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TREES, SOIL, AND CLIMATE: WHAT IS THE CONNECTION?

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YOUNG REVIEWERS:


ATHARV
AGE: 12


TAHIYAT
AGE: 11


TAHMID
AGE: 13


TANVIR
AGE: 14

Land plays an important role in climate, biodiversity, and people's lives. Plants and soils absorb carbon dioxide, store carbon, and recycle rainwater, affecting the planet's temperature and weather. Land also provides food, timber, and other products that we need to survive. Some land activities, like planting trees, can take carbon dioxide out of the atmosphere, reducing global warming. Other land activities, like restoring wetlands, can help protect infrastructure and ecosystems from the results of a changing climate, like flooding. This article will explain how land management can help reduce greenhouse gas emissions, help people respond to changes in climate, and improve biodiversity. We will also talk about how scientists measure and understand these activities and their effects.

THE ROLE OF LAND

BIODIVERSITY

The variety of all living things around the world, including plants, animals, and the ecosystems that they live in.

GREENHOUSE GASES

Gases in the atmosphere that can absorb heat and cause the planet to warm up. Human activity is putting more greenhouse gases into the air, leading to global warming.

DEFORESTATION

Removing forest and replacing it with another type of land cover, such as crops.

DEGRADATION

Damaging the forest but leaving it to remain as forest—but with fewer trees and bare areas within it.

Land plays an important role in climate, **biodiversity**, and people's lives. Land absorbs carbon dioxide, a **greenhouse gas** affecting Earth's temperature. Plants use carbon dioxide, sunlight, and other nutrients to grow and produce oxygen. Carbon is stored in plants and soils, but can be lost when land is cleared, such as by **deforestation** and **degradation**. When carbon dioxide is released by burning fossil fuels or by deforestation, some of it goes into the ocean, some of it is absorbed by plants as they grow, and some stays in the atmosphere. The carbon dioxide that stays in the atmosphere traps heat, warming our planet. Cows and sheep also produce methane, a potent greenhouse gas, as they digest their food. Light-colored and snow-covered land surfaces reflect sunlight, but darker surfaces like trees absorb sunlight, making the air above them hotter. Plants affect how energy flows across the land surface, influencing local temperature, winds, and rainfall.

Over the last 150 years, changes in land cover, such as cutting down trees to plant crops and grow livestock, have led to a release of greenhouse gases, contributing to global warming. Those changes have also produced more light-colored surfaces on Earth, which reflect more sunlight, and have caused some cooling [1]. However, the total global warming from increases in greenhouse gases is larger than the cooling from changing land cover. So, overall, Earth has warmed over the last 150 years by 1.15°C.

Land provides food and recycles and stores water. Farmers use land to grow crops, like wheat, maize, fruit, and vegetables. Land is also used for livestock, like cattle, pork, and poultry—both for the animals to live on and to grow their feed. Today, about 12%–14% of Earth's land is used to grow crops, around 37% is used for livestock, and 30% is covered by forests (both natural and managed) [2]. Forests can provide timber for building, paper, and energy production. Some forests are untouched and provide homes for a wide variety of plants and animals, which means they have high biodiversity. Ecosystems with high biodiversity are more resilient to future climate change.

Land is also impacted by changes in climate. Temperature over land has risen considerably faster than temperature over the ocean. Rainfall has also changed, with some parts of the world becoming drier and more at risk of drought and wildfires. Other areas are having more powerful floods and storms. These changes in weather patterns are affecting when, where, and how well plants grow, and whether animals thrive.

HOW DO WE KNOW?

Scientists have several ways of understanding the role of land in climate. We can take measurements of land cover from the ground,

from airplanes, and from space. For example, satellites can tell us where forests and crops are by taking very precise pictures from space. There is also an instrument on the International Space Station that uses lasers to measure how tall trees are (Figure 1A). Some of the tallest trees in the world are redwood trees in California, USA (Figure 1B). From the ground, we can measure the size of individual trees in a forest, and we can also measure the uptake and emissions of greenhouse gases from plants and animals. We can also get data from timber producers and farmers. We use all these types of data to work out how much carbon is stored, gained, or lost. By taking these measurements repeatedly, we can see how things change over time, and under different environmental conditions.

Scientists also use **computer models** to understand land and climate. These models use mathematical equations to represent various processes that happen on Earth, such as the way a tree grows, how much carbon it absorbs, how much sunlight the land reflects, and more. With these models, scientists can ask questions about what has happened in the past and what might happen in the future. For example, we can use a computer model to understand what would happen to the climate if we planted many more trees. This way, we can test what might happen before we try it in the real world.

COMPUTER MODELS

Computer programs which build a virtual copy of the world so that scientists can study how it might change.

HOW LAND CAN HELP ADDRESS CLIMATE CHANGE AND IMPROVE SUSTAINABILITY

The way we manage land can help limit climate change. Reducing deforestation and improving land management can reduce carbon dioxide emissions, while planting trees can remove carbon dioxide from the atmosphere (although it can take several decades for new trees to grow). People may consider changing their diets to eat less meat, or they may try to waste less food, because these actions will reduce greenhouse gas emissions. Good land mana gement can also free up land for forests and other natural ecosystems, increasing biodiversity and **food security** at the same time. Restoring natural ecosystems, like wetlands, can also help slow down natural river flow and prevent flooding. Increasing how much carbon is stored in soils can help farmers grow more food on the same amount of land.

FOOD SECURITY

Ensuring all people have reliable and affordable access to enough food.

BIOENERGY

Energy made by burning plants or wood rather than fossil fuels like coal, oil, or natural gas.

SUSTAINABILITY

Acting in a way so that our actions now do not damage the ability of future generations to also benefit from the land in the same way.

Land products can replace goods and services that produce a lot of greenhouse gases. For example, we can burn wood or crops (called **bioenergy**) as an energy source instead of fossil fuels like oil and coal; or we could use timber instead of concrete and steel in buildings. While these steps could reduce greenhouse gases, we would need to use large areas of land to produce this bioenergy. This might mean there is less land available to grow crops for food, which could lead to challenges for food security and **sustainability** [2]. While land can help limit climate change, it cannot stop it all: greenhouse gas emissions

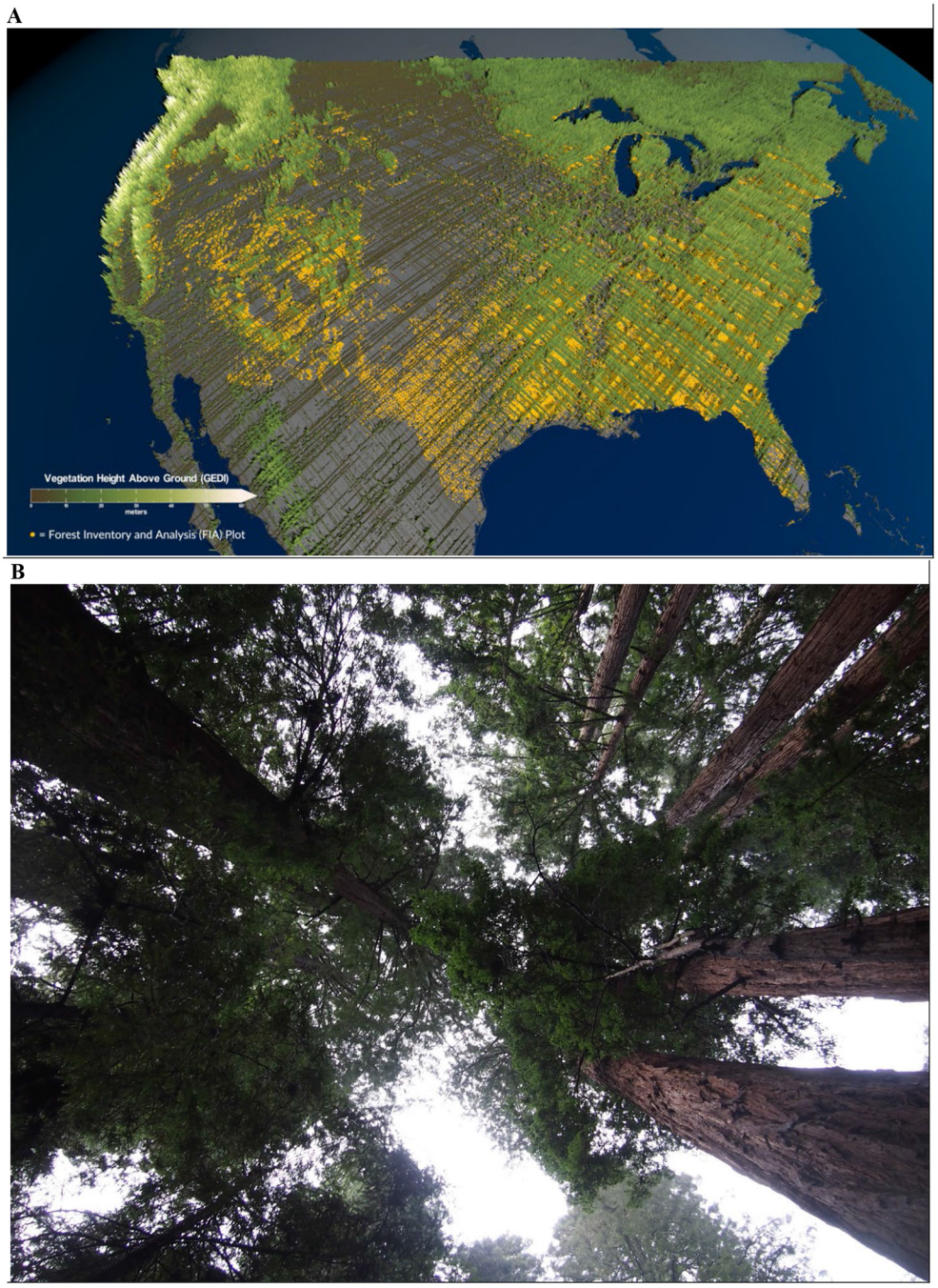

Figure 1

(A) How we measure the land: the orange dots show places where the U.S. Forest Service has special plots of land where people on the ground can measure the trees directly. The other colors show the height of the trees measured from space, by the Global Ecosystem Dynamics Investigation (GEDI)—an instrument onboard the International Space Station. **(B)** A stand of old-growth coast redwoods appears to reach to the sky in Muir Woods, a primeval forest north of San Francisco (Figure credits: NASA/Karlin Younger).

from burning fossil fuels would need to be reduced to near zero to stop global warming.

Using computer models, scientists can look at how different choices people make will change the land in the future. There are many choices we can make now that can improve life on land and limit climate change. For example, we could have a future in which the Earth has grown back much of the forest areas that have been cut down. Improved farming technology could help ensure that

food is available to everyone around the world, while still increasing forest areas.

Looking at the same area of North America shown in Figures 1, 2 shows the results of a computer model predicting how the world would look in the year 2100 if tree cover increased and greenhouse gas emissions were reduced. The green colors show where there are more trees—partly because more trees are planted in this scenario and partly because higher levels of CO_2 allow trees to grow a bit better. We hope that having this knowledge of our possible options for the future will help society make better plans to tackle climate change and produce enough food.

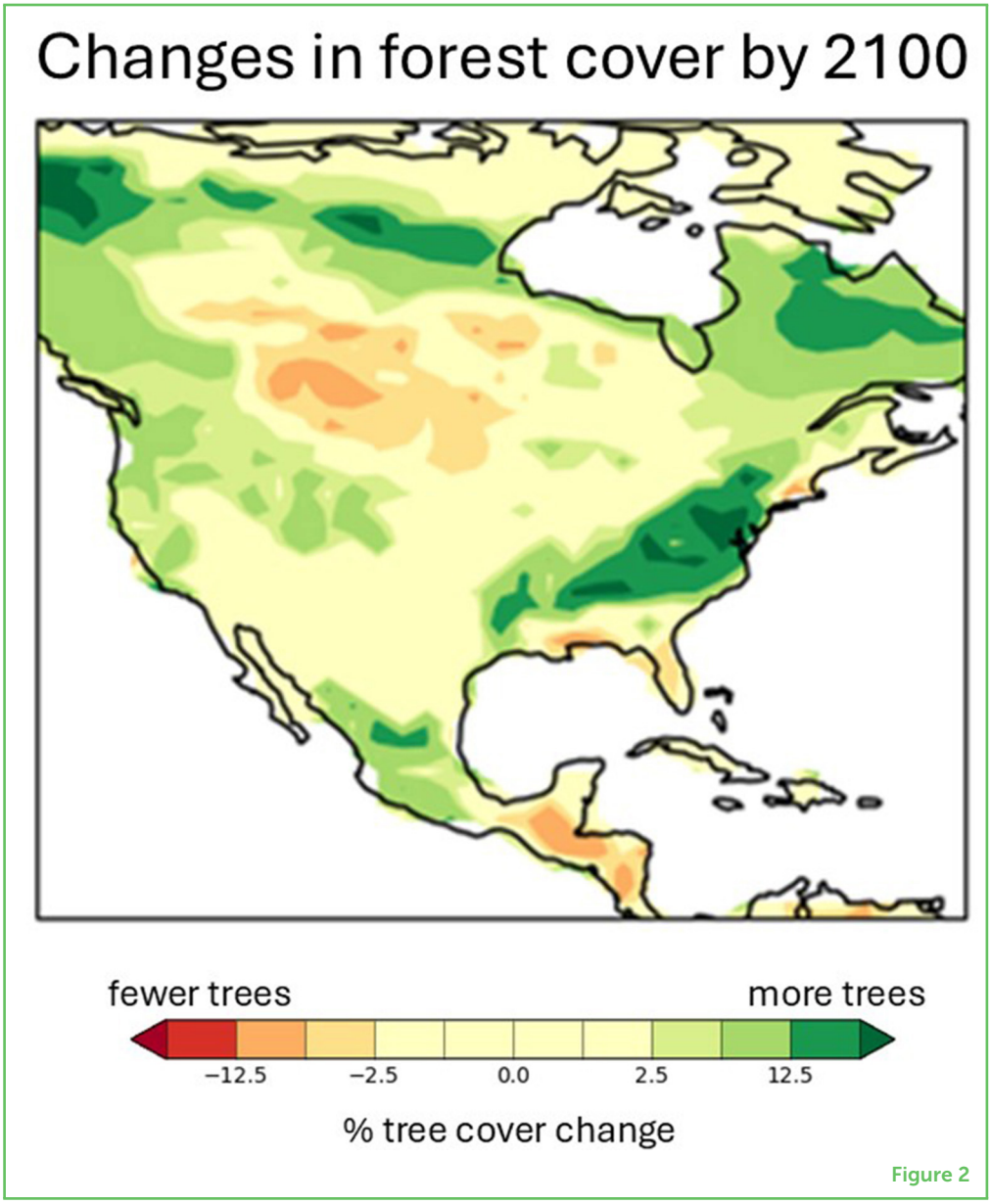

Figure 2

Changes in tree cover by the year 2100, from the UKESM1 computer model predicting the climate under a scenario known as SSP1-2.6 [3]. This scenario aims to limit global warming to around 2°C and includes a large increase in forest cover. The colors show changes in the percentage of land covered by trees, with the green areas showing where there are more trees.

Land is vital for our lives, and we know how to use it responsibly. Over many centuries, some communities and nations have learned how to use land sustainably. However, land is vulnerable to changes in climate as well as changes made by people. In recent decades, our use of the land has grown rapidly affecting climate, natural ecosystems, and biodiversity. We know that land management can help reduce greenhouse gas emissions and limit global warming. Our scientific knowledge of the problem can help us understand these issues and plan for a sustainable future.

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CONFLICT OF INTEREST: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

YOUNG REVIEWERS

ATHARV, AGE: 12

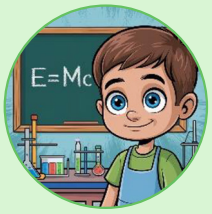
A curious and imaginative 12-year-old with a love for stars, stories, and science. Equally drawn to books, building things, and big questions about the universe. Calm yet adventurous, thoughtful yet playful, always exploring the world with wide eyes and a creative mind. Whether sketching dragons, designing paper airplanes, or decoding constellations, this young dreamer blends wonder with logic and magic with meaning, finding inspiration in the night sky and joy in every small discovery.

TAHIYAT, AGE: 11

My name is Tahiyat and I am 11 years old. I love drawing, painting and making paper crafts. I enjoy much wathing craftsmaing and "Origami" in youtube. My aim in life is to be a good doctor. In free time I love to sing and dance. My favorite cartoon character is Dipper, Mabel and Grunkle Stan from Gravity Falls.

TAHMID, AGE: 13

I am Tahmid and I am a big fan computer games. I love coding and making new friends in my virtual sports community. I also love music and spend a lot of time playing my guitar. My hobby is gardening and I love to germinate any seed I find. I wish one day I will be a great plant scientist.



TANVIR, AGE: 14

I am Tanvir. I love science and reading story books. Specially the universe, star, galaxy and science experiment attract me so much. My favorite TV show is Brainchild—A fun, science-based show answering cool kid-friendly questions.

AUTHORS

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Dr. Kate Calvin is NASA's chief scientist and co-chair of Working Group III of the Intergovernmental Panel on Climate Change for the 7th assessment cycle. She has also worked as an earth scientist at the Pacific Northwest National Laboratory's Joint Global Change Research Institute, where her research focused on relationships between human and Earth systems in the context of climate change. Calvin received her doctorate in management science and engineering from Stanford University and a Bachelor of Science in computer science and mathematics from the University of Maryland. Kate is also affiliated with Pacific Northwest National Laboratory, which did not provide specific support for this paper.

JO HOUSE

Dr. Jo House is a professor in environmental science and policy at Bristol University. Her research focuses on land and climate interactions, including carbon emissions from land use changes and climate mitigation through carbon dioxide removal techniques like afforestation and bioenergy. Her aim is to provide better evidence for climate policy. Jo has worked as head of climate advice for the Government Office for Science and has been an author for many reports of the Intergovernmental Panel on Climate Change including the Special Report on Climate Change and Land.

CHRIS D. JONES

Dr. Chris Jones is a climate research fellow at the Met Office Hadley Centre in Exeter in the UK, and a professor in climate science at the University of Bristol. He has over 30 years' experience writing computer programmes to model how climate affects our natural ecosystems and how the carbon cycle helps reduce the amount of CO_2 pollution in the atmosphere. He leads a research programme with partners in Brazil and has visited research sites in the Amazon rainforest. The photo here is on top of the Mauna Loa volcano in Hawaii where CO_2 is measured.
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