



UNIVERSITÀ  
DEGLI STUDI DELLA  
**TUSCIA**

**45**  
1979  
2024

**Il bosco, cambiamenti  
climatici e il ciclo  
dell'acqua:  
un sistema integrato e  
interagente.**

**23 aprile 2025**

71° Corso nazionale di formazione per insegnanti

**“Le forme dell'acqua nel Centro d'Italia”.**

▲ **Cascate, fiumi e laghi tra la Valnerina e il Reatino**

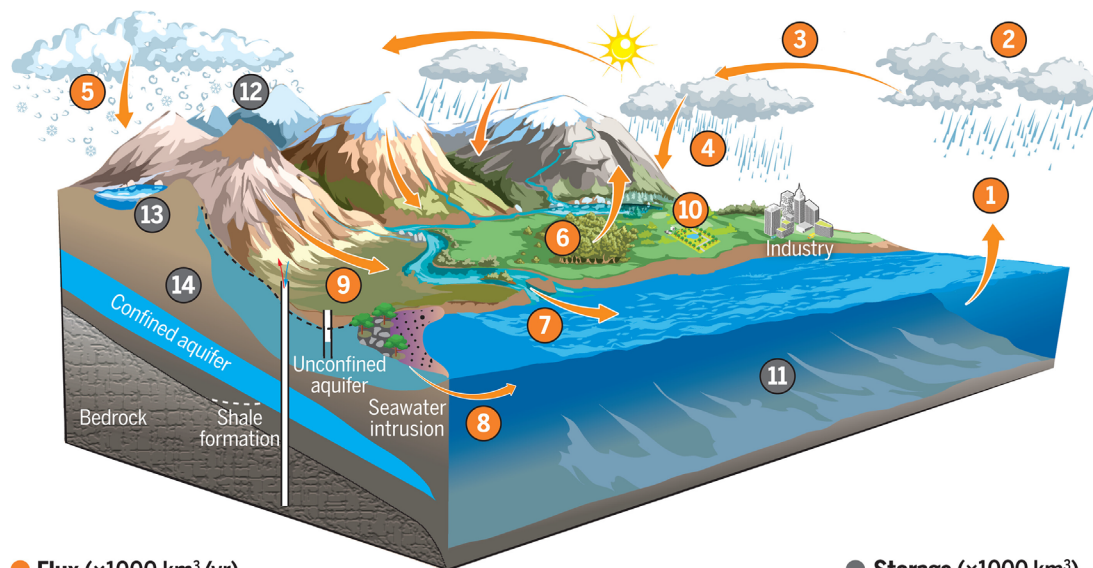
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*Università della Tuscia, Viterbo*



# Il Ciclo Globale dell'Acqua



● **Flux** ( $\times 1000 \text{ km}^3/\text{yr}$ )

- 1 Ocean evaporation ( $420 \pm 20\%$ )
- 2 Precipitation on ocean ( $380 \pm 20\%$ )
- 3 Net water vapor flux transport ( $46 \pm 20\%$ )
- 4 Rainfall ( $98.5 \pm 10\%$ )
- 5 Snowfall (12.5)

## 6 Terrestrial evapotranspiration ( $69 \pm 10\%$ )

- 7 Runoff ( $46 \pm 10\%$ )  
8 Groundwater discharge ( $4.5 \pm 70\%$ )  
9 Groundwater withdrawal ( $\sim 1.0$ )  
10 Managed aquifer recharge (MAR) 0.01

● **Storage** (×1000 km<sup>3</sup>)

- 11** Ocean 1,338,000
- 12** Glaciers and snow 24,064
- 13** Permafrost 300
- 14** Groundwater 23,400

## Acque Sotterranee

## Componente fondamentale del Ciclo Idrologico globale

- Fonte primaria di acqua dolce
- Acqua potabile per comunità
- >40% irrigazione
- Mitigazione scarsità d'acqua in risposta ai cambiamenti climatici

## I **FLUSSI** che interessano le Acque Sotterranee stanno diventando più variabili

- Cambiamento Climatico  
(ghiacciai, permafrost, variabilità precipitazioni)
- Attività Antropiche

# Science

## The changing nature of groundwater in the global water cycle

XINGDING HUANG  JINGDUO LIU  BRIDGET R. SCANLON  JIU JIMMY JIAO  SCOTT JASECHKO  MICHELE LANCIA  DORIS K. DISKABORN   
YOSHIOHIDE WADA  SUBODH LIL  I. J. AND CHUNMIAO ZHONG   **✉** authors [Authors Info & Affiliations](#)

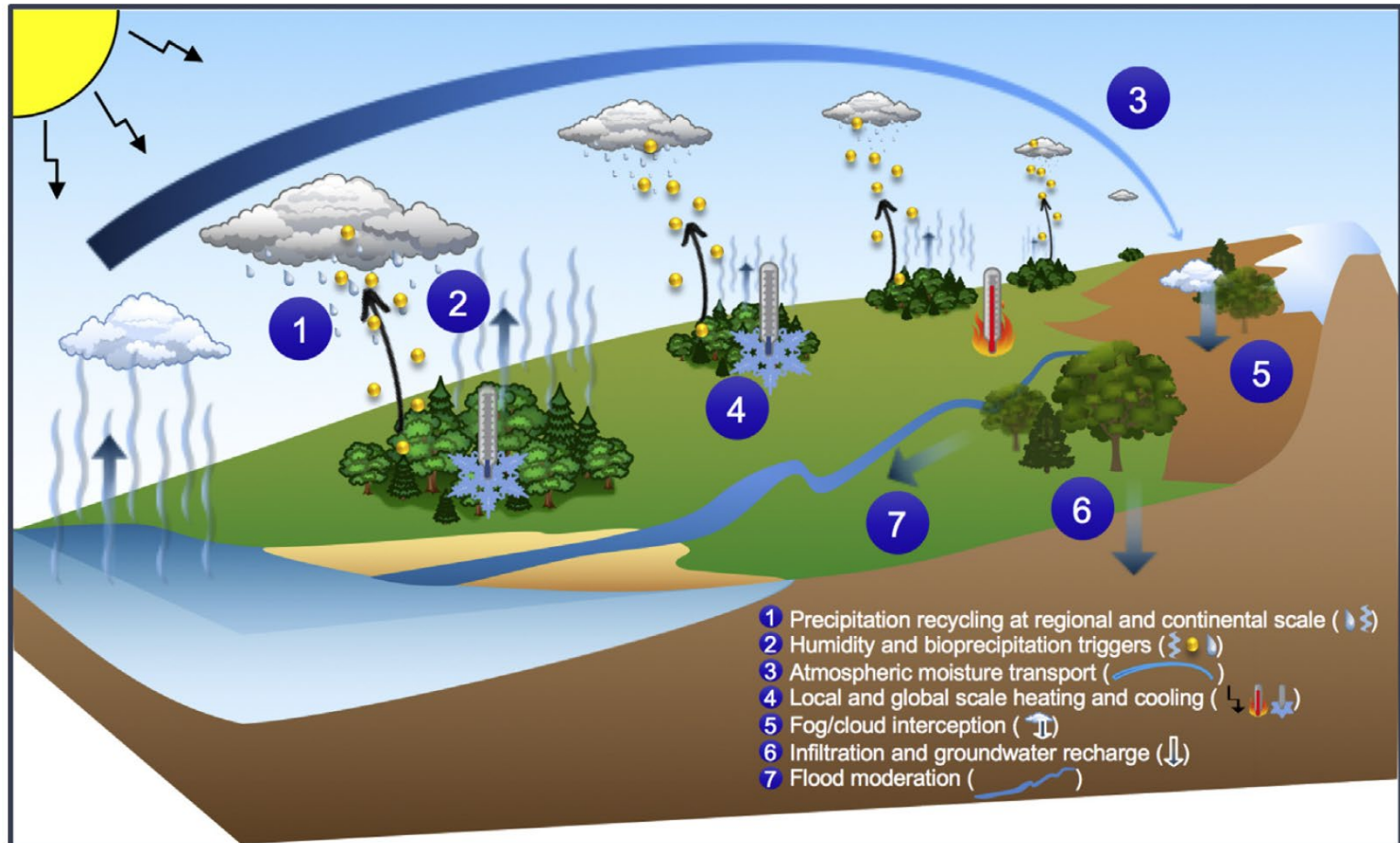
SCIENCE • 15 May 2014 • Vol 343, Issue 6165 • Epub 15 May 2014/science.s11260

## Research paper

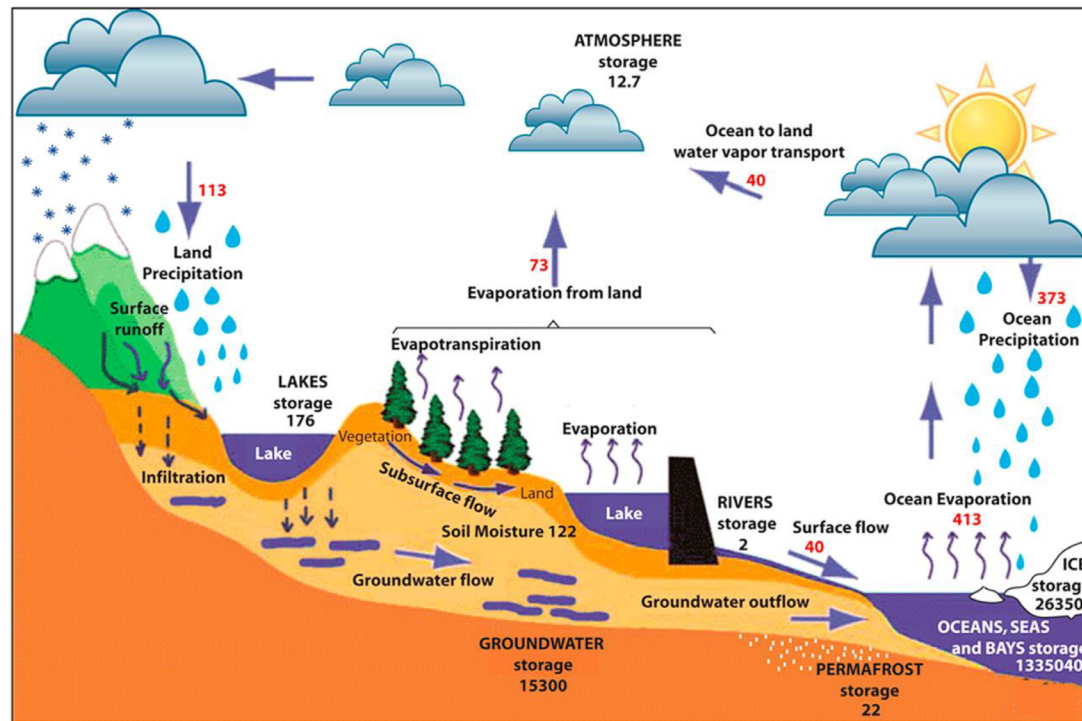
## Trees, forests and water: Cool insights for a hot world

David Ellison<sup>a,b,\*</sup>, Cindy E. Morris<sup>c,d</sup>, Bruno Locatelli<sup>e,f</sup>, Douglas Sheil<sup>g</sup>, Jane Cohen<sup>h</sup>, Daniel Murdiyarso<sup>i,j</sup>, Victoria Gutierrez<sup>k</sup>, Meine van Noordwijk<sup>l,m</sup>, Irena F. Creed<sup>n</sup>, Jan Pokorný<sup>o</sup>, David Gaveau<sup>i</sup>, Dominick V. Spracklen<sup>p</sup>, Aida Bargués Tobella<sup>q</sup>, Ulrik Ilstedt<sup>r</sup>, Adriaan J. Teuling<sup>s</sup>, Solomon Gebreyohannis Gebrehiwot<sup>t,u</sup>, David C. Sands<sup>v</sup>, Bart Muys<sup>l</sup>, Bruno Verbist<sup>l</sup>, Elaine Springgay<sup>u</sup>, Yulia Sugandi<sup>v</sup>, Caroline A. Sullivan<sup>w</sup>

# Le Foreste ed il Ciclo dell'Acqua



# Le Foreste ed il Ciclo dell'Acqua



**Figure 4: The Global Hydrologic Landscape**

Though evaporation from ocean surfaces provides a very large share of the global atmospheric moisture budget, most of this moisture returns as rainfall over ocean surfaces. Approximately 35% of terrestrial precipitation is fed by oceanic evaporation, while approximately 65% is fed by land-atmosphere interactions (evaporation and evapotranspiration (ET) from water bodies, forest and other vegetation cover, including croplands). While the direct share of ET from forests varies dramatically from landscape to landscape, this share is heavily influenced by land use practices and land use change. Land conversions from forest to agriculture and urban settlements are assumed to have a significant impact on the global surface contribution to atmospheric moisture, and thus precipitation on terrestrial surfaces.



# Alberi, Traspirazione ed Acque di Falda

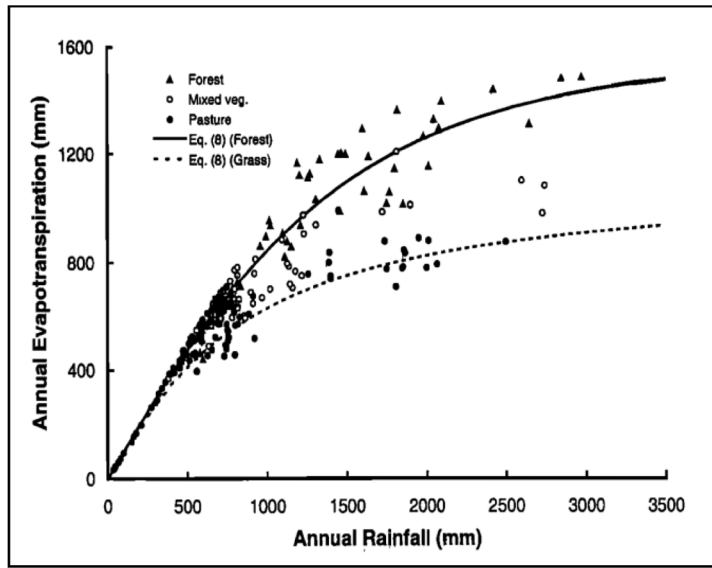
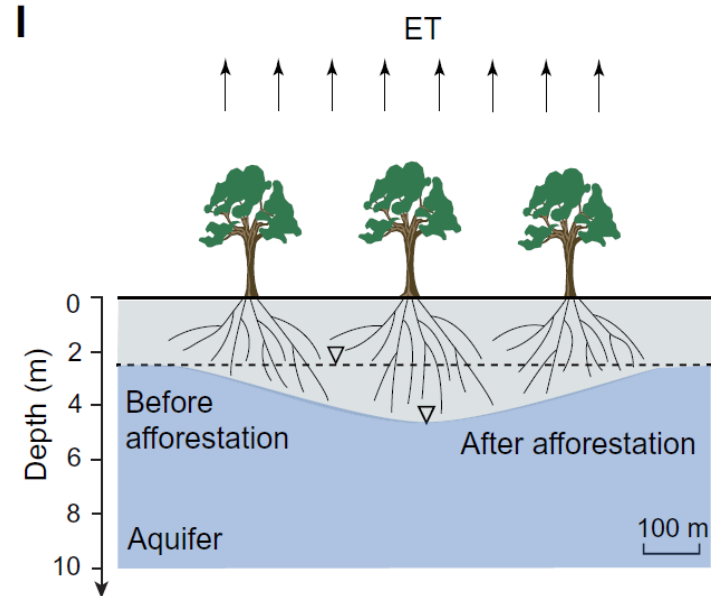


Figure 2 : Comparison of Evapotranspiration Rates from Forest and Other Vegetation Types  
Source : Zhang et al (2001 : Fig. 9).

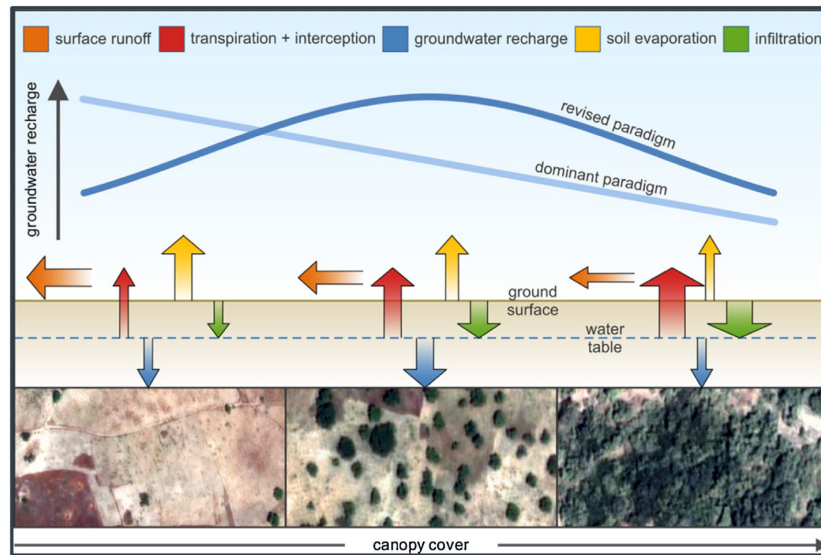




# Alberi, Traspirazione ed Acque di Falda

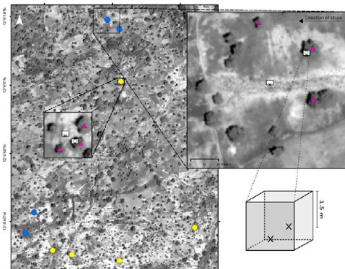
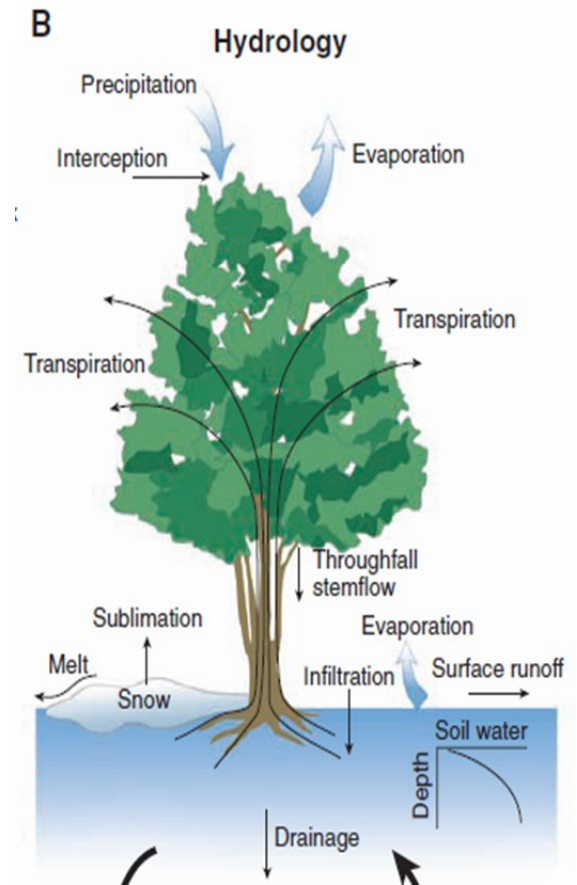
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D. Ellison et al. / Global Environmental Change 43 (2017) 51–61



**Fig. 3.** Infiltration and groundwater recharge relative to canopy cover.

Source: adapted from (Ilstedt et al., 2016). The relationship between tree cover and groundwater recharge, as theorized by the dominant paradigm (the trade-off theory) and the revised paradigm (optimum tree cover theory). Arrows depict the conceptual water budget based on the optimum tree cover theory. The size of the arrows is proportional to the magnitude of each component of the water budget. Groundwater recharge is expressed as a share of annual rainfall.

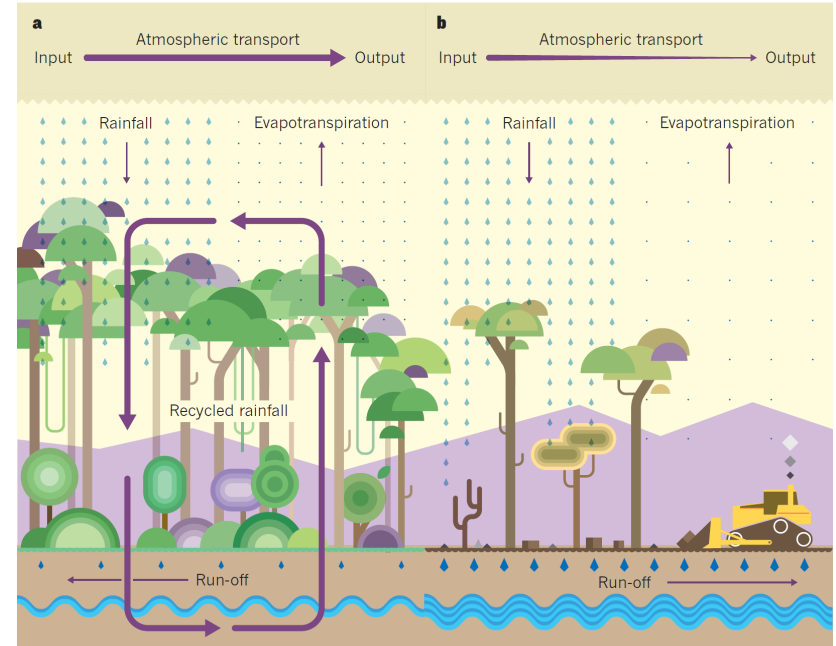
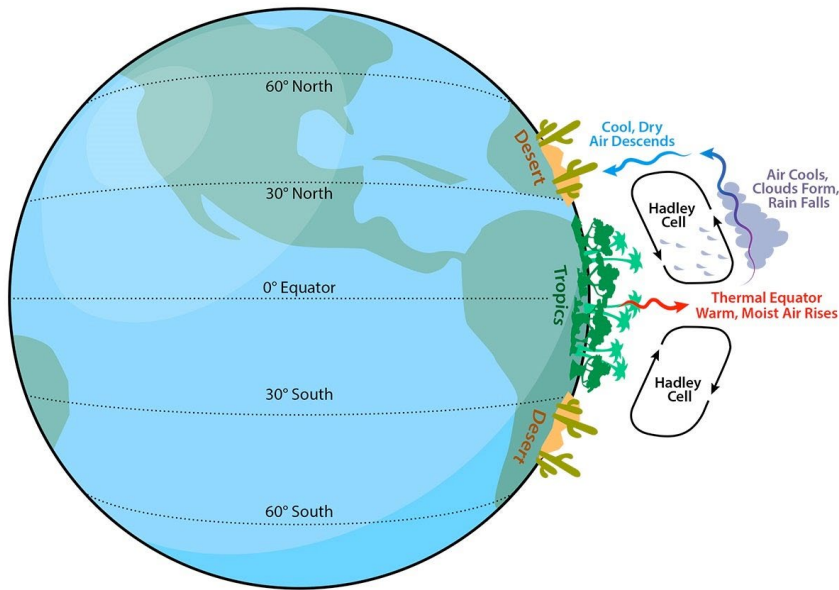




# The rainforest's water pump

An investigation of naturally occurring water recycling in rainforests finally marries the results of global climate models with observations. Alarming, it also suggests that deforestation can greatly reduce tropical rainfall. [SEE LETTER P.282](#)

## Le Foreste come Pompe d'Acqua Regolatrici del Clima Globale



**Figure 1 | Effect of deforestation on rainfall in the tropics.** **a**, Much of the rainfall over tropical forests comes from water vapour that is carried by the atmosphere from elsewhere. But a large component is 'recycled' rain — water that is pumped by trees from soil into the atmosphere through a process called evapotranspiration<sup>2</sup>. Water exits from forests either as run-off into streams and rivers, or as evapotranspirated vapour that is carried away by the atmosphere. The atmospheric transport of water vapour into the forest is balanced by the exit of water in the form of vapour and run-off. **b**, Spracklen and colleagues' analysis<sup>6</sup> suggests that deforestation reduces evapotranspiration and so inhibits water recycling. This decreases the amount of moisture carried away by the atmosphere, reducing rainfall in regions to which the moisture is transported. Decreasing evapotranspiration may also increase localized run-off and raise river levels.

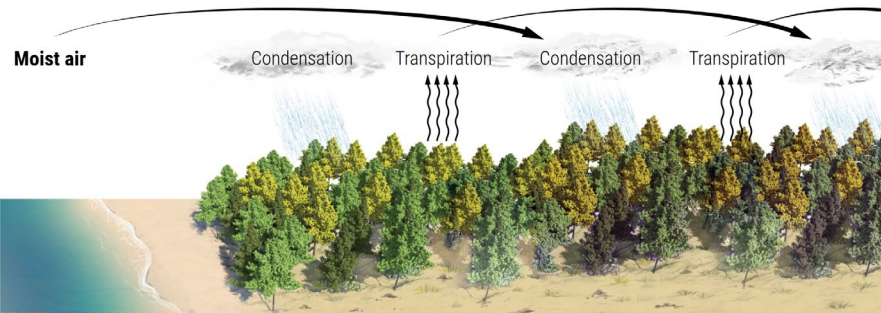


# Fiumi Volanti



## Sowing the wind

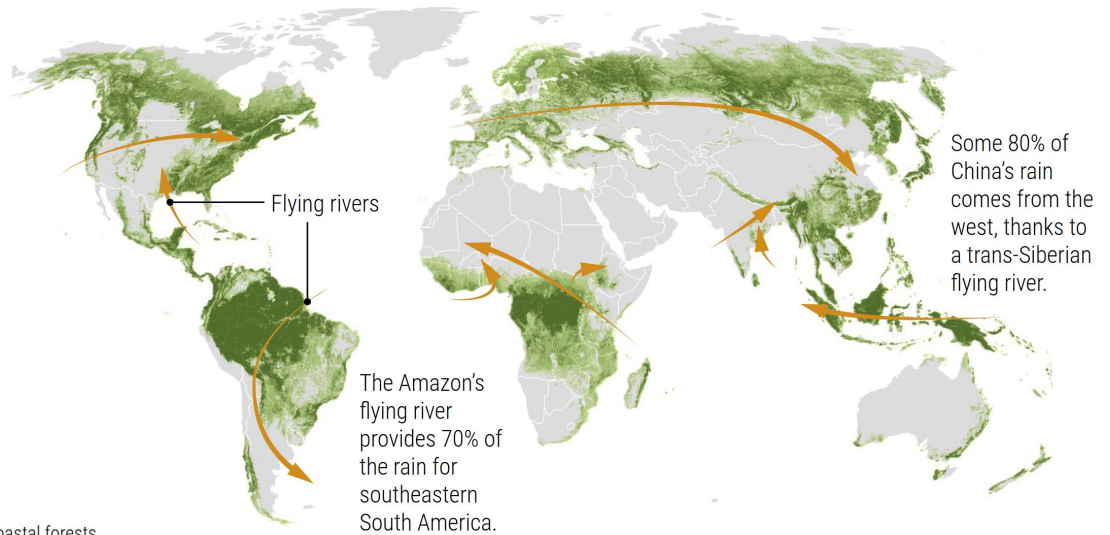
The biotic pump theory suggests forests not only make rain, but also wind. When water vapor over coastal forests condenses, it lowers air pressures, creating winds that draw in moist ocean air. Cycles of transpiration and condensation can set up winds that deliver rains thousands of kilometers inland.



(GRAPHIC) N. DESAI/SCIENCE; (DATA) HANSEN ET AL., SCIENCE, 342 (6160) 2013

## Rain parades

So-called flying rivers are prevailing winds that pick up water vapor exhaled by forests and deliver rains to distant water basins. A controversial theory suggests forests themselves drive the winds (bottom).





## THE FLYING RIVERS OF THE AMAZON

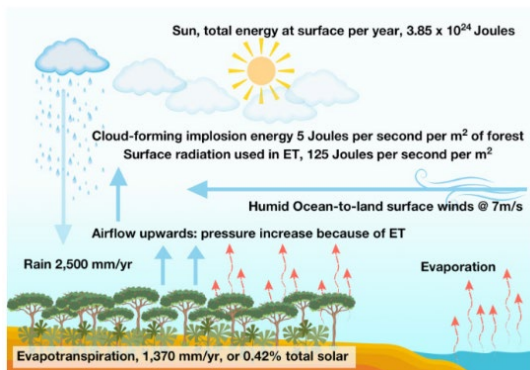
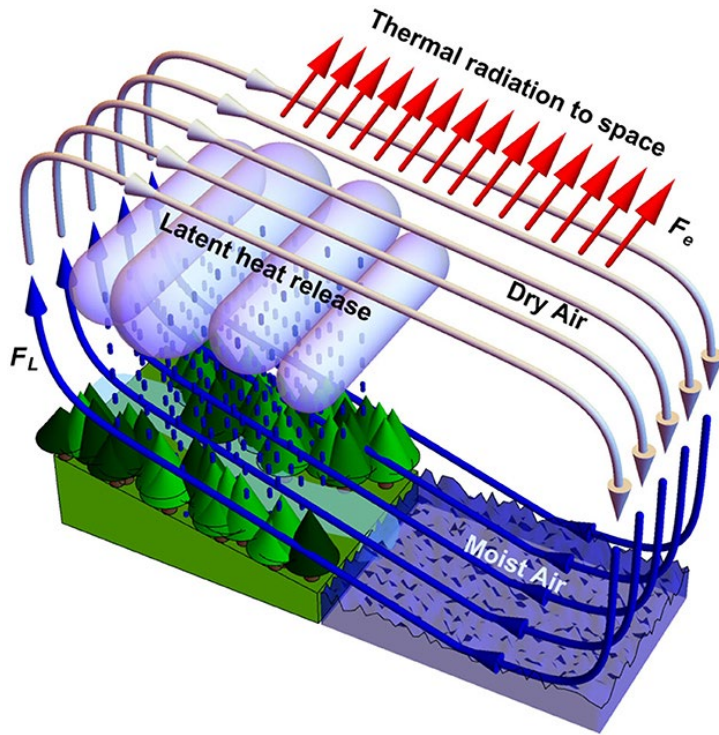
- 1 In the Amazon Forest, the heat causes evaporation of the water accumulated in the soil and in the transpiration of trees whose roots absorb water from the underground. The process is called evapotranspiration.
- 2 On land, this steam generates charged clouds and a lot of rain in the Amazon.
- 3 The heat in the equatorial region of the Atlantic Ocean provides strong evaporation; winds carry this humidity for the mainland, towards the Amazon.
- 4 Once again this steam forms clouds, which are displaced by winds to the West. Find one barrier in the Andes Mountains and back towards the Southwest.
- 5 Part of these clouds generates rain in the central regions West, Southeast and South, which concentrate production agriculture and a good part of the hydroelectric plants with large reservoirs.
- 6 In practice, water from the Amazon is transferred to the Center South of Brazil through winds and rains. That's why these runners atmospheric moisture are called flying rivers.



Fonte: Instituto Nacional de Pesquisas Espaciais. INPE

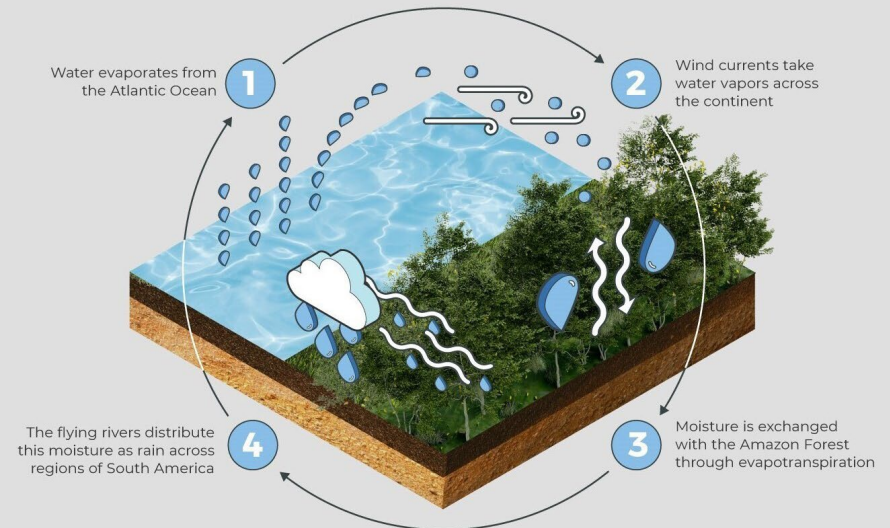


## How Forests Attract Rain: An Examination of a New Hypothesis



### Rainfall

i "Flying rivers" are created by air currents that carry enormous amounts of water vapor across the sky.



These atmospheric rivers play a critical role in regulating the rainfall in the Amazon region and beyond.



Only **-6% of cropland in Brazil is irrigated**, making the region heavily dependent on rainfall.



**20 billion tonnes of water is released daily into the atmosphere** by the trees of the Amazon. That's around 13 times more than is discharged by the Mississippi River.

Brazil relies heavily on the water cycles created by the Amazon rainforest to support crop growth that feeds local and global communities.

Source: WWF, Forbes, The Future Climate of Amazonia, Rios Voadores, NPS



## Precipitation on land versus distance from the ocean: Evidence for a forest pump of atmospheric moisture

Anastassia M. Makarieva<sup>a,b,\*</sup>, Victor G. Gorshkov<sup>a,b</sup>, Bai-Lian Li<sup>b</sup>

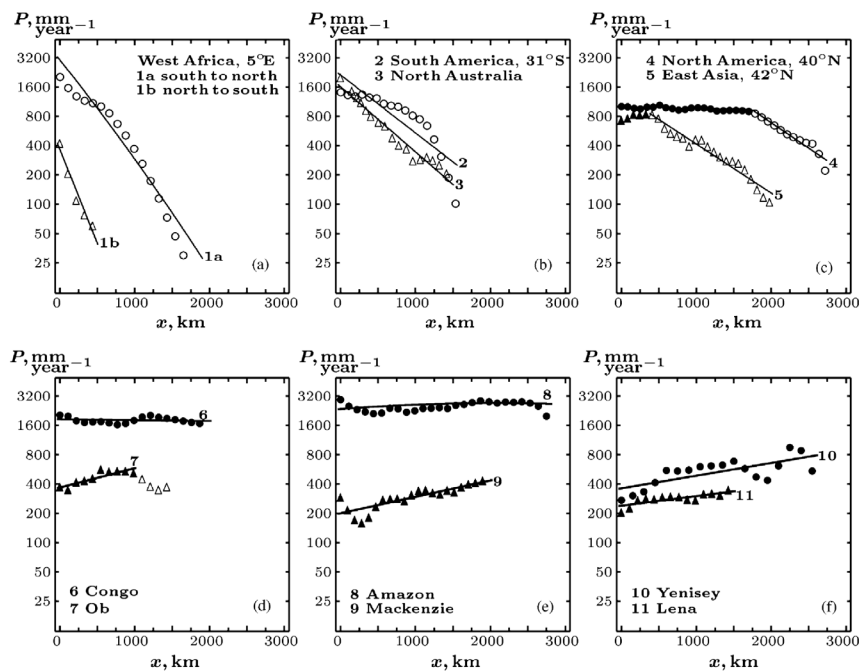
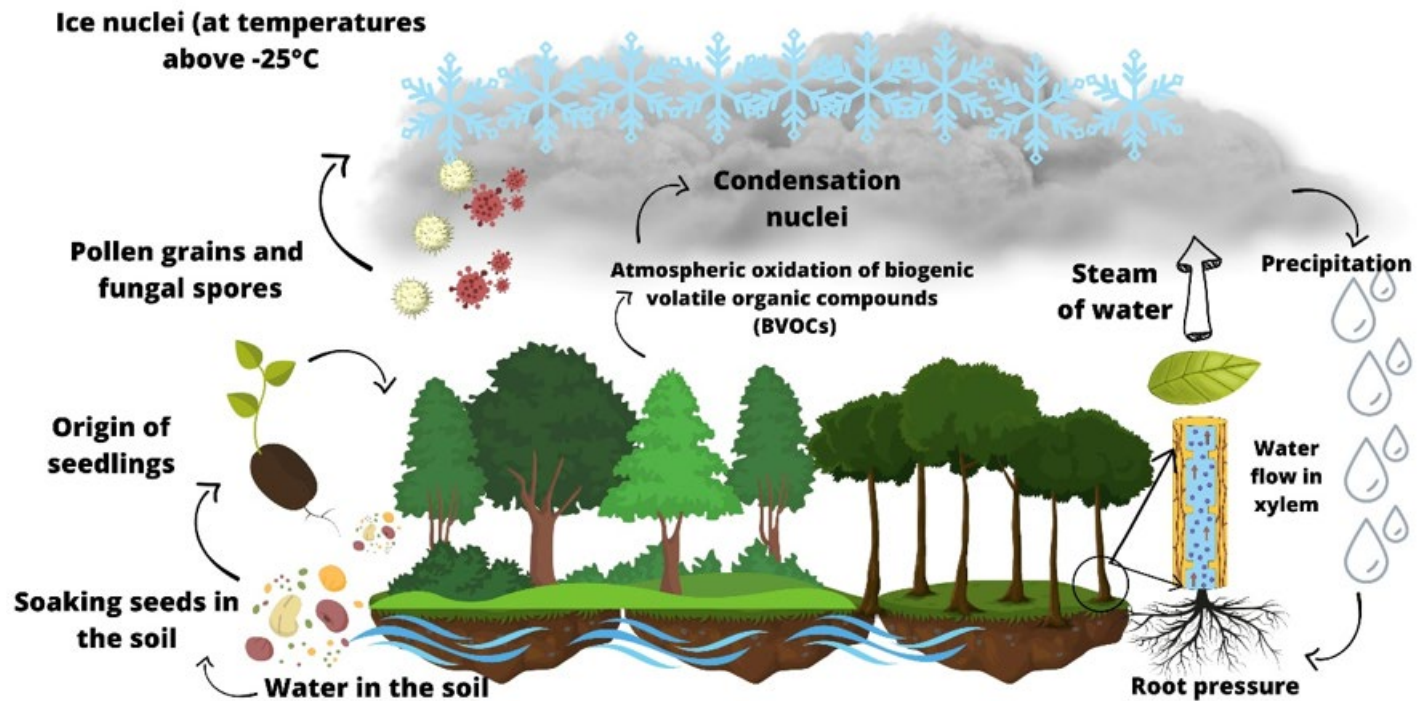


Fig. 2 – Dependence of annual precipitation  $P$  (mm year<sup>-1</sup>) on distance  $x$  (km) from the ocean over non-forested territories (open symbols) and forest-covered territories (closed symbols). Regions are numbered as in Table 1, where parameters of the linear regressions are also given.



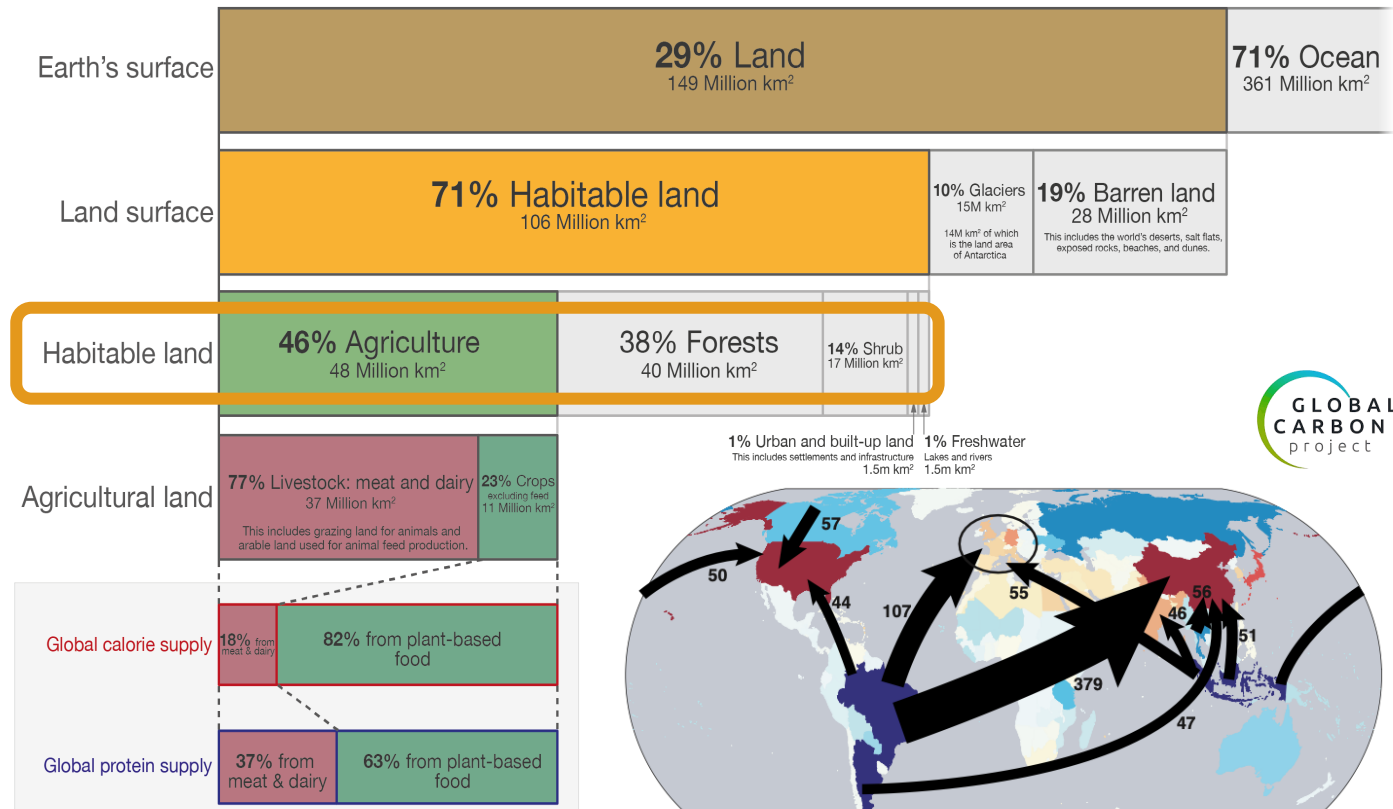


# Le Foreste come generatrici di pioggia



# Global land use for food production

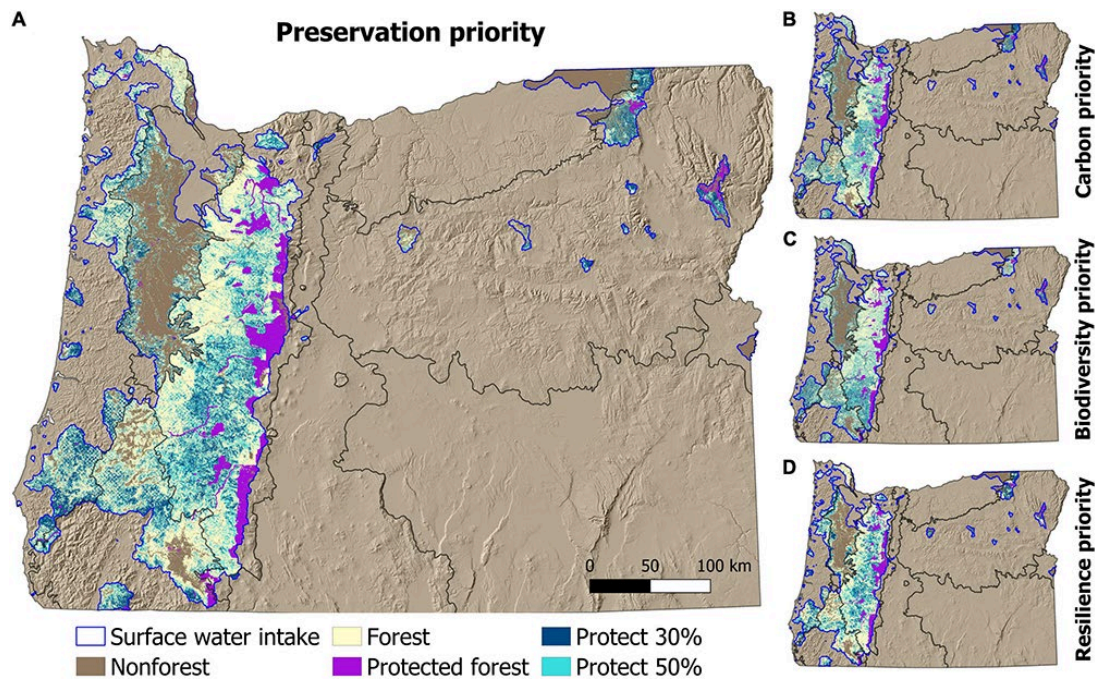
Our World  
in Data



Data source: UN Food and Agriculture Organization (FAO)  
OurWorldinData.org – Research and data to make progress against the world's largest problems.

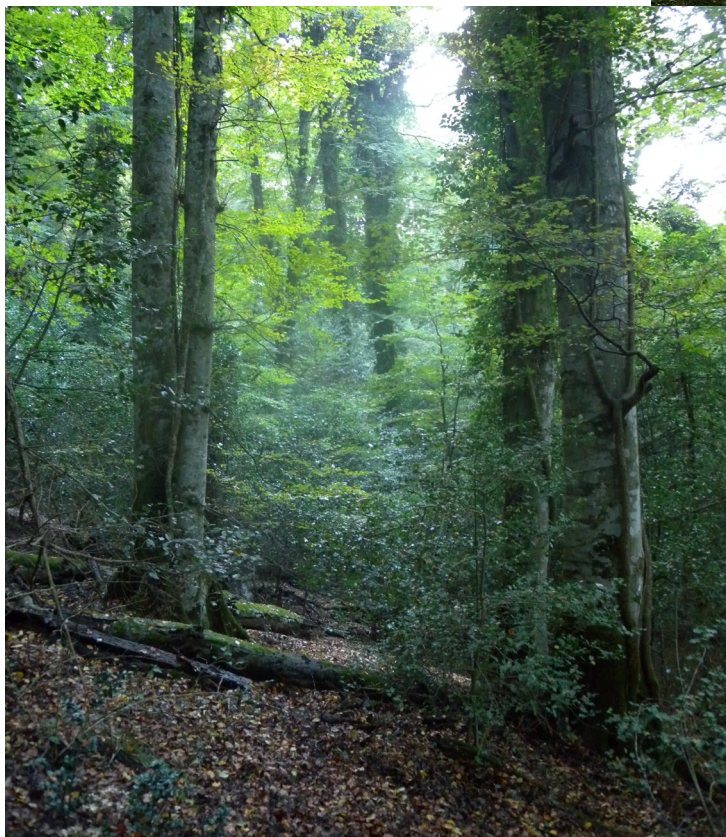
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Date published: November 2019.



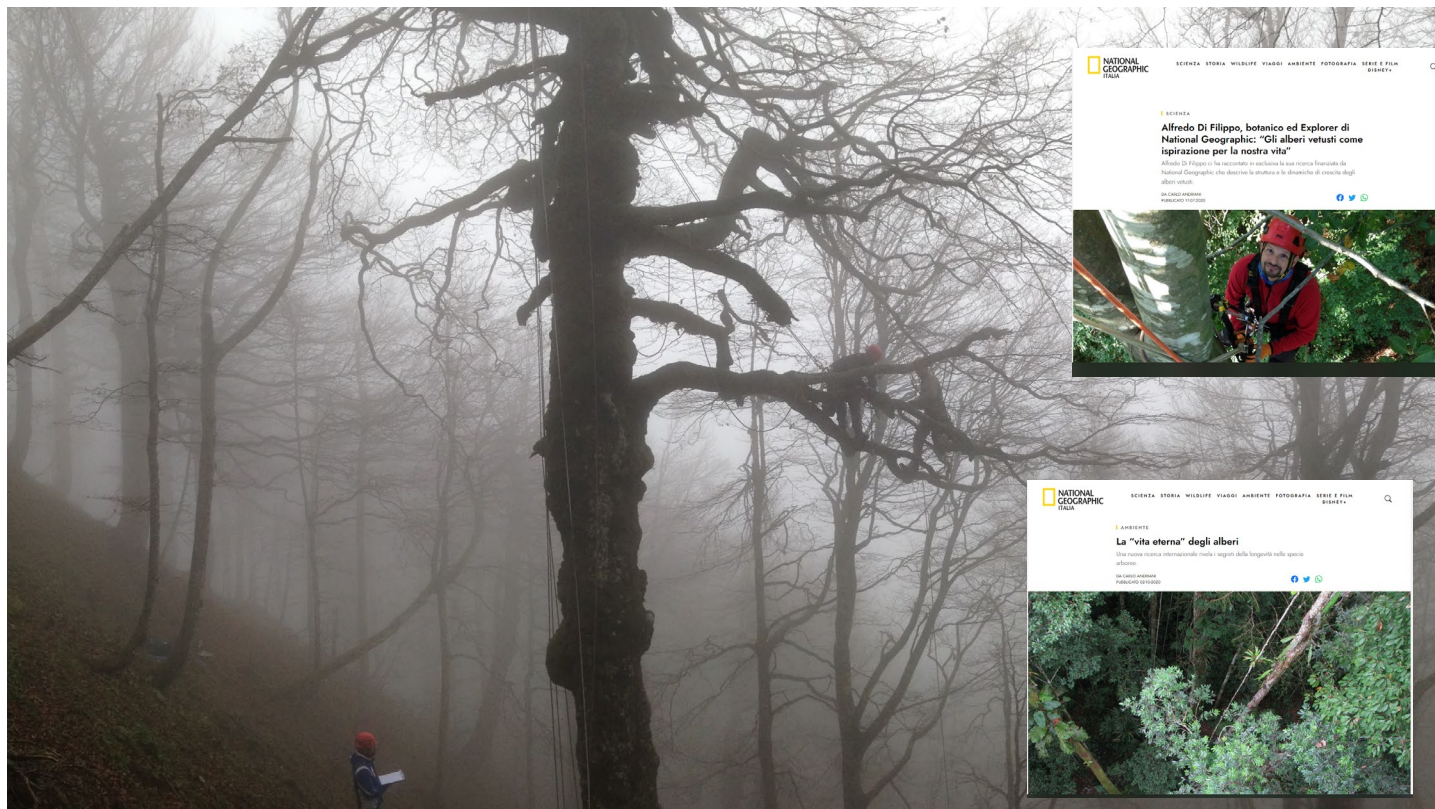


# Foreste Vetuste

Nesso cruciale per contrastare la perdita di biodiversità e la crisi climatica

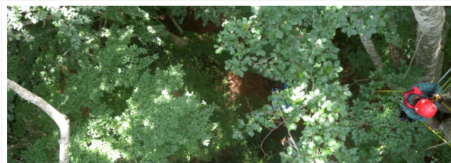






## Climbing the oldest Angiosperm trees in Europe

*Age vs. size effects on beech shape and growth under contrasting bioclimates*



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