Laboratoire d'Excellence ARBRE

Recherches Avancées sur la Biologie de l'Arbre et les Ecosystèmes Forestiers

Call for Proposal 2021
Incitative projects in research or translational research

Project Title: Effect of repeated early drought events on nutrient uptake of beech trees during the post drought period

Acronym: PostDroughtNUT

Project Leader (name and Research Unit): **Bernhard Zeller et Marie-Pierre TURPAULT, UR1138 BEF**

Co-applicants (names and Research Unit): **Aurélie DEVEAU, UMR1136 IAM**

ARBRE work package: WP2

Other ARBRE work package(s) concerned: WP1

Start and end dates of the project: March 2021-December 2022

Confidential reviewing: no

A) Executive Summary (1/2 page)

The last three years (2018 – 2020) gave us a preview about possible effects of global change on forests ecosystems (Grand Est, France, Grande Region) now and in the next decades. Forests are under pressure and the society questions about the most likely impacts and demands for solutions to keep forests healthy and to preserve the multiple services provided by forests (e.g. Labex ARBRE supported research at Domaine de Gentilly, commune de Masevaux, Vosges mountains). Drought events stress trees in a multiple way through shortage of water and nutrient availability, heat, insects and other pathogens…… Effects of drought on tree physiology, nutrient uptake, microbiome… has been rather intensively studied (e.g. DFG Beech research group). But, less attention has been given to the post drought period. **PostDroughtNut** aims to study the nutrient uptake of trees during the post drought period and more in detail, soil N fluxes and the temporal dynamic of root uptake of plant available N. We will evaluate the physiological impact of drought on the capacity of fine roots (ectomycorrhizal fine roots) to take up nitrate during late summer and autumn. Together with an increase of the lengths of the annual vegetation period, nutrient availability and uptake may sustain vital plant physiological processes as photosynthesis, phloem transport of assimilated C and root growth thus cushion more or less the negative effects of drought events on tree fitness.

B) Proposal (5 pages max.)

1) **Context and background information** (1/2 page max.)

Increase of drought events is one supposed effect of current climate change scenarios for French forests. Drought periods have multiple effects on trees, leading from reductions in photosynthesis until tree mortality through embolism and/or insect (e.g. bark beetle) attacks (Bolte et al., 2016, Chuste et al., 2020; Leuschner, 2020). Drought events reduce leaf photosynthesis, sugar export from the leaves and subsequent phloem transport of carbohydrates to roots and ectomycorrhizal fungi (Meier & Leuschner 2008; Ruehr et al., 2009; Chuste et al., 2019; Hesse et al., 2019). Less energy and highly reduced water fluxes to the roots decrease nutrient uptake by fine roots at least during the drought periods but perhaps also later (Meier & Leuschner 2008; Gessler et al., 2017) (Figure 1). In the soil, drought followed by drying – rewetting events provokes perturbations of nutrient cycles, particularly the N cycle (mineralization, nitrification) often resulting in a flush of nitrate and a steep increase of nitrate leaching in winter and during the following year (Leitner et al., 2017, Leitner et al., 2020). In beech seedlings, drought affected ectomycorrhizal community structure and the partitioning of the uptake of organic and mineral N more on calcareous soils than on acid soils (Leberecht et al., 2016). Although, forests and drought, has been studied intensively (Rennenberg et al., 2009, Simon et al., 2017), there is still a knowledge gap about (i) the nutrient uptake capacity of fine roots and ectomycorrhizal fungi during soil rewetting in late summer and autumn (ii) the resilience and possible adaptions of fine roots to repeated early drought events (iii) the partitioning of mineralized and nitrified N among soil N pools during soil rewetting cycles in late summer and autumn (microbial biomass, soluble N) (iv) consequences for the production of root and leaf litter, both feed C pools in the soils, thus impacting soil C dynamics in the soils.

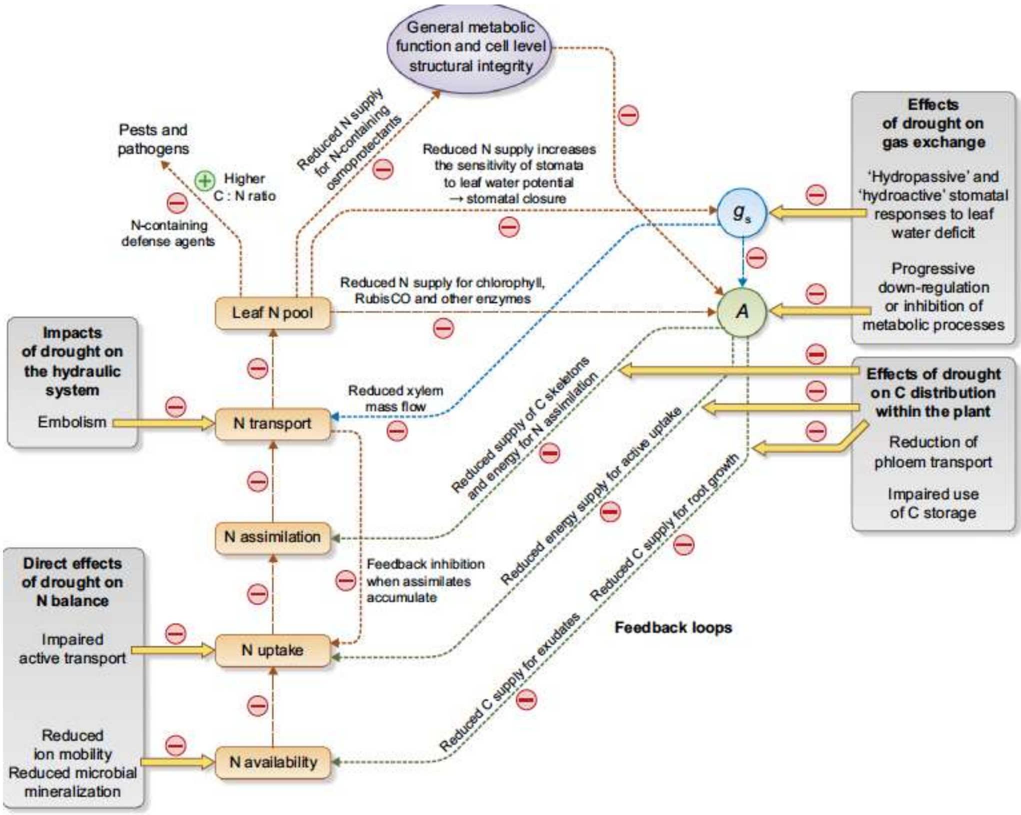

Figure 1: Impact of drought on the regulation of tree N uptake (g = stomatal conductance, A = assimilation (from Gessler et al., 2017).

2) Rationale and specific objectives (1/2 page max.)

Acute drought reduces drastically OM mineralization, mineral weathering, water and nutrient uptake of trees but also photosynthesis and the phloem transport of C compounds. Altogether, trees move into a survival mode to outlast this period and, ultimately, sacrifice leaves and fine roots. Rewetting of the soil after the drought period awake the microbial biomass in the soil and probably restore to a certain degree the water and nutrient uptake of the trees. The magnitude of this post-drought period is crucial because it is a period of overproduction (flush of mineralization) of plant available nutrients, especially N, while the uptake of nutrients is limited by the restoration of the fine root – mycorrhizal network. The scheme of Gessler et al. 2017, describes the feedback loops during acute drought events. Our project focus on the post drought period and the evaluation of the degree of recovery of the N availability in the soil and subsequent tree N uptake dynamics. Our data is a first brick to adapt this scheme to the post drought periods, beginning with N availability, N uptake and N assimilation.

Thus, our project is based on the hypothesis:

(i) that the N and nutrient uptake capacity of tree roots restore during the post drought period.

(ii) that the rewetting of the soils results in a flush of mineral N and nutrients which are probably drained into into deeper soil layers because the lag between root system restoration and nutrient availability,

The rain exclusion experiment set up at Montiers in 2020 is designed to create spring and early summer drought events during following years thus resulting in a “recurrent” annual drought stress. At this site, in the control plot and the drought plot our objective are:
(i) to determine the N uptake of tree roots during the post drought period (^{15}N tracer study),
(ii) to determine the net production and losses by drainage of nutrients (nitrate and cations) at the ecosystem level

- **Description of the project** (2 page max.)

Task 1- Post drought recovery of soil N availability and tree N uptake

The tracer study approach is based on the application of a small quantity of a ^{15}N enriched nitrate solution to small, undisturbed drought and control plots (100 cm^2). The repartition of the ^{15}N in soil N pools and beech roots (ectomycorrhizal fine roots) is monitored over a short temporal sequence (4h, 8h, 32h). Tracer application is planned in spring, after bud burst, at the beginning of the rain exclusion period in May, then at the end of the exclusion period when the topsoil is rewetted (soil humidity is continuously monitored at both plots) and finally once or twice a few weeks later (when leaves are still green). Sap fluxes during the post drought period are recorded in order to document active water and nutrient uptake in drought and control trees when the ^{15}N is applied to the soil (coll. UMR SILVA). *In 2021, in case of a prolonged “natural” drought after the end of the rain exclusion period, we will discuss with the project leader (MP Turpault) if it is possible to irrigate a surface of 10m² around à single tree in both plots. This backup solution is technically possibly and results in a single water supply to the soil of 10 – 20 l/m²/day.* Highly ^{15}N enriched nitrate (20 atom % ^{15}N) is injected stepwise (1 cm intervals) with a syringe into the organic and the mineral soil until 10 cm depth, by taking care to realize a homogenous distribution of the applied ^{15}N in the soil column.
At each ^{15}N labelling event (spring, post drought I, II maybe III), after 4h, 8h, 32h, soil samples are collected with a corer (n = 5) from the organic horizon and from 0 – 10 cm depth in both plots. Roots are collected separately from the organic and the mineral soil. Mycorrhizas are identified visually (binocular magnifier) and the number of root tips per species are counted (coll. UMR IaM), further, root length is measured, roots are scanned prior to WinRHIZO™ analysis and at last root mass is measured. Organic soil samples are weighed, dried at 65°C and pulverized prior to analysis (C, N, ^{15}N). Mineral soil samples are homogenized by sieving them through a 5 mm grid, humidity is measured in sub-samples at 105°C and concentration of N and ^{15}N is measured in various soil pools. Pools are: nitrate and ammonium (0.5M K_2SO_4 extracts) microbial biomass (fumigation extraction method), total soil N. Roots and mycorrhizal root tips are pulverized and the concentration of C, N, ^{15}N is measured (maybe also nutrients and starch). In the n+1 year the same experimental protocol is applied. One additional measurement is root growth, which is obtained by resampling the soil cores of n-1. In detail, after collection of soil cores the holes were immediately filled with sieved soil, labelled with sticks and resampled one year after their setup. Roots are weighed, scanned and analyzed with WinRHIZO™. Both plots, the control and the rain exclusion plot are highly instrumented. Soil humidity and soil temperature are continuously recorded. Soil solutions are collected at different depths and sampled once a month. Both, datasets are available for this study. In order to respond to our hypothesis, we compare root uptake of ^{15}N and soil N dynamics in the rain exclusion plot with the control plot before and after the drought period. Our results about fine roots (mass, root lengths, mycorrhiza) and the dynamic of their ^{15}N uptake (before end post drought), together with the sap flux measurements provide a first view into the post drought period.

Task 2- Effect of post drought rewetting on nutrient fluxes

Both, the control plot and the rain exclusion plot (3 blocks) had been fully equipped with a series of collectors of free draining soil solution (below the humus, at 10 and 30 cm depth), tension lysimeters (at 10, 30, 52 cm depth), sensors of soil humidity and temperature at the same depths than the lysimeters and collectors for throughfall and stemflow solutions. Litterfall is collected, sapflow is recorded and tree diameter growth is measured monthly. Soil respiration is measured in both plots. This instrumentation allows us in particular to carry out lysimetric and hydrological monitoring at different levels of the ecosystem (above ground, under humus, -10cm, -30cm, -55cm)

The flow calculation (determination of the production at each level and of the drainage) will be done by following the method defined in Turpault et al, 2018, 2019. This will allow us to specify the annual flows and the monthly dynamics of the net production by level and the loss by drainage for both the rain exclusion plot and the control plot. This task is part of the ongoing PhD project of J. Touche (UR BEF, connected to DEEPSURF LUE).
The monitoring of *in situ* nutrient fluxes/drainage during the post drought periods provides an evaluation of the amplitude of the perturbations of biogeochemical cycles through repeated drought events. Loss of nitrate is a powerful process to acidify soils and decrease soil fertility. This decrease is more pronounced in soils with a low fertility than in more fertile soils.

Project positioning according to the different work packages (cf Annexe 2)
The Montiers rain exclusion experiment provides an unique option to study the effect of repeated early season drought on trees and the soil – tree continuum.
Our project belongs to WP2 which will study how tree- and associated microbial diversity can change the resilience of forest ecosystems to natural and human disturbances and how the interacting cycles of carbon, water and nutrients shape the functioning of whole ecosystems. Our research fits to the ITEM 2020 "Elucidating the impact of nutrient and water availability on carbon allocation in trees and carbon sequestration in soil". More in detail, we evaluate properly if and how drought stressed trees adapt to repeated stress and if such trees during the post drought period have the potential, if yes, the amplitude, to take up water and nutrients. In parallel, we evaluate the combined effects of reduced nutrient uptake during the drought period and the flush of mineralization on nutrient input – output budgets (plot level).

Benefits to the Labex (1/2 page max.)

The rain exclusion experiment at Montiers supports cross disciplinary research of Labex ARBRE. Compared to earlier rain exclusions often setup as permanent exclusion of a part of the precipitations this site offers modulable rain exclusions (from weeks to months) with a mobile roof system. This study increases our expertise about the post drought period and how trees may adapt or not to repeated well defined drought events. It allows us a better evaluation of possible scenarios for the two ongoing Labex ARBRE applied science – society projects/ at Masevaux and at Chantilly, with a much better idea about the role of soil fertility and nutrient uptake potential of drought stressed trees.

Inside and outside collaborations (1/2 page max.)
The PostDroughtNUT project is not currently connected to another Labex. The project is carried out by two research units partner of the Labex ARBRE, BEF (B ZELLER and MP TURPAULT) and IaM (A DEVEAU) in collaboration with other scientists of the BEF and IAM units and including the unit SILVA (D. Bonal). This project is a seed project corresponding to strong axis of research developed or initiated in the BEF, IAM and SILVA.
Out of Labex ARBRE, collaborations with members of the Beech research Group in Germany worked or working on the link between drought and plant nutrition/plant physiology (Judy Simon, University of Konstanz, Michael Dannenmann, KIT) are planned.

Financial Information (1/2 page max).

Total 10000€

Consumables (including equipment <4000€ : 9000€ (4000€ PTEF for analysis of C, N, ^{15}N, 1500€ for ^{15}N labelled KNO_3, and filters, K_2SO_4…, 3500€ solution sampling and chemistry analyses, …)

Travel : 1000€ (solution sampling and ^{15}N experimentation)

Requested or current supplemental funding (Agreenskills, ANR, Région Lorraine…) no

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