Lasse Keetz

Can modelling adaptive roots help to improve climate predictions?

Roots are often overlooked – not only in the obvious sense that they are usually belowground and therefore hidden from sight, but also in terms of the amount of scientific attention they have received in comparison with aboveground vegetation properties and processes. Yet roots and the domain within soils where they closely interact with their surroundings, the rhizosphere, play key roles in many ecosystem mechanisms. For instance, fine roots - commonly defined as roots with a cross-cut smaller than 2 mm - mediate plant transpiration (that is water which is lost from the plant to the atmosphere through evaporation) by being chiefly responsible for water uptake from the soil, thereby influencing global and regional water and climate systems. They are further mainly in charge of nutrient uptake which is an important factor for plant growth. They transport carbon that was previously drawn from the atmosphere in the process of photosynthesis belowground, where under certain circumstances it can be stored for thousands of years. Consequently, they are also directly linked to the global carbon cycle and the vivid debate of how it will interact with global climate in the future. Understanding and quantifying the role roots play and how they will, in turn, react to changing environmental conditions is therefore crucial.

One common approach to study the often very complex mechanisms that govern plant growth and distribution are dynamic global vegetation models. The relationships between environmental variables, such as *e.g.* temperature and precipitation, with plant growth and behaviour are abstracted by mathematical approximations, usually derived from “real life” experiments. The competition for *e.g.* light and other resources between different plants is thereby simulated over time using computers. In this thesis, the representation of fine roots in one such model, the Lund-Potsdam-Jena General Ecosystem Simulator (LPJ-GUESS), is revamped. In the previous version, plant resource uptake from the soil is determined by the fraction of fine roots that is assigned to one of 15 soil layers. However, these fractions are static and thus stay identical over time. The new approach developed here makes the fraction of roots adaptive to environmental conditions. If a plant is under water stress, root fractions get shifted to soil layers where more soil water is available. Additionally, roots cannot be located in permanently frozen soil layers anymore. The model outputs for gross primary production (GPP, *i.e.* carbon assimilated through photosynthesis) and actual evapotranspiration (AET, *i.e.* evaporation plus transpiration) are contrasted with the old representation. Additionally, it is compared to observational data from 15 exemplary FLUXNET sites, chosen to represent a set of Arctic (mainly for the influence of permafrost), water-limited, and non-water-limited ecosystems.

Results cannot be generalized

The main finding of the work is that the vertical root distribution has an important influence on both output parameters. The overall error (RMSE, *i.e.* a measure of mean differences between modelled values and observations) when considering the annual fluxes is reduced with the new root algorithm. However, while the error is reduced in some of the sites, other sites are better represented by the old root implementation. It is therefore very important to analyse individual locations and further to differentiate between monthly and annual model accuracy - an annual error reduction does not necessarily mean an improved overall model agreement. Due to the number of parameters that influence the output variables, it is difficult to draw

general conclusions for specific ecosystems. In Arctic sites with low plant productivity, the dynamic adaptation to permafrost does not considerably change the modelled fluxes. Further development of the novel rooting scheme is therefore needed which would ideally be supported by additional observational root data.

Keywords: Physical Geography and Ecosystem Analysis, Ecosystem Modelling, LPJ-GUESS, Vertical Root Distribution, Dynamic Root Distribution, Carbon and Water Fluxes

Advisor: **Paul Miller, David Wårlind**
Master degree project 30 credits in Physical Geography and Ecosystem Science, 2019
Department of Physical Geography and Ecosystem Science, Lund University. Student thesis series INES nr 493
Original title: Implications of a dynamic vertical root distribution for modelled water and carbon fluxes across selected ecosystems - Incorporating a novel rooting scheme into LPJ-GUESS