Carbon smart forestry under climate change

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How will the carbon sequestration of forests be impacted by climate change?

How can forest management be adapted to improve forest resilience under a changing environment?

How can forest management contribute to the climate change mitigation function of forests by strengthening and sustaining their carbon sink potential?

How can forest utilisation be optimised towards a low source of carbon emission?

Knowledge transfer - transnational cooperation - inter-sectoral exchange - capacity building

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The role of forests and forestry in the global carbon cycle

Forest ecosystems are important components of the global carbon cycle. Four billion hectares of forest ecosystems (about 30 per cent of the global land area) store large reservoirs of carbon, together holding more than double the amount of carbon in the atmosphere. Each year they remove nearly 3 billion tons of anthropogenic carbon through net growth, absorbing about 30 per cent of all CO_2 emissions from fossil fuel burning and net deforestation.

Meanwhile, climate change triggers changes in growth dynamics and poses more frequent and severe hazards to forests. Adapting forest management to the challenge of climate change first requires the evaluation of its possible impact in the medium to long term. From this knowledge, measures to reduce these impacts can be developed. Forest management also includes forest utilisation for providing timber to society. Here, forestry acts as a carbon emitter.

The CARE4C ambition

In a changing climate, we see the challenge that forestry needs to contribute to a low-carbon emitting society. Our ambition is to learn how to improve carbon sinks and sources of forests and forestry. We strive to develop carbon smart forest management for different forest types and climates to adapt to and mitigate climate change. We promote capacity building for climate-smart forest management.

Strategy of CARE4C

Our consortium comprises highly experienced academic and non-academic partners covering different forest disciplines and complementary methods from five European countries and South Africa. We utilise transect studies to benefit from our complementary methods. This enables a more comprehensive and transferable understanding of how the carbon cycle in forests is mediated by climate change and forest management. Networking activities and secondments support knowledge transfer. The combined involvement of experienced researchers and early-stage researchers guarantees high-quality research and profound capacity building.

Topics of CARE4C

Acclimation of tree species to climate change

We aim to identify the physiological adjustments of Scots pine *(Pinus sylvestris)* to extreme drought events, exploring the variability of wood anatomy and water use efficiency patterns along tree-ring chronologies. Preliminary results suggest a higher susceptibility to climate change for pines in monospecific forests compared to mixed forests at different site conditions. Applying higher-resolution approaches of carbon isotope analysis and quantitative wood anatomy will provide a better understanding and interesting insights on the ability of trees to respond to climate change and extreme drought events. We repeat the study for *Olea europaea subsp. africana* in an Afromontane forest ecosystem that characterises a variety of habitats in the Cape Region, from stream banks to woodland. It is considered a key species in the ecology of such habitats.

Enhancing productivity and tree resilience by species mixing

We analyse different tree species mixtures in terms of productivity and resilience to drought. Comparing monospecific and mixed stands of Norway spruce *(Picea abies)* and Scots pine *(Pinus sylvestris)* revealed that mixing those species only slightly increased productivity (2 per cent). The effect varies strongly across different site conditions (Ruiz-Peinado *et al.*, 2021). On average, we found that mixed-species stands show higher resistance and resilience to drought events than monospecific stands (Pardos *et al.*, 2021). However, there was a large variability in tree growth response to drought depending on the tree species identity, type of admixture and site conditions. The positive effect of species mixing on resilience was greater for conifer-broadleaved than for other types of mixtures, indicating the importance of species traits complementary in mixed stands to cope with climate change.

In Mediterranean mixed pinewoods *(Pinus pinaster-Pinus pinea)* the resistance to drought events is lower for *P. pinaster* but greater for *P. pinea* than in respective monospecific stands. In the long term, the sensitivity of *P. pinaster* to the climate was reduced in mixed stands, highlighting the complexity of the interaction between inter-specific competition and climate effects on tree growth (Vergarechea *et al.*, 2021). Overall, the results suggest that mixing species can mitigate climate change impacts by between species temporal niche complementarity (del Río *et al.*, 2021).

The effect of forest management on tree and stand growth and resilience

Based on long-term dendrometer recordings, we could detect the potential of silvicultural modification of stand density through thinning in reducing water stress for Aleppo pine (Pinus halepensis) stands. A similar trial set-up was established and equipped in different pine plantations in South Africa to analyse the effect of varying thinning types on the productivity and resilience of trees and stands. We analyse growth dynamics and growth stability in managed structurally

"The measurement time at BNP was an excellent opportunity to get a unique insight into structural diversity of the Białowieża Forest and to get in touch with staff members of BNP. We believe that this is a good start for further collaborations between TUM and BPN."

Andreas Rais, TUM.

diverse mixed forests across Europe and South Africa utilising long-term records of tree growth. Results will deliver valuable information about forest dynamics supporting forest managers in carbon-smart forestry.

Diversification of landscape management

A growing number of studies have identified diversification of forestry activities as a powerful means for risk management. Product diversification bears an underutilised potential in commercially oriented forest sectors, such as in South African forestry. Here a landscape view would provide new opportunities. We developed a land-use portfolio model applied to different types of avocado, eucalyptus and pine plantations in South Africa. It revealed the benefit of optimally diversified landscape compositions in terms of reconciling carbon sequestration with economic return, while minimising trade-offs among objectives

Carbon emission in forestry

Active forest management requires forest operations. There are plenty of wood harvesting systems applicable but not all coincide with an efficient performance in terms of emissions per unit produced. We set up a common protocol allowing for an accurate and replicable assessment of fuel consumption in forest operations. The research activity focused on the acquisition of data via the CAN-BUS network on the fuel consumption and other operating parameters of the machines. Preliminary results in the application of the protocol show that in the process of wood chips production, the logistics and organisation of transport is essential to control emissions per unit, particularly in remote forests located in mountain areas.

The use of hybrid diesel-electric machines that recover energy during work is advantageous in reducing emissions per production unit. A hybrid diesel-electric cable crane was tested to verify the practicability of this technology in real conditions. The recovery of energy from the system significantly reduced fuel consumption and consequently carbon emission.

Dissemination

CARE4C participated in the scientific conference "Forests in Science, Practice and Education" on the occasion of the centenary of the Faculty of Forestry, Warsaw University of Life Sciences, in June 2019. We will deliver a session at Forstwissenschaftliche Tagung, the main forest science event in Germany, in September 2021. Organised by Stellenbosch University, South Africa, the conference "Managing for resilient forests in a variable future climate" occurs in March 2022 and is targeted at both scientists and practitioners.

Research activities within the frame of CARE4C have contributed to 24 scientific publications thus far, covering the various aspects of carbon smart forestry (see www.care4c.eu).

"We aimed at providing standardised protocols for characterising thinning prescriptions, designing thinning trials, and programming thinning algorithms. For forest managers, practitioners and modellers, these achievements have relevance, since they permit their direct application and testing."

Rafael Calama, INIA.

"The cross linking of activities during the secondment to FBZ turned out to be very valuable. This was considered especially important, as hereby operational skills were enhanced, which are crucial for CO_2 efficient operations."

Markus Rufener, FBB.

Networking activities

Training and workshops

We particularly emphasise the training of young researchers and offer courses and skill promotion utilising partner organisations' specific and inter-sectoral expertise.

Implemented

- Airborne LiDAR and drone technology for forest inventory and management
- Models used in forestry for upscaling and prognosis
- Silvicultural concepts across diverse climate zones and their implications for stand structure and dynamics
- Efficient use of forestry machines using the innovative simulator TIMBERSKILLS.

Forthcoming

- Forest eco-physiology and its linkage to wood characteristics and dendrochronology
- Methods for multi-criteria forest management optimisation on landscape scale, including carbon balance.

Secondments

The MSCA RISE funding schemes aims at exchanging research and innovation staff between countries and sectors. Up to now, CARE4C has seconded 49 staff members comprising 29 experienced researchers, 18 early-stage researchers and two technical staff members. All secondments sum up to a total duration of 65 months (Figure 1).

"The secondment to TUM in Freising, Germany was a unique type of travel for me as an experienced researcher. I had this opportunity to make new connections to the people who share my concerns about science and research interest. The new academic experience was an emerging environment for me and is surely essential for any researcher to be able to expand support and knowledge in their area of science."

Zahra Mahani, SU

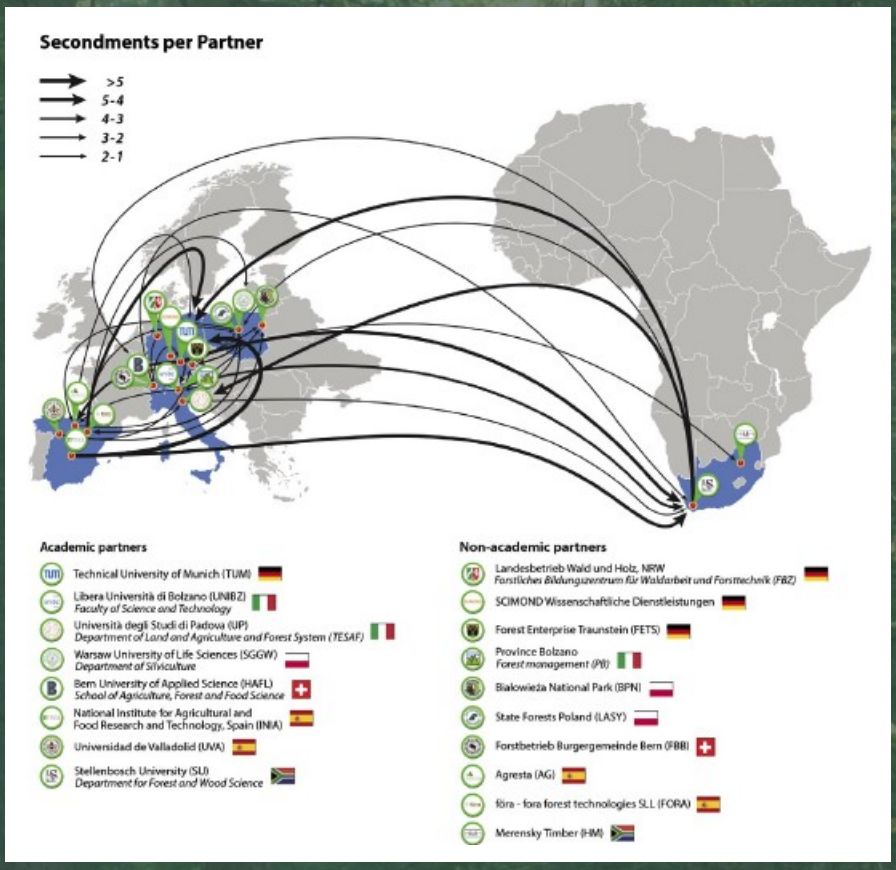

Figure 1: Consortium partners and implemented secondment activities.

Click here for references/publications

PROJECT SUMMARY

In the fight against climate change, forestry needs to contribute to carbon sink and a low carbon-emitting society. Forests sequester carbon and simultaneously release carbon during forest operations. Our ambition is to achieve an integrated picture of carbon sink and source; to adapt forest management for different climate and management regimes. CARE4C strives to develop carbon-smart forest management systems for adaptation and mitigation in view of climate change. The CARE4C Project runs from January 2018 to December 2022.

PROJECT LEAD

Prof. Dr Hans Pretzsch heads the Chair of Forest Growth and Yield Science, Technical University of Munich and has done so for nearly 30 years. His main focus lies on understanding the dynamics of tree and stand growth in various environments and growth dynamics under stress and climate change, and on growth modelling. He has been named a "Highly Cited Researcher" on more than one occasion and has published more than 300 peer-reviewed publications.

PROJECT PARTNERS

Technical University Munich, Free University Bolzano, National Insitute for Agriculture & Food Research & Technology, University Padova, University of Applied Sciences Bern, Warsaw University of Life Sciences, University Valladolid, Stellenbosch University, Forest Enterprise Traunstein, Landesbetrieb Wald und Holz NRW, Bialowieza National Park, Agresta S. Coop, Province of Bolzano, Forstbetrieb Burggemeinde Bern, State Forests Poland, Scientes Mondium UG, and Merensky Timber.

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