University of Reading
UNIVERSITY OF SURREY
Scenario
DOCTORAL TRAINING PARTNERSHIP
UKRI
Natural Environment Research Council

Carbon gain vs water loss – using state-of-the-art simulation models and remote sensing to examine the potential impacts of woodland expansion

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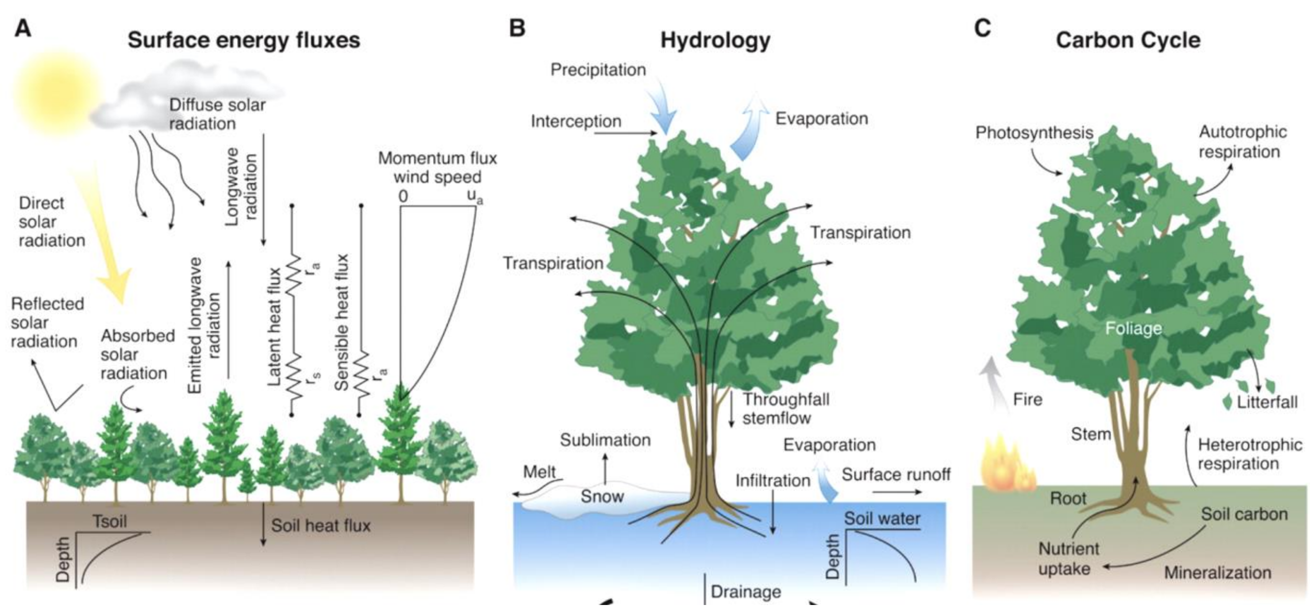
Forests play an important role in the Earth's hydrological, energy and biogeochemical cycles, and control land-atmosphere interactions and feedbacks (Bonan, 2008). Due to their potential considerable water use and related cooling effects, forests can significantly affect local climate and have both positive and negative impacts on water flows, reducing both dry weather and flood flows. Moreover, in turn forests are impacted by climate, affecting forest condition, growth and thus water, carbon dioxide and energy exchange. For example, climate warming is predicted to lead to more frequent droughts, with significant implications for forest functioning and related services and potential disbenefits.

A major driver for the *expansion of UK woodland* is carbon sequestration but this poses a well-known threat to water resources (although there are conflicting estimates, and woodland design and management can exert a strong influence). There is a need for a reliable assessment of: **"How woodland expansion will affect water-, energy- and carbon exchange under a future climate"**.

Current forest modelling tools have severe shortcomings and are deemed to deliver unreliable estimates of forest hydrological, energy and carbon cycle processes. Hence there is an urgent need for a scientifically robust Forest Benchmark Model-Data system. Such a system will generate more reliable estimates of the interplay between forest carbon gains and water trade-offs, plus potential synergies, for different treescape designs and placements, and climate scenarios.



Feedbacks between forests , soil and atmosphere via the surface energy-, water- and carbon balance. Reprinted from Bonan (2008).

As mentioned above, there is an urgent need to better understand the complex interactions between forest carbon sequestration and water use. Currently, we have relatively limited knowledge of how tree type, intra-seasonal and inter-annual changes in forest structure (as affected by stand density, phenology and the distribution of tree size and age) affect evapotranspiration, as well as energy and carbon exchange across the UK landscape.

Our current understanding of forest ecosystem functioning is based on a mix of monitoring and assessment tools ranging from inventories, in-situ measurements, remote sensing data and model simulations. Current forest models are limited to species suitability models, empirical growth and yield models, and stand-scale detailed models that predict CO_2/H_2O fluxes, typically highly tuned to the specific site.

Unfortunately, there are a number of major draw-backs to these kinds of models, i.e., (i) the inherent simplification or neglect of certain processes (e.g. interception of rainwater by the tree foliage and subsequent evaporation), (ii) ignoring of the vegetation 3-D structure and within-stand species-, age-, and height diversity (iii) neglecting of the spatio-temporal variation in forest functioning (e.g. in relation to tree and leaf age), by using, for example, structural and physiological parameters that are constant in time.

The student will develop a novel stand-level process model, that will address the shortcomings outlined above and utilise the latest in-situ and satellite information, to better characterise forest form and function.

Ultimately this model will inform the development of climate-smart forest strategies, plans and guidance to maximise carbon benefits of forest expansion while protecting future water resources.

Training opportunities:

The student will be trained by supervisors in process-based modelling on the soil-vegetation-atmosphere system with regard to hydrological processes, radiative transfer, plant physiological processes, energy- and carbon exchange. They will train the student on the environmental monitoring of forests and in the use of remote sensing data. Furthermore, training will be provided on sensitivity/uncertainty analyses, and constructing climate scenario driving data. The student will be encouraged to take full advantage of additional training provided by the University of Reading (UoR), Scenario DTP, NERC and Forest Research.

The student will attend Flux Course 2023 in Colorado; a world leading, two-week residential course providing training on a wide range of aspects of estimating water and carbon fluxes from vegetation. They will benefit from close interaction with experts in the UK land-surface community, including in the Land Surface Processes Group at UoR, the UK JULES modelling community, and will have contact with tree physiologists/modellers in projects that the supervisors are involved with.

The placement at Forest Research will provide training in forest monitoring and silviculture, woodland design and forest policy. It will also expose the student to a research environment outside of the university setting.

Student profile:

The student should have a strong background in the natural sciences or geography and experience of computer programming. Willingness to learn to program is essential. Previous experience of modelling and/or remote sensing would be an advantage.

Funding particulars:

This project has CASE co-sponsorship from Forest Research (Forest Research will provide £1k per year, host the student for 4 weeks per year (this includes field work on their sites), and provide field monitoring data).

References:

Bonan, G. (2008) Forests and Climate Change: Forcings, Feedbacks, and the Climate Benefits of Forests, *Science:* 1444-1449.

https://research.reading.ac.uk/scenario/