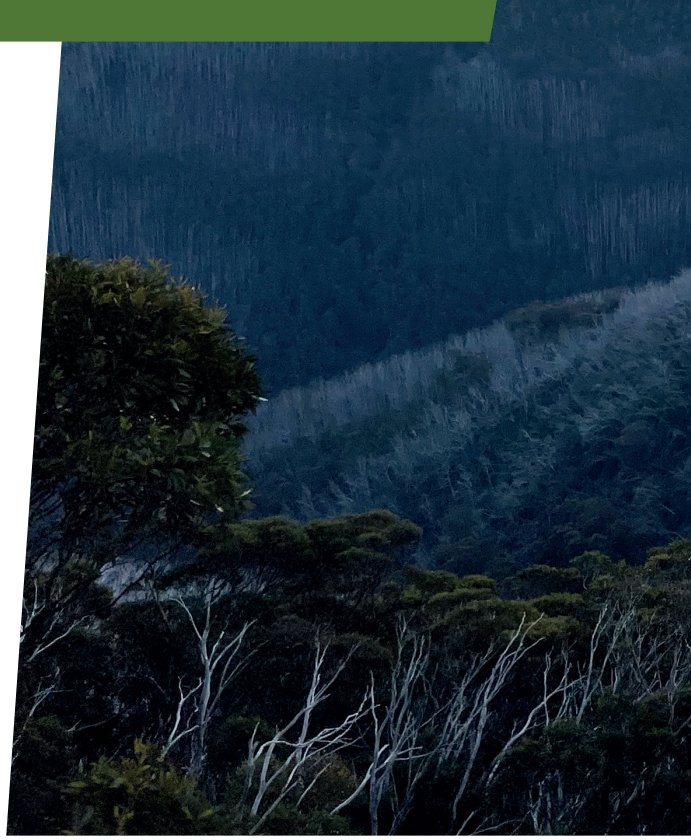
HOW WILL CLIMATE CHANGE AFFECT FORESTS?

As the Earth's climate continues to heat up, forests will have to adapt. **Associate Professor Craig Nitschke** of the **University of Melbourne** in Australia studies how the distribution of plant species might change as the climate does.



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PROFILE

Field of research
Forest and Landscape Dynamics

Research project
Modelling plant species distributions to understand species' suitability under climate change

Funders
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TALK LIKE A ... FOREST ECOLOGIST

Anthropogenic — caused by human activity

Ecophysiology — the study of how plants or other organisms respond to changes in environmental conditions, such as water availability and temperature

Ecological niche — how an organism or population interacts with the resources and competitors in its environment

Forest regeneration — the process by which plant seeds spread and new seedlings become established

Hydraulic conductivity — the measure of water being conducted

Simulation and statistical model (SSM) — a type of model that predicts the distribution of a species based on environmental data, such as temperature and precipitation

Stomatal conductance — the measure of how much a plant's stomata (the tiny pores on its leaves and stem) open, taking in carbon dioxide and releasing water vapour

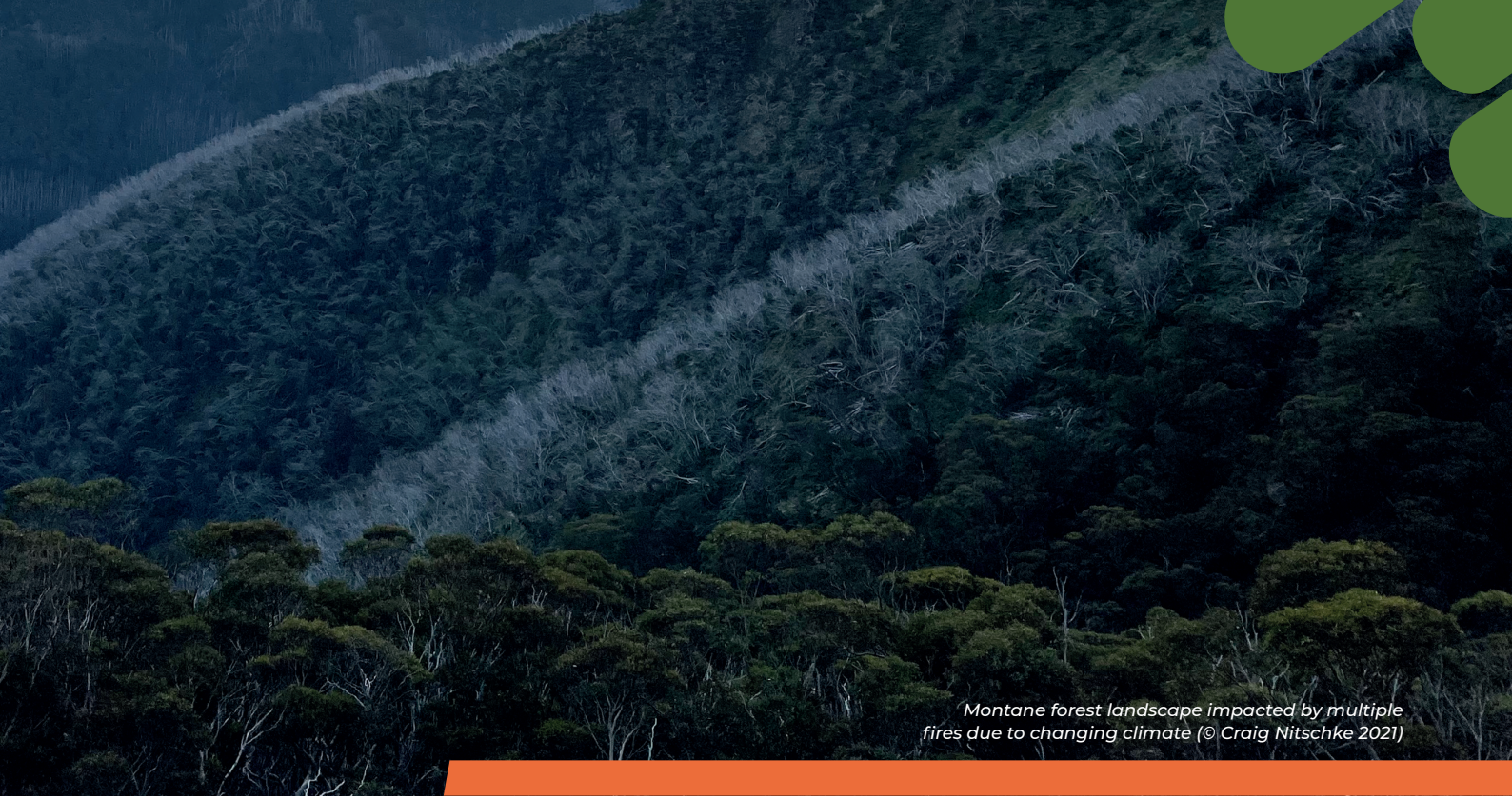
Turgor loss points (TLP) — a plant's capacity for retaining cell pressure in a dehydrated state

Anthropogenic climate change is affecting every corner of the Earth, from the icebergs of the Arctic to the forests of Australia. As our environment transforms, scientists are racing to understand how, why and what the future may look like. Dr Craig Nitschke of the University of Melbourne uses plant science and sophisticated computer modelling to study how the distribution of tree species in Australia could evolve as the climate changes. As a forest ecologist, he is helping to provide answers to many important questions: What are the most dangerous negative effects on forests? How are plant species already adapting? What species might even benefit from climate change?

How is climate change affecting Australia?

We are all aware that climate change is impacting every country on Earth. For example, while headlines about Australian bushfires captured the world's attention in 2019-2020, so too did deadly wildfires in California and along the west coast of the United States. Daily news reports drive home the global character of climate change and its role in disasters around the world. As average temperatures rise, many regions of the world will become warmer and drier, desiccating plant life and creating more fuel for fires.

"Climate change is a major driver of forest fires, but it is having many other impacts in Australia," explains Craig. Extreme weather events, such as droughts and floods, are occurring more frequently. These affect plants and other life. Average temperatures in continental Australia have risen by 1.4 °C since 1910. Night-time temperatures have risen more than daytime ones, enough to affect nocturnal animals. Rainfall is also changing all over the continent. In northern Australia, rainfall has increased by 15-20% since the 1950s, while in most other regions, including Tasmania and southern Australia in general, it has decreased. Less rainfall means a drier climate. Droughts lead to dry and compacted earth, and floods are often too intense and rapid to rehydrate the soil. Craig says, "These changes pose grave challenges to Australia's existing ecosystems."



Montane forest landscape impacted by multiple fires due to changing climate (© Craig Nitschke 2021)

How might these environmental changes affect plants?

The germination, regeneration and growth of plant seeds and seedlings is sensitive to local environmental conditions. Some species require cold winters to germinate and will not germinate if temperatures are too high or the soil is too dry. These species will struggle to reproduce in a warming, drying climate. "Arid conditions also reduce productivity in many species because soil moisture is crucial for supporting plant growth," explains Craig. Soil moisture can also impact nutrient availability. Some species can grow in nutrient-poor soils, but others cannot as they require nutrient-rich environments. Changes in moisture and nutrition will likely reduce plant productivity, which has implications for the capacity of forests to absorb carbon dioxide.

Species vary in their resilience to drought, and this can change the composition of a forest as some species survive repeated droughts while others are unable to thrive. Older trees also tolerate drought better than younger ones, meaning that a forest will have fewer and fewer young trees as it undergoes stresses due to a drier climate. At some point, however, even drought-resistant species and mature trees will die. "In a drought, regeneration will fail first, then growth, then mortality," Craig explains. "In extreme heatwave and drought events, however, mortality can occur quickly."

Forest ecologists research how plants respond to environmental challenges and how they die. They look at individual plants, especially at leaves. "We measure, amongst many variables, photosynthesis, stomatal conductance, hydraulic conductivity and turgor loss points (TLP)," Craig says. "The latter indicates the ability of a plant to maintain cell pressure while drying out and is a good predictor of drought response in plants." Species that are less resistant to drought cannot maintain their cell pressure while drying out and must slow or stop photosynthesis, leading to reduced growth and eventually death. Ecophysiology gives forest ecologists clues about how plant species may respond to climate change in the future.

> **"BEING ABLE TO PREDICT WHERE PLANTS CAN REGENERATE, AND WHERE THEY CANNOT, PROVIDES CRITICAL INSIGHTS INTO A KEY LIFE HISTORY STAGE. IF A FOREST CANNOT BE REGENERATED, WE CANNOT MANAGE IT SUSTAINABLY!"**

How can computer modelling help predict the future of forests?

Simulation and statistical models (SSMs) are types of mathematical models used in ecology. In forest ecology, SSMs use data on the absence, presence and/or abundance of plant and animal species in the current environment, combined with other information such as climate, physical features and land-use. SSMs relate key processes such as regeneration, growth, and mortality with species abundance/occurrence or, more simply, relate the presence or absence of a species to the other variables in the model and calculate the statistical strength of the relationship. "When used with climate variables, these models allow for what we call the 'ecological niche' to be identified," Craig says. "If a robust model influenced by climate can be produced, these models can be used to predict where a species' niche may shift to under climate change."

So, can SSMs foretell the future? Craig is careful to emphasise that models are "always wrong". Modelling can suggest possible trajectories or trends, calculate the likelihood of some outcomes over others, and place limits on what we think is possible. However, models are full of uncertainties and simplifications. SSMs cannot take into account the individual history of a forest or the genetic adaptive capacity of a living species. "Improving models and developing more sophisticated methods is an important task for future forest ecologists," says Craig.

What do we know about how forests are responding to climate change?

Forests have adapted to environmental challenges many times in the past. In a warmer, drier climate with more fires, forest composition will change to favour drought- and fire-resistant species. Craig also expects some species to evolve through natural selection pressures and give rise to new ones, like Darwin's famous finches. Species that cannot adapt will die out.

Although evolution can shape the forests of the future on its own, humans have a role to play in maintaining the forests we need. Modelling forest regeneration, germination and survivorship of seeds, and the impact of temperature and moisture on young tree growth can help us manage forests sustainably. "Being able to predict where plants can regenerate, and where they cannot, provides critical insights into a key life history stage," Craig says. "If a forest cannot be regenerated, we cannot manage it sustainably!"

We need forest ecologists like Craig to tell us where to plant what kind of trees, so we can protect our existing forests and plant new ones – an indispensable tool in drawing down carbon dioxide from the atmosphere and supporting biodiversity. Forests matter, and we do not need a computer model to tell us they will matter even more in the future.

ABOUT *FOREST ECOLOGY*

A branch of forest science, forest ecology is the study of the ecosystems in forests, including trees and other plants, animals, fungi and micro-organisms. Forest ecosystems are very complex because of the high density and diversity of species and their interdependence. Because forests are also important to human comfort and well-being as producers of timber and other products – not to mention oxygen —, forest science is closely associated with forest management. Forest management aims to keep tree populations at certain levels and maintain biodiversity and soil fertility. Forest scientists may study something as tiny as soil microbe populations or as large as the contribution of global forests to the carbon cycle.

What makes forest science a rewarding field to study?

It is a fantastic field for people who love nature and the outdoors. Forest and other environmental scientists often spend a lot of time doing fieldwork in their habitat of choice, amidst giant trees and awe-inspiring landscapes. Studying forests is intellectually rewarding because of the complexity and dynamism of these ecosystems. As an interdisciplinary field, forest science also offers the opportunity to bring together many different skills and areas of knowledge. It is an important field because of our reliance on forests. "Without forests, we would not be able to live on this planet," Craig says. "Research into how forests work and how they change is rewarding because it addresses the needs of humanity, as well as the needs of flora and fauna."

What research opportunities await future forest scientists?

Forests will remain crucial ecosystems and levers in the fight against climate change. The changing climate will be the central challenge for future forest scientists, as well as environmental scientists of all kinds. Craig lists some of the key questions the next generation of researchers will address: "Where and what type of adaptation do we undertake? Where do we fight to maintain forests in their existing state? Where do we transition forests based on human values? Where do we allow forests to find their own way? Where and how do we restore forests? What are the consequences of these decisions?" If you feel inspired by any of these questions, forest science might be for you!

Pathway from school to *forest ecology*

- Becoming a forest ecologist starts with studying fundamental sciences like biology and chemistry in school. Some schools may offer classes or units in ecology. Statistics is also a useful subject for ecologists.
- The first step towards becoming a professional forest scientist or forester is a bachelor's degree in forest science, forestry, ecology, forest management or a similar field. This level of qualification is enough to work in commercial forestry. An alternative pathway is to complete an apprenticeship in forestry.
- In Australia, Forestry Australia (**www.forestry.org.au**) is the professional organisation for tree professionals. The UK equivalent is the Institute of Chartered Foresters (**www.charteredforesters.org**). Other countries will have their own national organisations which provide advice to students interested in a career in forestry.
- Working as an academic researcher in forest science requires a PhD. Research in this area is very interdisciplinary, and people with training in other fields can enter a forest science PhD programme, as long as they have the skills needed for their research project.

Explore careers in *forest ecology*

- Craig emphasises that the most important asset for aspiring forest scientists is a love of forests, nature and the outdoors.
- One way to dip your toes into forest science is to participate in a field school or programme such as the Rainforests of Australia field school offered by the School for Field Studies: **fieldstudies.org**
- The University of Melbourne (**ecosystemforest.unimelb.edu.au**) is one of the top Australian universities for forestry. In the UK, the University of Bangor (**www.bangor.ac.uk/courses/undergraduate/d500-forestry-bsc-hons**) has the oldest and most well-known forestry department.
- In Australia, an average salary for foresters falls between AU$70,000 and AU$90,000. University professors in Australia earn AU$150-200,000 a year, depending on the field and years of experience.

Q&A

Meet Craig

What were your interests when you were growing up?

Fishing, hiking, camping, horse riding, playing ice hockey and taking part in biathlons!

Who or what inspired you to become a scientist?

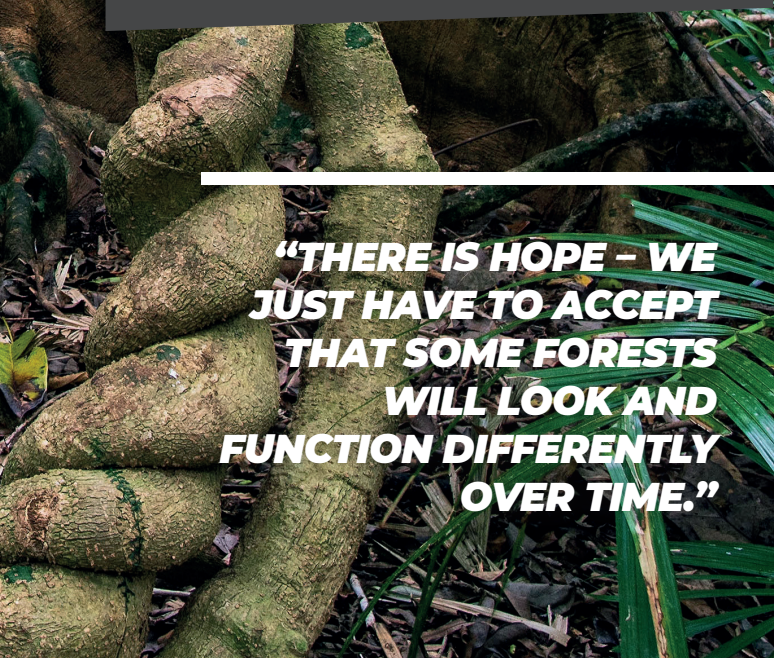
I fell into being a scientist by accident! I owe my journey to my lab mates at the University of British Columbia in Canada who encouraged me to pursue my PhD.

Which experiences have shaped you as a scientist?

I grew up in a forest-dependant community and spent many hours in nature when I was growing up. I ended up in forest science through living in this environment. What shaped me was a series of challenges that exposed the conflict between society's use of forest resources with conserving forests. At the nexus of these two opposing forces, I found myself inspired to understand the complexity of forests and people.

How do you stay motivated when focusing on climate change?

When I started my research into climate change and forests, I received many eye rolls and headshakes. "An interesting academic exercise" was a common retort to my work. What has motivated me is the change that has occurred in governments and people in the climate change space. It was slow, but this has sped up with time. It is inspiring to see the research mainstreamed and the arguments of "is climate changing?" shifting to "what we do about this?" because we are now seeing the impacts of the changing climate. I am optimistic because not every place or species will be impacted negatively.



"THERE IS HOPE – WE JUST HAVE TO ACCEPT THAT SOME FORESTS WILL LOOK AND FUNCTION DIFFERENTLY OVER TIME."

Measuring the forest – establishing and monitoring plot in montane ash forests in Victoria, Australia (© Craig Nitschke 2021)

Understanding the vulnerabilities and risks of forests means we can manage these if we desire. Forests are complex and full of surprises. I have seen this in the fire-impacted landscapes of southeast Australia. In areas burned three times in 15 years (that usually burn once every 75-100 years) we still find a functioning ecosystem. There is hope – we just have to accept that some forests will look and function differently over time. But this has always been the case! The one constant in forests is change.

What are your proudest career achievements so far?

Every master's and PhD researcher I supervise to graduation is a proud achievement. They are courageous, inspiring and brilliant. They make my career as a forest scientist.

Craig's *top tips*

1. Find your passion! Your passion for a subject is what will motivate you.
2. Spend lots of time outdoors.
3. Focus on positive change and stay optimistic!