Designing sustainable agrosystems by copying the biogeochemical organization of natural ecosystems

Sébastien Fontaine, Luc Abbadie, Gaël Alvarez, Michaël Aubert, Sébastien Barot, Juliette Bloor, Delphine Derrien, Olivier Duchene, Nicolas Gross, Ludovic Henneron, et al.

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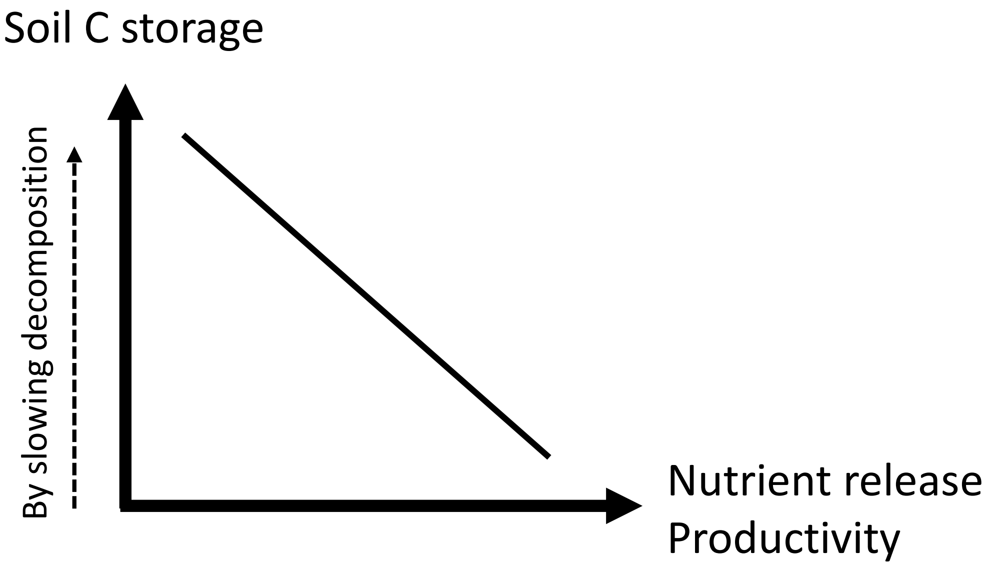
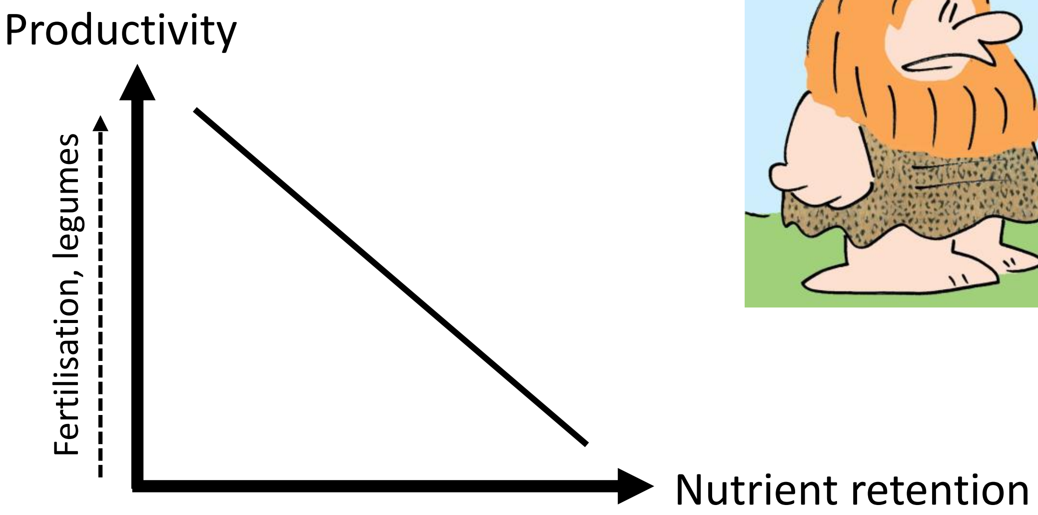
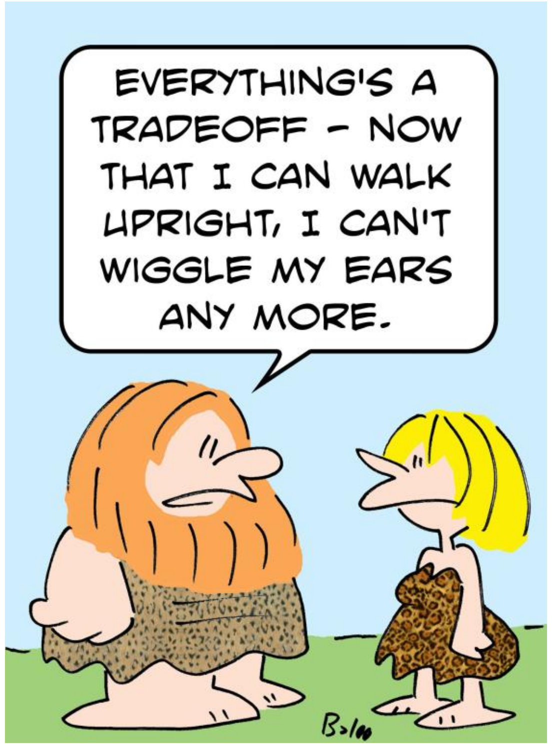
Cropping systems: can get out of the issue of tradeoffs ?



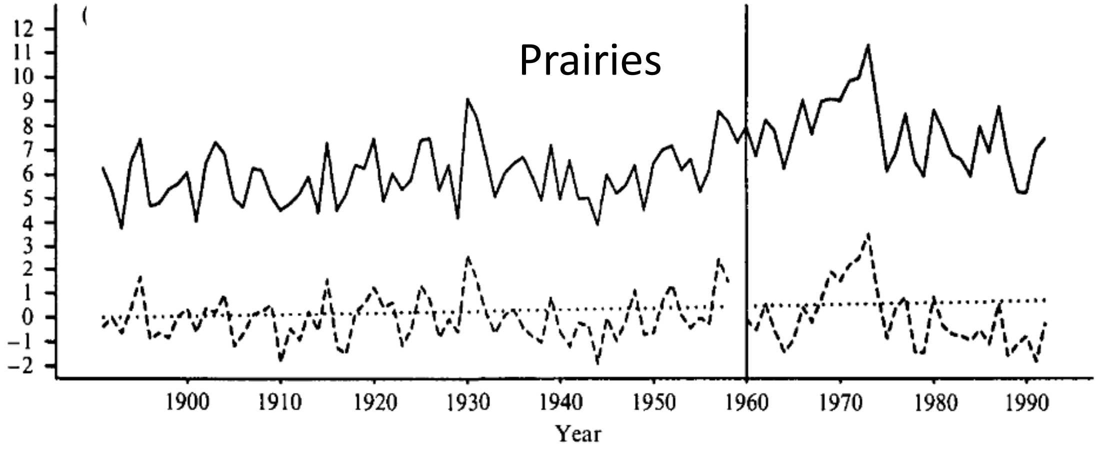




Gregorich et al., 2005; West et al, 2010; Wang et al, 2018

Old forest & prairie multifunctionality

Yield (T ha^{-1})



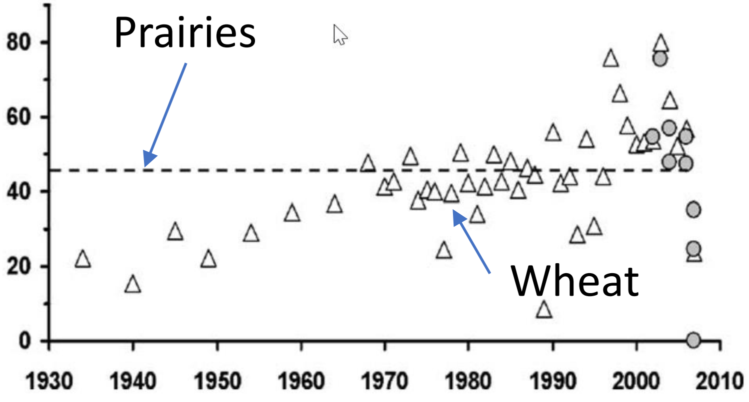
Jenkinson et al 1994

LTE Rothmasted

No fertilization

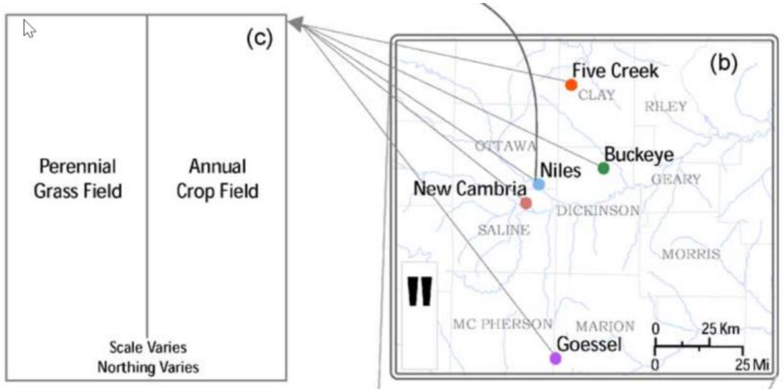
Continuous exportation

Harvested N (kg N ha^{-1})



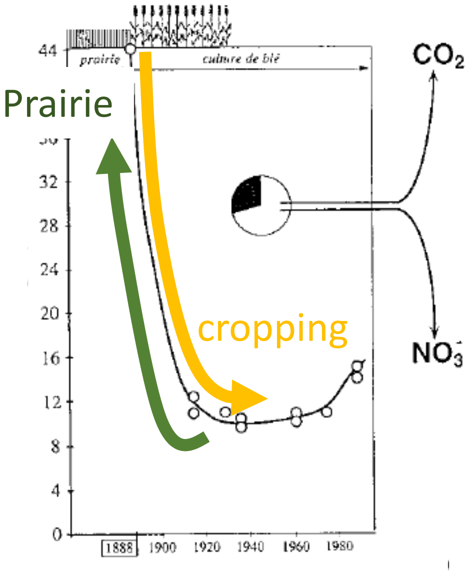
Glover et al 2010

Study of pair sites (Kansas)



Old forest & prairie multifunctionality

Soil C stock (g C kg^{-1} soil)

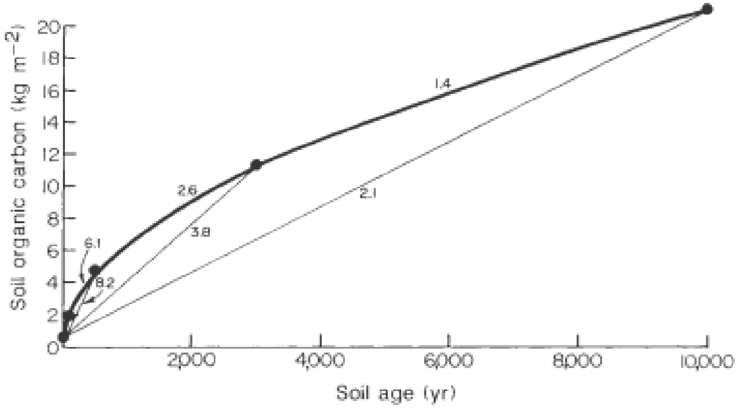


Years

Balesdent et al., 1988

Soil inventories under different land uses

Long-term C storage(kg C m^{-2})

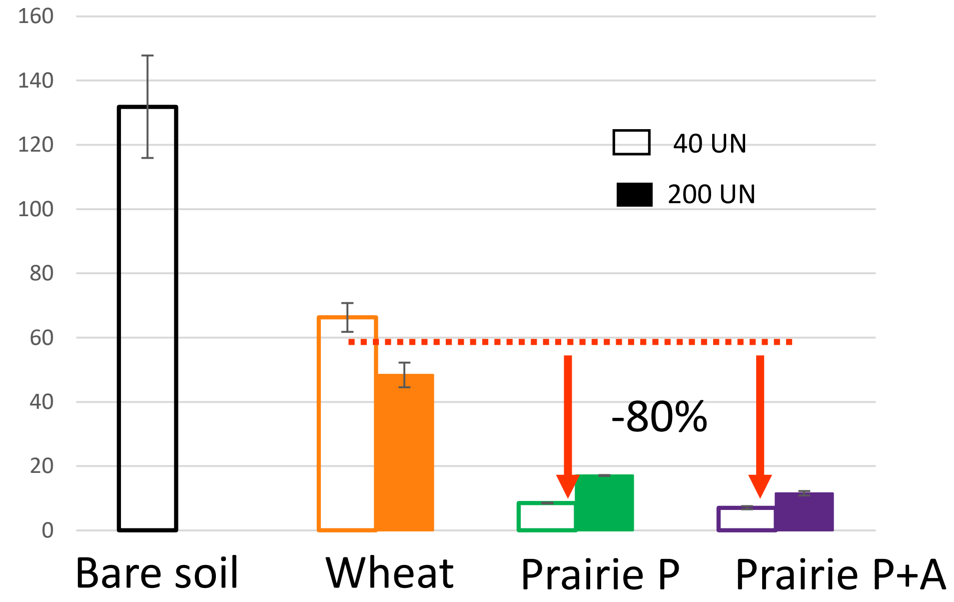


Schlesinger 1990

Chronosequence study

Old forest & prairie multifunctionality

Nitrate leaching (kg N ha^{-1})

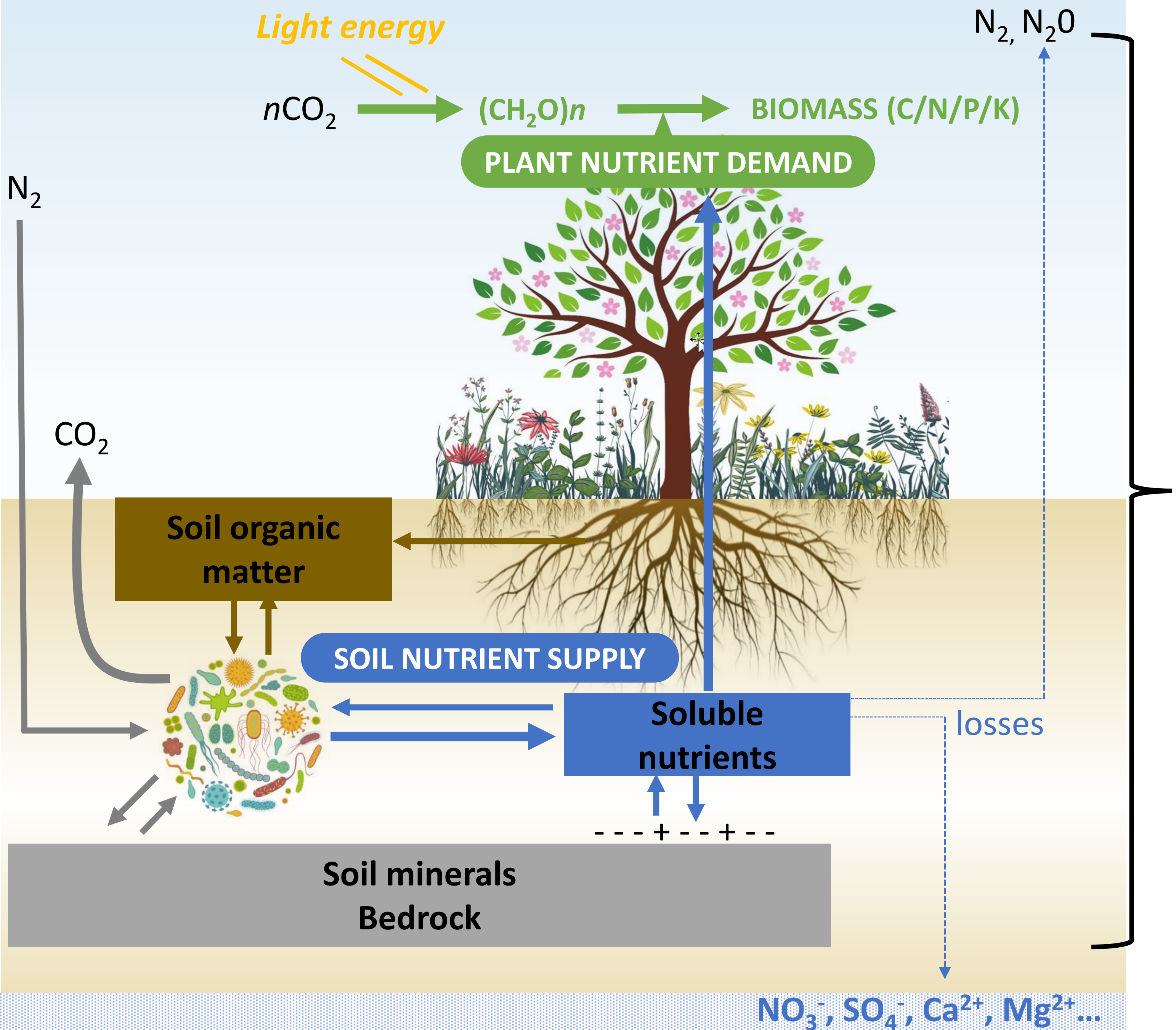


Mesocosm study with lysimeters

Cros 2019

Ecosystem multifunctionnality results from a better organisation of species and functions

Ecosystem performances depends on the synchrony between plant N demand and soil N supply

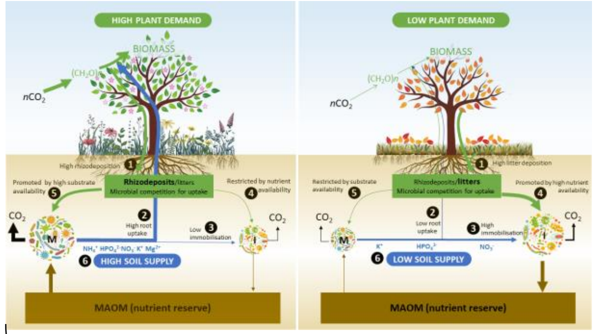


A high level of synchrony

- ↑ biomass production by ↓N limitation
- ↓ excess of soluble N, N losses (<5%)
- ↑ nutrient and C retention in SOM

Need of an organization…provided by 4 systems

1



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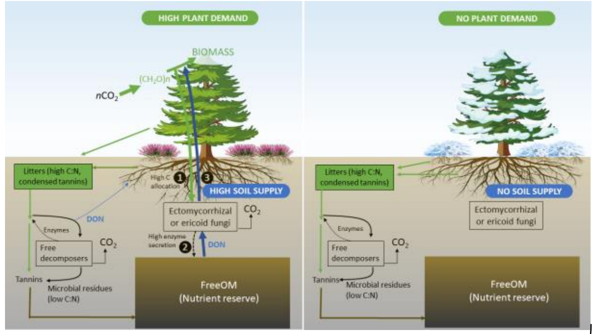
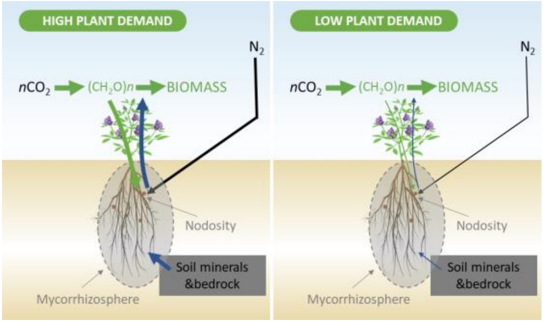


Soil organic nutrient reserves

3



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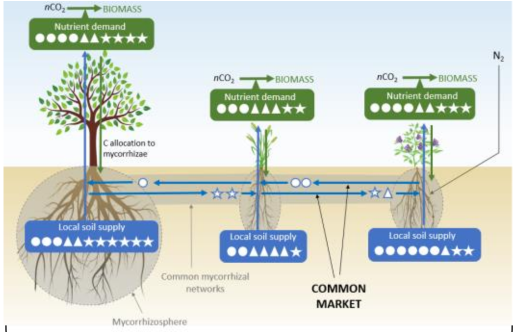


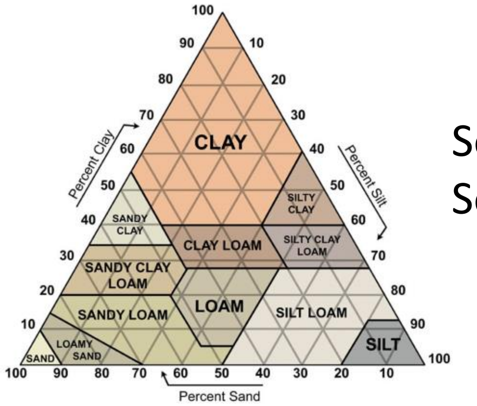
Nutrient retrieved from Atmosphere and soil minerals

Common nutrient market

Designing productive, sustainable ecosystems requires to improve the efficiency of the system as a whole

(not specific functions)

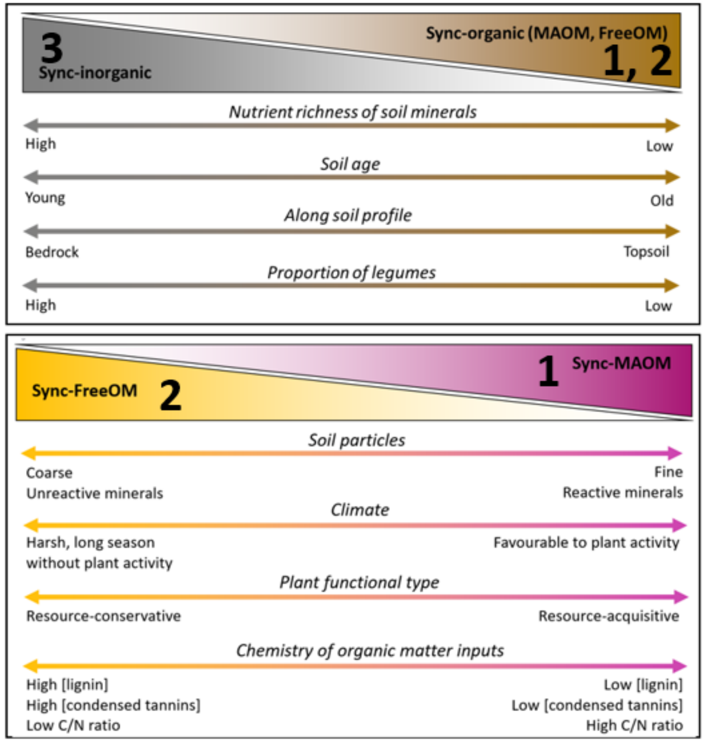
Step 1 : characterizing the local pedoclimatic content



Soil texture, pH
Soil mineral reactivity

Evapotranspiration
Rainfall
Extremes temperatures

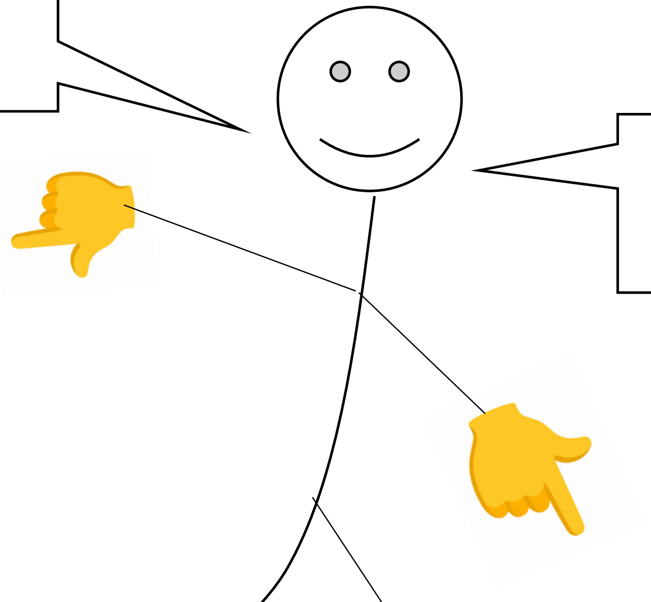
Identify the more adapted organization systems



Step 2 : installing the organization systems in agrosystems

On the POSTER, a magic table suggests how to install the targeted systems in agrosystem

Synchrony	Conditions of synchrony	Combination of practices to set up for promoting the targeted synchrony
Sync-MAOM	-Acquisitive plant species -Continuous activity of microbes M & I -Reserve of MAOM in soil	- Use or genetically select acquisitive species with high C rhizodeposition rate - The C/N of plant species or organic residues must be high enough. Ideally, the different plant species have contrasting C/N ratios (a, c, j, k) - Maintain a continuous cover of active plants fueling microbes in energy (all pictures but e) - Recycle organic nutrients at local scale (farm-watershed) to preserve soil organic reserve on the long-term (d, e, f)
Sync-FreeOM	-Conservative plant species -Mycorrhizal fungi -Reserve of FreeOM in soil	- Use or genetically select conservative species producing recalcitrant litter with reactive compounds (e, f)* - Amendment of recalcitrant organic residues harboring reactive compounds partly charged in organic nutrients (e) - Recycle organic nutrients at local scale (farm-watershed) to preserve soil organic reserve (d, e, f)
Sync-Inorganic	-Plant symbiosis with mycorrhizal fungi & N_2 fixing bacteria -Nutrients stored in bedrock, soil minerals and/or precipitates	- Use or genetically select of species with strong capacity of mobilizing nutrients from rock and soil minerals - Use of plant with deep roots colonizing bedrock (g, h, i) - Use of legumes (a, c, k) - Inoculation with mixed mycorrhizal fungi & N_2 fixing bacteria in highly degraded soils
Sync-Market	-Plant species with complementary nutritional needs -Common mycorrhizal networks	- Mix plant species with different nutrient acquisition strategies and carbon:nutrient ratios (a, c, l, j, k) - Promote perennial plants (f, g, h, I, k) and/or permanent plant cover (all pictures but e) to fuel mycorrhizae in energy-rich carbon - No or limited use of soil tillage (b) and pesticides to preserve mycorrhizae networks - Inoculation with mixed mycorrhizal fungi in highly degraded soils
Increasing overall synchrony	-Synchrony systems adapted to pedoclimatic context -Complementary synchrony systems -Plant plasticity & reserve	- Analyzing the soil profile and climate, adapt the proportion of the different synchrony systems accordingly - Mixing plant species with different nutrient acquisition strategies (a, c, I, j, k) - Select crops species for their suitability to association - Promote perennial plants with high reserve and organ plasticity (f, g, h, I, j, k)



Let's continue around a Riga Black Basalm !