Building knowledge bridges

Enno Uhl and **Hans Pretzsch** are in no doubt that to meet the challenges posed by impending climate change building international alliances with scientific partners from different geographic areas is essential

How has the Climate-Fit Forests project benefited from multidisciplinary and international collaboration?

It is logical and critically important to collaborate internationally in order to combine the available and extensive expertise of scientists from countries in a north-south orientation with different climates and complementary forest management expertise, in one synergistic consortium. Projected climatic changes will have a major impact on forestry, typically because of the long-term nature of forests and their production cycles. The synergies we have capitalised on chiefly involve the different climatic regions in the participating countries, as well as varying forest management backgrounds and methodological knowledge.

In what ways have the participating countries contributed to the project and learned from one other?

One example is that South Africa is exposed to a warmer and drier current climate than Europe. This could be used to pre-empt scientific studies and investigations in Europe, which will be exposed to similar conditions in the future if climate change predictions hold true. The partners were therefore aligned along a natural gradient in temperature and water availability from Germany, through to Italy, to South Africa, creating a unique real-world research laboratory.

Can you give an insight into the innovative methods borne from this research?

We have developed the principle of continent- and climate-zone overarching transect studies in order to understand the species drought reaction patterns at the edge of and beyond their natural range. In addition, the evaluation of existing long-term experimental plots (in Europe) and of new long-term plots in partner countries have enabled monitoring of climate change and the human footprint on forests. One of the interesting areas the project team has been working on is the development and testing of combined root and stem analysis for the development of allometric functions, which allows below ground biomass and carbon stock to be estimated. We have also been working on computer tomography as a method to describe climate-induced density changes and anatomical changes in wood.

The Climate-Fit Forests team has further developed simulation models regarding drought stress reaction patterns, enabling prognosis and decision support for forest management under climate change. Another area of development has been the Integrated Forest Operations Software (IFOS), which presents opportunities for usage in an enterprise environment to quantify the carbon dioxide emission footprint of forest machines.

The CO2 FORMEC database is an additional development. Through CO2 FORMEC, values of CO_2 emissions related to 523 different forestry operating conditions are listed and analysed at different levels of detail. The database allows for a comprehensive overview of the quantities of emissions that can be expected under certain conditions and with certain machines in selected harvesting systems.

Can you explain portfolio theory and what this means for forestry management?

Portfolio theory offers the possibility to integrate risk assessment into forest management, and therefore evaluate silvicultural decisions on a comprehensive basis. As the climate changes, natural hazards such as wind, fire and drought will most likely increase in the future. Forest product diversification can be crucial for coping with these hazardous events and their associated CO_2 emissions.

To what extent is the project benefiting the next generation of forestry scientists?

Most of our work's data, applied methodology and results have been made publicly available through scientific journals. During secondments, numerous teaching and training activities of forestry students by the Marie Curie fellows have been undertaken. As a project deliverable we drafted an international summer school where we teach up-to-date methodology in climate impact research and impart the main findings of Climate-Fit Forests. More than half of the implemented secondments have been completed by early-stage researchers. In most cases those fellows exploited their secondments to both strengthen their PhD work and for networking purposes. One bachelor's thesis and seven Master's theses have been successfully finished within Climate-Fit Forests.

What steps are taken to encourage communication with the project's geographically separated partners?

The basic concept of continent- and climate-zone overarching analysis of tree growth along an ecological gradient on long-term plots has brought people together and fostered a number of valuable outcomes. These have included standardisation in measurement, data analysis and modelling, as well as the composing of common publications. Workshops for knowledge exchange and preparation of follow-up projects have been instrumental in supporting improved communication. In addition, we have supported a number of students, PhDs and senior scientist exchanges.

Forests fit for climate

By learning from a climate gradient across Europe and into South Africa, the **Climate-Fit Forests initiative** aims to support the development of adapted forest management strategies under the threat of climate change

AS THE WORLD begins to prepare for and adapt to global warming, there is increasing focus on how changes in climate will impact key ecosystems, particularly forests. Climate-Fit Forests, an EU-FP7 Marie Curie project, is undertaking long-term observations of forest ecosystems and looking into practical solutions for the adaption of forest management threatened by climate change. Their work revolves around looking at the transformations seen in the climate gradient from Germany over Italy and to South Africa. In particular, this project is revealing more about the basic relationships between environmental conditions, functioning of forests and structure dynamics.

A substantial body of research has highlighted that there has been around a 10 per cent increase in net primary production and growth in forests from pre-industrial time to the present day, but that this increase may have been balanced by sporadic droughts, which are also likely to increase with global warming. "With carbon dioxide concentrations in the atmosphere increasing from 280 parts per million (ppm) in pre-industrial times to almost 400 ppm in 2015, the importance of forests as a sink for carbon to mitigate climate change effects is steadily increasing," explains Hans Pretzsch, chair holder for Forest Growth and Yield Science, Technische Universität München, Germany, and leader of Climate-fit Forests.

A SPATIAL CLIMATE GRADIENT

Pretzsch and his team are focusing on the unique temperature and moisture gradient that is occurring from Germany/Switzerland to Italy and South Africa. The hope is that by understanding more about South Africa's existing warmer climate and environmental conditions, the effect on forests can be extrapolated out to simulate Europe's anticipated future climate. Working with this spatial gradient, the team is investigating the different ways forestry might be impacted by a changing climate, and how best to manage these changes and minimise carbon emission rates from forest operations in Europe.

The forest management approach in South Africa is mainly plantation based, whereas Europe's approach is more aligned to a close-to-nature focus. "Since societies are currently demanding increased delivery of green and carbon neutral biomass, much attention is being given to questions around the stability and productivity of forests," Pretzsch expounds. Both approaches exhibit pros and cons in that context. The Climate-Fit Forests project aims to synergistically exploit the existing country-specific knowledge about ecosystem functioning to improve the provision of a number of forest carbon services.

WELL-DEFINED WORK PACKAGES

Collaboration with project partners is an essential part of Climate-Fit Forests, with project management also supported by the Professor Raffaele Cavalli at the University of Padua, Italy, Professor Martin Ziesak at Berner Fachhochschule, Switzerland, and Pierre Ackermann at the University of Stellenbosch, South Africa. "In addition to our own research contribution we took a great deal of care to ensure that the project's progress remained in line with the objectives and communication within the consortium was maintained throughout and was as effective and engaging as possible," explains Project Coordinator Enno Uhl.

This project is being delivered through three work packages. The first addresses the carbon sequestration abilities of forests being affected by climate change in plantations and close-to-nature forests. The second delves into carbon emissions from forests and forest operations, looking at how these are being affected by climate change and climate change induced risks, as well as different management regimes. The final package involves developing a toolbox with tools for adapted forest management under the threat of climate change, including a summer school to disseminate the findings by teaching.

OVERCOMING KNOWLEDGE GAPS

There are a number of key themes surrounding climate change and forests, including vulnerability of trees, adaptation measures and mitigation contributions in forestry, of which gaining insight into the vulnerability of trees against climate change is probably the most challenging. When influenced by climate change, forest growing conditions, such as size-growth relationships within a stand, can become altered. "The mechanisms behind those growth reactions are not yet fully understood. Even less is known to what extent the vulnerability may be modified

The findings from these experiments have been integral to influencing the existing concepts of analysing and modelling approaches for forest dynamics

by forest management, such as by regulating stand density or mixing tree species," Pretzsch reveals.

In order to better understand these mechanisms, the researchers have established trial series along a significant climatic gradient. Because of the complexity of the processes at play, they elected to take a multidisciplinary approach, drawing on a number of scientists with experience in tree measurement, dendroecology, ecophysiology and modelling. "This has allowed us to analyse growth dynamics on different scales including cell-, organ-, tree- and stand-level," states Uhl. "We looked at different stand types encompassing plantations, mixed stands and natural forests."

The Climate-Fit Forests team also studied a comparison between close-to-nature and plantation forestry; regarding the disposal of CO_2 through forest operations and how to manage climate relevant emissions of the gas. Here, the objective was to identify potential practices to minimise the carbon footprint.

MODELLING FUTURE FOREST DEVELOPMENT

The findings from these experiments have been integral to influencing the existing concepts of analysing and modelling approaches for forest dynamics. As the Climate-fit Forests project has progressed, trials have been further developed to include recording intra-annual growth and inter-specific interactions in natural mixed species stands. "We also advanced growth models regarding root-shoot growth and tree growth under water limitation," Uhl adds. The researchers now plan to further differentiate competition regimes in simulation between water and light-limited situations.

The team's work has assisted with gaining specific understanding about the phenomenon where reduced water supply is a contributing factor to tree and forest vulnerability. "The conclusion is that in spite of the capacity of the species to extract water from deep soil layers to sustain transpiration, tree growth was heavily limited by shortages in rainfall," Pretzsch reveals. As a result, the researchers concluded that variation in tree growth can be estimated by using the variation of tree sap flow.

NETWORKING FOR SUCCESS

The group intends to continue maintaining a network of monitoring plots and incorporating the information that comes from these into their studies. "Additionally, we will focus on studies of long- and short-term growth dynamics based on year ring analyses, as well as progress our empirical and process based growth models which we can use for scenario analyses," Pretzsch expounds.

The next stages for the collaboration will focus on identifying specific mitigation actions that can be implemented today and in the future. The team will also continue to develop the knowledge exchange programmes they have fostered with staff and students, as well as building on the linkages with experts that provides a sustainable network to support dissemination of theoretical and practical knowledge of forest ecosystem management. Eventual expected outcomes include guidelines for sustainable forest management that support adaptation and mitigation.

CLIMATE-FIT FORESTS

OBJECTIVES

To use climate gradients from Germany, Italy and South Africa to examine the impact of climate change on forests • To estimate the carbon footprint by forest management and forest operations • To combine existing expertise in order to identify and address gaps in the current understanding of climate impact • To strengthen research partnerships through staff exchanges and networking activities across Europe and South Africa

KEY COLLABORATORS

Hans Pretzsch, Technische Universität München, Germany

PROJECT PARTICIPANTS

Technische Universität München, Germany • University of Padua, Italy • Berner Fachhochschule, Switzerland • Stellenbosch University, South Africa

PARTNERS

Institute for Commercial Forestry Research (ICFR) **• Sappi • Mondi • Cape Pine Forests and Timber Products • South African National Parks** (SANParks)

FUNDING

European Commission FP7-PEOPLE • Marie-Curie Actions, International Research Staff Exchange Scheme (IRSES), GA 295136 • Institute for Commercial Forestry Research (ICFR) • Sappi • Mondi

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ENNO UHL has been assigned to the Chair of Forest Growth and Yield Science from the Bavarian Forest Service since 2005. He is responsible for the scientific coordination of the network of long-term yield monitoring plots in Bavaria. His work is focused on drought effects on tree and stand growth.

HANS PRETZSCH has been Professor of Forest Growth and Yield Science at Technische Universität München, Germany, since 1994. For the past 20 years, he has focused his work on general rules of tree and stand growth, tree and stand dynamics under stress, urban trees, and tree and stand modelling.