**LEMONTREE experimental group outline**

Below we outline a list of six experimental projects, including their relevance to model development and proposed coordination amongst groups. We discuss how these might be grouped into PhD and postdoc projects and outline expected deliverables from each project. This list of project ideas was developed based on the current stage of model development and is subject to change based future model developments as well as discussions with other LEMONTREE subgroups.

We propose the following experimental projects as well-defined work packages:

* Project 1: Timescale of acclimation
* Project 2: Water and nutrient use efficiency tradeoffs
* Project 3: C3/C4 competition
* Project 4: Effect of microbial symbionts on plant carbon and nutrient economies
* Project 5: The temperature responses of the quantum efficiency of photosystem II
* Project 6: Experimental links to remote sensing

These projects are specifically designed to facilitate close collaboration between TTU and UU by sharing experimental facilities and conducting closely related experiments in both institutes. The specific details of each project are provided in the 2nd part of this document.

We propose to divide the tasks associated with the six projects as two separate themes in the LEMONTREE consortium:

*Scaling of modelled processes (PhD UU1 & PhD TTU1):*

* Project 1: Timescale of acclimation
* Project 5: The temperature responses of the quantum efficiency of photosystem II
* Project 6: Experimental links to remote sensing

*Impacts of below ground resources on modeled processes (PhD UU2 & Postdoc TTU1):*

* Project 2: Water and nutrient use efficiency tradeoffs
* Project 4: Effect of microbial symbionts on plant carbon and nutrient economies

For all PhD thesis collaborations students have a primary location for completing their studies but collaborate closely with their counterpart project in the other institute via short exchanges and sharing of experimental results.

**Detailed description of experimental projects**

* Project 1: Timescale of acclimation
  + Purpose: To determine the time it takes for physiological processes to acclimate to environmental change.
  + Brief description: The project would specifically address how long it takes plants to adjust their stomatal conductance and leaf biochemical parameters to changes in environmental conditions. This would include, but not be limited to, changes in light, temperature, CO2, and VPD. This would be done primarily through experiments that expose plants to new conditions and measure their responses in high temporal frequency (e.g., daily) over extended periods of time (e.g., months). This would be combined with direct or remotely sensed observational data to facilitate scaling to model-relevant spatial scales.
  + Relevance to model development: These results would help determine the timeframe under which the acclimating plant physiological parameters (e.g., ζ, Vcmax) respond to changing conditions in the model.
  + Coordination amongst UU and TTU: UU would lead the stomatal conductance portion of the project and TTU would lead the biochemical portion. UU and TTU facilities would be suitable for the project. Results of both experiments will be integrated in collaboration with the modelling community.
  + PhD/postdoc project: This could encompass a portion of a PhD thesis. Sub-projects could also be separated and comprise portions of PhD projects at different institutes.
  + Expected deliverables: Acclimation timeframes that could be easily incorporated into models, likely without any change to the framework of the model. This would also lead to 2+ papers on the biological mechanisms underlying these timeframes.
* Project 2: Water and nutrient use efficiency tradeoffs
  + Purpose: To determine the degree to which plants can alter the nutrient use and water use efficiencies to achieve maximum assimilation (least-cost hypothesis) at the lowest cost under differing soil nutrient and water regimes.
  + Brief description: The project would explore constraints on the least-cost hypothesis within individuals of species that vary in their nutrient and water acquisition strategies. To do this, we will manipulate soil nutrient (N and P) and water availability at on-campus greenhouse facilities. We would then explore leaf-level and whole-plant responses expected from least cost theory. Notably, we would test whether plants trade nutrient-use efficiency to increase water use efficiency under low soil water conditions and vice versa under low soil nutrient conditions at the time scale of a growing season. Data acquisition from on-campus facilities would be supplemented with data from water (DroughtNet) and nutrient (NutNet) manipulation studies. These responses in individual plant species would be compared to cross-site responses evaluated elsewhere (Wright et al., 2003, Prentice et al., 2014, Paillasas et al., in review).
  + Relevance to model development: This would specifically address the a and b parameters that make up the β parameter in the stomatal conductance portion of the P-model.
  + Coordination amongst UU and TTU: TTU would focus primarily on nitrogen and water limitations whereas UU would focus on the interaction between phosphorus and nitrogen limitation. UU and TTU facilities would be suitable for the project.
  + PhD/postdoc project: This could comprise portions of PhD projects at the two institutions.
  + Expected deliverables: The experiments would produce model-relevant parameters, specifically a and b, under different soil conditions. The project would also produce 2+ papers on these responses.
* Project 3: C3/C4 competition
  + Purpose: To test differences in theoretical responses of C3 and C4 species to changes in environmental conditions.
  + Brief description: The project would build on recent theoretical work in the Smith lab at TTU and elsewhere on differences in C3 and C4 plant responses to aboveground environmental conditions. Specifically, this project would expand the data availability for C4 species, which is lacking in both experimental and observational contexts. This would involve targeted manipulation experiments as well as data acquisition from observational studies. Data and modeling work would be used to explore past changes in the relative abundance of C3 and C4 species, as well as expectations for the future and the impact on ecosystem carbon and nutrient cycling.
  + Relevance to model development: The data acquired will consist of parameters that acclimate in the C3 and C4 version of the P-model, including χ, Vcmax, Jmax, and Rd. The targeted experiments will specifically address deficiencies in C4 data.
  + Coordination amongst UU and TTU: This project would be coordinated among both institutions to increase the breadth and diversity of species sampled for the comparisons. UU and TTU facilities would be suitable for the project.
  + PhD/postdoc project: This could compromise the entirety of a PhD or postdoc project.
  + Expected deliverables: Improvements to the C4 photosynthesis scheme of the P-model, notably the cost parameters. The project would be expected to lead to 3+ papers.
* Project 4: Effect of microbial symbionts on plant carbon and nutrient economies
  + Purpose: To explore how plant symbionts, mycorrhizae and nitrogen fixing bacteria, alter plant carbon and nutrient economies.
  + Brief description: The project would use atmospheric CO2 and soil manipulation experiments to determine the impact of plant symbionts on plant carbon, nitrogen, and phosphorus economies. Specifically, plants will be grown with and without their respective symbionts, under both high and low soil nitrogen and phosphorus (labeled for tracking), and under both high and low CO2 (labeled for tracking). Isotopic signatures of the plants and symbionts will be measured to determine differences in nutrient economies, including nutrient demand under different CO2 conditions as well as differences in costs to acquire nutrients under varying symbiont and soil nutrient conditions. Sensitivity of the responses to soil water status will be explored to quantify the impact of plant symbionts on the carbon-water optimality.
  + Relevance to model development: This project will specifically address the b parameter in the P-model, which defines the cost to acquire nutrients to maintain photosynthetic capacity.
  + Coordination amongst UU and TTU: Both UU and TTU researchers are interested in these questions and have the facilities to perform the suggested experiments. As above, UU will focus on the interaction between phosphorus and nitrogen limitation and TTU will focus on the interaction between nitrogen and water limitation.
  + PhD/postdoc project: This could comprise portions of PhD projects at the two institutions.
  + Expected deliverables: The project will provide formulations for the cost to acquire nutrients for maintaining photosynthetic capacity under different contexts. These can be directly used to improve the functioning of the P-model. The project will lead to 4+ papers.
* Project 5: The temperature responses of the quantum efficiency of photosystem II
  + Purpose: To determine the long- and short-term temperature response of the quantum efficiency of photosystem II.
  + Brief description: The project will develop parameterizations for the temperature response of φ, the quantum efficiency of photosystem II. This will be done using temperature manipulation experiments followed by measurements of the instantaneous response of φ in differing plant species acclimated to different temperatures. This will test the universality of the temperature response used in the P-model.
  + Relevance to model development: This project will provide direct parameterizations of the temperature response of φ, which can be incorporated into the P-model without changing the model structure. Note: the model is very sensitive to this parameterization.
  + Coordination amongst UU and TTU: The project could be performed at either institute, potentially linking up with the other proposed combined projects.
  + PhD/postdoc project: This would be too little to comprise a PhD or postdoc project, but would instead be a side-project to be combined with project 1.
  + Expected deliverables: Parameterizations for the temperature response of φ for the P-model as well as manuscript.
* Project 6: Experimental links to remote sensing
  + Purpose: To determine the spectral signal of leaf nutrient status and stoichiometry.
  + Brief description: The project will measure the spectral signal of leaf nutrient status (N and P) and leaf stoichiometry (C:N:P) at the scale of the plant and plot, and will link to airborne (if possible) and spaceborne remote sensing (SIF, NIR, and other indices).  When experiments allow, we will do these measurements under optimal and drought conditions. Plot scale field measurements are needed to scale experiments to spaceborne remote sensing.
  + Relevance to model development: This project will result in leaf level nutrient and stoichiometry data for model optimization.
  + Coordination amongst UU and TTU: The project could be performed at either institute. UU has experimental experience and technical facilities and materials available to run the project.
  + PhD/postdoc project: This could comprise portions of PhD projects at the two institutions. (I think it is too little for a complete PhD project). The project could therefore be combined with the tasks outlined in project 2.
  + Expected deliverables: spatial maps for leaf level nutrient and stoichiometry.  Expected output: 2-3 manuscripts