Imagine living in an area where it starts getting uncomfortably hot. Would you and your family just pack up and move somewhere else to be more comfortable? Unlike people, trees cannot escape to other climates quickly when temperatures rise as a result of global climate change. Will they suffer when it gets hotter? Or would they benefit instead?

We wanted to understand how trees in northern (or boreal) forests would respond to rising temperatures. We analyzed results from transplant experiments that took seeds from one area and planted them in areas with different climates. We found that where a tree is located within its geographical range determines how it will be affected: trees growing in the northern part of their range will likely benefit from rising temperatures and grow faster, but trees growing in the southern part of their range will likely grow more slowly. Keep in mind that factors other than just temperature changes also have to be considered to understand how forests will respond to climate change.

Abstract

Forests are important ecosystems. They provide habitat for many species of animals, insects and birds. But they also provide many valuable goods to people: lumber for furniture and houses, and tree pulp for paper and cardboard. Forests also keep a lot of carbon dioxide (CO₂) out of the atmosphere, which is an important greenhouse gas and significantly contributes to changing our climate. How? Wood is made out of carbon, among other elements, so when trees grow they are taking CO₂ out of the air to make their roots, trunks, and limbs.

Northern forests, called boreal forests, are especially important to humans because a third of all global lumber and paper products come from there (Fig. 1). Northern conifers (like spruce, pine, fir and larch) are the most economically important trees in these regions. We wondered what would happen to these northern conifers now that the climate is warming. Will warmer temperatures make them grow faster, or will the heat slow them down?

Introduction

Figure 1: Pine plantations in northern Ontario, Canada.
We know that tropical forests, despite being ‘used to’ heat, have a hard time dealing with a warming climate, because they are already at their maximum temperature tolerance. Would conifer forests in cooler climates have the same problem? We analyzed two seed transplant experiments and also data from other studies to answer this important question.

**Methods**

We wanted to know if conifer trees grew faster or slower under a changing climate. First we had to determine what a ‘changing climate’ means and how to measure it.

Therefore, we looked closely at several climate parameters—measureable factors that might impact growth of conifer trees. Some of them were: average annual temperature, average hottest and coldest temperature in a given month, and amount of rainfall in a year (or in especially cold or hot months). We found that average annual temperature had the biggest effect on tree growth, so we chose this factor to be the focus of our analysis.

We looked closely at temperature-related changes in tree growth in five conifer species: black spruce, jack pine, white pine, lodgepole pine and scots pine (Fig. 1).

Because we could not experimentally alter the climate for trees in the forest, we analyzed data from existing seedling transplant experiments instead. The black spruce experiment was initiated in the 1960s: seeds were collected from 45 different locations (or populations) and planted at 18 test sites. The jack pine experiment was also initiated in the 1960s: seeds from 57 populations were collected and planted at 16 different test sites (Fig. 2).

Decades after planting the height of these trees was measured. Since the seeds had been planted at a variety of sites, each with a different temperature, we were able to determine the optimal growing temperature for each population – the temperature at which each conifer population grew best.

For the other three tree species (white pine, lodgepole pine and scots pine), we calculated the optimal growing temperatures using data and information from older studies we gathered from journal articles.

**Figure 2:**
A map of Canada with the test sites (circles) and populations (triangles) used in the jack pine transplant experiment.

Blue triangles = populations growing at cooler than optimal temperatures
Green triangle = populations growing at near-optimal temperatures
Red triangles = populations growing at warmer than optimal temperatures
Shading = mean annual temperature values
Hatching = geographic range of the species
DO NORTHERN TREES HAVE COLD FEET ABOUT CLIMATE CHANGE?

Results

We calculated temperature dependent growth curves for black spruce and jack pine trees from all the different height and climate measurements (Fig. 3). These curves show the relationship between average yearly temperatures and tree growth. They allowed us to determine the optimal temperature for each population.

Interestingly, we found that trees that originated from warmer climates grew faster at colder temperatures than at their original location. The opposite was true for trees that came from colder climates (further north): they grew faster when transplanted into warmer climates.

Discussion

What does this mean for future tree growth under warmer temperatures due to global climate change? The answer depends on where the tree is located!

1. Trees that grow in the northern part of their geographical range will probably grow a bit faster when temperatures rise. This is because their optimal growing temperature is higher than at their current location.

2. Trees that grow in the southern part of their range will grow more slowly. They like it a bit cooler than where they already are – so more heat will slow them down even more.

So, different populations of the same species of conifer trees will respond differently to changing climates. You can see the question is not so straightforward to answer.

However other factors might further complicate how trees will respond. A changing climate does not only mean a change in temperatures but also a change in rainfall patterns and other environmental factors. Longer and more severe droughts could occur and harm the trees. The same is true for forest fires. Another factor is forest insects that damage trees; these species could do more damage when temperatures rise (because they have a longer reproductive season). Extremely fluctuating temperatures (like suddenly going from warm to very cold) or frosts can also be damaging to trees.

To get a good understanding of forest response to a changing climate, we need to take all these factors into account. But understanding the changes to tree growth caused by rising temperatures alone is an important first step.

Our analysis shows that at least 5 different conifer tree species respond to changing temperatures in the way we described. But we think our results show a consistent pattern and could be applicable to many other tree species as well.
Conclusion

How do you think your life will be affected by a changing climate? Do you live in an area where a warmer climate will make life easier, or do you live somewhere that is already uncomfortably hot in the summer? If so, could you just pack up and leave? Keep in mind that many organisms - especially plants - do not have that option (at least not on such short notice!)

Glossary of Key Terms

Conifers – The word “conifer” means ‘cone-bearing’ in Latin. It describes trees with needles that have seeds in cones. Most conifers are evergreen, which means they don’t shed all their needles in the winter, like broadleaf trees do. For more information see: http://www.thecanadianencyclopedia.ca/en/article/coniferous-trees/

Boreal forests – (also known as “Taiga’, or ‘snow forests’) are forests consisting of by conifer trees (mostly pines, spruces and larches). The taiga is the world’s largest biome apart from the oceans. In North America, it covers most of Canada and Alaska.

Global climate change (global warming) – The planet Earth is warming. Earth’s average temperature has risen by 1.5°F over the past century, and is projected to rise another 0.5 to 8.6°F over the next hundred years. Other aspects of the climate are also changing, such as rainfall, snowfall etc. Scientists are certain that humans are mainly responsible for this change in climate by emitting large amounts of greenhouse gases into the atmosphere (mainly from burning fossil fuels such as coal, gasoline and natural gas).

Greenhouse gas – Carbon dioxide (CO2) is the greenhouse gas we emit the most. Although it naturally occurs in the atmosphere, its concentration has been rising dramatically over the last 150 years due to human emissions. Other greenhouse gases are methane (from melting permafrost soil or agriculture) as well as nitrous oxide. (NO2). These gases enter the atmosphere and then act like the glass in a greenhouse, heating up the earth. This is called the “greenhouse effect”.

Parameter – a factor we measure. In our case, a climate parameter can be amount of rainfall, maximum or average temperature, length of drought periods etc.

Seed transplant experiment (also called ‘common garden experiment’) – An experiment in which seeds are taken from one area and planted in a different area, in our case in a different climate. After a certain time, trees are measured and examined and compared to trees that grow in the original seed location to see how the environmental factors in their new surrounding impacted them. Transplant experiments let us distinguish environmental factors (such as climate, temperature, rainfall) from genetic factors (which also affect growth of trees).

Geographic range – in biology, this describes the geographical area in which a species can be found.

Population – for animals or plants, this means all the members of one type of animal or plant (a species) that occur in a certain area. The same is true for humans: we can look at populations of a village, a city, or even the whole planet Earth.

Ecosystem goods and services – describe the way people benefit from nature. Nature can give us goods, such as forests, tree pulp for paper, or food. Nature (or part of nature, such as a pine forest) also provides services for us, such as cleaning our air, giving us oxygen to breathe or an area to go hiking or camping, as well as making us relaxed and peaceful (recreation services).

REFERENCES


Climate impact on forests https://www.epa.gov/climate-impacts/climate-impacts-forests
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We showed that warming temperatures impact the growth of conifer trees. What other factors associated with changing climates could also affect trees?

You read in the article that forests provide ecosystem goods (lumber, paper) and services (storage of CO2) to us. Can you think of other ways we are benefiting from forests?

Animals (and humans) can migrate to different climates if temperatures get too hot. How about trees? Are they completely stationary?

We chose a seed transplant experiment to find out how plants (in our case: conifer trees) respond to changing climates. Can you imagine other experiments that approach that same question in a different way?

Think of different ways your life may be impacted by global climate change.

Check your understanding

1. We showed that warming temperatures impact the growth of conifer trees. What other factors associated with changing climates could also affect trees?

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