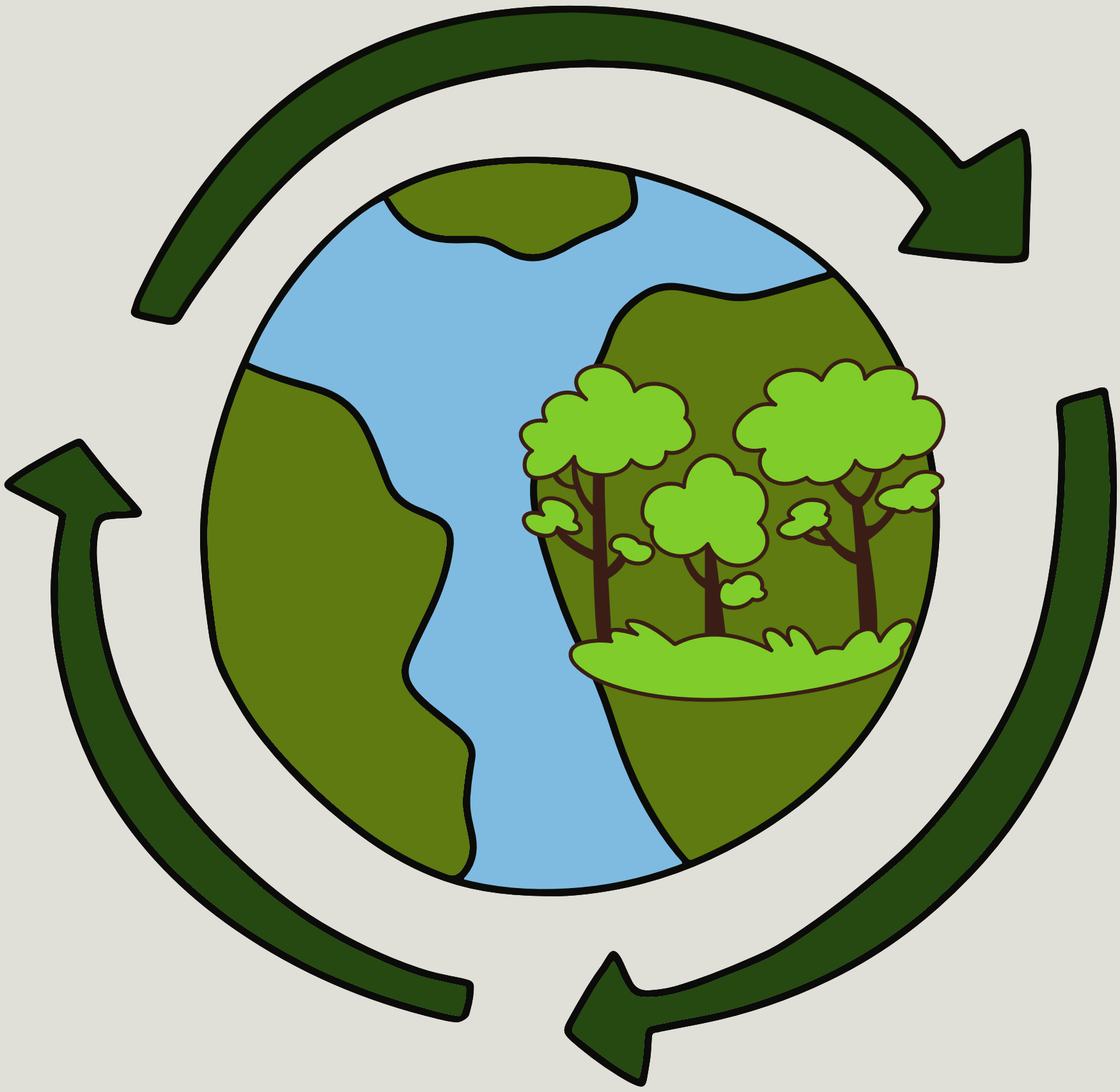
MODULE 3
FORESTS ECOSYSTEM



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Contributors to the contents and review:

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The third module delves into forest ecosystems, emphasizing their role in regulating, provisioning and supporting services. It also covers the forest recycling system, highlighting how nutrients are cycled within forests to maintain their health and resilience.

Key threats to forests, such as deforestation, climate change, and wildfires, are discussed, along with the concept of tipping points, where ecosystems can become irreversibly damaged.

CONTENT

Throughout this module, you will learn about:

1.What is a Forest
2.Components of a forest ecosystem
3.Forest Recycling system
4.Forest ecosystem services
5.Key threats to forests
6.The interaction between threats
7.Tipping point in a forest ecosystem
8.Examples of Tipping points I forest ecosystems

WHAT IS A FOREST

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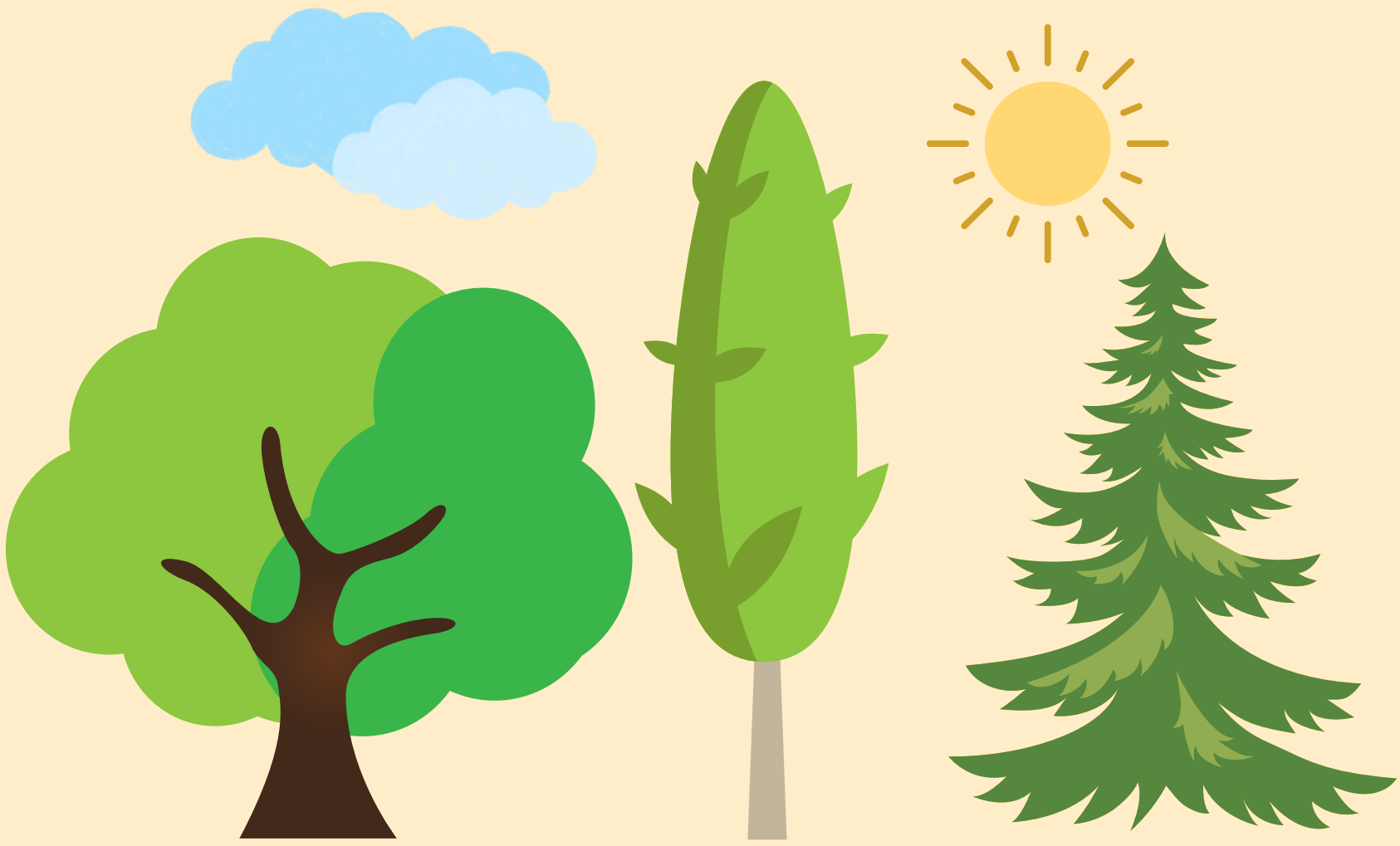

The definition of the word "Forest" varies depending on the region and country, influenced by factors like land use, vegetation type, and altitude. There are many definitions worldwide. Here, we provide a general definition by FAO (**F**ood and **A**griculture **O**rganization of the United Nations):

FOREST

Land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent, or trees able to reach these thresholds in situ. It does not include land that is predominantly under agricultural or urban land use.

OTHER WOODED LAND

Land not classified as “Forest”, spanning more than 0.5 hectares; with trees higher than 5 meters and a canopy cover of 5-10 percent, or trees able to reach these thresholds in situ; or with a combined cover of shrubs, bushes and trees above 10 percent. It does not include land that is predominantly under agricultural or urban land use.

NATURAL FOREST

A forest consisting of indigenous trees, not classified as a forest plantation.

FOREST PLANTATION

A forest created through planting or seeding as part of afforestation or reforestation efforts. It may contain introduced species or indigenous species.

COMPONENTS OF A FOREST ECOSYSTEM

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A forest ecosystem is like a big, living community where plants, animals, and other organisms all live together and help each other out. Let's break it down into simpler parts with pictures to understand it better:

TREES AND PLANTS

These are like the tall and short members of the forest family.

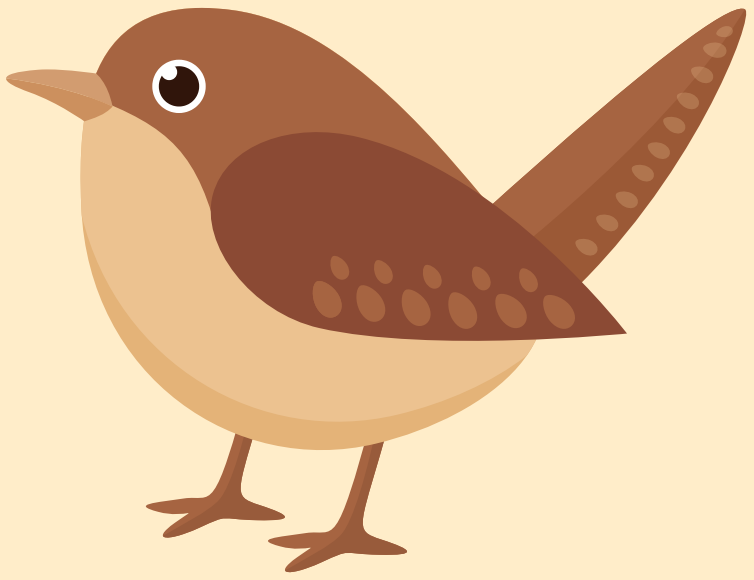
They make their own food using sunlight, provide oxygen for us to breathe, and give shelter to many animals.

ANIMALS

From tiny insects to big bears, animals are important members of the forest. They all have different roles, like eating plants or other animals, which helps keep the forest healthy.

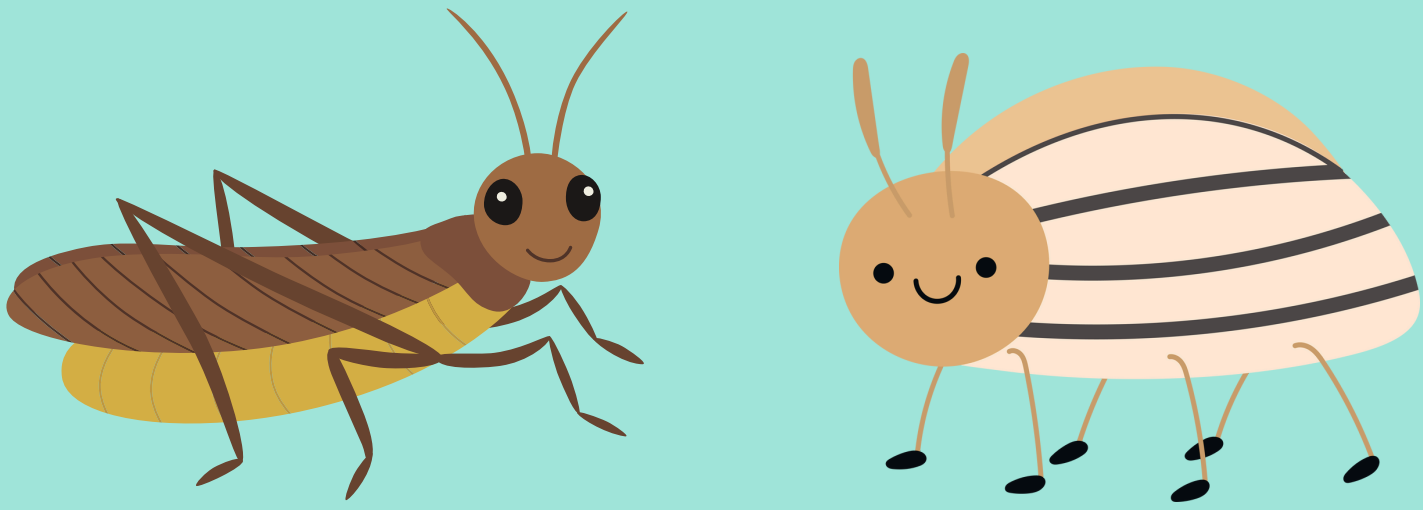
BIRDS

Birds are special because they can move seeds around, helping new plants grow in different parts of the forest. They also eat insects, controlling their numbers.



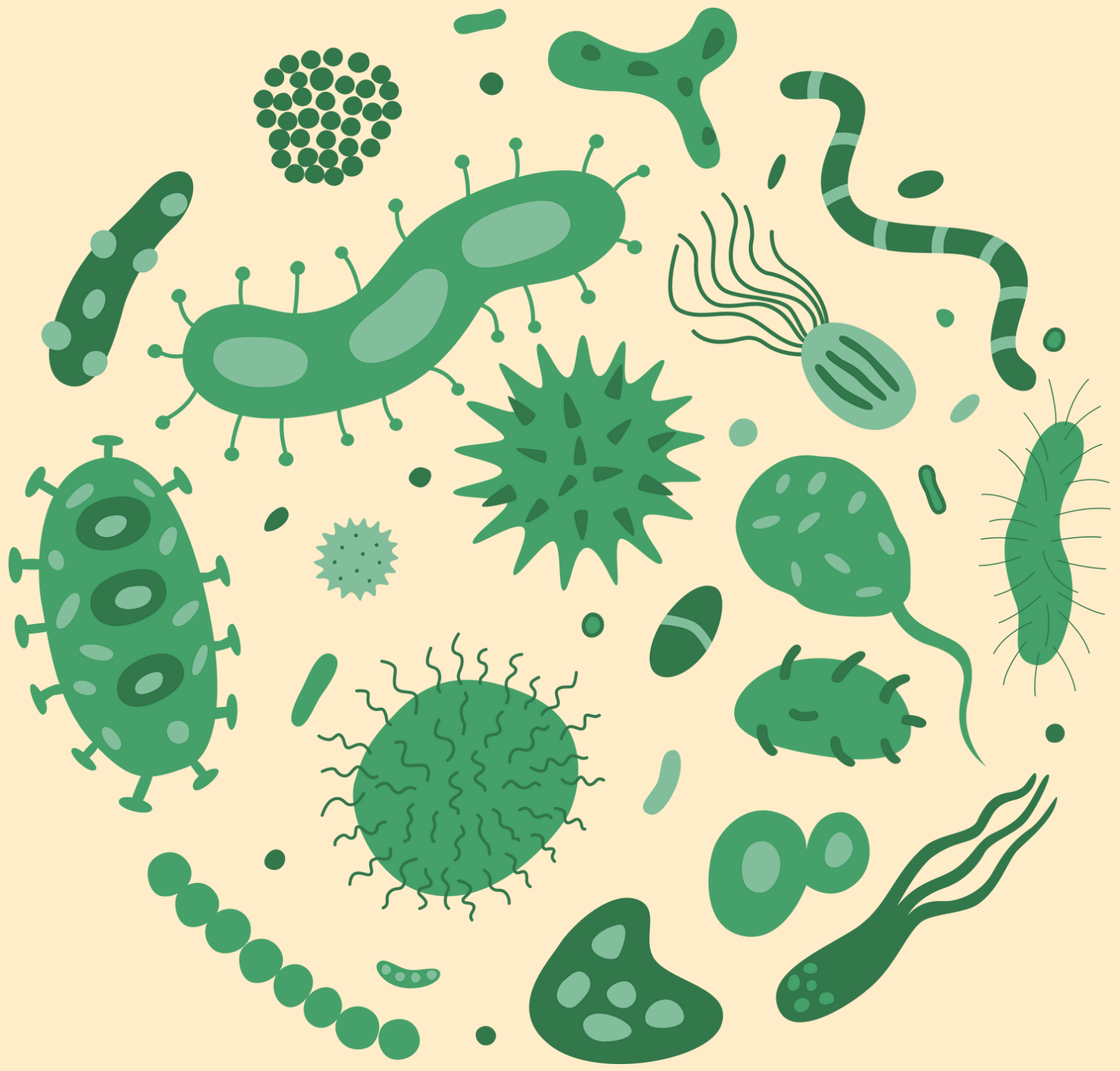
INSECTS

Insects might seem small, but they have a big job. They help break down dead plants and animals, turning them into soil nutrients. They're also food for many other forest creatures.



MICROORGANISMS

These are super tiny living things in the soil, like bacteria and fungi. They're like the cleanup crew, breaking down dead stuff so plants can use the nutrients to grow.



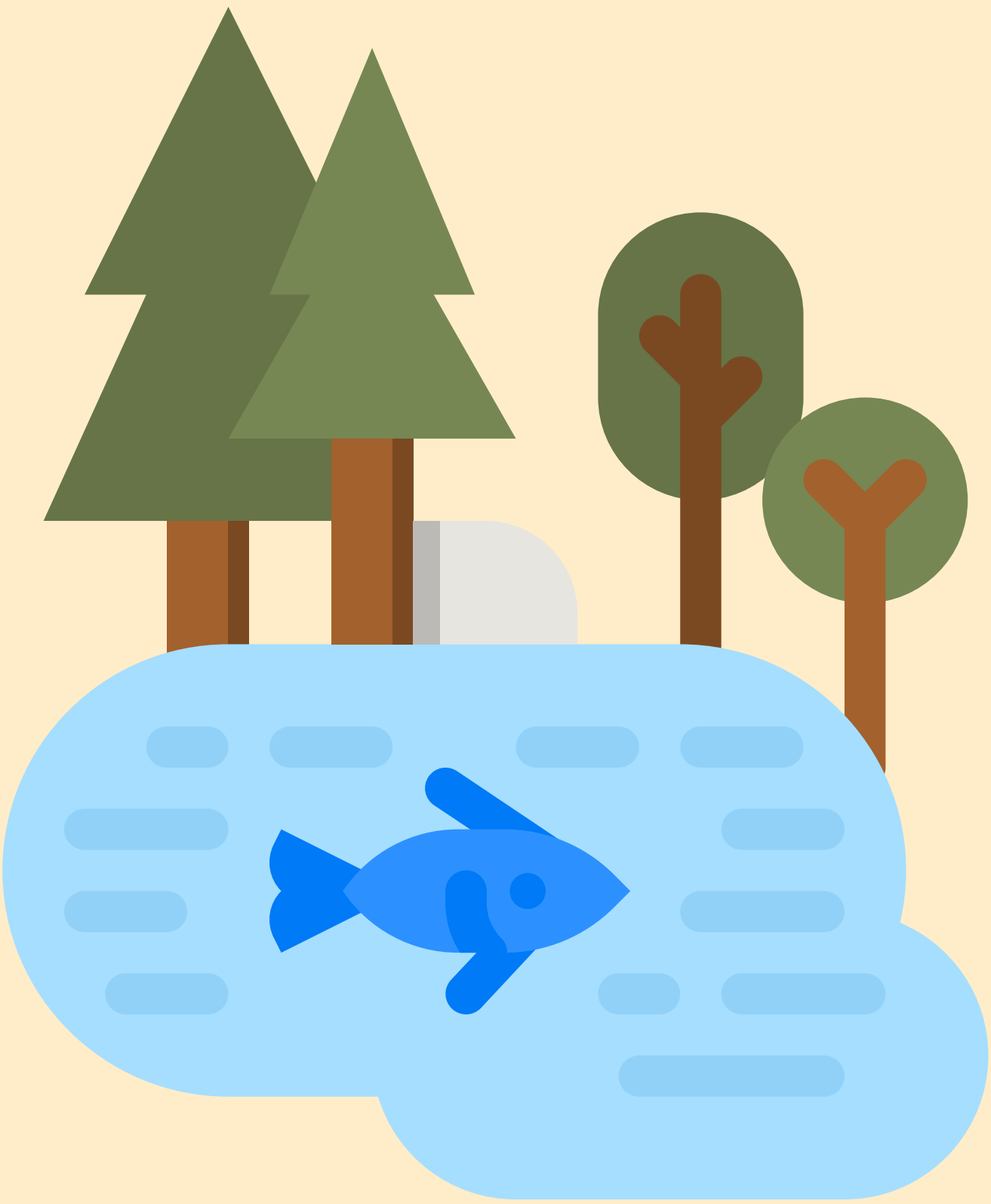
SOIL

The soil isn't just dirt; it's a mix of minerals, dead plants and animals, and living organisms.

It's where plants root and get their water and nutrients.

WATER

Rivers, lakes, and rain in the forest are like the forest's drink of water. They help plants grow and provide homes for many animals.



SUNLIGHT

Just like you need food, plants need sunlight to make their food in a process called photosynthesis. It's essential for the energy flow in the forest.

DECOMPOSERS

These are the recyclers of the forest, including certain insects, fungi, and bacteria. They break down dead things, returning nutrients to the soil.

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FOREST RECYCLING SYSTEM

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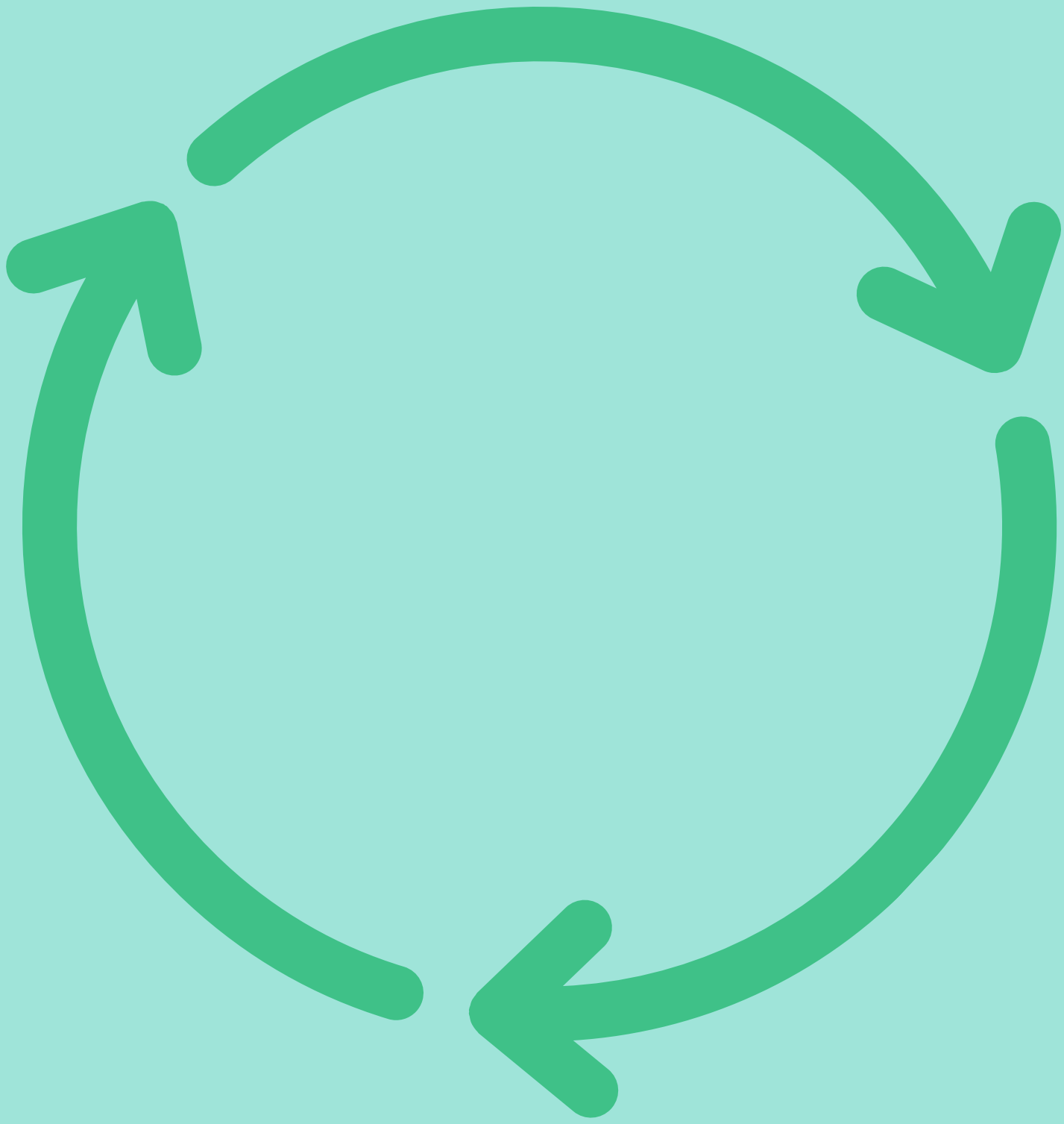


Biogeochemical cycles in a forest are like nature's recycling system. They are ways that elements (like carbon, oxygen, nitrogen, and water) move between the air, land, plants, animals, and soil in a forest. Let's break it down into simpler terms:

WATER CYCLE

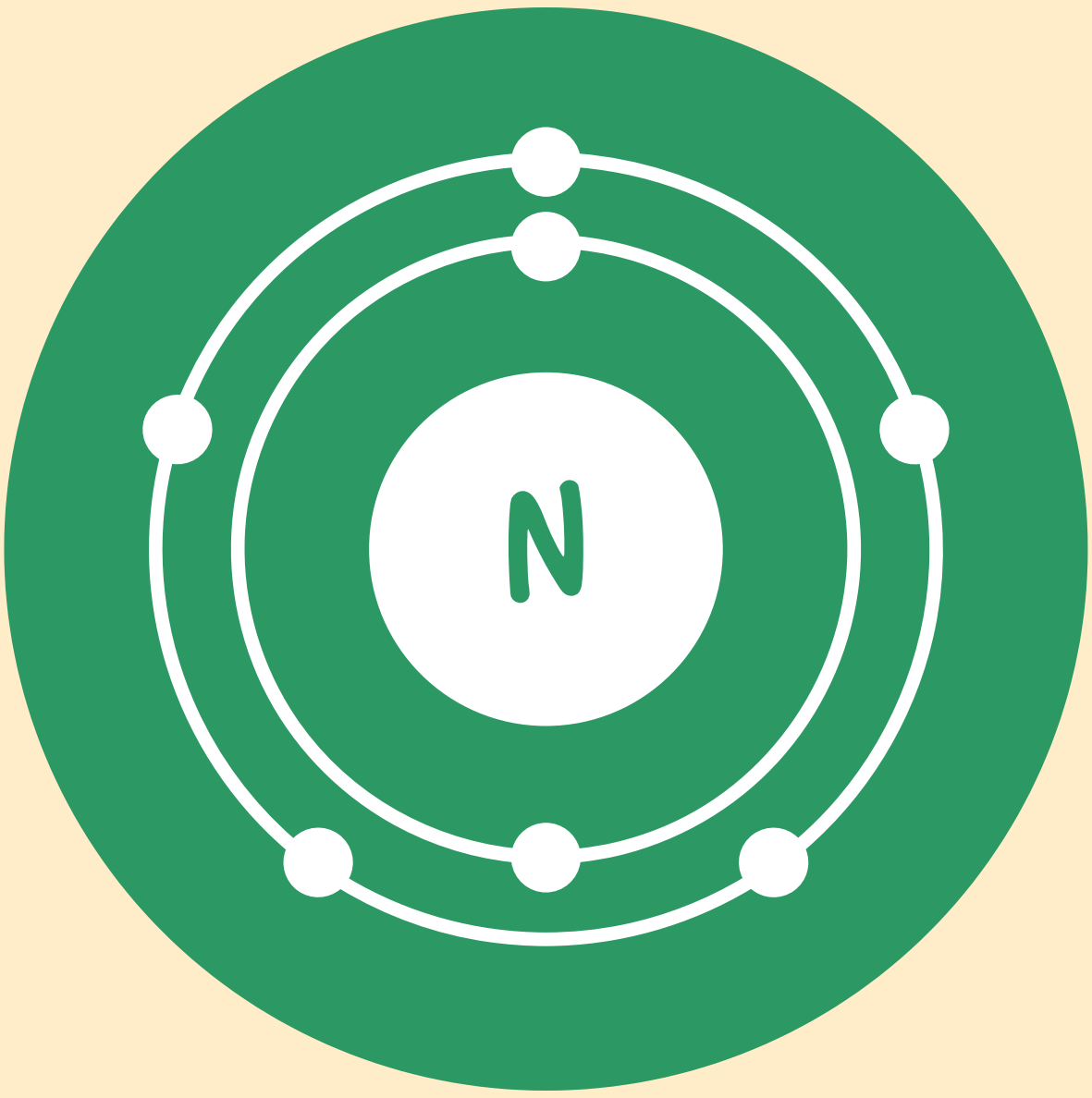
Imagine the forest's water cycle as a big loop. Water falls from the sky as rain, lands on trees and the ground, and then either gets soaked up by the soil or flows into rivers and lakes.

Trees and plants also release
water into the air
(a bit like how we sweat) in a
process called transpiration.
Eventually, this water evaporates
back into the sky, forming clouds,
and the cycle starts all over again.

CARBON CYCLE

The carbon cycle is all about how carbon dioxide in air moves around. Plants in the forest take in carbon dioxide from the air to make their food using sunlight. The trees also produce oxygen as a by-product through this process.

When animals eat plants, they take in the carbon, and when they breathe out, carbon dioxide goes back into the air. Also, when plants and animals die, decomposers (like fungi and bacteria) break them down, returning carbon to the soil and air.



NITROGEN CYCLE

Nitrogen is a key part of all living things but most living things can't use the nitrogen in the air directly.

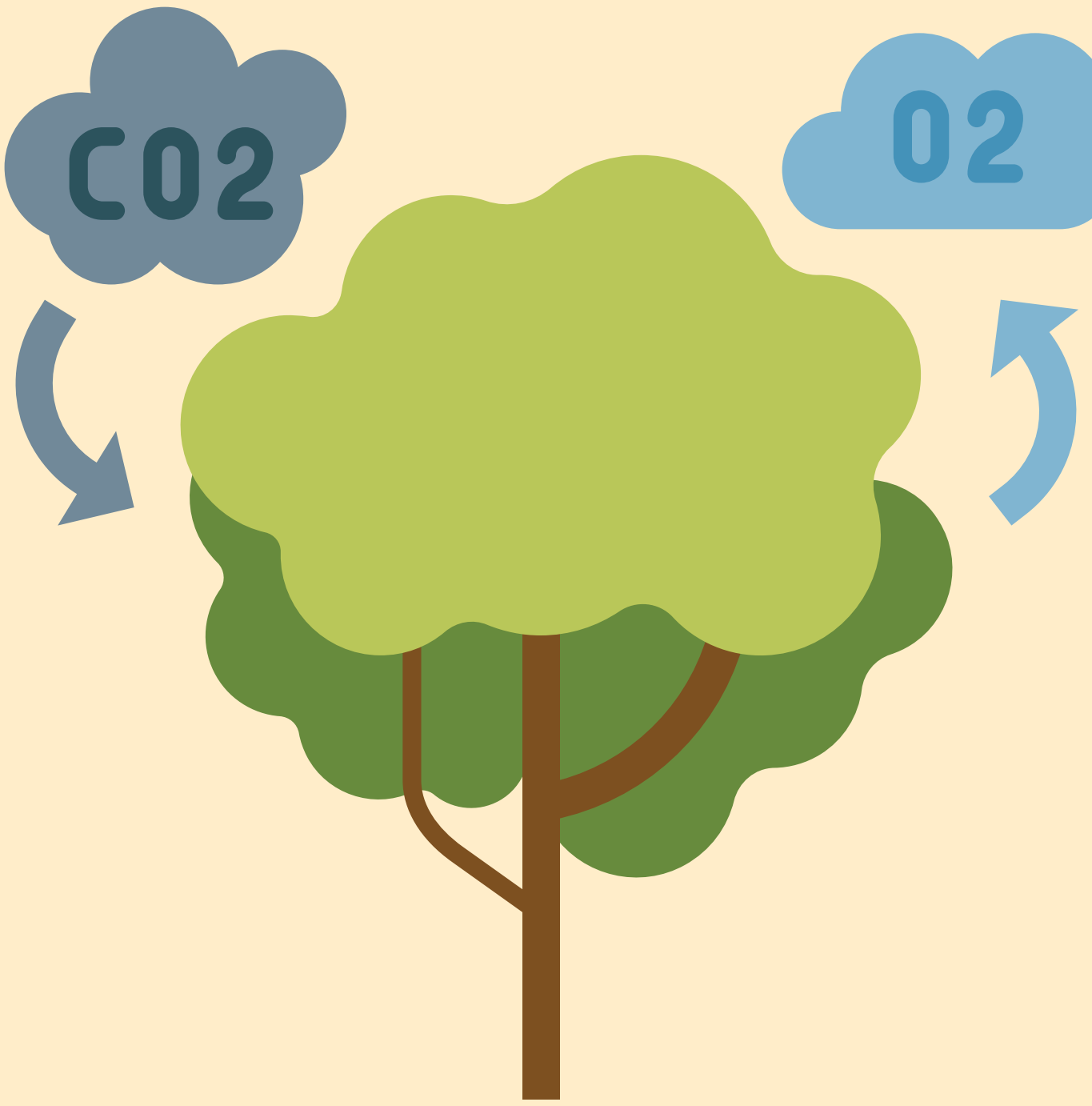
In the forest, special bacteria in the soil and on some plant roots can grab nitrogen from the air and change it into a form that plants can use.

When animals eat the plants, they get nitrogen too. After plants and animals die, other bacteria in the soil turn the nitrogen back into a form that can go into the air or be used by new plants.

OXYGEN CYCLE

The oxygen cycle is closely linked with the carbon cycle. When plants make their food, they release oxygen into the air – the oxygen we breathe!

Animals and plants use oxygen to turn their food into energy and release carbon dioxide, which plants need to make more food.



So, biogeochemical cycles in a forest help make sure that important elements keep moving around in nature, supporting life and keeping the forest healthy. It's like a big, natural recycling system that helps everything in the forest live and grow.

ECOSYSTEM SERVICES OF FORESTS

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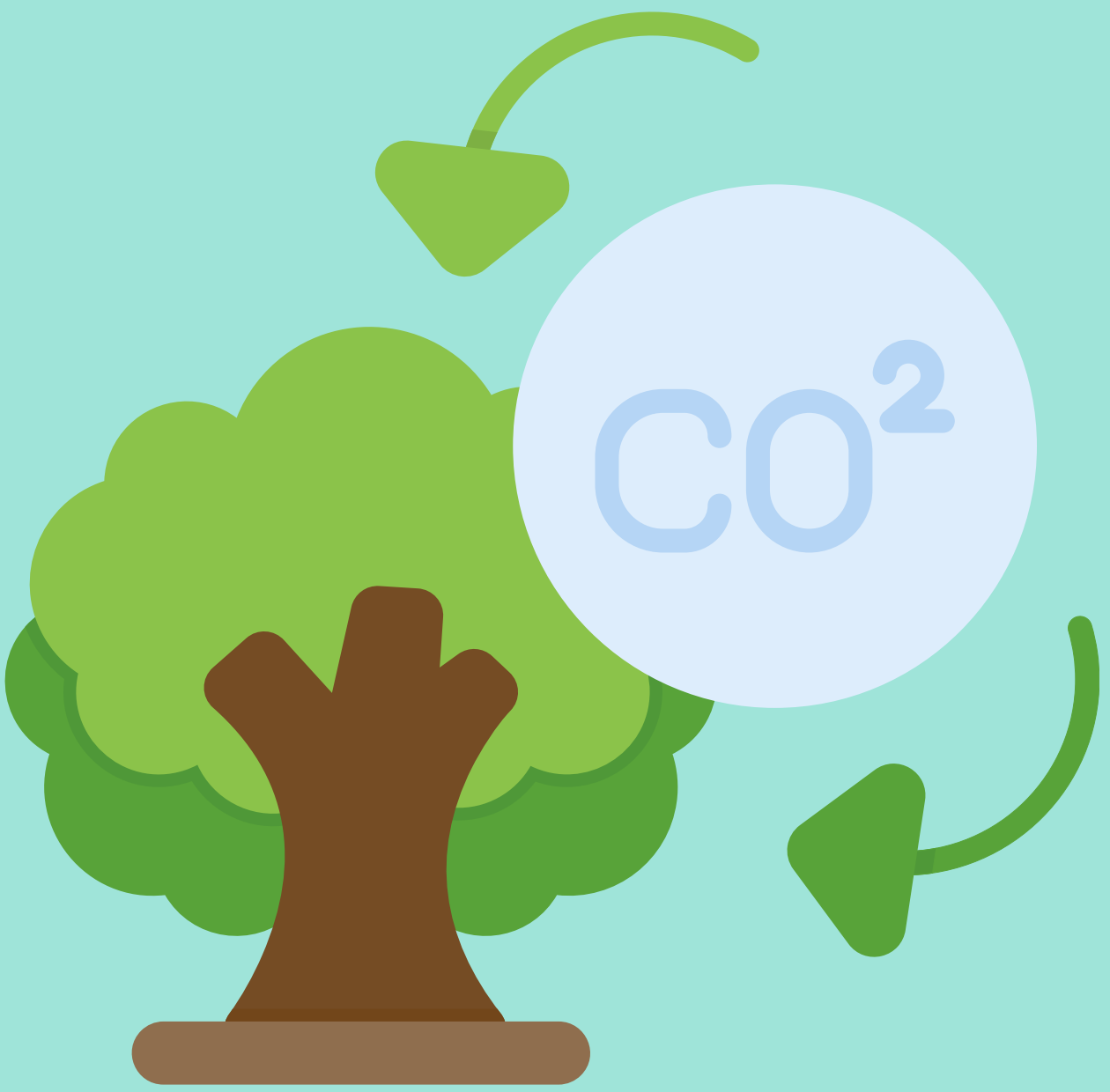
Forest ecosystem services are like the benefits or help we get from forests, which make our lives better and the planet healthier. Forests play a crucial role in human well-being in many ways, impacting both our physical environment and our mental health. Here are some simple explanations of these services:

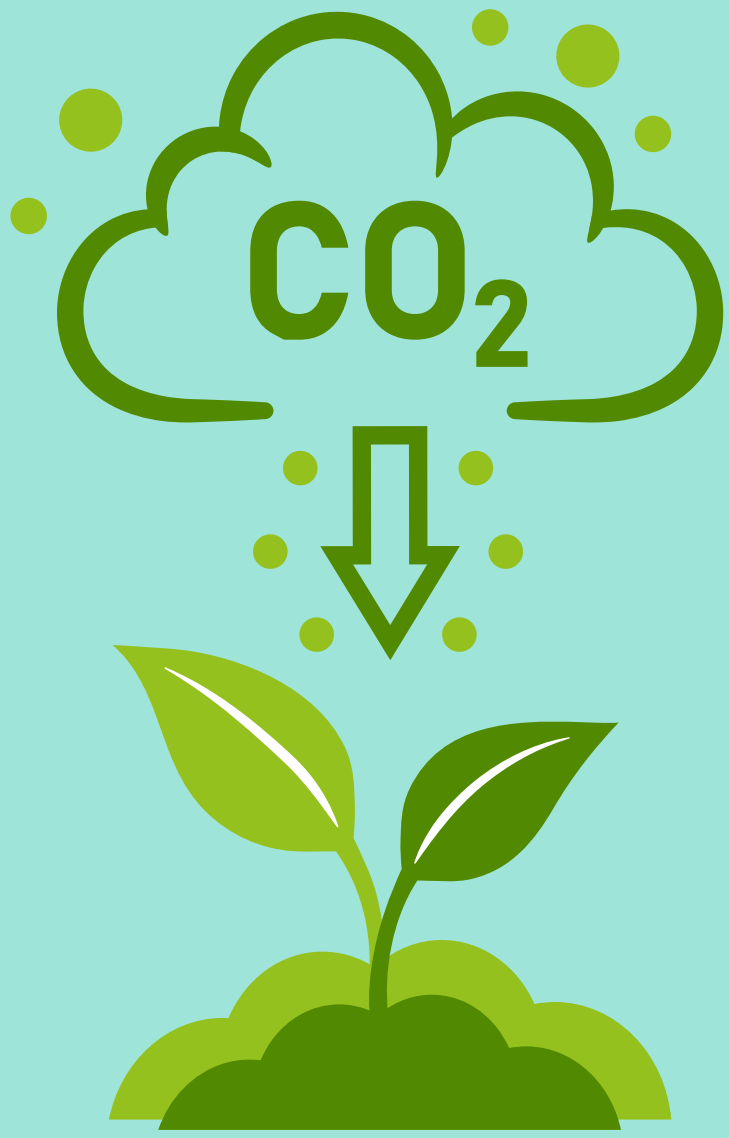
REGULATING SERVICE

Forests act like large air filters. They absorb gases like carbon dioxide and release oxygen, which we need to breathe. This helps reduce the concentration of carbon dioxide in the atmosphere, combats climate change, and keeps the air clean.

PHOTOSYNTHESIS AND CARBON STORAGE

Trees and plants absorb carbon dioxide (CO_2) from the air and, using sunlight, convert it into oxygen (O_2) and glucose. This oxygen is then released into the atmosphere, which supports life on Earth.





Trees and plants take in carbon dioxide to make their food through a process called photosynthesis, and they store (or "sequester") the carbon in their trunks, branches, leaves, and roots. Forests, especially tropical rainforests, act as significant "lungs of the planet," producing large amounts of the oxygen we breathe while also helping to absorb and store carbon dioxide, mitigating climate change.

PURIFICATION OF AIR

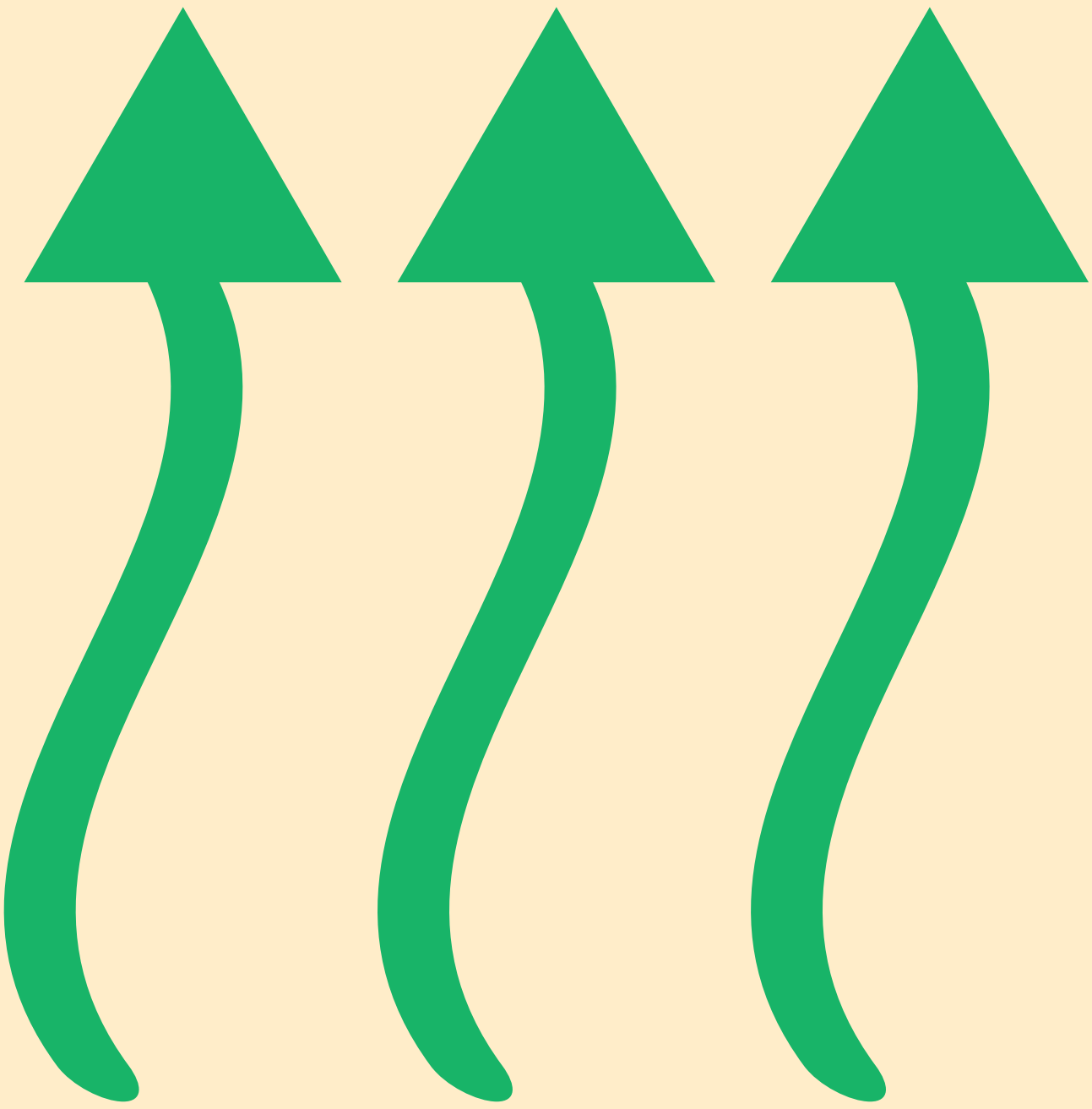
Besides taking in carbon dioxide, forests also clean the air by absorbing pollutants and releasing oxygen. Just like carbon sequestration, this process of photosynthesis helps to make the air healthier for us to breathe.

PURIFICATION OF WATER

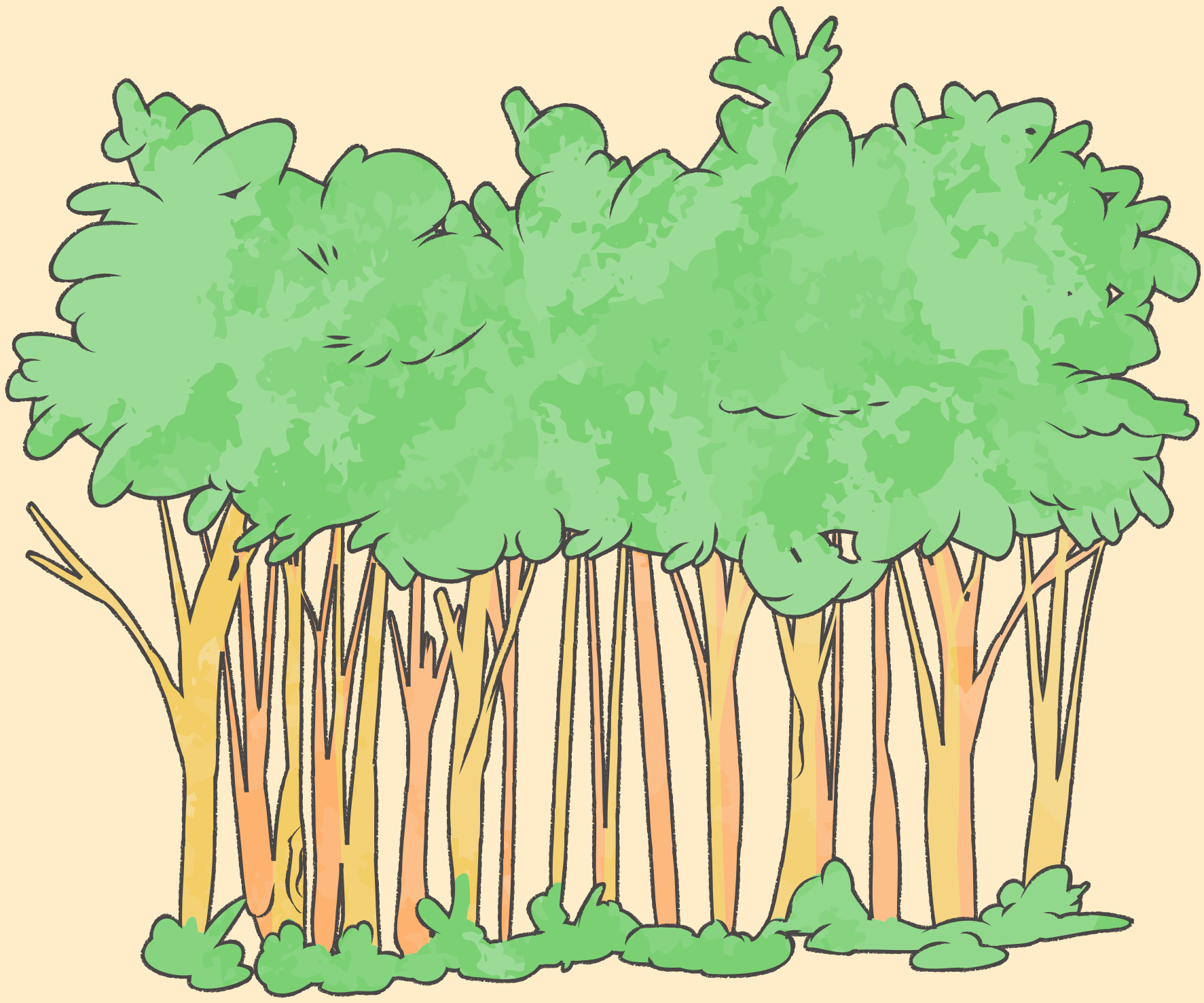
Forests play a vital role in purifying water by acting as natural filters. The roots of trees and plants stabilize the soil, preventing erosion, while the soil itself acts as a sponge, trapping pollutants, sediments, and excess nutrients before the water reaches rivers, lakes, and groundwater sources. Microorganisms in the soil further break down harmful substances.

FLOOD MITIGATION AND WATER REGULATION

Forests are like nature's water managers. They catch rainwater with their leaves and soil, which helps to reduce flooding by slowing down how fast water flows into rivers and lakes.

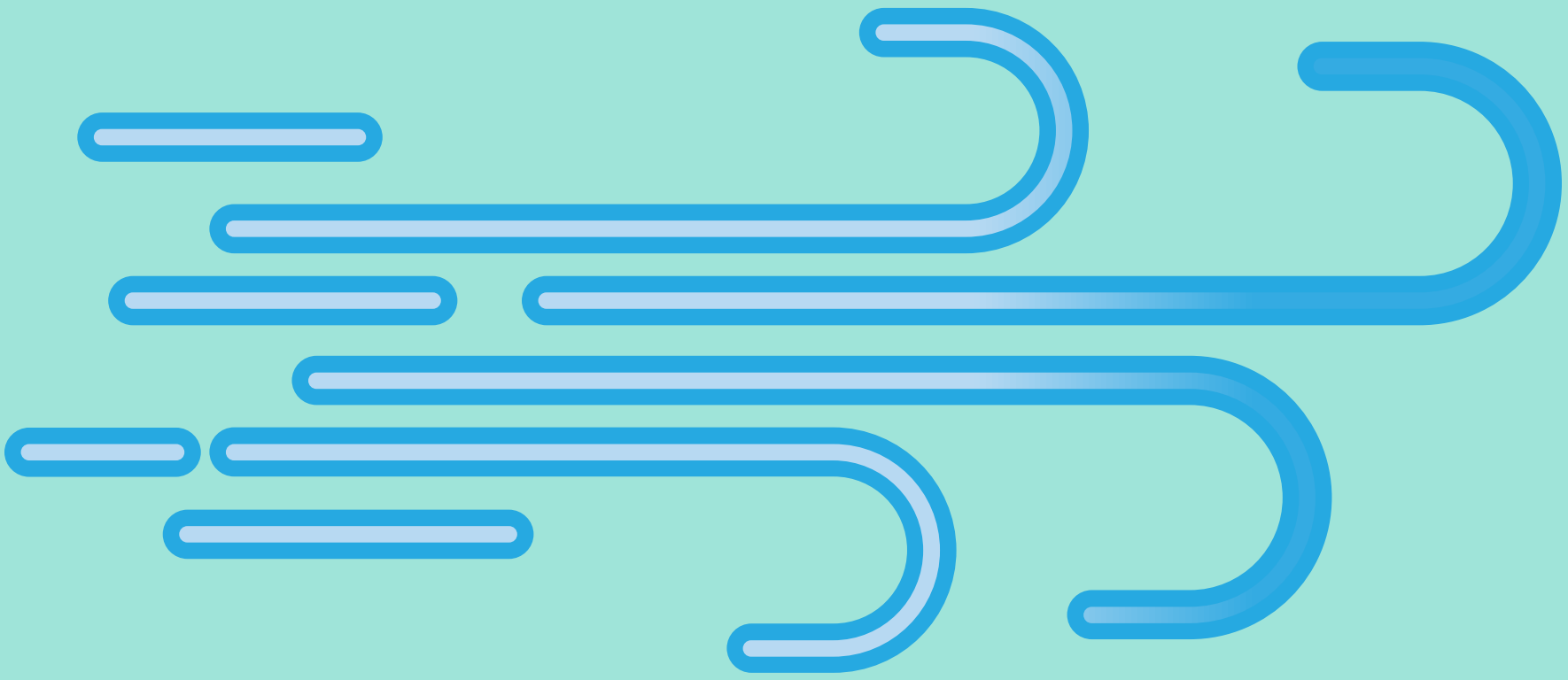


The trees also release water vapour into the air through a process called transpiration, which can help to form clouds and eventually rain. This way, forests help to keep the water cycle going and make sure there's water for us to use.



CLIMATE REGULATION

Forests can influence the climate both locally and globally. They can cool the air by providing shade and releasing water vapour. On a larger scale, by taking in carbon dioxide, forests play a part in controlling the global climate.



COOLING THE AIR

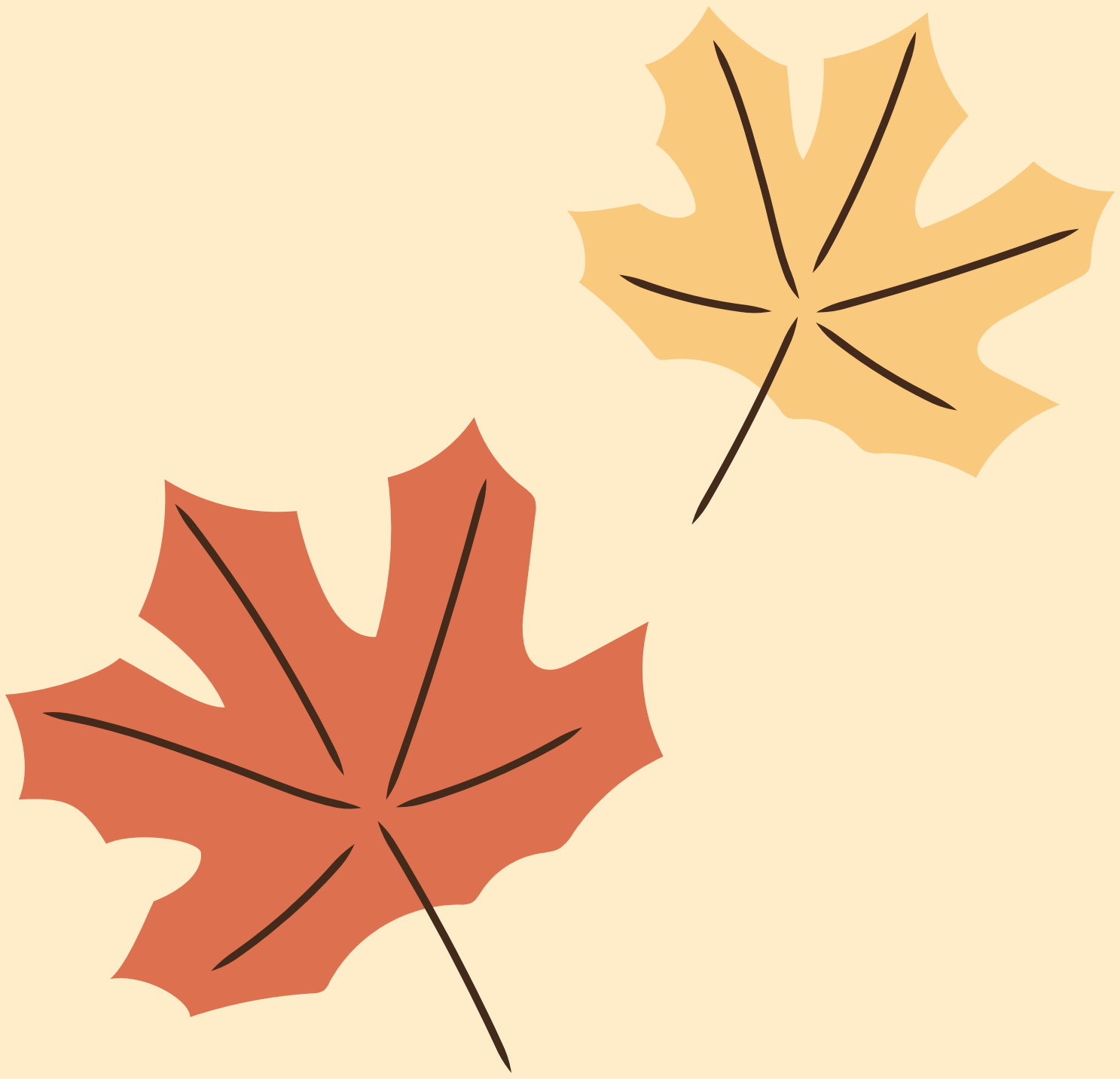
Forests are natural air conditioners. They release water vapour into the air through a process called transpiration, which helps cool down the air temperature. This is especially important in cities where it can get really hot.

SUPPORTING SERVICES

Forests are like big, natural homes for lots of different plants and animals. They provide food, shelter, and a place to live for countless species, including some that are rare or endangered.

BIODIVERSITY SUPPORT

This variety of life, called biodiversity, is important because it makes the ecosystem strong and able to handle changes or threats, like diseases or natural disasters.



SOIL PROTECTION AND FORMATION

Forests protect the soil by covering it with leaves and branches, which helps to stop the soil from washing away when it rains (erosion).

The roots of trees and plants also help to hold the soil together. Plus, when leaves and other plant parts fall to the ground and break down, they make the soil rich and good for growing things.

PROVISIONING SERVICES

Many people around the world depend on forests for their way of life. Forests provide wood for building and fuel, food, medicines, and other resources that people need to live.

ECONOMIC BENEFITS

Beyond providing raw materials like timber and paper, forests contribute to economies through tourism and recreation.

Sustainable management and conservation of forests can support livelihoods, particularly in rural areas.

FOOD SECURITY

Forests are a source of diverse foods, including fruits, nuts, seeds, and mushrooms, contributing to nutritional diets. They also support the habitats of pollinators and other wildlife, which are essential for the pollination of many crops.

MEDICINAL RESOURCES

A significant portion of modern medicines are derived from plants found in forests. These natural compounds have been used for centuries in traditional medicine and continue to be a resource for developing new treatments.

MENTAL AND PHYSICAL HEALTH

Studies have shown that spending time in forests can lower blood pressure, reduce stress, and improve overall mood and mental health. This connection with nature is an essential aspect of human well-being.

CULTURAL AND SPIRITUAL

For many people, forests are important not just for physical reasons, but also for cultural and spiritual reasons. They are places of beauty and inspiration, and they hold cultural significance for many communities around the world.

KEY THREATS TO FORESTS

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Forests around the world face several key threats that can lead to their destruction or degradation. These threats not only harm the forests themselves but also the biodiversity they support and the ecosystem services they provide. Let's break down these threats into simpler terms:

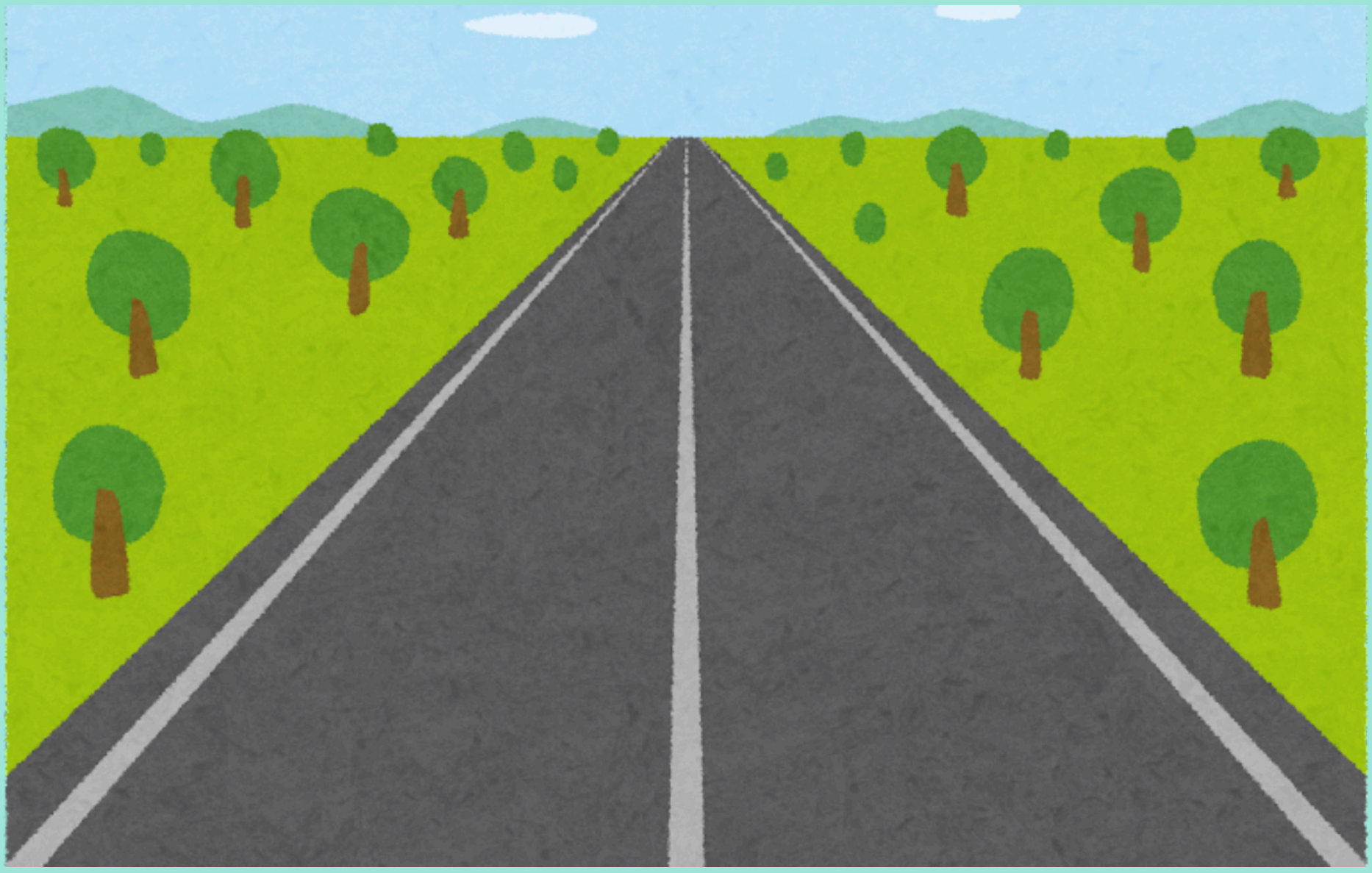
DEFORESTATION

Deforestation is when trees are cut down on a large scale and the land is used for other purposes like agriculture, mining, or urban development.

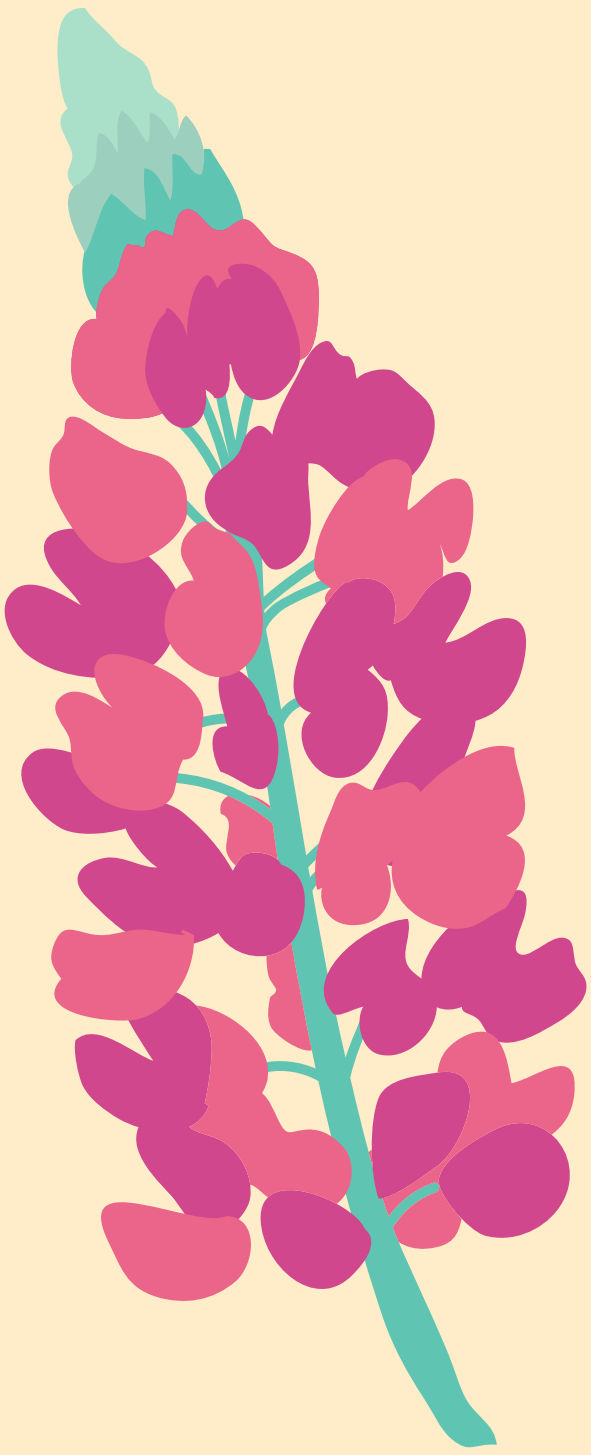
Imagine a giant eraser wiping away a green patch of forest to make room for farms, cities, or mines. This not only reduces the number of trees but also harms all the animals and plants that lived in the forest, leading to loss of biodiversity.

DEGRADATION AND FRAGMENTATION

Degradation happens when forests are damaged but not completely destroyed. This can be due to logging, pollution, or unsustainable use of forest resources. Imagine a forest being slowly chipped away at, becoming less healthy and vibrant over time.



Fragmentation is when large areas of forest are broken into smaller pieces by roads, cities, or farms. Imagine a puzzle that's being pulled apart, where each piece has less of the original picture. This makes it hard for animals to find food, mates, or shelter, and can isolate populations, making them more vulnerable to extinction.



INVASIVE SPECIES

Invasive species are plants, animals, or pathogens that are not native to a forest but enter it and start to take over. They can be like uninvited guests who eat all the food and take over the house, pushing out the original inhabitants.

These species can outcompete, prey on, or bring diseases to native species, leading to changes in the ecosystem and loss of biodiversity.

FIRE

While some forests have adapted to regular fires that can help rejuvenate them, excessive or uncontrolled fires can be devastating.

These can be caused by natural factors like lightning or by human activities such as land clearing and arson. Imagine a fire getting out of control and burning large areas of forest, destroying habitats and killing wildlife. Climate change is making these fires more frequent and severe.

CLIMATE CHANGE

Climate change exacerbates all the other threats to forests. It can lead to more extreme weather events, like storms and droughts, changing temperature and rainfall patterns.

This can affect the health of forests, making them more vulnerable to diseases, pests, and fires. Imagine the weather acting like a bully, stressing out the forest and making it harder for trees and animals to thrive.

Forests are under threat from a variety of human-induced and natural factors. Protecting them requires addressing these threats through sustainable management practices, conservation efforts, and global cooperation.

By understanding and mitigating these threats, we can help ensure that forests continue to support a rich diversity of life and provide essential services for the planet.

THE INTERACTION BETWEEN THREATS

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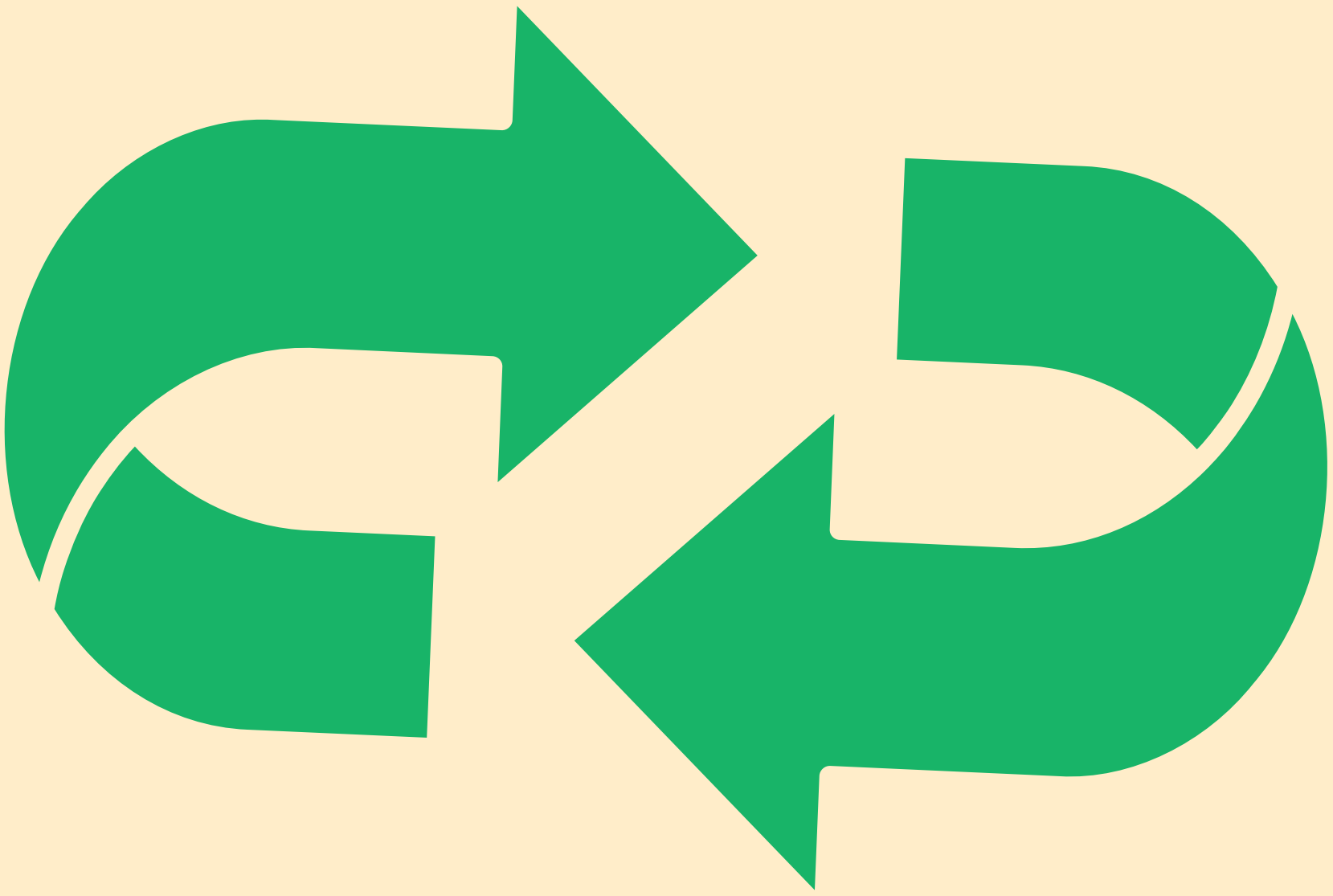
The key threats to forests–deforestation, degradation and fragmentation, invasive species, fire, and climate change–do not operate in isolation. Instead, they interact with each other in complex ways, often exacerbating the impact of one another.



Understanding these interactions is crucial for developing effective conservation strategies. Here is a simplified explanation of how these drivers can interact:

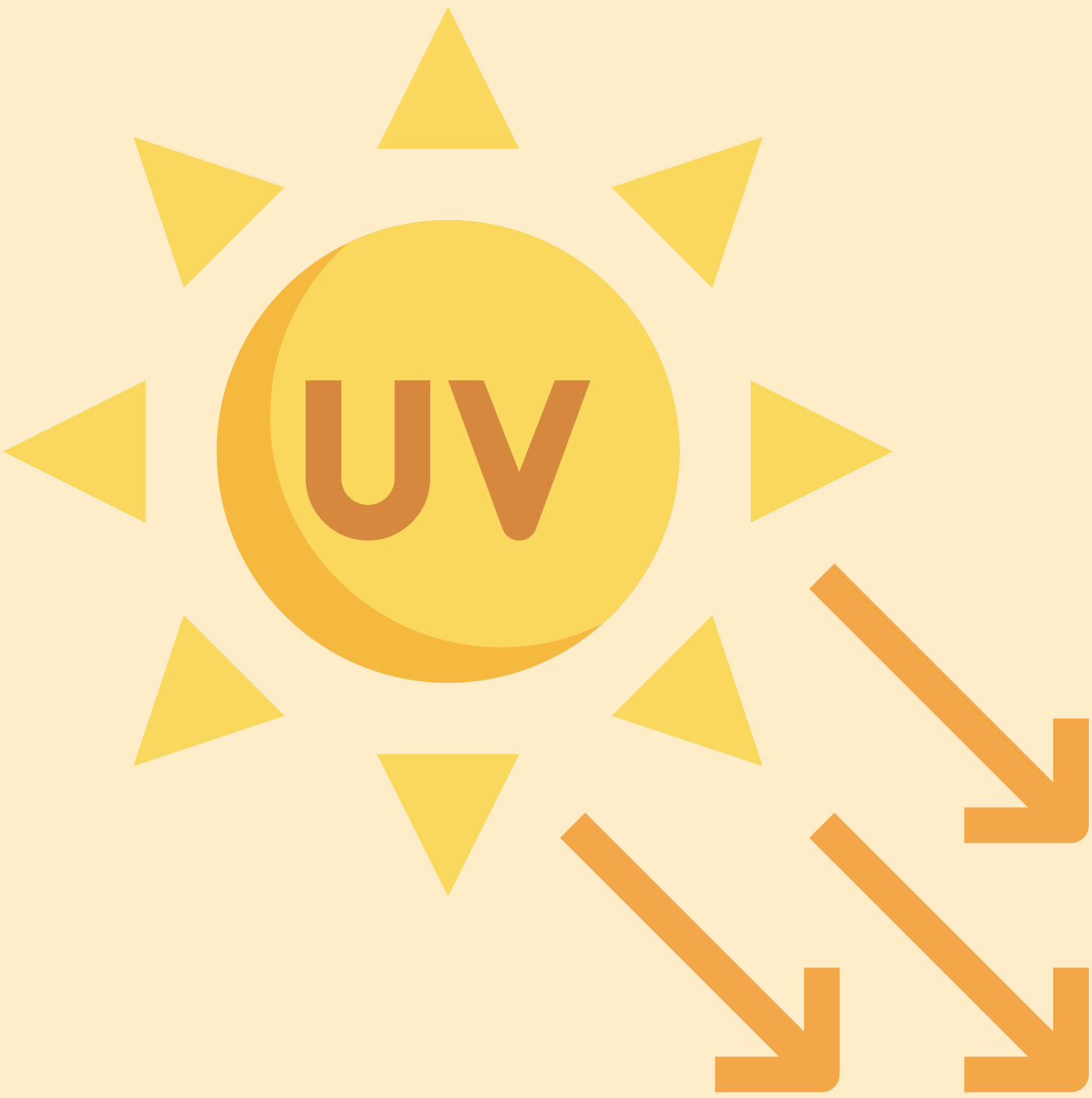
DEFORESTATION AND CLIMATE CHANGE

Deforestation contributes to climate change by releasing stored carbon dioxide (CO_2) into the atmosphere when trees are cut down and burned or left to rot. Forests act as carbon sinks, absorbing CO_2, so their removal decreases this capacity, further accelerating climate change.

Climate change, in turn, can exacerbate deforestation, as changing weather patterns can make certain areas more suitable for agriculture or other land uses, leading to increased clearing of forests.

FRAGMENTATION AND INVASIVE SPECIES

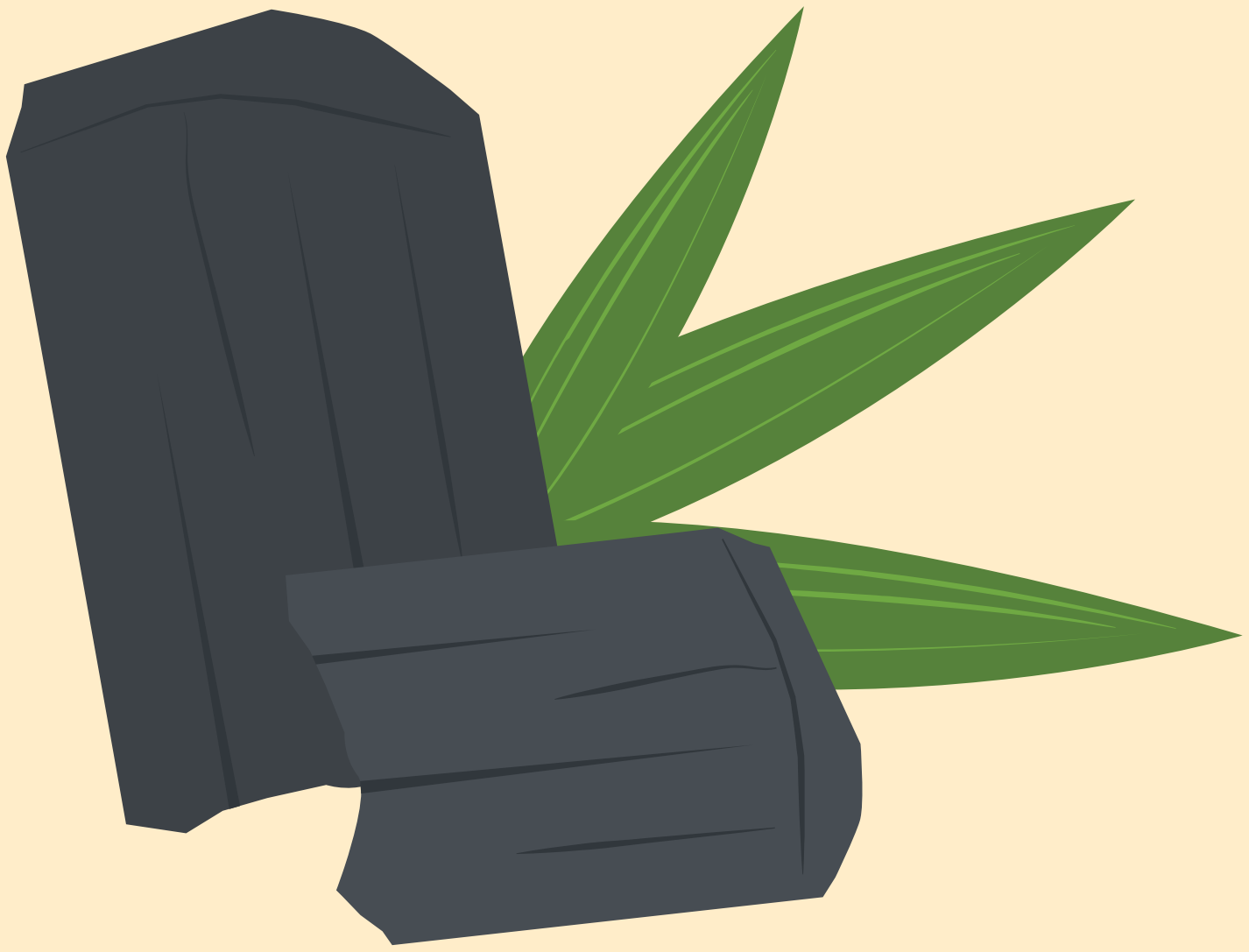
Fragmentation creates smaller, isolated patches of forests that are more easily invaded by invasive species.



These species can spread more rapidly in fragmented landscapes because the edges of these patches are more accessible and often have conditions that favour invasives, such as more sunlight and disturbed soil.

Invasive species can further degrade habitat quality within these fragments, reducing the resilience of native species and leading to a loss of biodiversity.

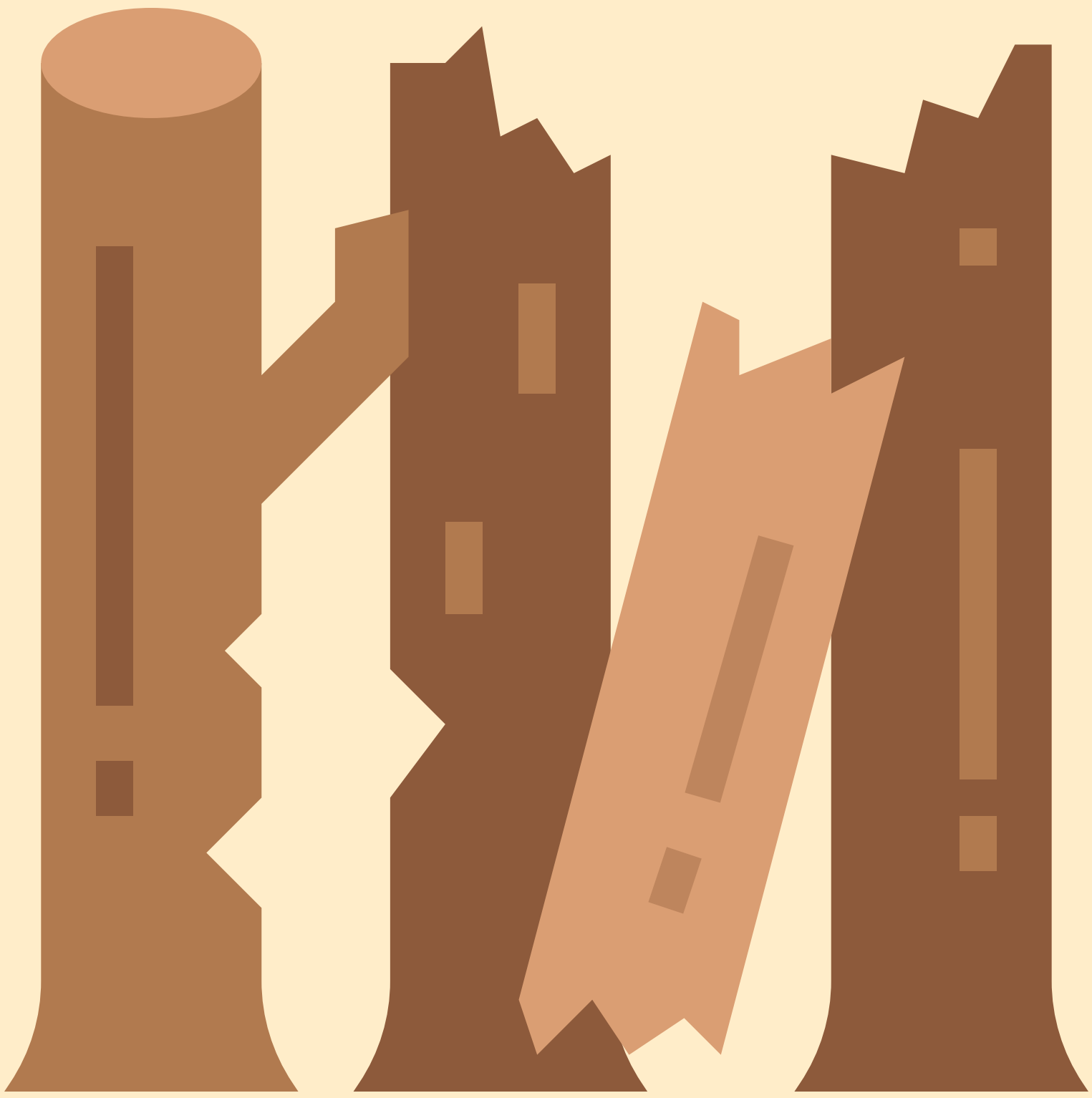
FIRE, CLIMATE CHANGE, AND DEGRADATION



Climate change increases the risk and intensity of fires by creating hotter, drier conditions in many regions. This not only makes forests more susceptible to burning but can also turn them from carbon sinks into carbon sources, further contributing to greenhouse gas emissions.

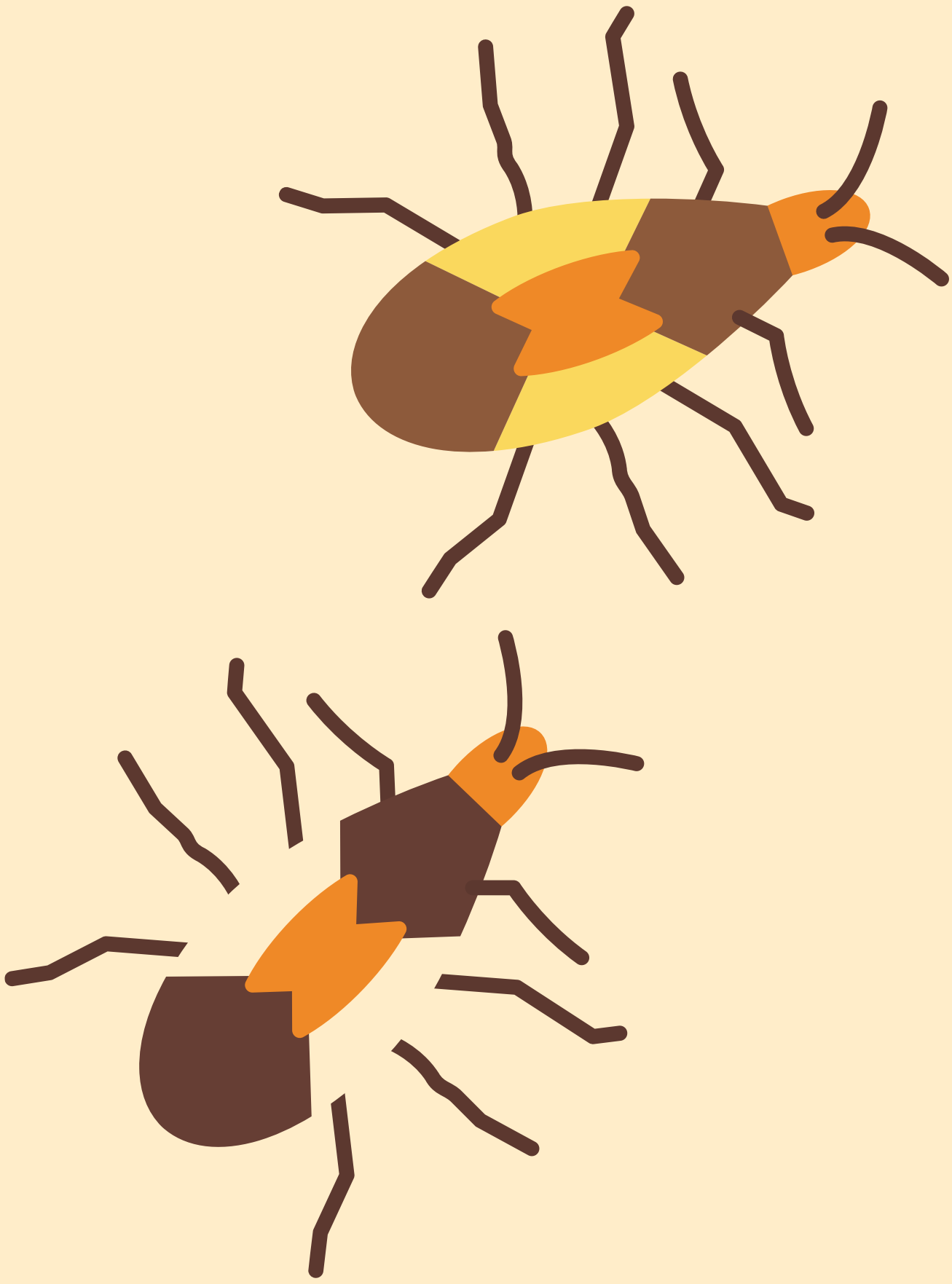
Fires can lead to immediate and long-term degradation of forest ecosystems, affecting their ability to recover. Repeated fires can prevent the regeneration of certain tree species and alter the composition of the forest, and lead to loss of biodiversity.

Degraded forests are less resilient to fire and other stresses, creating a feedback loop where degraded conditions increase fire hazard, which in turn leads to further degradation.



DEGRADATION, CLIMATE CHANGE, AND INVASIVE SPECIES

Degraded forests are more vulnerable to the impacts of climate change, such as changes in precipitation patterns and increased temperatures, as their reduced health makes them less resilient.



Climate change can facilitate the spread of invasive species by altering habitat conditions to favour these species over native ones. For example, warmer temperatures might allow invasive insects to expand their range into new forest areas, causing further degradation.

OVERALL INTERACTIONS

The interplay between these drivers creates a complex web of cause and effect that can lead to the acceleration of forest loss and degradation. For example, climate change can exacerbate the severity of invasive species outbreaks and increase the frequency and intensity of wildfires.

In turn, fires can make forests more susceptible to invasion by altering their structure and composition. Meanwhile, deforestation and fragmentation can increase the vulnerability of forests to all these threats by reducing their size and connectivity, which diminishes their resilience and ability to recover from disturbances.

Understanding these interactions is vital for crafting holistic conservation and management strategies that address the multifaceted challenges facing global forest ecosystems.

TIPPING POINT IN A FOREST ECOSYSTEM

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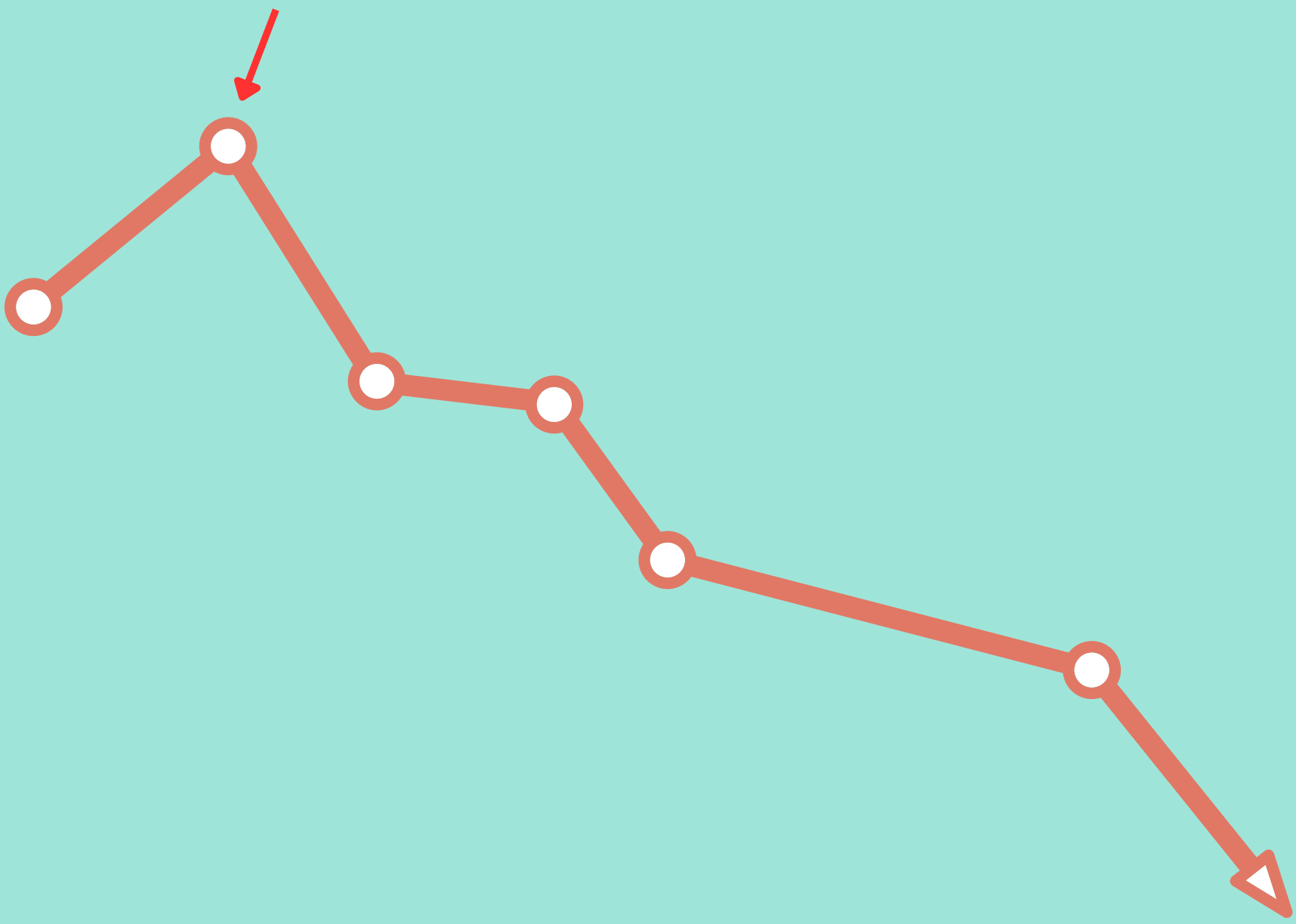
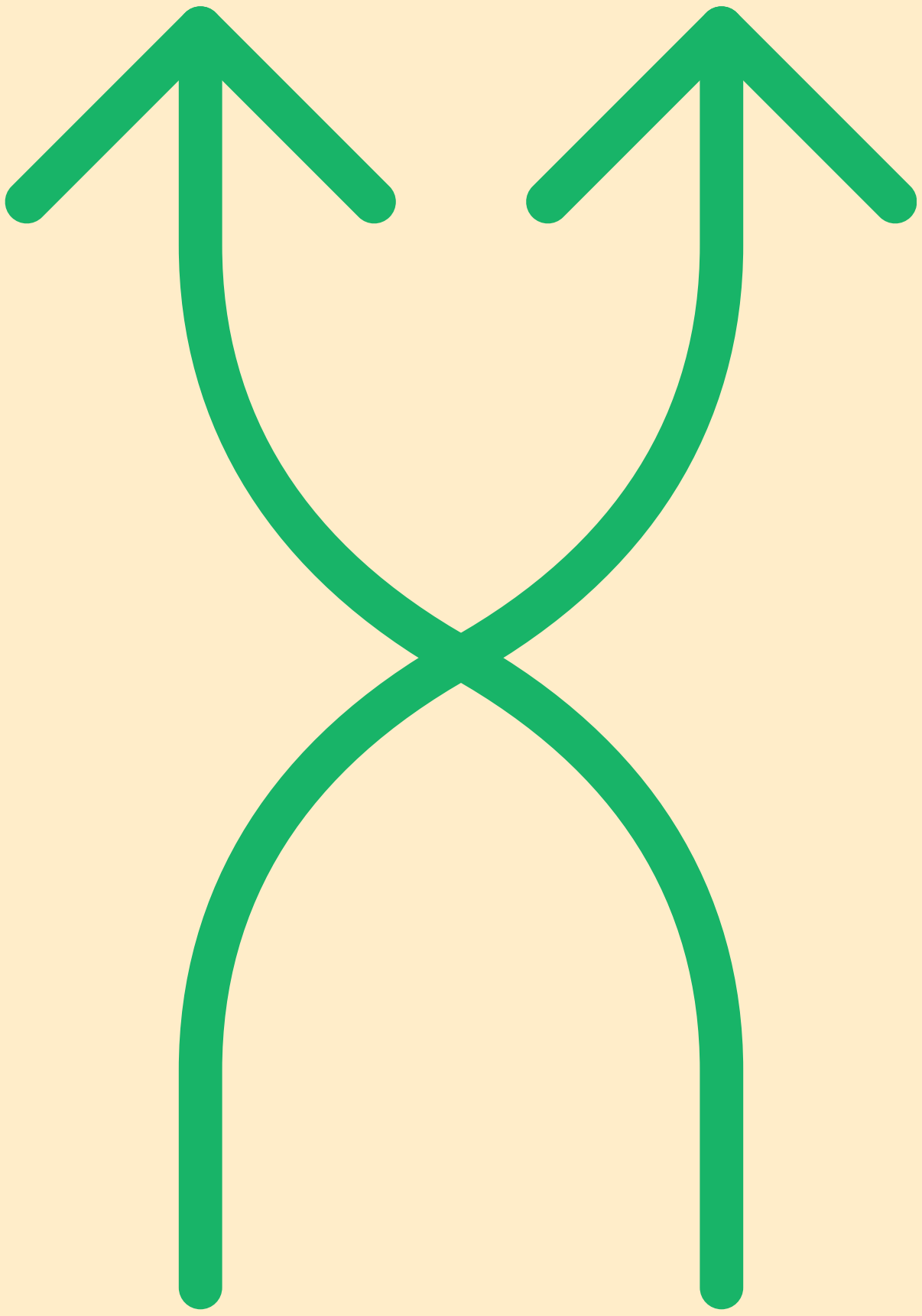
A tipping point in a forest ecosystem refers to a critical threshold at which a relatively small change or disturbance in external conditions can lead to a significant and often irreversible shift in the state or function of the ecosystem.





Understanding these interactions is crucial for developing effective conservation strategies. Here is a simplified explanation of how these drivers can interact:

EXAMPLES OF TIPPING POINTS IN FOREST ECOSYSTEMS

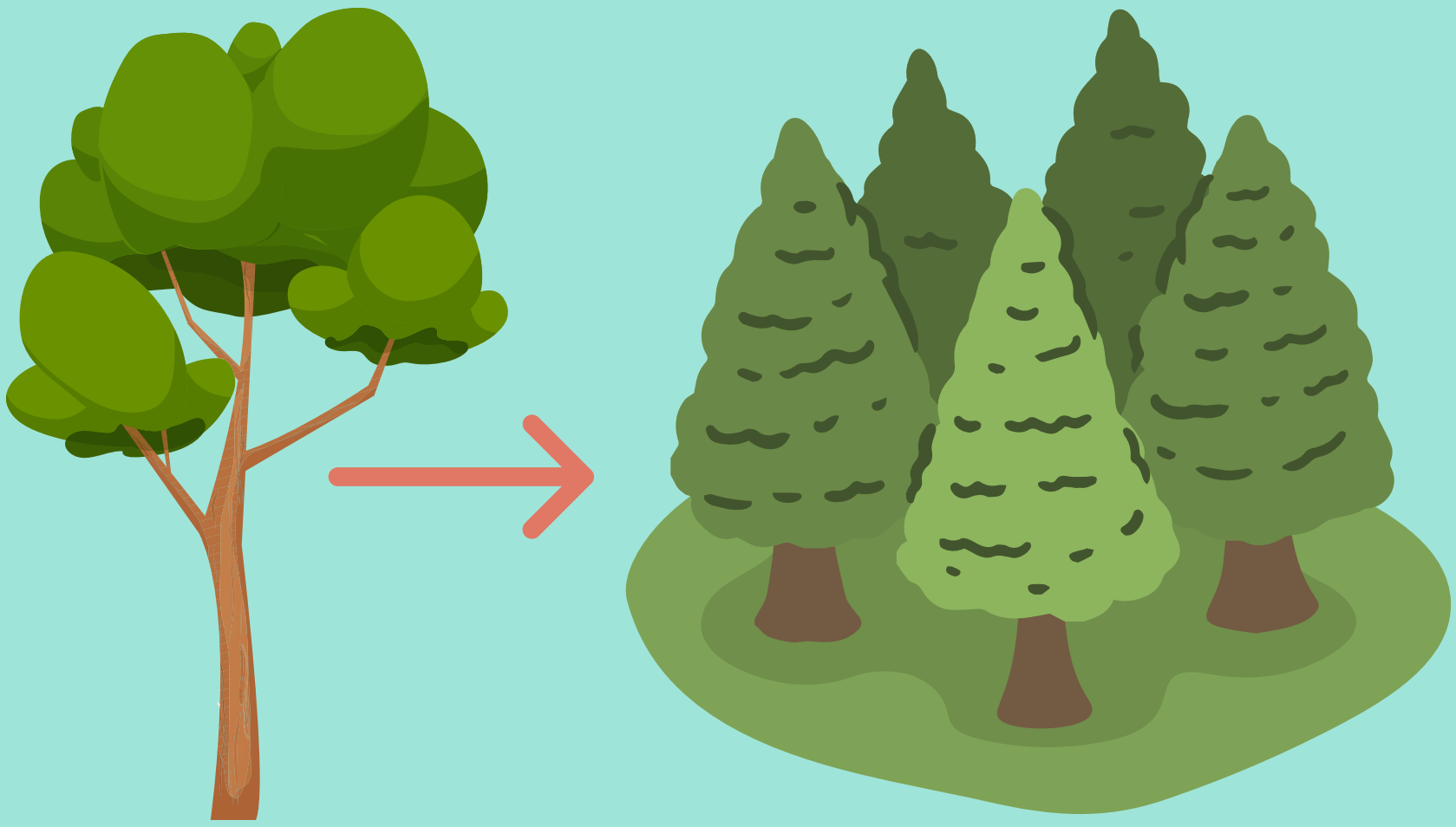
DEFORESTATION AND FRAGMENTATION

When forest cover is reduced to a certain extent due to logging, agriculture, or urban development, the remaining fragments may not be large or connected enough to support viable populations of certain species.

This can lead to a loss of biodiversity and changes in ecosystem function that are difficult to reverse.

CLIMATE CHANGE-INDUCED SHIFTS

Forests are sensitive to changes in temperature and precipitation patterns. A tipping point might be reached when these changes lead to the death of key tree species that are unable to adapt or migrate. This can result in a shift from forest to savannah or grassland in some tropical and subtropical regions.



INVASIVE SPECIES

The introduction and spread of invasive species can alter fire regimes, nutrient cycling, and water availability in a forest. If the impact of these species reaches a critical level, it can change the forest structure and composition permanently, pushing it past a tipping point.

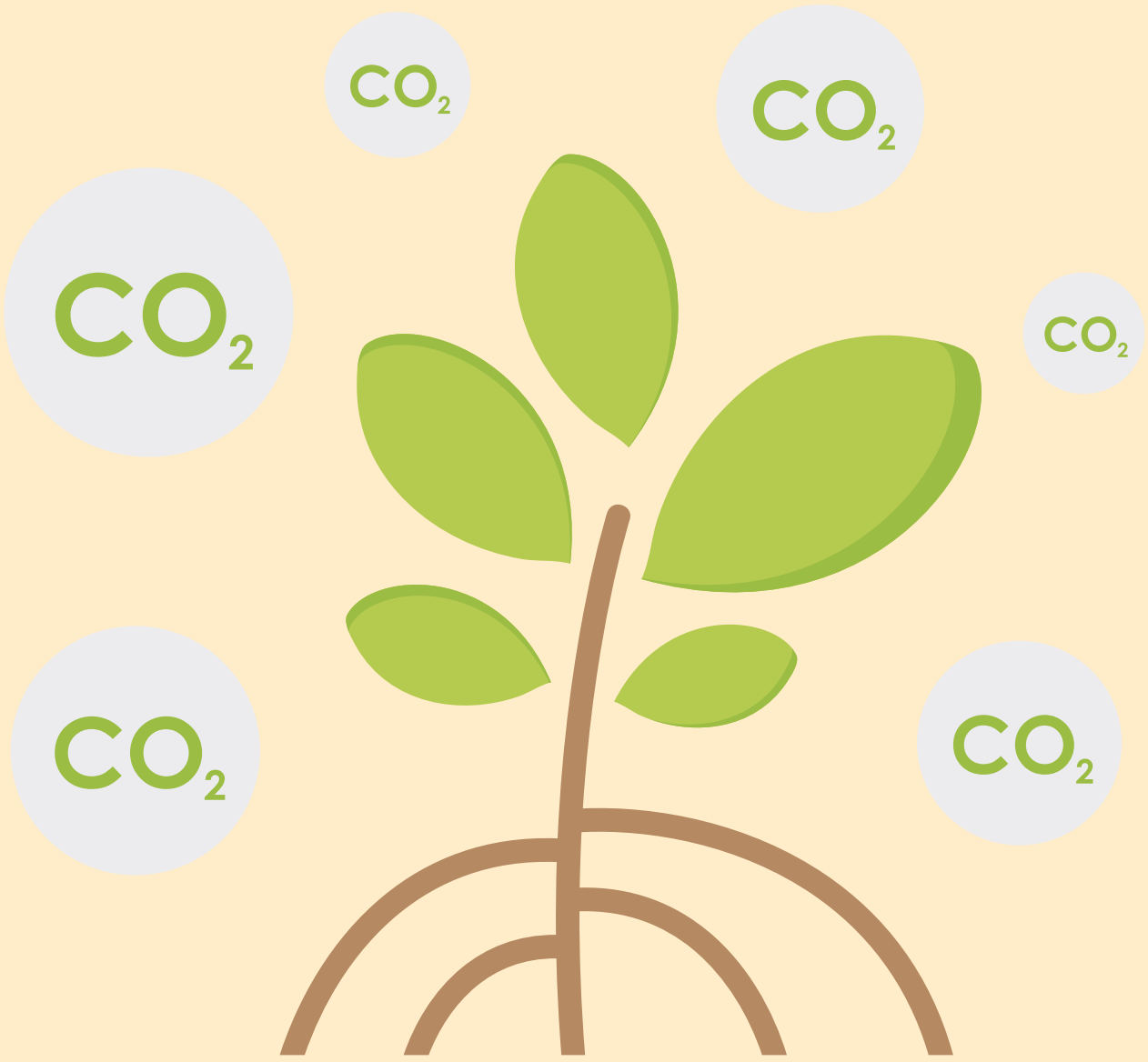
PEST OUTBREAKS

Climate change and human activity can also increase the vulnerability of forests to pests and diseases. An outbreak can decimate specific tree species, leading to a shift in forest composition and structure that may not be reversible if it crosses a certain threshold.

FIRE REGIME CHANGES

Increased frequency and intensity of wildfires, often exacerbated by climate change and human activities, can push forests beyond a tipping point where they cannot regenerate. Instead, they may transition to a different type of ecosystem, such as grassland or shrubland.

IMPLICATIONS



Crossing a tipping point can have profound implications for ecosystem services, including carbon storage, water filtration, and biodiversity support. Once a forest ecosystem undergoes a state change, it can be extremely challenging, if not impossible, to return it to its original state.

This underscores the importance of identifying potential tipping points and implementing management and conservation strategies to prevent their crossing.

Understanding and predicting tipping points in forest ecosystems is complex due to the intricate interactions between various factors and the uncertainty around how these factors will change in the future.

However, recognizing the existence of these thresholds is crucial for the effective conservation and management of forest resources in the face of global environmental change.

EXAMPLES OF TIPPING POINTS IN FOREST ECOSYSTEMS

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AMAZON RAINFOREST - TRANSITION TO SAVANNAH

The Amazon rainforest, often referred to as the "lungs of the Earth," is approaching a tipping point due to deforestation and climate change.

Scientists have warned that if the Amazon forest is partially destroyed (with estimates varying between 20% and 50%), it could trigger a self-sustaining process of savannization–a transition from rainforest to savannah-like conditions.

This change would result from a decrease in rainfall and loss of the forest's ability to recycle water, crucial for maintaining its ecosystem. The consequences would include massive biodiversity loss, changes in regional climate, and reduced carbon storage capacity.

BOREAL FORESTS - SHIFTS DUE TO CLIMATE CHANGE AND FIRE REGIMES

Boreal forests across the northern hemisphere are experiencing increased temperatures and changing precipitation patterns due to climate change.

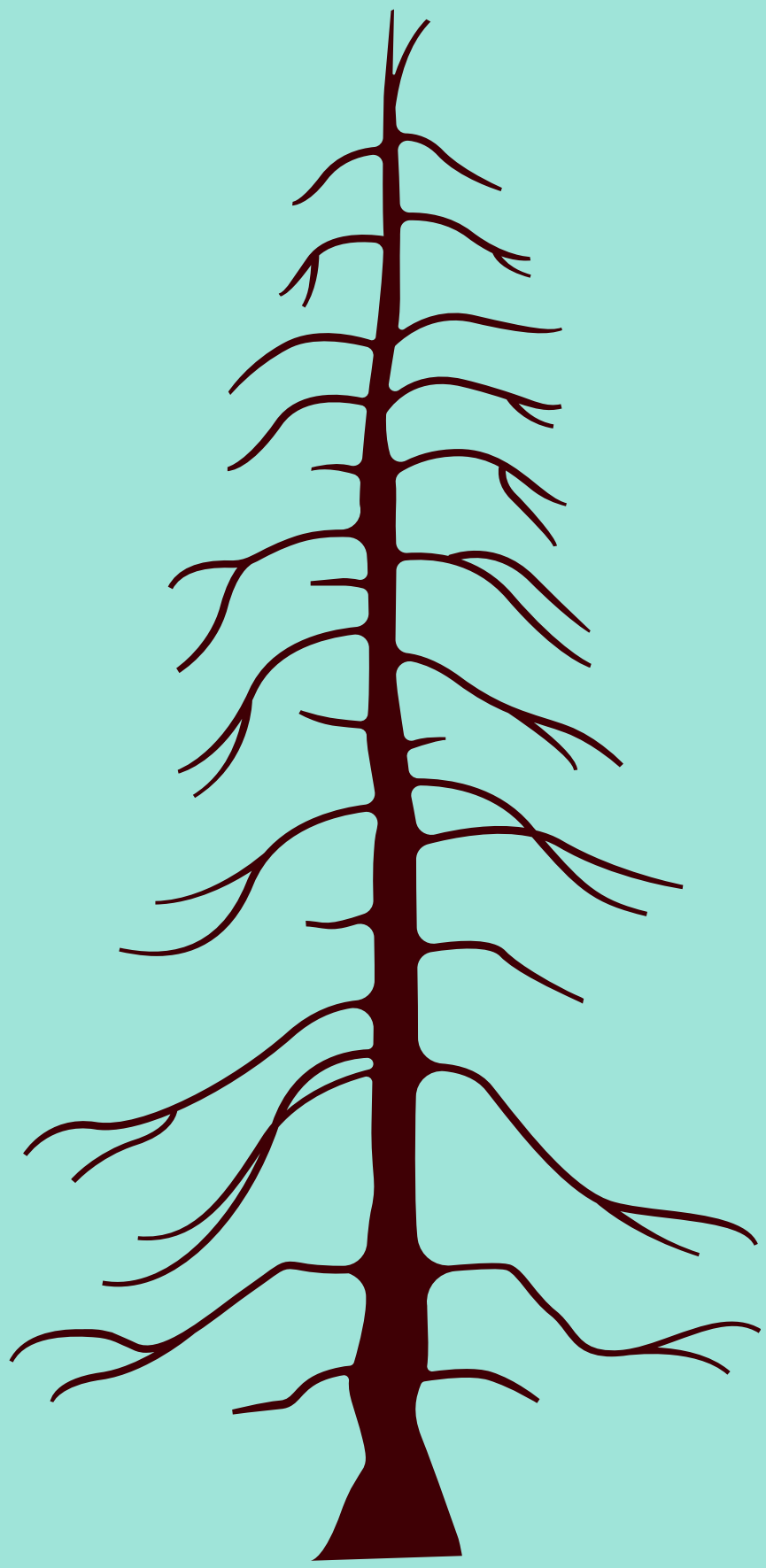
These changes, coupled with an increase in fire frequency and intensity, could push these forests past a tipping point.

The forests might shift to a different ecological state characterized by different dominant tree species or even transition to non-forest ecosystems in some areas. This shift could have significant implications for global carbon cycles and biodiversity.

MOUNTAIN PINE BEETLE OUTBREAK IN NORTH AMERICA

The mountain pine beetle has devastated large areas of pine forests in North America, particularly in British Columbia, Canada, and the Rocky Mountains in the United States.

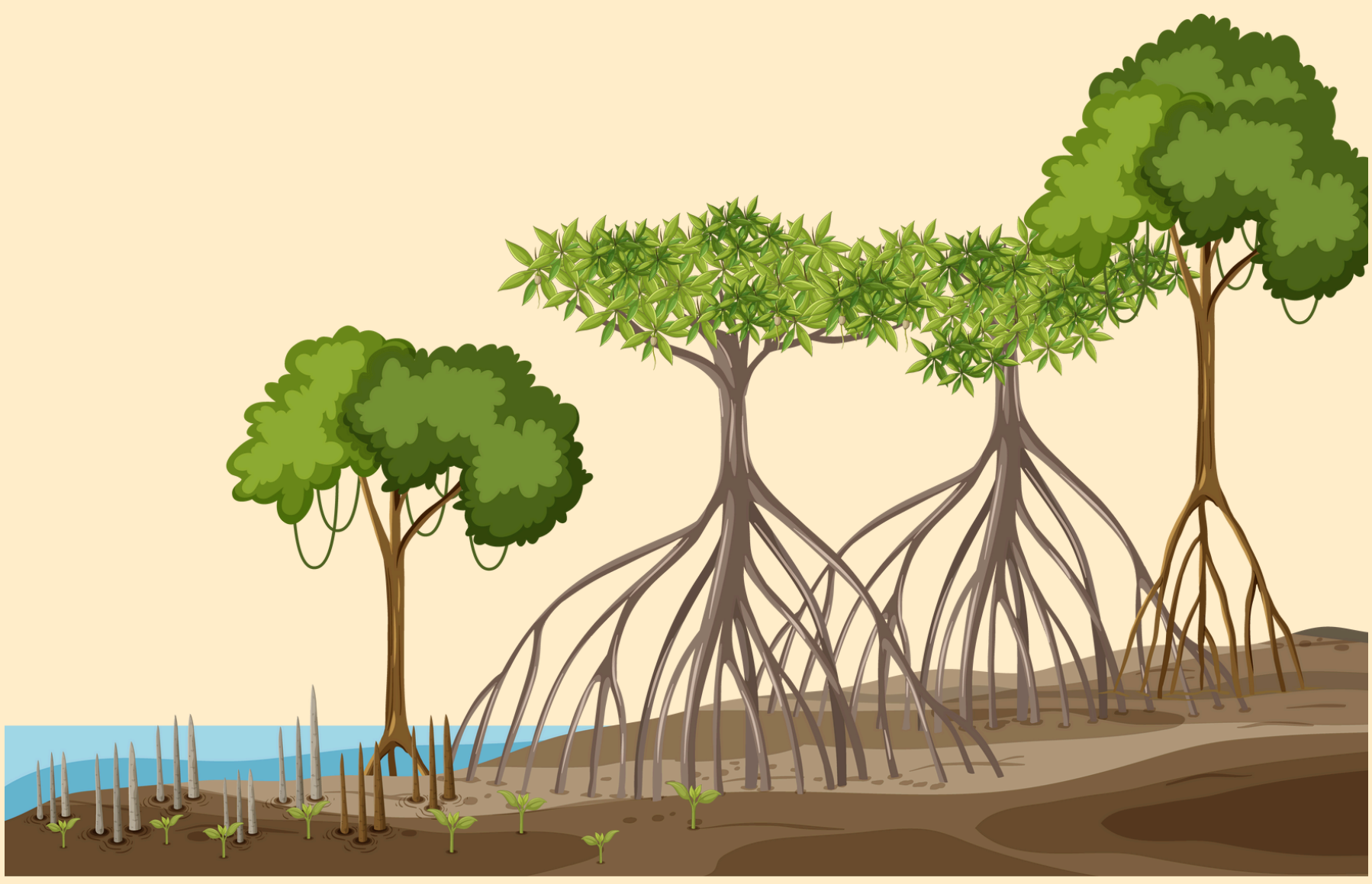
Warmer winters and longer summer seasons due to climate change have allowed the beetle population to explode beyond control, killing off vast swathes of pine trees.



This outbreak can be seen as a tipping point where the affected forests transition from healthy pine-dominated forests to dead forests or different ecosystems, significantly impacting forest structure, wildfire regimes, and carbon storage.

DIEBACK OF MANGROVE FORESTS IN AUSTRALIA

In 2015, extreme temperatures and drought conditions led to the sudden dieback of a large portion of mangrove forests along the Gulf of Carpentaria in northern Australia.



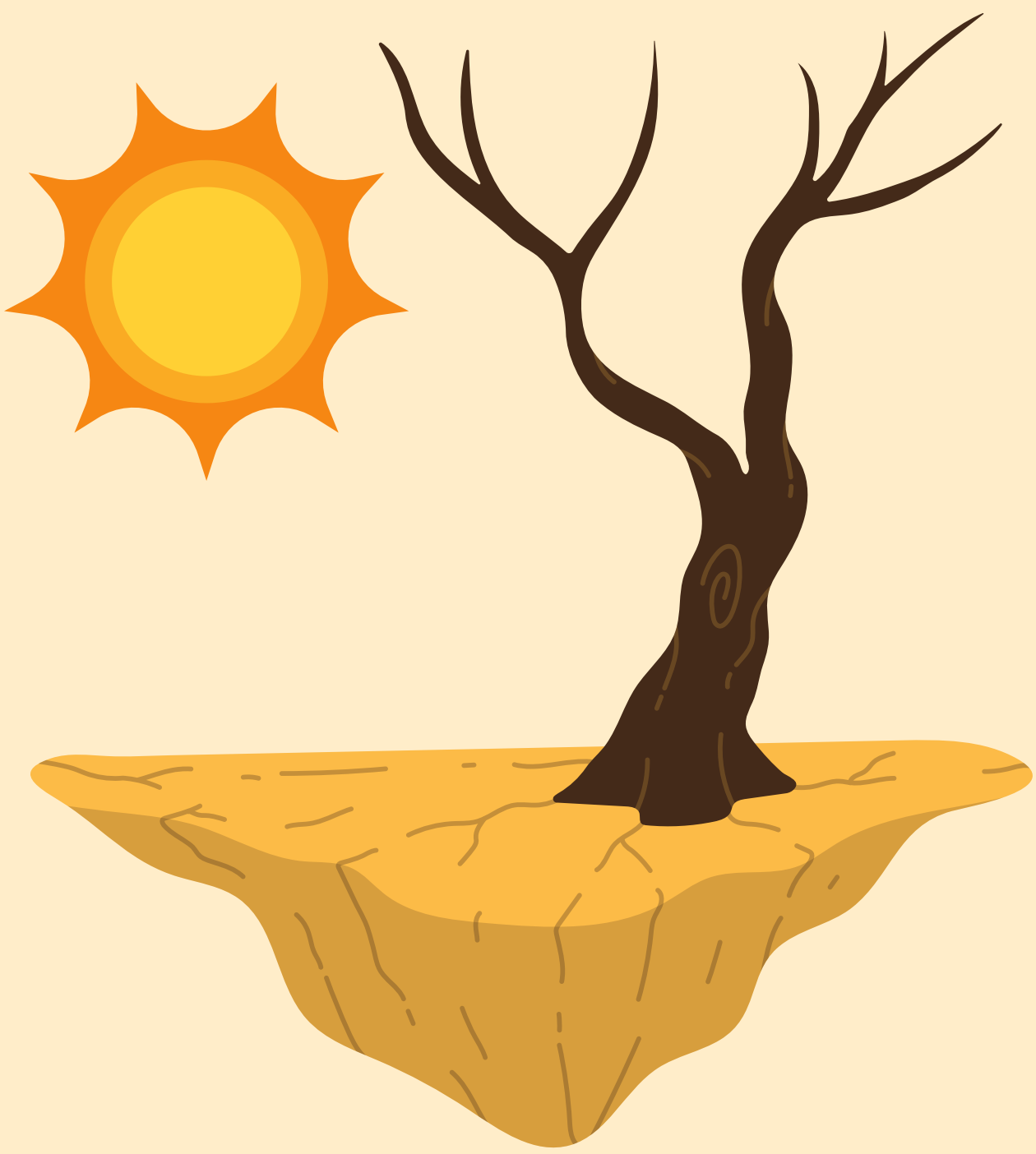
This event, covering around 7,400 hectares, represents a tipping point triggered by a combination of high temperatures and low water levels.

Mangroves are crucial for carbon storage, coastline protection, and supporting biodiversity. Once lost, the ecosystem services they provide are difficult to restore, and the area may transition to a different ecological state with lower biodiversity and resilience.

TROPICAL FORESTS AND EL NIÑO EVENTS

Tropical forests worldwide are susceptible to tipping points induced by El Niño events, which bring drought and higher temperatures.

These conditions stress trees, leading to increased mortality and vulnerability to fires. If such events become more frequent and severe due to climate change, they could push these forests beyond a recovery threshold, leading to significant changes in their composition, structure, and function.



This could include shifts from dense, moist forests to drier, more open ecosystems with different species and reduced capacity for carbon storage and biodiversity support.

These examples underscore the importance of understanding and monitoring the conditions that could lead to tipping points in forest ecosystems. Preventing or mitigating these shifts requires concerted global efforts in conservation, emission reductions, and sustainable management practices.