Forests

GLOBE		Associated SDG	Type of Activity
Sphere	**Protocols**		
Atmosphere	Air temperature. Surface Temperature. Wind Direction and Speed. Precipitation. Relative Humidity	6 (Clean Water and Sanitation) 13 (Climate Action) 14 (Life Below Water) 15 (Life on Land)	Exploratory
Biosphere	Land Cover. Biometry. Phenology		
Pedosphere	Soil Characterization. Fertility. Humidity. pH. Temperature		
Hydrosphere	Water Temperature. pH. Alkalinity. Electrical Conductivity. Transparency. Salinity. Nitrates.		
Bundle	Agriculture Air quality ENSO Water Cycle. Water Quality Soils		

Overview

Satellite images, satellite data and maps are analyzed to characterize forests (tropical, subtropical, temperate and mangrove forests) and urban parks, and to establish differences and similarities. Students analyze cases of different types of forests and parks in Latin America and the Caribbean. Extensions of the activity are suggested by taking field measurements to supplement the satellite information.

Time

4 or 5 classes

Prerequisites

Basic knowledge of ecosystems, photosynthesis, meteorology and ICT. Ability to interpret satellite images and maps. Ability to locate points using latitude and longitude.

School level

Upper Elementary, High School and University students

Purpose

To understand the environmental conditions that allow the development of different types of forests, and the trends of short and long term changes in the interrelationship among the spheres of the Earth System.

Student Outcomes

- Students will identify the main types of forest cover in satellite images
- Students will characterize the environments where different types of forests grow and compare them with urban parks.
- Students will analyze changes in forest cover and tree height through the use of satellite images.

Background

Currently, almost a third of the planet's surface is covered by forests. The 2020 FAO report indicates that the greatest extension is occupied by tropical forests with high biodiversity, followed in extension by the boreal forest, then the temperate forest and finally, the subtropical forest. The Latin America and the Caribbean forests are megadiverse and, according to the latest estimates, are home to approximately 49% of the world's tree species diversity (Cazzolla Gatti, et. al, 2022). Fig. 1.

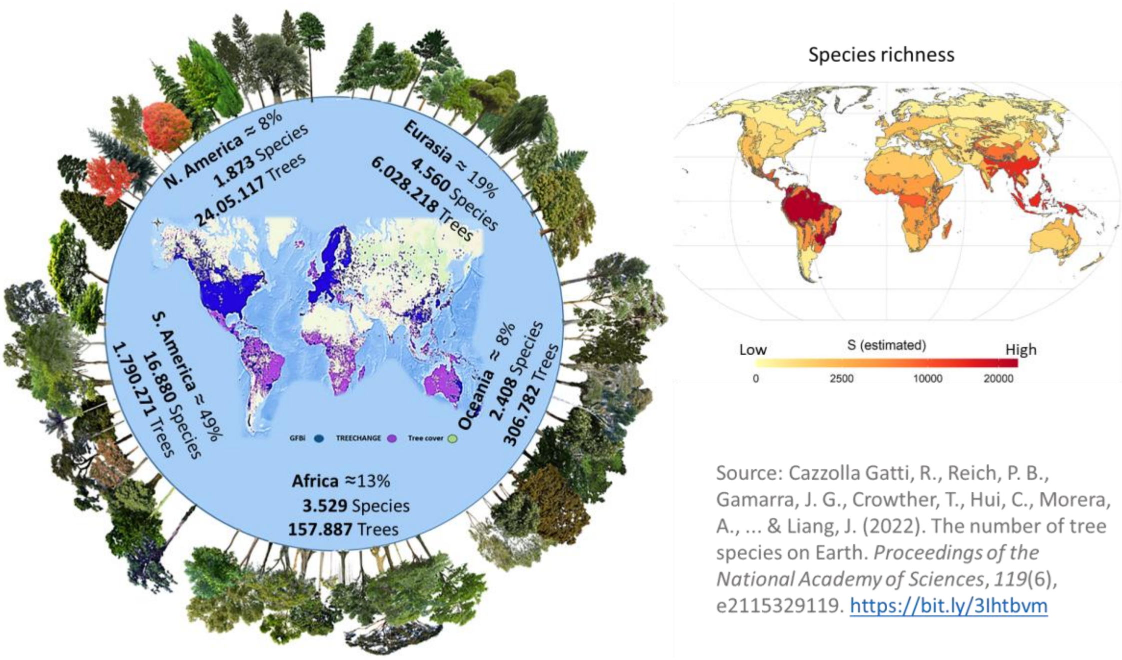


Fig. 1. Tree species richness

Conducting forest inventories to know the existing biodiversity in forests is useful because: a) It helps to infer the evolutionary mechanisms that generated the diversity and to predict how these same mechanisms will develop in the future. 2) It helps to evaluate which systems can be more resistant to global change. 3) It allows us to know the rare species and their vulnerability to extinction risk in order to manage biodiversity preservation. 4) It allows understanding total species assemblages to quantify the impacts of regional conservation efforts and improve the ability to predict extinctions.

People who live far from forests are not likely to think of them when they pour themselves a glass of water or watch the rainfall in city parks. But forests near and far affect daily life far more than most people realize. In large cities, the benefits of urban trees in reducing stress, sequestering carbon, cleaning and cooling the air are increasingly recognized, but the benefits of distant forests (in regulating global climate, water quality and availability, biodiversity benefits essential to health, people's quality of life, and others) are not always considered. The Cities4Forests initiative summarizes the benefits that forests provide to cities at three scales: internal, near and distant to help cities conserve, restore and sustainably manage their forests. Fig. 2. In addition to the services mentioned above, forests provide global consumer products such as latex, cork, fruits, nuts, timber, fibers, spices, oils, natural resins and medicines, among others.

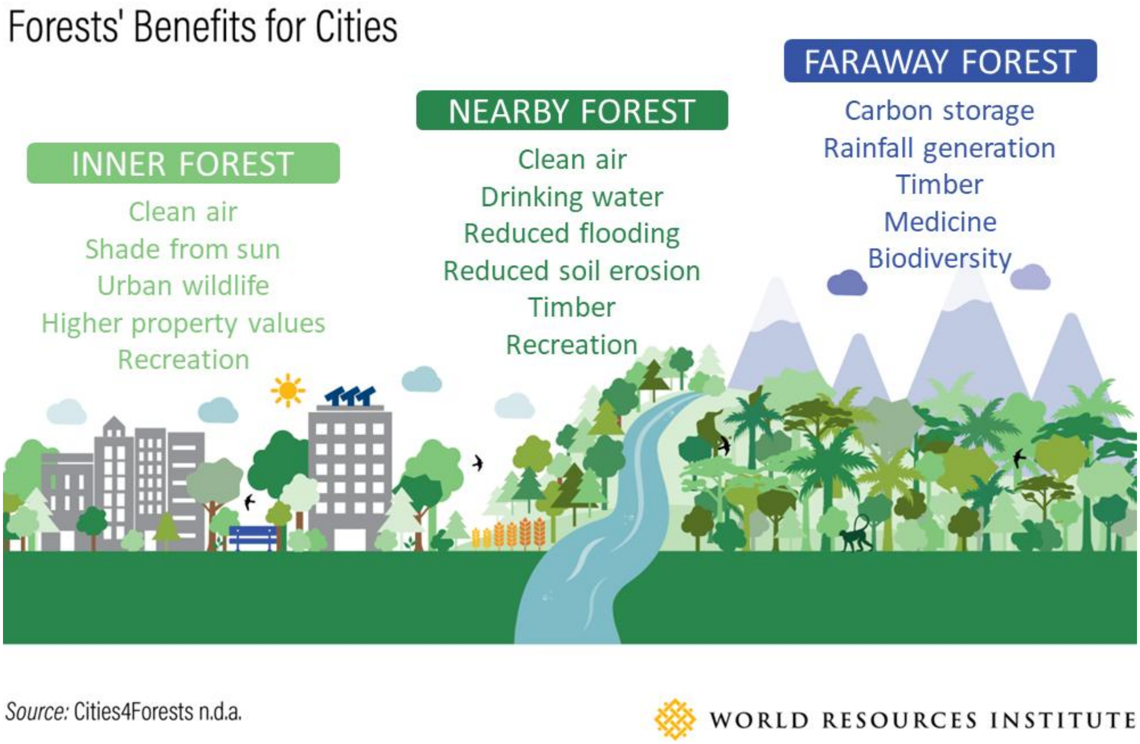
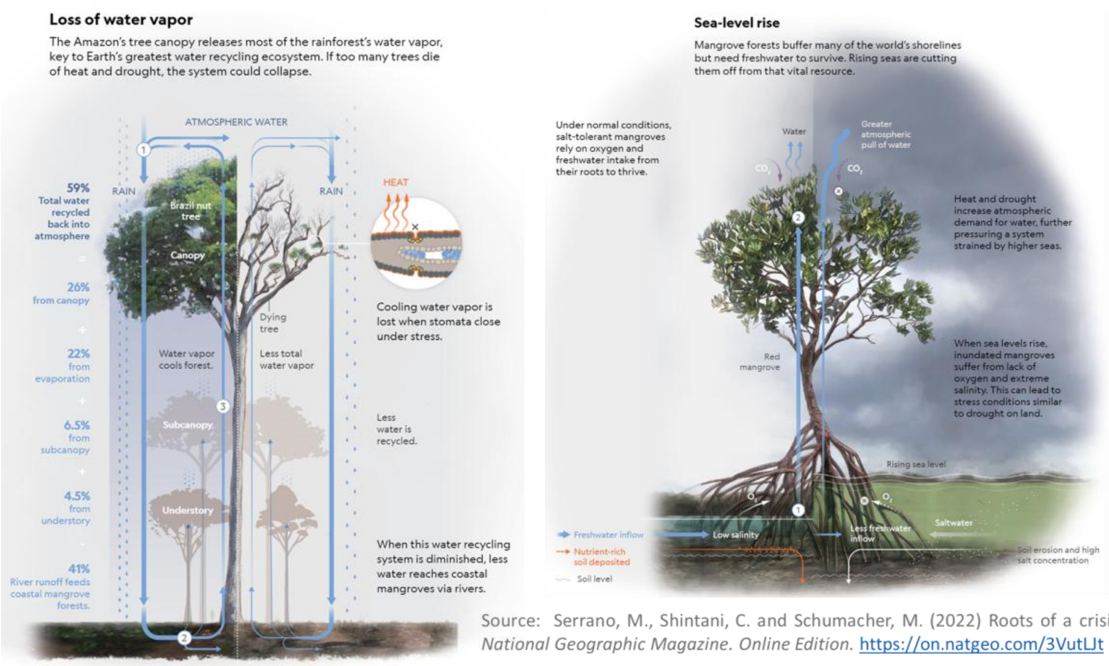


Fig. 2. Benefits provided to cities by the three levels of forests and their contribution to the achievement of the SDGs. Source: Cities4Forests (Wilson, et. al, 2022) https://www.wri.org/insights/forests-benefit-cities

The trees in the cities, with their shade, help to reduce the heat island effect. Many trees are used in parks and plazas, in some cases with artistic and recreational designs such as the labyrinths found in most of Latin America and the Caribbean: Labyrinth of Apaneca, El Salvador, Labyrinth in Ancon, Peru, Labyrinths Borgeano, Patagonian and Las Toninas, Argentina. But there are also other designs that can only be seen from the air, such as the Guitar-shaped park built with 7,000 trees near the city of General Levalle, Argentina. Another curiosity about trees is their height and, especially, their long life. Some forests are home to very old trees that have managed to survive diseases, fires, droughts, etc. In the Andean-Patagonian forests live the araucaria (*Araucaria araucana*) with some specimens that are over 1000 years old. In the city of Santa María del Tule, Oaxaca, Mexico, there is the Tule Tree, a specimen of Montezuma Cypress (*Taxodium mucronatum*) whose estimated age is close to 2000 years. In the Los Alerces National Park in Argentina is the larch (*Fitzroya Cupressoides*) called "El Abuelo" (The Grandfather) with 2600 years old. In Brazil, near Sao Paulo, there is Jequitibá-rosa (*Cariniana legales*) also called "Patriarca da Floresta", approximately 3,020 years old. Although it seems incredible, these trees have been widely surpassed by another larch (*Fitzroya cupressoides*), even older, called "El Gran Abuelo" (The Great Grandfather) which is found in the Alerce Costero National Park in Chile and its estimated age is of 5484 years. Old trees are extremely useful because they allow us to know the environmental conditions of the site where they grow, such as temperature, precipitation and competition with others. Valuable environmental records and past events remain in their growth rings. If they have survived a fire, marks are left between the rings. The formation of a growth ring begins in spring and ends when temperatures drop again in the fall. In the growth period, a wide light ring remains and, in the cold stage, a narrow, dark ring remains. By counting these rings it is possible to know the age of the tree, but also the changes in the thickness of the rings indicate a response to climate variability; for example, if there is water scarcity, the growth ring will be narrow, and in wet years, it will show wide rings. Climatology uses tree rings to study interannual variability in past climates and large-scale climate forcings such as ENSO (El Niño-Southern Oscillation) and PDO (Pacific Decadal Oscillation). In hydrology they are used for reconstructions of river flows, floods and water tables. In ecology, they are used to study population dynamics, age structure in a forest, temporal and spatial patterns of species establishment and disturbances, such as fires. In geomorphology, they are used to date glacial retreat, landslides, volcanic eruptions and earthquakes. Forests that lived in earlier geological eras and are now petrified have provided important information for reconstructing the Earth's past at some sites. Petrified forests have been found in Argentina, Peru, Brazil and even in Antarctica.



Source: Serrano, M., Shintani, C. and Schumacher, M. (2022) Roots of a crisis. *National Geographic Magazine. Online Edition.* https://on.natgeo.com/3VutLJt

Fig. 3. Impact of water vapor loss and sea level rise on trees.

Climate change is currently affecting the growth of trees; for example, heat waves and droughts cause greater water loss through transpiration, stomatal closure, and requires greater demand from the soil. The dry soil retains moisture and stresses trees that are unable to access it, even causing death. Under stress conditions, trees are more vulnerable to diseases caused by pathogens, and offer little resistance to insect pest attack. In the Amazon, tree transpiration creates clouds that produce precipitation of more than half of the water in the same place. The loss of water vapor due to prolonged droughts could cause this system to collapse. Mangroves need freshwater to survive and sea level rise is affecting them (Fig. 3).

Forests are capable of storing significant amounts of carbon in their biomass, as well as in dead wood, litter and soil. Monitoring tree health and the changes in: a) forest cover (whether gradual by species succession or abrupt by fire, deforestation), b) biomass density, its response to seasonal changes (such as green intensity, impacts of droughts and floods), c) its growth in height and diameter allows detecting trends and establishing management plans to conserve them in the future. Field measurements combined with the use of satellite data improve knowledge of forest conditions, the changes in forest cover, the anthropogenic impacts and those caused by climate change, among others.

For example, measuring tree height improves the estimates of how much carbon is stored in large forests, and field measurements help to verify data and improve models. In addition, field measurements can detect causes of changes such as tree mortality, degradation due to diseases or insect attacks, etc.

Guiding Research Questions

- Why are/aren't there trees in my local environment (perhaps because the environmental conditions are optimal, or on the contrary, the place is too dry, cold or windy)? Are the trees native or exotic?
- What animals use the trees around me?
- What factors affect tree growth in my locality? Are environmental conditions changing in my environment? How will tree growth be affected in the future?
- What is the impact of the trees in your city: how does the surface temperature decrease in the shaded area under the tree? How much does the brightness change in the shade and in the sun?
- Is the approximate age of the trees in your locality known?
- Were there forests in your locality? Are there fossils of petrified trees?

Scientific Concepts

- Ecosystems. Tropical, subtropical and temperate forests.
- Land cover
- Carbon cycle
- Satellite images

Materials and Tools

1. ArcGIS StoryMaps https://storymaps.arcgis.com/
2. State of conservation of natural World Heritage sites
3. FAO (2020). *Global Forest Resources Assessment 2020. Key findings*. - Map: Global Forest area by climate zones, 2020. P. 3
4. Consult satellite information data of different types of forests:

Case 1. Tropical forest. State of Amapá, Brazil:

- Google Map - Location
- Google Earth (Sequence 1985 to 2020)
- Total precipitation per month.
- Surface temperature - Monthly average
- Soil moisture. Monthly average - 0 to 10 cm.
- Tree cover. Gain and loss.
- Tree canopy height - GEDI Data
- Overall tree height 2020
- Changes in tree height between 2000 and 2020.
- Biomass density of tree canopy cover
- Protected areas
- Biodiversity

Case 2. Subtropical forest. Araucárias National Park, Santa Catarina, Brazil:

- Google Map - Location
- Google Earth (Sequence 1985 to 2020)
- Total precipitation per month
- Surface temperature - Monthly average
- Soil moisture. Monthly average - 0 to 10 cm.
- Tree cover. Gain and loss.
- Tree canopy height - GEDI Data
- Overall tree height 2020
- Changes in tree height between 2000 and 2020.
- Biomass density of tree canopy cover
- Protected areas
- Biodiversity

Case 3. Temperate forest. Corcovado National Park, Chile:

- Google Map - Location
- Google Earth (Sequence 1985 to 2020)
- Total precipitation per month
- Surface temperature - Monthly average
- Soil moisture. Monthly average - 0 to 10 cm.
- Tree cover. Gain and loss.
- Tree canopy height - GEDI Data
- Overall tree height 2020
- Changes in tree height between 2000 and 2020.
- Biomass density of tree canopy cover
- Protected areas
- Biodiversity

Case 4. Mangrove forest. Panama City:

- Google Map - Location
- Google Earth (Sequence 1985 to 2020)
- Total precipitation per month
- Surface temperature - Monthly average
- Soil moisture. Monthly average - 0 to 10 cm.
- Mangrove cover 2016
- Tree cover. Gain and loss.
- Tree canopy height - GEDI Data
- Changes in tree height between 2000 and 2020.
- Biomass density of tree canopy cover
- Protected areas
- Biodiversity

5. Consult satellite information data of urban parks

Case 5. José Enrique Rodó Park, Montevideo, Uruguay

- Google Map - Location
- Google Earth (Sequence 1985 to 2020)
- Total precipitation per month
- Surface temperature - Monthly average

- Soil moisture. Monthly average - 0 to 10 cm.
- Tree cover. Gain and loss.
- Tree canopy height
- Changes in tree height between 2000 and 2020.
- Biomass density of tree canopy cover
- Biodiversity

Case 6. Simon Bolivar Central Park, Bogota, Colombia

- Google Map - Location
- Google Earth (Sequence 1985 to 2020)
- Total precipitation per month
- Surface temperature - Monthly average
- Soil moisture. Monthly average - 0 to 10 cm.
- Tree cover. Gain and loss.
- Tree canopy height - GEDI Data
- Changes in tree height between 2000 and 2020.
- Biomass density of tree canopy cover
- Biodiversity

What and how to do it

- ***Beginning***

Show your students the following videos: a) *The Sustainable Development Goals need forests*, b) Forests and sustainable cities and visualization of the height of the world's trees in 3D (with data collected by the GEDI instrument on board the Satellite Space Station).

Ask your students to record the places in Latin America and the Caribbean with the tallest trees. Then make a list of the benefits that these trees offer them in their daily lives considering the distance they are from them.

- ***Development***

1. Ask your students to read the introduction to this activity and make a concept map with the information.
2. Divide the class into student groups and assign one case study to each group. Tell your students:
    a. Look on Google Map at the current satellite image. What do you see in that image (forest, parks, plantations, roads, rivers, lakes, etc.)? Is the forest/park near a city or within a city?
    b. Considering the conceptual map, analyze what ecosystem services the forest or park provides to nearby cities. How could they be influencing your locality?
    c. Open the Google Earth sequence and observe the changes in each year. Note the changes you observe, or if the area remains unchanged.
    d. Consult environmental data (precipitation, temperature and soil moisture) and record the most common values for the analyzed site to understand why trees grow in that location.

    Note: In WorldView you can change the month and year, bottom left

e. Analyze the tree cover- gain or loss. Compare years of tree cover loss and sudden changes in height with environmental conditions. Record the coincidences- if any.
f. Analyze the tree cover at different heights. Are there very tall trees in the analyzed site? What are the predominant heights? Have the trees grown, remained stable or decreased in height between 2000 and 2020?

   Note: Layers are available in GFW for the years 2000 and 2020, and of tree heights. ≥3, ≥4, ≥5, ≥7, ≥10, ≥15 y ≥20 m

g. How is the biomass density in the site analyzed? What is the predominant percentage of tree canopy density?

   Note: In GFW, layers are available for tree canopy densities > 10%, > 15%, > 20%, > 25%, > 30%, > 50%, and > 75%.

h. Is the site under analysis a protected area?
i. What is the predominant percentage of biodiversity?

3. Ask your students to develop a presentation on their case study. They can make a story with maps (using ArcGIS StoryMaps), or a slide presentation. To develop the presentation consider the following questions: How do forests change over time, did they observe long-term changing trends? What changes are seasonal?
4. Bring all the groups together and ask them to explain the analyzed cases and compare the similarities among them: Tropical forest, subtropical forest, temperate forest and the analyzed city parks.
5. Complete the conceptual map with the main characteristics of each case study.
6. If there are forests in your area or if you have a square or park nearby, you can use the same tools to analyze their condition and changes in recent years.

- ***Closing***

Due to the relevance of this problem, it is important to develop outreach activities. Students can develop a story with maps (Story Map), a video, or flyers to post on social networks summarizing the analyzed cases and highlighting the importance of their conservation.

Frequently Asked Questions

Where can I find satellite images? - Worldview - Google Earth - Google Map

Where can I find forest cover information? Global Forest Watch (GFW) has a wealth of information on forests. ResourceWatch gathers information from different sources.

Suggested resources for further information

As an extension of this activity, students can consult satellite images from different dates and locations to explore other sites of interest. Global Forest Watch collects a wealth of information on forests that can be used to supplement the research. The OpenAltimetry site, which collects data from NASA's ICESat-2 satellite, provides highly accurate terrain and vegetation heights (data are only available for some sites).

You can use the GLOBE Program protocols to take manual measurements in your environment. You can visit a forest, a park, a city square to study species diversity, take measurements of tree height (using a clinometer or the GLOBE Observer Trees App), surface temperature, precipitation (or consult nearby weather service records or Wundermap, which gathers particular weather stations). You can also take measurements of trees near your environment (school or home) to characterize the type of tree cover and the environmental services it provides. You can supplement this information with other biosphere measurements such as phenology (measuring the green-up or green-down), or atmosphere, pedosphere and hydrosphere measurements.

Websites

- Cities4Forests https://cities4forests.com/
- FAO. Global Forest Resources Assessments https://www.fao.org/forest-resources-assessment/en/
- GFW Tree canopy height (2000-2020) ≥ 3m to ≥ 20m https://bit.ly/3u6h2Ba
- GFW Tree canopy changes https://www.globalforestwatch.org/map
- GFW Biomass density in trees > 10% to > 75% https://bit.ly/3ARcXV0
- GFW Biodiversity slides https://bit.ly/3Z8rgzd
- Global Tree Canopy Height 2020. 0 to ≥ 50m https://bit.ly/3VdP1mT
- OpenAltimetry https://openaltimetry.earthdatacloud.nasa.gov/data/icesat2/
- World Natural Heritage https://worldheritageoutlook.iucn.org/es
- Protected Planet (Map of Protected Areas) https://www.protectedplanet.net/en
- ResourceWatch 2000 - 2020 Tree Height Change https://bit.ly/3IgX1Qo
- UN Biodiversity Lab https://unbiodiversitylab.org/es/

Videos:

- FAO (2018) *The Sustainable Development Goals need forests*. Youtube https://youtu.be/EoxB5IxTig8
- FAO (2018) *Forests and sustainable cities.* https://youtu.be/ucXz3EqzRLo
- GLOBE Observer Trees https://observer.globe.gov/de/toolkit/trees-toolkit
- National Parks (2017) *Grandfather Larch in National Park.* YouTube: https://youtu.be/_dzkTKsd4z8
- SVS (2019) GLOBE Observer Trees, https://svs.gsfc.nasa.gov/13211
- SVS (2021) GEDI Forest Height. https://svs.gsfc.nasa.gov/4950 (3D Map of World Tree Height)

Infographics:

- National Geographic (2022) Roots of a crisis: heat and drought [In English] [In Spanish] - pests and pathogens [In Spanish] - loss of water vapor and sea level rise. [In Spanish]

Articles

- Botosso, P. C., & de Mattos, P. P. (2002). Conhecer a idade das arvores: importância e aplicação. *Embrapa Florestas.* https://bit.ly/3jKr2y1
- National Geographic Magazine (2022) *What is the oldest tree on Earth and will it survive climate change*? [In Spanish] [In English] - *The world's forests decades of loss and change*. Special supplement. [In Spanish] [In English]

Other resources:

- Tutorials by: Worldview, Story Map

Bibliography

Cazzolla Gatti, R., Reich, P. B., Gamarra, J. G., Crowther, T., Hui, C., Morera, A., ... & Liang, J. (2022). The number of tree species on Earth. *Proceedings of the National Academy of Sciences*, *119*(6), e2115329119. https://bit.ly/3Ihtbvm.

FAO (2020). *Global forest resources assessment 2020 - Key findings*. Rome. https://www.fao.org/3/CA8753EN/CA8753EN.pdf

FAO (2022) *The State of The World's Forests 2022. Forest pathways for green recovery and building inclusive, resilient and sustainable economies.* Rome, FAO. https://www.fao.org/3/cb9360en/cb9360en.pdf

Lang, N., Jetz, W., Schindler, K., & Wegner, J. D. (2022). A high-resolution canopy height model of the Earth. arXiv preprint arXiv:2204.08322 https://bit.ly/3VdP1mT

Lara, A., Villalba, R., Urrutia-Jalabert, R., González-Reyes, A., Aravena, J. C., Luckman, B. H., ... & Wolodarsky-Franke, A. (2020). +A 5680-year tree-ring temperature record for southern South America. *Quaternary Science Reviews*, *228*, 106087. https://bit.ly/3IfpCWi

Locosselli, G. M., Brienen, R. J., Leite, M. D. S., Gloor, M., Krottenthaler, S., Oliveira, A. A. D., ... & Buckeridge, M. (2020). Global tree-ring analysis reveals rapid decrease in tropical tree longevity with temperature. *Proceedings of the National Academy of Sciences*, *117*(52), 33358-33364. https://www.pnas.org/doi/10.1073/pnas.2003873117

McCullum, A. and Torres-Pérez, J. (2020). *Understanding Phenology with Remote Sensing.* NASA Applied Remote Sensing Training Program (ARSET). https://go.nasa.gov/3WI6dSs

McCullum, A., and Torres-Pérez, J. L. (2022). *Evaluating Ecosystem Services with Remote Sensing.* NASA Applied Remote Sensing Training Program (ARSET). https://go.nasa.gov/3ClVxRo

NASA Earth Observatory (2011) *The Carbon Cycle.* https://go.nasa.gov/2vsWS60

NASA Earth Observatory (2022) *Coniferous Forest.* https://go.nasa.gov/3OEXBbQ

NASA Earth Observatory (2022) *Rainforest.* https://go.nasa.gov/3u2MjET

NASA Earth Observatory (2022) *Temperate Deciduous Forest.* https://go.nasa.gov/3XAP4L8

Ramírez, C., Alberdi, I., Bahamondez, C., and Freitas, J., coords (2021). *National Forest Inventories of Latin America and the Caribbean: Towards the harmonization of forest information.* Rome, FAO. https://doi.org/10.4060/cb7791es

Schmidt, C., Herold, M., McCullum, A., Domke, G., Wilson, T., Olofsson, P., Green, C. and Flifet, H. (2016). *Remote Sensing of Forest Cover and Change Assessment for Carbon Monitoring.* NASA Applied Remote Sensing Training Program (ARSET). https://go.nasa.gov/3CkRULs

Schmidt, C., McCullum, A. and Hewson, J. (2018). *Change Detection for Land Cover Mapping.* NASA Applied Remote Sensing Training Program (ARSET). https://go.nasa.gov/3WZ24cC

Spalding, M. D. and Leal, M. (Eds.) (2021). *The state of the world's mangroves 2021.* Global Mangrove Alliance. https://bit.ly/4129Wfv

The GLOBE Program (2022) *GLOBE Protocol Bundles. https://www.globe.gov/es/web/earth-systems/*

Wilson, S.J., E. Juno, J.R. Pool, S. Ray, M. Phillips, S. Francisco, and S. McCallum (2022). *Better Forests, Better Cities. Report.* Washington, DC: World Resources Institute. https://www.wri.org/research/better-forests-better-cities