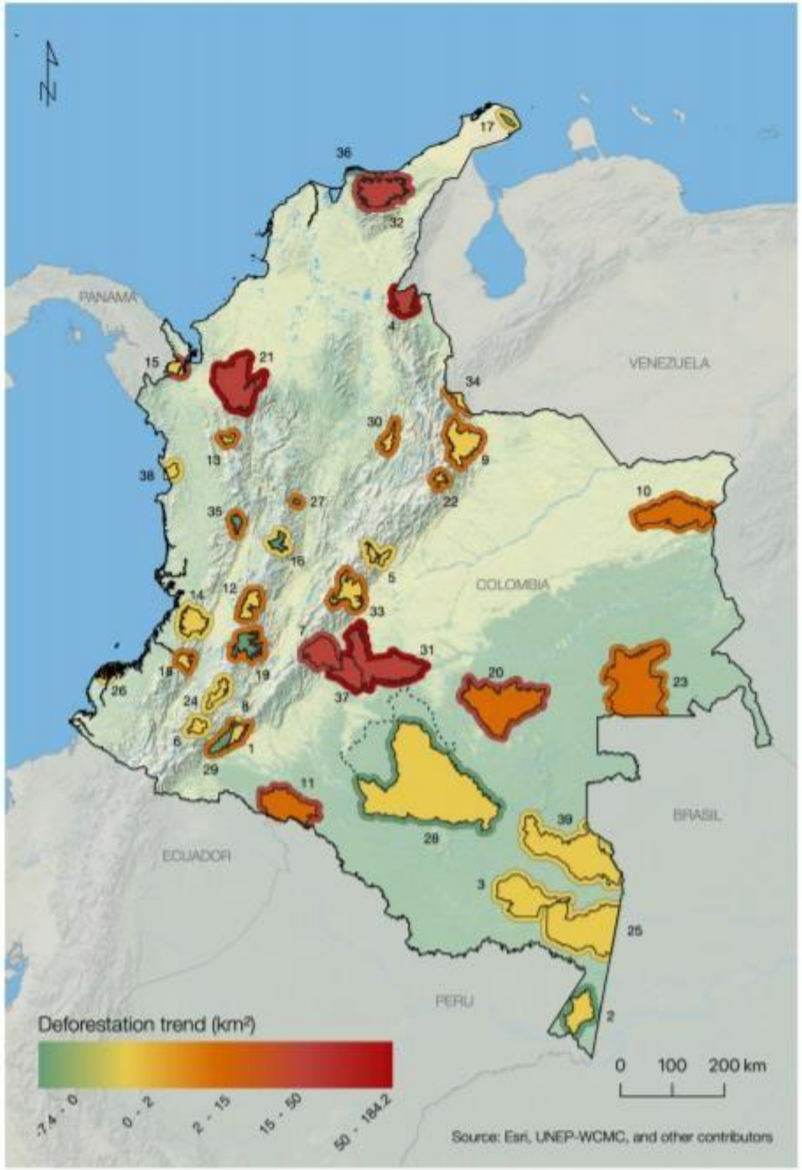

Annual loss of primary forest in the Amazon between 2002 and 2019
Brazil
Bolivia
Colombia
Ecuador
Guyana
French Guiana
Peru
Suriname
Venezuela
7%
6%
5%
4%
3%
2%
1%
2002
2004
2006
2008
2011
2013
2015
2017
2019
Source: Global Forest Watch
BBC


Loss of primary forest in Brazil, 2002-19
3,000,000
2,500,000
2,000,000
1,500,000
1,000,000
500,000
Hectares
2014-2019
Deforestation rises again after changes to conservation policies and cuts to environmental agencies' budgets
2002
2004
2006
2008
2011
2013
2015
2017
2019
Source: Global Forest Watch
BBC

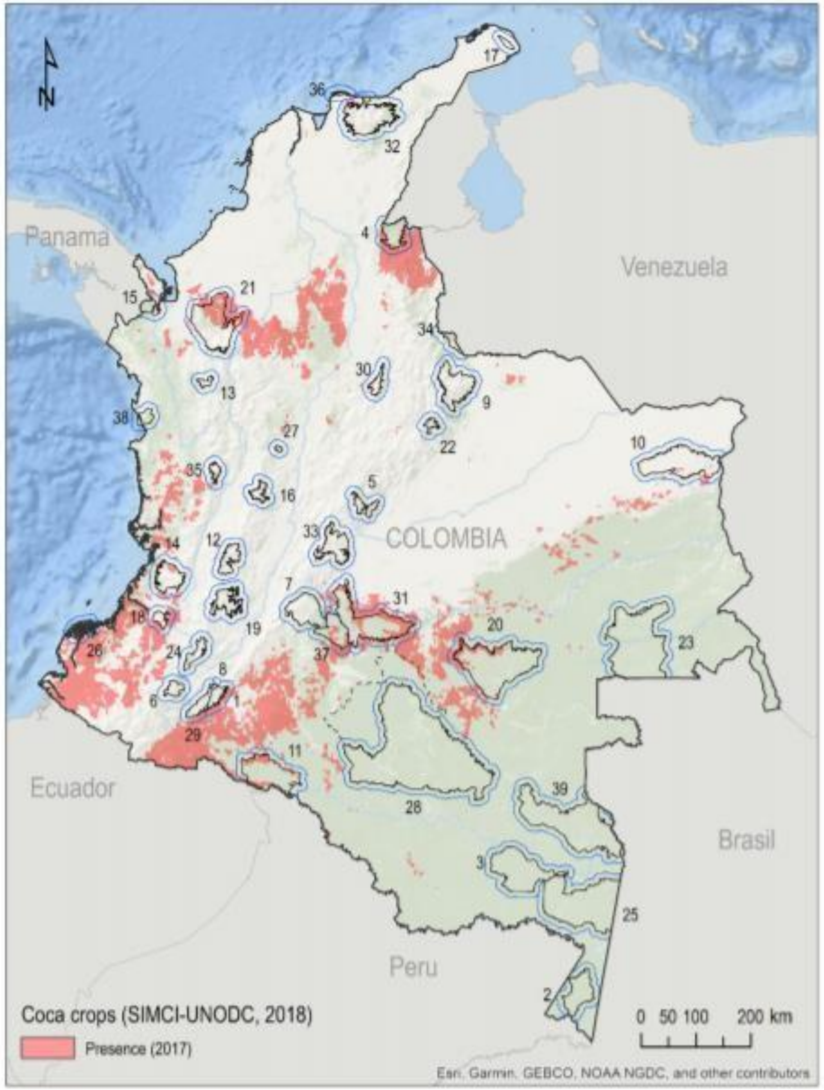
Loss of primary forest in Colombia, 2002-19



Source: Global Forest Watch



Change in deforestation extent (km²) before and after the peace agreement with FARC (2013–2015 vs. 2016–2018) in continental Colombian National Natural Parks and National Natural Reserves and buffer areas (10 km). Dotted line: 2018 enlargement of Serranía de Chiribiquete NNP (not used in calculations). Numbers correspond to protected area IDs, detailed in Table 1. Figure created using ArcGIS software by Esri, used herein under license.



Presence of coca crops in Colombia in 2017 (source: SIMCI-UNODC, 2018). Protected area boundaries in black, buffer areas (10 km) in blue. Dotted line: 2018 enlargement of Serranía de Chiribiquete NNP (not used in calculations). Numbers correspond to protected area IDs, detailed in Table 1. Figure created using ArcGIS software by Esri, used herein under license.

Clerici et al. 2020. Deforestation in Colombian protected areas increased during post-conflict periods. *Scientific reports*, *10*(1), pp.1-10.

Tropical Forests and Climate Change

- Tropical forests contain about 25% of the world’s carbon, and other forest regions of the world add another 20% of the world’s carbon. In just the Amazon basin, studies estimate that forests contain 90-140 billion tons of carbon, which could be equivalent to 9-14 decades of human carbon emissions.

- Previous statements by the IPCC (Intergovernmental Panel on Climate Change) estimated tropical deforestation and land use change to contribute about 20% of global carbon emissions, although more recent studies have placed this percentage closer to 10%.

- REDD+ (or REDD-plus) refers to "reducing emissions from deforestation and forest degradation" in developing countries, and the role of conservation, sustainable management of forests, and enhancement of forest carbon stocks in developing countries“.

- At the smaller level, forests affect local climate patterns; trees transpire water, so deforestation can reduce rainfall and contribute to desertification.

- At the global level, increased carbon could potentially benefit forest growth in a “fertilization” scenario, but climate change could also result in a rise in temperatures and increased water stress, causing a decrease in forest growth.

- Studies in the Amazon basin predicts a “dieback” scenario, where a rise in temperature corresponds with a 10-20% reduction in rainfall, followed by change from forest ecosystems to savanna ecosystems.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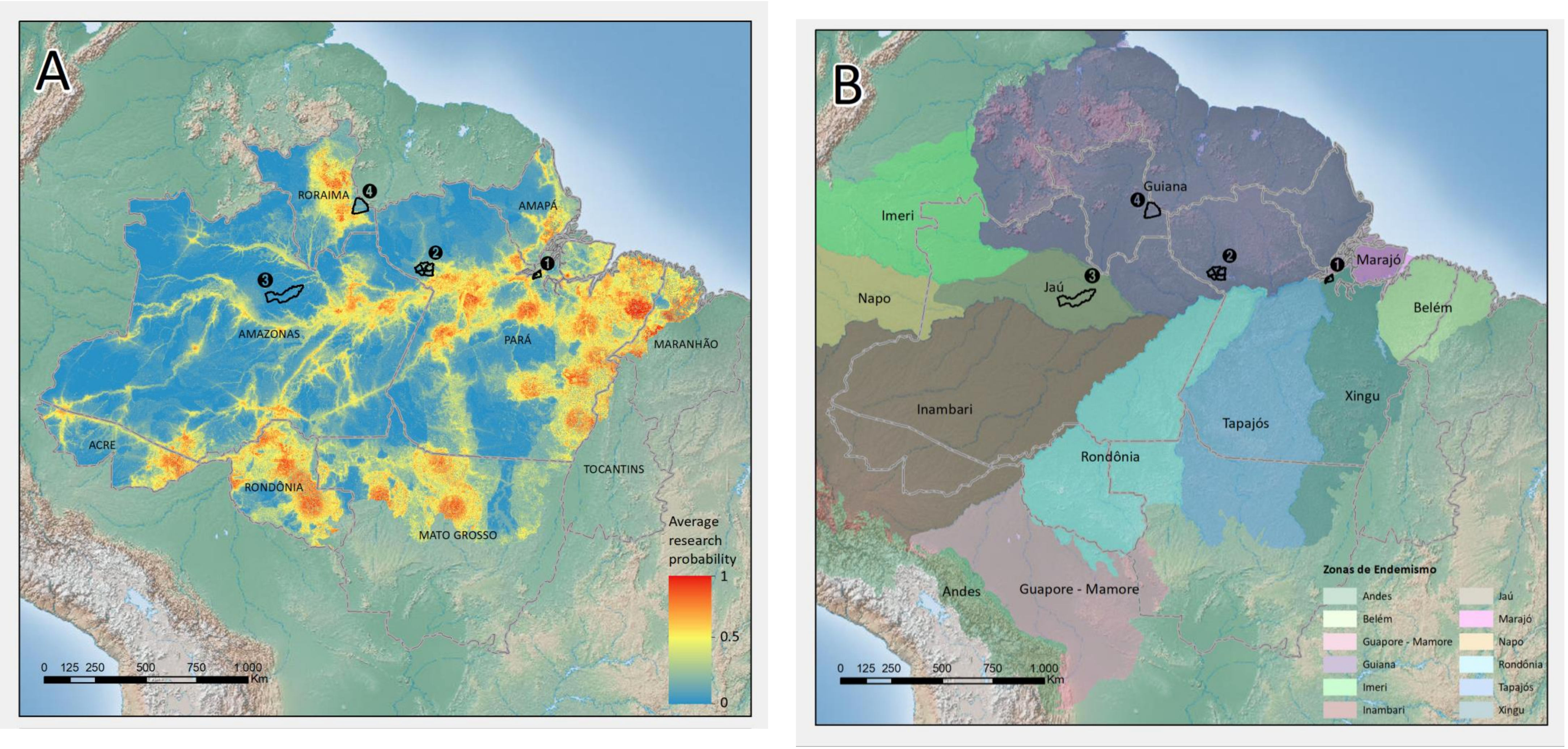
Polyanna da Conceição Bispo, UK-PI within the *"Amazon +10 Initiative: Research Expeditions to the Amazon"* Her project involves the funding agencies UKRI (UK), SNSF (Switzerland), FAPESP (Brazil), FAPESPA (Brazil), FAPEAM (Brazil), FAPERR (Brazil), and CNPq (Brazil). Total funding: ***£1,972,651.43*** (with the UKRI component funding *£999,726.00*). More than 40 scientists and 10 Quilombola leaders

Amazonian BioTechQuilombo

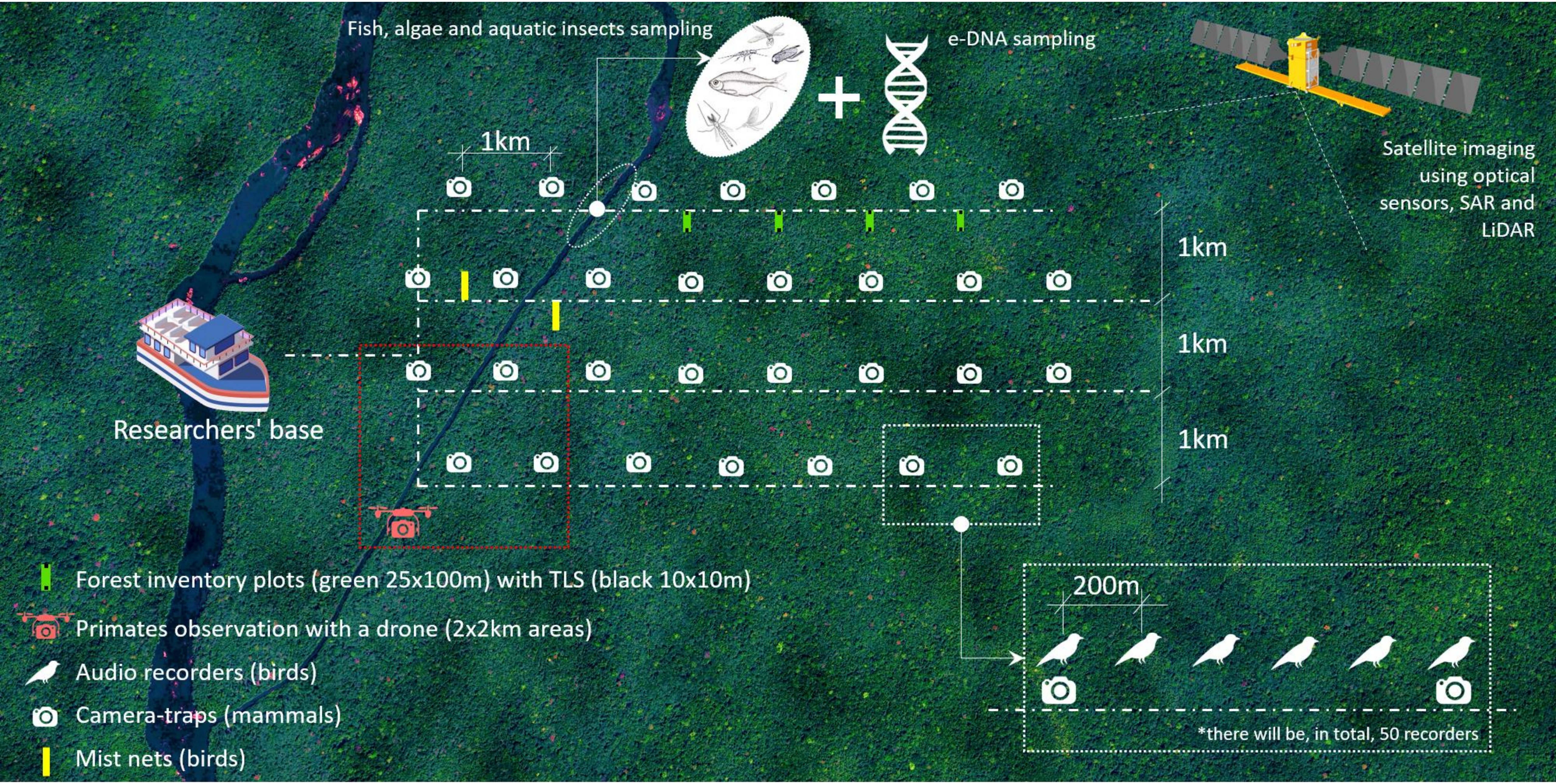
- Collaboration with Quilombola communities to analyse biodiversity data gaps in Amazonian region.

- We aim to develop automated systems for community based biodiversity measurement, involving Quilombola communities throughout all the research process.

- Specific objectives include promoting conservation, strengthening relationships, empowering communities, and enhancing research capabilities



(A) Study sites of the expeditions: 1. Quilombola community of Gurupá (PA); 2.Quilombola community of Oriximiná (PA); 3. Quilombola community of Novo Airão (AM);and 4. Traditional community of Entre Rios (RR). The background represents the average research probability across all organism groups and habitat types (Carvalho et al., 2023); (B)Study sites of the expeditions on the boundaries of endemic zones (the currently accepted Areas of Endemism classification of the Amazon, depicted here, was proposed by Cracraft (1985)and subsequently modified by Silva et al. (2002), Naka (2011) and Borges & Silva (2012).



Fish, algae and aquatic insects sampling
e-DNA sampling
Satellite imaging using optical sensors, SAR and LiDAR
1km
1km
1km
1km
Researchers' base
200m
*there will be, in total, 50 recorders
Forest inventory plots (green 25x100m) with TLS (black 10x10m)
Primates observation with a drone (2x2km areas)
Audio recorders (birds)
Camera-traps (mammals)
Mist nets (birds)

https://www.youtube.com/watch?v=pCjFWTp2J_k

Thank you!

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