

Why and how to craft a trade-of in a plant functioning model

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May 30, 2017

This document describes why and how a trade-of has been designed in the model MountGrass. This trade-of has the objective to allow for different strategies based on the level of resources. The same trade-of is used in shoot and roots. Parameters effects over the phenotype determination is explored for a balanced design where area cost is the same for both organs.

Why a trade-of

different conditions = different phenotypes
could be anything, needed one. Explain WUE, nitrogen and others.
Try to keep independences between strategy axis to keep it simple.
Need for plastic driver. Explain the role of plasticity.

How to craft a trade-of

The idea of trade-of suggest that you cannot invest in all strategies at the same time. To be relevant, it must be associated to a range conditions favouring different strategies along this trade-of. In other word, depending on a position on a gradient, the gradient should lead different niches. This can be visualizes as Gaussian's curves (see figure)

The challenge is to go beyond the Gaussian function, and craft these niches from the plant physiology and ecology. Taking as a basis the usual functions used in plant modelling and the theoretical background upon which MountGrass is built, we will try to model different niches.

In MountGrass, the Leaf Economic spectrum (LES)¹ is explained by a differential investment between active and structural tissues (supported by analysis of Shipley²). This allocation constitutes a major strategic differentiation axis, along which plastic plants can move to optimize their fitness. To keep the approach simple, we hypothesize that such trade-off would also rule the allocation of organic matter in the below-ground compartment³. As explained above, plant can modify both the shoot:root ratio, and the relative proportion of active tissues in shoot, and in roots. The first dimension is mainly driven by a balance between availability of above-ground versus below-ground resource, while the second can be driven by other strategic aspects.⁴

Crafting a trade-of for shoot

The aim of this paragraph is explain how to set up a shared plasticity mechanism that allow different phenotypes to emerge from different

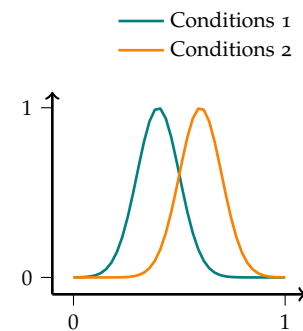


Figure 1: Different niches corresponding to different environmental conditions.

¹

²

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⁴ This part does not belong to this section.

estimations of climatic conditions. The general principle exposed earlier is illustrated here with the example of shoot allocation strategies in MountGrass.

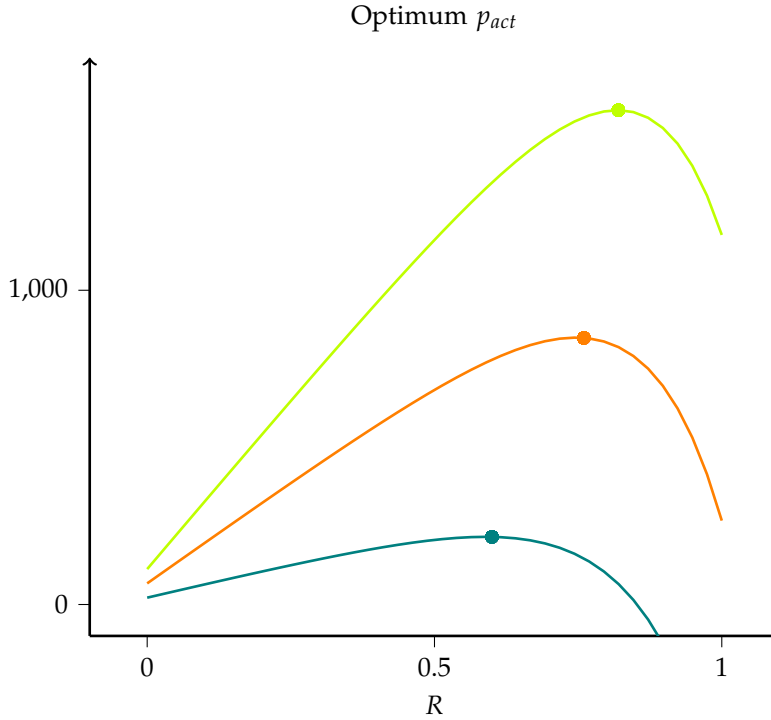
Carbon allocation is driven by a gain function that quantify daily gain of the examined phenotype. This is goes against the general principle of maximizing the overall fitness, but we hypothesize that the optimization of daily gain function participates to the optimization of overall fitness function. The daily gain function is described as follow:

$$sdf = qsd f \quad (1)$$

It is composed by the gross gain function that determine the amount of carbon assimilated by the organ during a day, and the loss function, itself the sum of respiration and turn-over cost (loss of organic matter). The net gain function result from the difference between these two functions. In order to have an optimum for $0 < p_{act} < 1$, the loss function must have a greater power than the gross gain function. Since, the respiration and carbon assimilation have linear relationships with p_{act} , the net gain function can be rewritten as follow :

$$qsd f = qsd \quad (2)$$

with $\gamma > 1$.



How about root

Root fol

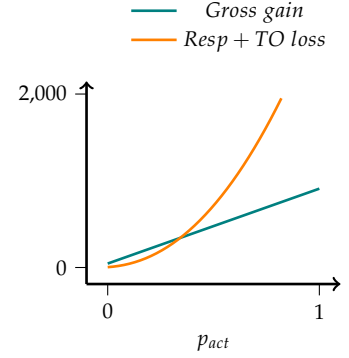


Figure 2: Comparison of "gain" function and "cost" function. Parameter values: $p_{act} = 0.05$, $p_{str} = 1$, $k = 7$ and $vol_{prop} = 1$. The area between the two curves is the total gain by the plant.

Figure 3: ◀ Comparison of "gain" function and "cost" function. Parameter values: $g_2 =$, $g_2 =$, $k = 7$

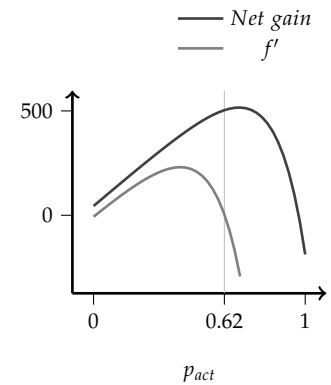


Figure 4: Net gain function and its first derivative.

Looks like there is some kind of mismatch here.

How do the two trade-of merge ?

The complexity of the model is that different objectives are in line to maximize the fitness: the optimization of carbon allocation at the scale of the organ (organ efficiency), the equilibrium between the organ (whole plant balance), and other mechanisms at the plant scale (reproduction, reduction of grazing or frost risk). All these components are translated into carbon gain and losses and summed to give the net gain function. Two major components influence the balance between these components (and the resulting phenotype): the weight of species specific memory in future estimation, and the distance from optimum for each sub-function.