EARTH AND ITS RESOURCES
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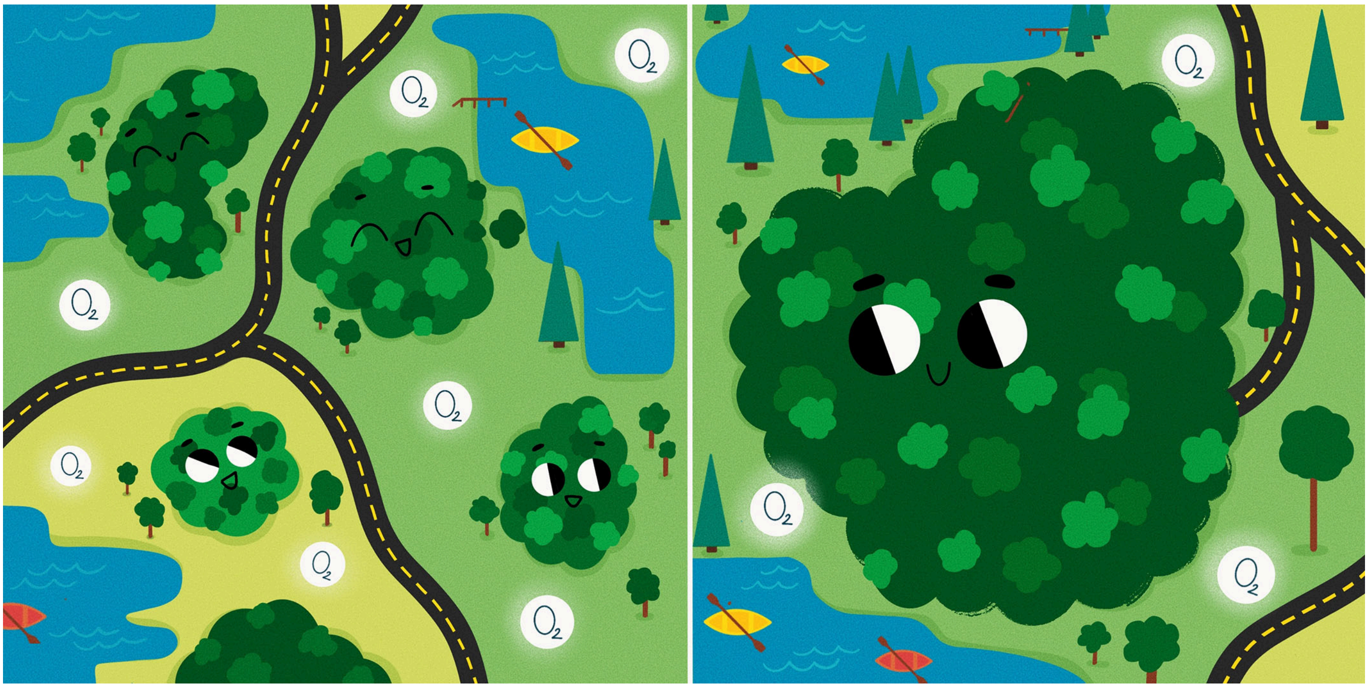

EVEN SMALL FOREST PATCHES CAN HELP FIGHT CLIMATE CHANGE!

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YOUNG REVIEWERS:

ANTONIO
AGE: 9

YEONWOO
AGE: 15

Climate change is caused by humans emitting polluting gases. Carbon dioxide (CO_2) is one of the most important and well-known polluting gases we emit. Forests are carbon vacuum cleaners: *via* their leaves, trees take up carbon and store it in their wood, roots, and leaves. We found that forest edges, where it is warmer and sunnier, can store more carbon than the forest interior, where it is cooler and shadier. This is important, because the amount of forest edges has increased due to large forests being split up into small forest patches by roads, towns, or agriculture. In Europe, this extra carbon storage in forest edges is not usually considered important, but it represents the equivalent of a forest with an area of more than 1.4 million football (soccer) fields! To maximize carbon storage, we should not only protect small forests, but also plant new forests—even very small ones.

THE EARTH'S CLIMATE IS WARMING BECAUSE HUMANS RELEASE TOO MUCH CARBON INTO THE AIR

GREENHOUSE EFFECT

A process that occurs when greenhouse gases in the Earth's atmosphere trap the energy and heat from the sun, like a blanket around the Earth.

The **greenhouse effect** is a process that occurs when certain gases in the Earth's atmosphere trap the energy and heat from the sun (Figure 1). These gases are called **greenhouse gases**. You can think of this layer of gases as a blanket around the Earth: it keeps the Earth warm. Without the greenhouse effect, most heat would escape back into space and the Earth would be too cold for us to live on.

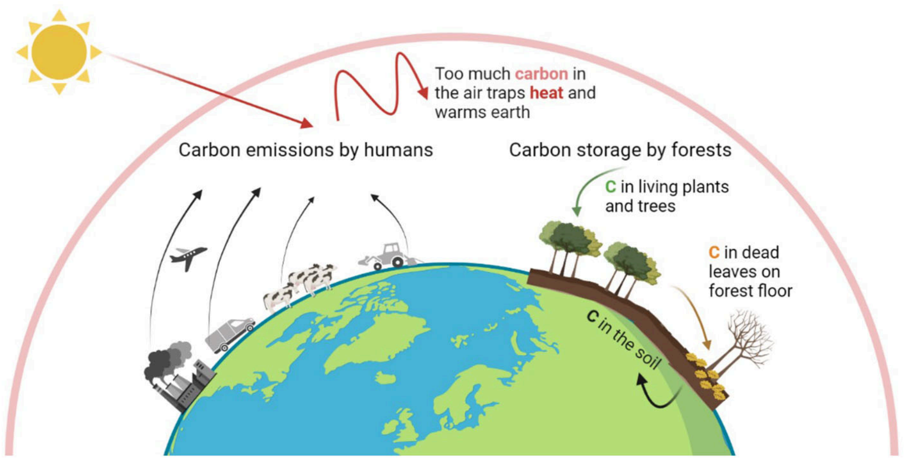

Figure 1

Figure 1

The most important greenhouse gas emitted by humans is CO_2. The main sources of CO_2 are electricity and heat production, agriculture, deforestation, factories, and vehicles [1]. The carbon (C) in the air acts like a greenhouse: It traps the heat from the sun and warms the earth. This enhanced greenhouse effect causes climate change. Forests can help to reduce the amount of carbon in the air by storing carbon in living trees, in the dead leaves on the forest floor, and in the soil.

However, due to human activities such as driving cars, deforestation, burning coal and gas to make electricity, and raising cows for meat and milk, we emit more greenhouse gases into the atmosphere than in the past. Carbon dioxide (CO_2) is one of the most important greenhouse gases we emit. CO_2 emissions have caused the greenhouse effect to become stronger, leading to increasing temperatures across the globe. This global warming is changing Earth's ecosystems and weather and resulting in major climate changes. For many locations, this means hotter heatwaves, longer periods without rain (droughts), or too much rain at once, causing floods! You may have noticed such events occurring more often where you live, too.

GREENHOUSE GASES

Gases in the atmosphere that can trap the energy and heat from the sun at the Earth's surface. Carbon dioxide (CO_2) is an example of an important greenhouse gas.

To combat climate change, we need to think about ways to reduce our CO_2 emissions. We can eat less meat, use less electricity or gas to warm our houses, and ride our bikes instead of driving. To help us, nature has come up with a nice solution as well: trees!

TREES DRAW CARBON FROM THE AIR

Trees store carbon in their trunks, roots, branches, and leaves. Trees need carbon to grow—they draw CO_2 from the air like vacuum cleaners. Air enters the leaves through tiny pores and, once inside, the carbon is captured from the air, while oxygen is released back into the environment.

Trees can store carbon in two more ways, which are perhaps less easy to see, but not less important (Figure 1). In addition to storing carbon in their bodies, trees also increase the amount of carbon stored in on the forest floor and in the soil (Figure 1). In autumn, most trees let go of their leaves, which form a carpet of dead leaves, called the **litter layer**, on the forest floor. Carbon makes up more than half of the mass of the litter layer. In autumn, earthworms, woodlice (pill bugs), and other tiny organisms living in the soil break down the litter layer into smaller parts. The dead plant material becomes part of the soil. In this way, forest soils can form a massive invisible carbon-storage room. More than half of the carbon stored in a forest is actually below our feet, in the soil [2].

LITTER LAYER

The layer of dead leaves on the forest floor.

FOREST EDGES CAN TAKE UP MORE CARBON THAN FOREST INTERIORS

Not every tree captures the same amount of carbon. We found that forest edges store more carbon than forest interiors! The **forest edge** is the outer area of the forest, the part that is close to surrounding grasslands, agricultural fields, or roads. The forest interior is the inner part of the forest, far away from the edges. Forest edges are champions of carbon storage. First, forest edges store more carbon in their wood and leaves than forest interiors do. Second, in the litter layer, it is a tight race between forest edges and interiors. In cold, northern Europe, the litter layer in forest edges has a higher carbon stock than the litter in the interior. In warm, southern Europe, the litter layer in the forest interiors is the winner. Whether edges or interiors store more carbon in the litter layer thus depends on the climate. Third, the forest edges and the interiors store about the same amounts of carbon in the forest soil—a shared first place! Overall, if we sum up the three ways in which forests store carbon, forest edges are the carbon champions (Figure 2) [3].

FOREST EDGE

The outer area of the forest, close to surrounding grasslands, fields, or roads.

There are several reasons that forest edges have higher carbon stocks—light, temperature, and nutrients. Imagine a tree growing in the forest interior, surrounded by many large trees where it is cool, humid, and dark. In the forest edge, at least part of each tree is not surrounded by other trees, since forest edges border open spaces such as streets or agricultural fields. Edge trees thus receive more sunlight and warmth. Edges also receive more nutrients, like nitrogen, from outside the forest. Read more in this Young Minds article. More nitrogen enters the forest edge than the forest interior (Figure 2). Hence, in forest edges, conditions are very good for trees to grow quickly and produce lots of wood and leaves, in which they store carbon. Sometimes, when part of a forest is cut, a new edge is created. Trees that were previously growing in the shady forest interior end up at the forest edge. These trees start to take up more

Figure 2

Forest carbon stocks change from the forest edge **(Left)** to the interior **(Right)**. The height of the lines represents how much carbon is stored. Most carbon is stored in wood and leaves (black), and wood and leaves in forest edges store much more carbon than they do in the interior. The soil (yellow) stores less carbon than the wood and leaves do, but more than the litter layer. In warm countries, litter stores more carbon in edges (blue), while in colder countries, the litter in forest interiors stores more carbon (red).

FOREST FRAGMENTATION

Splitting up large forests into multiple smaller forests. Fragmentation happens when humans cut forests to create space for agriculture, roads, or towns.

Figure 2

carbon because they receive more nutrients and sunlight than they did before.

FOREST EDGES WORLDWIDE ARE INCREASING DUE TO FRAGMENTATION

It is important to know how forest edges differ from the forest interior because the total area of forest edges is increasing worldwide. Forests are cut when humans need land for agriculture, roads, or towns. As a result, large forests are split up in multiple smaller forest patches, with other land uses in between. This process is called **forest fragmentation**. Due to forest fragmentation, the proportion of forest land that is close to a forest edge increases (Figure 3).

Figure 3

(A) A landscape with one large forest of 200 hectares. A hectare (ha) is a unit of area equal to about 1.5 football fields. **(B)** A fragmented landscape with several small forests. Together, these small forests also have a total area of 200 ha. While both landscapes have the same amount of forest area, the fragmented landscape has more than twice the amount of edge area (light green), and much less interior area (dark green) than the landscape with one large forest.

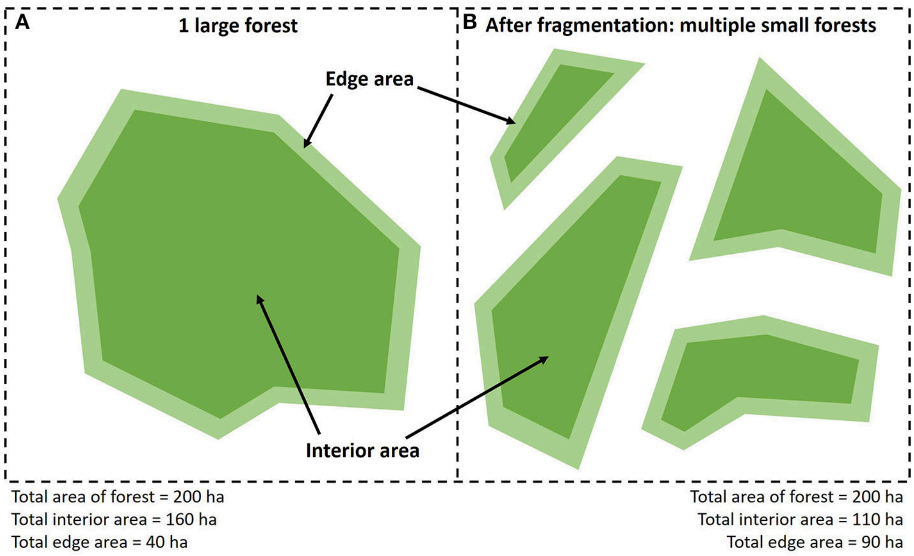

Figure 3

In the European Union (EU), 40% of all forests lie close to an edge [4]. Hence, there are 4 million km^2 of forest edge in the EU, which is equivalent to 580 million football (soccer) fields. The total length of forest edges in the EU equals 100 times the distance from the Earth to the moon. Impressive numbers, right? Yet, forest edges are currently ignored when the carbon storage of forests is estimated. The carbon storage of forests is thus underestimated, because forest edges can store more carbon than forest interiors. If we take the edge effects into account, the extra carbon stored in forest edges in the EU is the equivalent of a forest area of more than 1.4 million football (soccer) fields, or one third of the size of Belgium.

Does this mean that fragmentation is a good thing, because it creates more edges that capture a lot of carbon? No, definitely not! Our study *does* show that it is important to protect even very small forest patches. Small forest patches are often carelessly removed, because people think they do not make a big difference—but they do, thanks to their large proportion of edge areas. Therefore, we should both protect small forests and plant new forests, even very small ones. In the fight against climate change, small forest patches should not be neglected!

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ORIGINAL SOURCE ARTICLE

Meeussen, C., Govaert, S., Vanneste, T., Haesen, S., Van Meerbeek, K., Bollmann, et al. 2021. Drivers of carbon stocks in forest edges across Europe. *Sci. Total Environ.* 759:143–497. doi: 10.1016/j.scitotenv.2020.143497

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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.

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Antonio loves learning about plants and is an avid birder. He enjoys reading about topics in botany, chemistry, and zoology, but also makes time for playing soccer and watching Naruto.

YEONWOO, AGE: 15
Hi, my name is Yeonwoo. My favorite subjects are Math and Science, and I want to be a math teacher. I like watching Youtube in my free time.

AUTHORS

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Hi, I am Leen. I work as a researcher at the Forest and Nature Lab at Ghent University, in Belgium. Although I love every piece of nature, in my research, I am mainly interested in the forest understory: the tiny plants at the forest floor that are often forgotten and overlooked, as they live in the shade of

large trees. But they turn out to be very important for the forest ecosystem! I investigate how global change will affect the composition and diversity of the forest understory, and how we can protect it, for instance through changing the forest management. *leen.depauw@ugent.be

CAMILLE MEEUSSEN

Hi, I am a young researcher with a big heart for forests. I am mainly interested in how forests differ in their abilities to store carbon. Currently, I am about to finish my Ph.D. in which I focused on the how forest edges differ from forest cores in terms of structure, carbon stocks, microclimate and tree regeneration. Besides research, I also love spending time outside in nature and travel around the world, to meet new people and discover new places!

EMIEL DE LOMBAERDE

Emiel De Lombaerde is a postdoc at the Forest and Nature Lab at Ghent University. He is studying how different drivers such as climate warming, forest management and nitrogen deposition are affecting the plants growing at the forest floor. His main research interests are looking at the interactions between these understory plants and young trees and studying the effects of microclimate conditions on understory plants. †orcid.org/0000-0002-0050-2735

KAREN DE PAUW

Hi there! My name is Karen, and I love to watch the living things all around us. Have you ever seen squirrels jumping after each other from tree to tree? Or wondered where the mushrooms in autumn suddenly come from? I wanted to know everything about nature, so I went to study biology. As I got to know more, I wanted also to learn ways to protect nature, so I decided to go study engineering. Today, I am looking closely at forest ecosystems, trying to understand what will happen to them in the future and how we can protect them. †orcid.org/0000-0001-8369-2679

KRIS VERHEYEN

Hello, my name is Kris Verheyen. I have always wanted to become a forest ranger, but ultimately became a professor in forest ecology and management. That certainly is a good 2nd choice! Indeed, I can spend a lot of time in the forest, try to understand how this intriguing ecosystem functions, and teach students about the global importance of forests and how we can conserve, manage and restore them.

PIETER DE FRENNE

My name is Pieter De Frenne and I am a plant scientist. I study how plants respond to climate change, in forests, but also in grasslands, mountains and crops. As a professor at Ghent University, I also teach our students how to recognize plants, how they grow and function, and why they are important in our everyday life. †orcid.org/0000-0002-8613-0943