

Upscaling STICS to management zones: a way to enhance N fertilization?

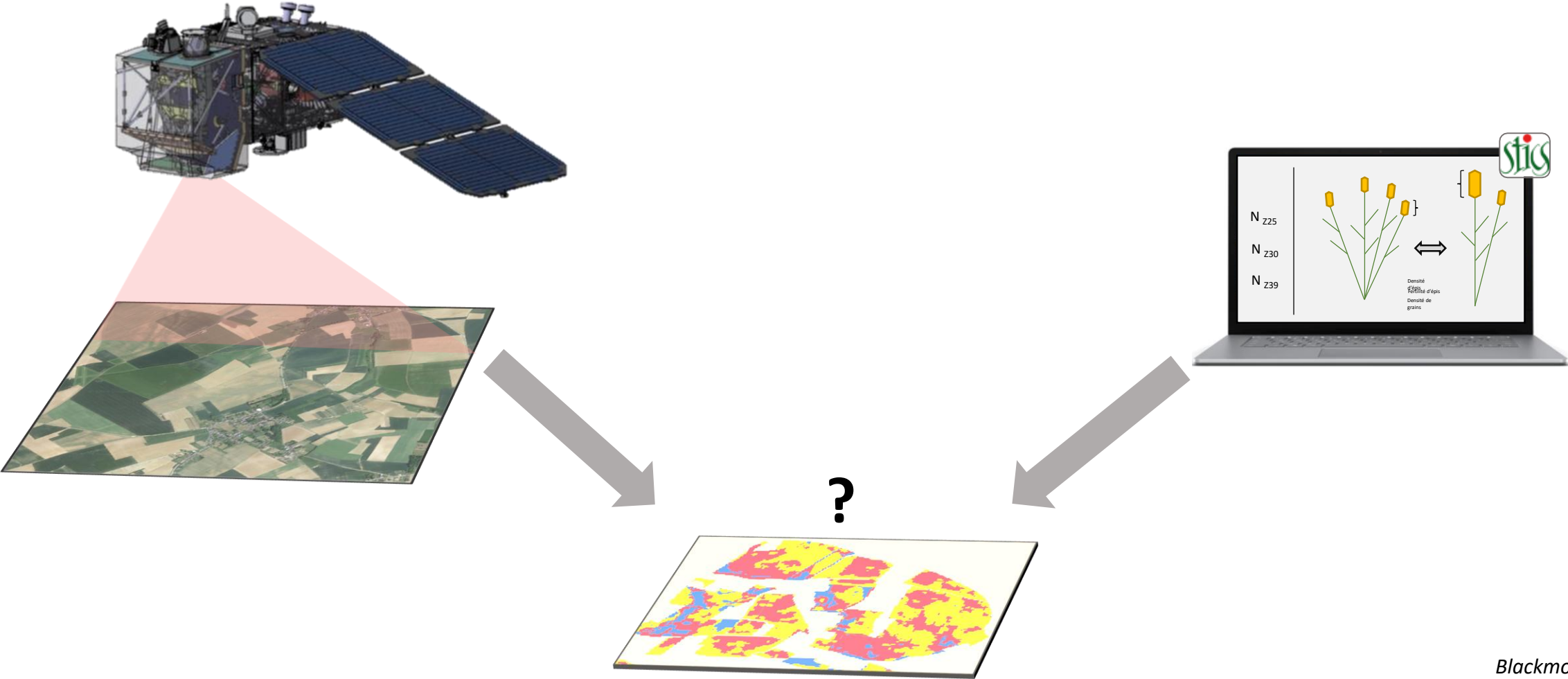
XIVth STICS seminar, 17-19 March 2026, organized by ULiege-GxABT & INRAE

Arthur Lenoir¹, Benjamin Dumont²

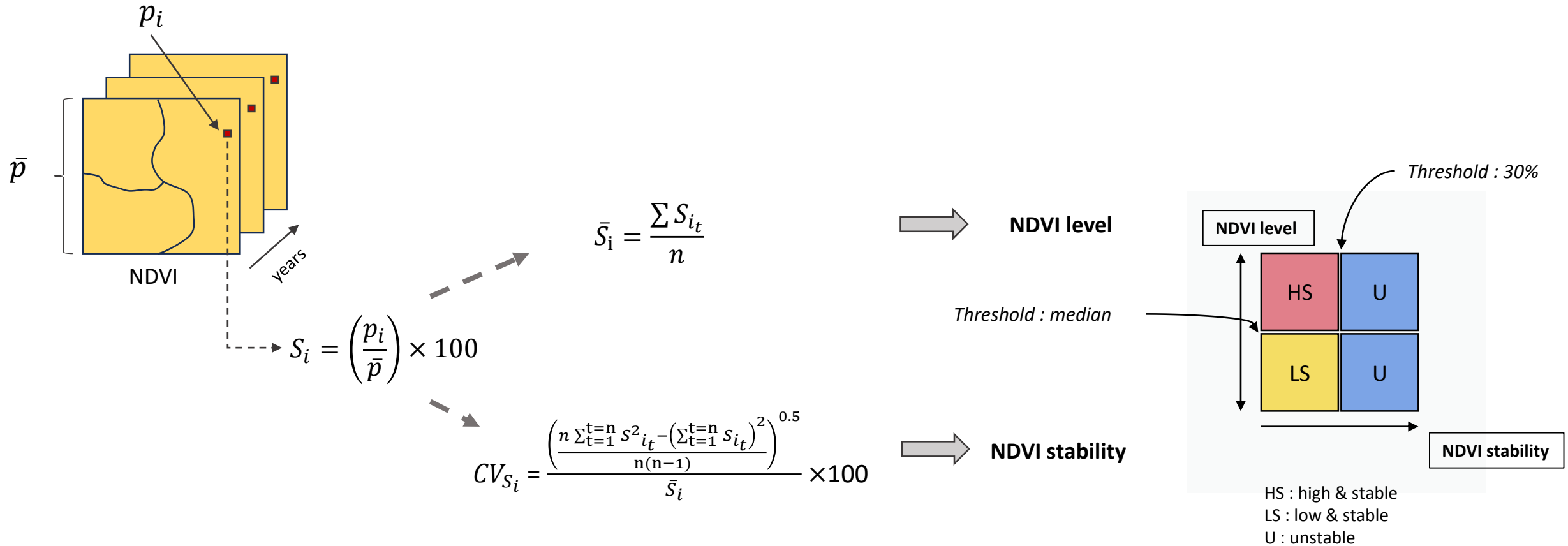
¹ Université de Lorraine, INRAE, LAE, F-68000 Colmar, France

² Plant Sciences Axis, TERRA Teaching and Research Centre, Gembloux Agro-Bio Tech, Liege University, Passage des Déportés 2, 5030, Gembloux, Belgium

Are satellite-derived management zones agronomically meaningful?



Adapting the delineation algorithm to Sentinel-2 images



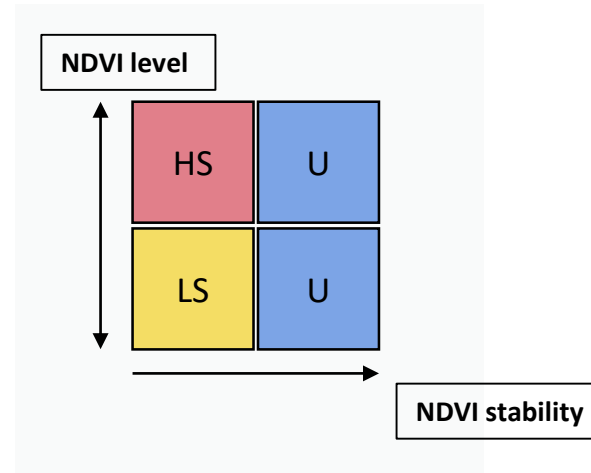
Adapting the delineation algorithm to Sentinel-2 images

NDVI level

$$\bar{S}_i = \frac{\sum S_{i_t}}{n}$$

NDVI stability

$$CV_{S_i} = \frac{\left(\frac{n \sum_{t=1}^n S_{i_t}^2 - (\sum_{t=1}^n S_{i_t})^2}{n(n-1)} \right)^{0.5}}{\bar{S}_i} \times 100$$

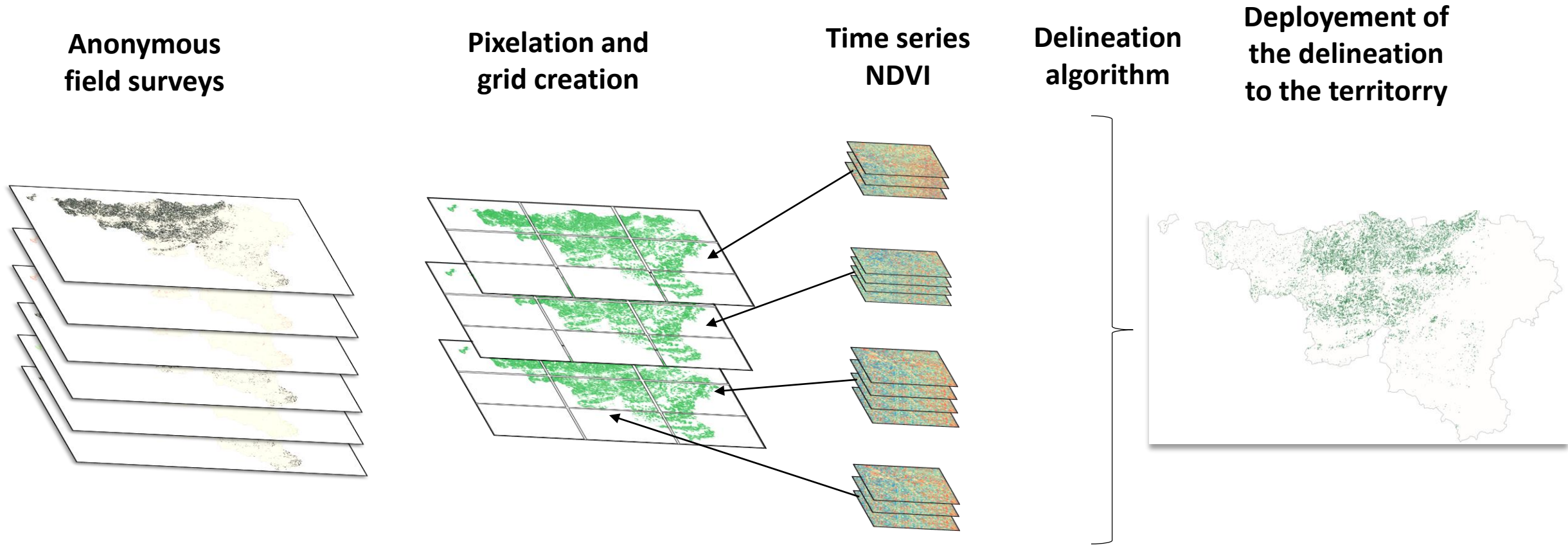


Hypotheses :

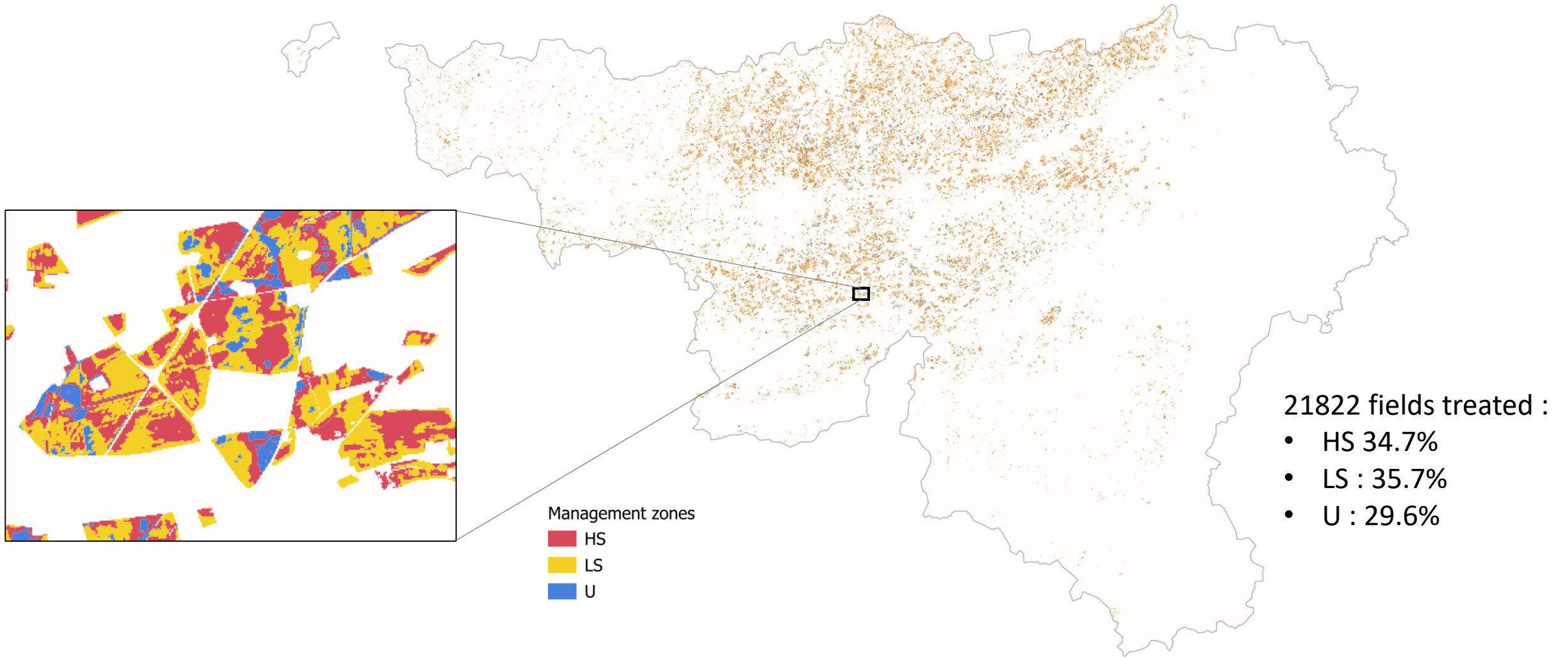
1. Yields in HS zones should be higher than in LS zones.
2. Nitrogen use efficiency (NUE) in HS zones should be higher than in LS zones.
3. HS zones should be able to sustain higher nitrogen inputs than LS zones.

*Blackmore, 2000
Basso et al. 2019
Basso et al. 2012
Lenoir et al. 2024*

Territorial implementation of management zones – Workflow

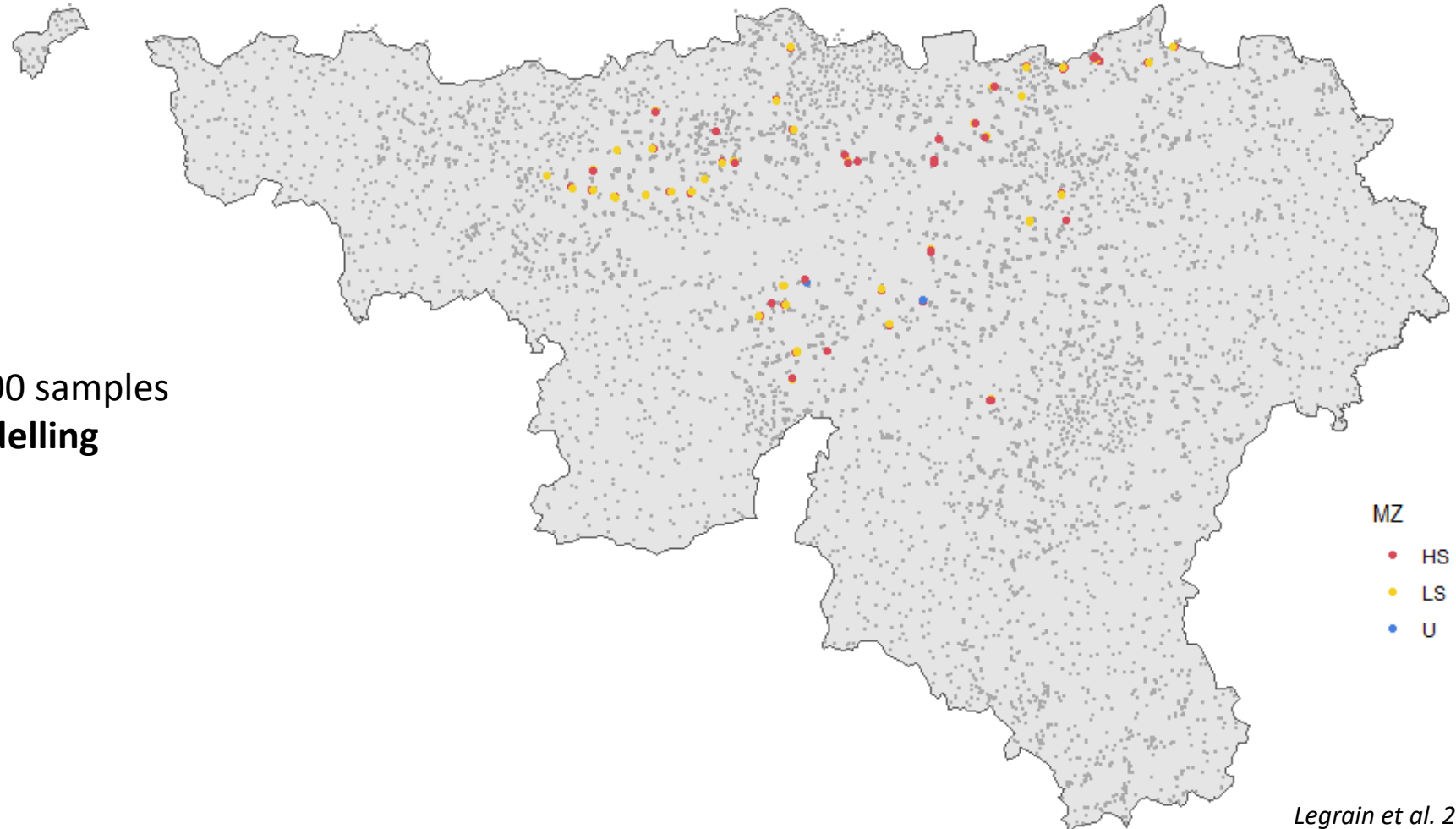


Territorial implementation of management zones – Spatial distribution

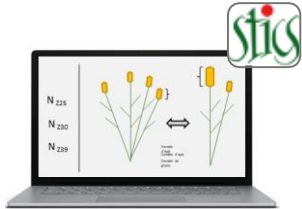


Integration of management zones with soil database

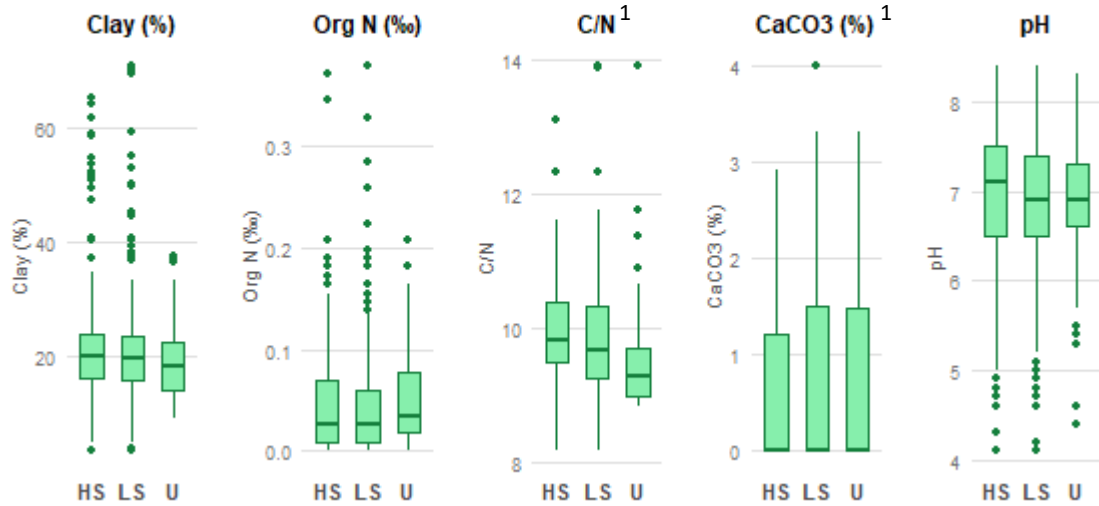
Soil database (Aardewerk): >6,000 samples
=> **Selection of 105 soils for modelling**
distributed in **41 fields**



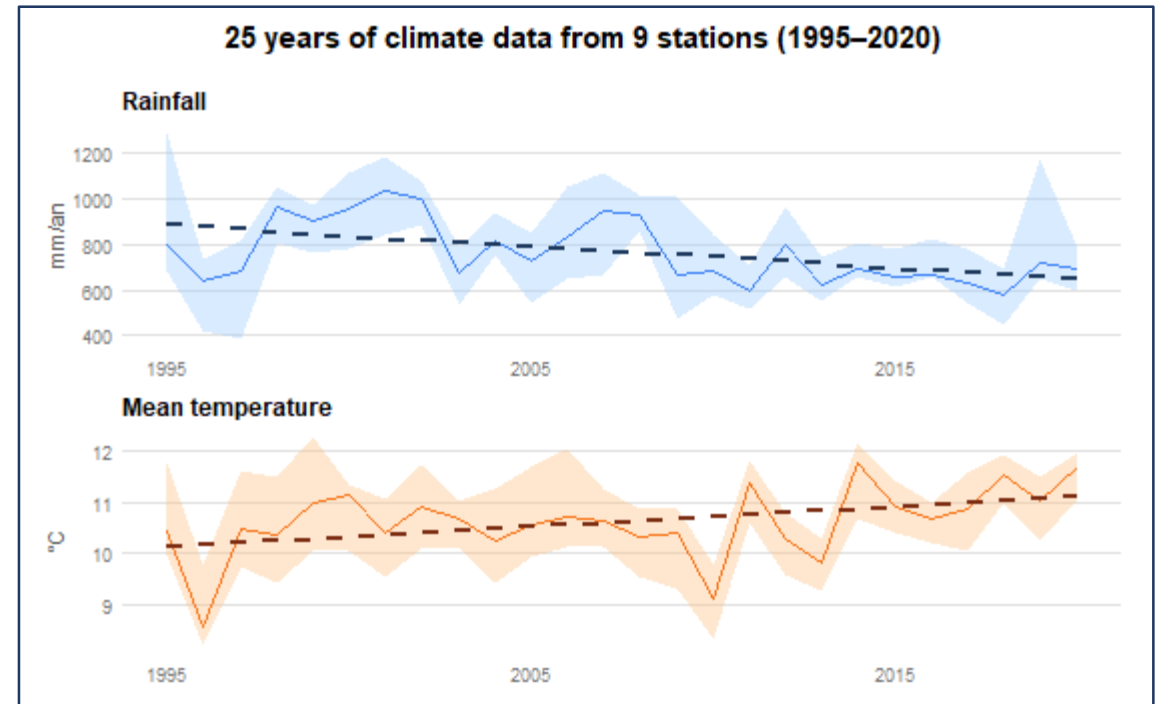
Modelling framework



Soil properties per MZ (105 soils)



¹ Data extracted from LUCAS Topsoil 2015 database (EC, 2020)



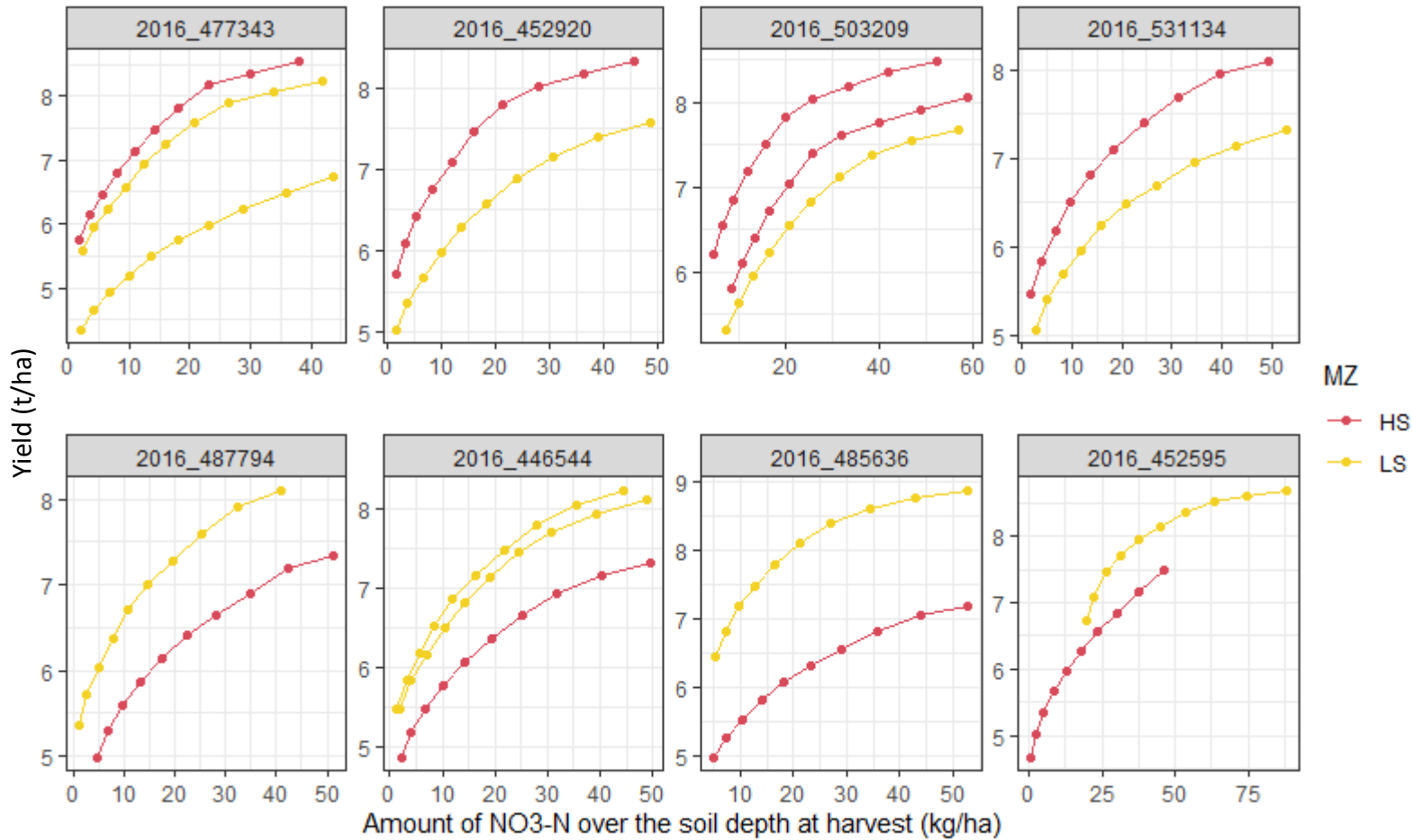
Fertilization design

Growth stages	N doses applied (kgN /ha)
GS 25	0 → 90 (11 increasing doses)
GS 30	0 → 90 (11 increasing doses)
GS 39	0 → 90 (11 increasing doses)



Analysis of HS and LS zones differences

Mean Yield per Plot vs. Soil NO₃-N in HS and LS zones



Over the 41 plots :

- Yield range : 1.26 – 11.1 t ha⁻¹

Yield difference between HS and LS :

- Mean difference : 0.46 t
- Highest difference : 2.53 t
- Lowest difference : 0.03 t

- Are yield differences between MZ significant ?
- What explain these differences ?

Analysis of HS and LS zones differences

Linear models per plot :

(Mod 1) $Yield = NO3 \times MZ \times Year$

(Mod 2) $Yield = NO3 \times MZ$

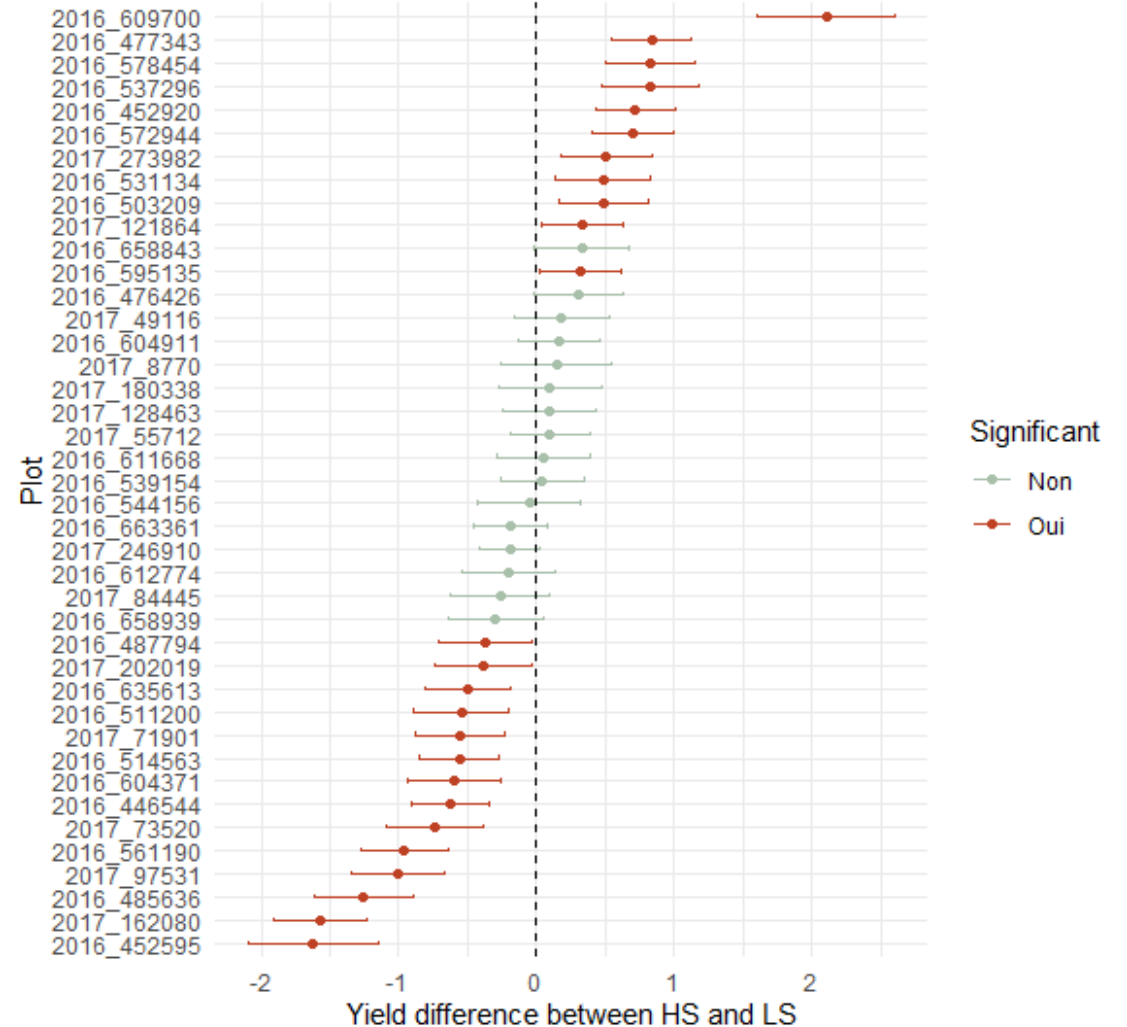
(Mod 3) $Yield = NO3 + MZ$

(Mod 4) $Yield = MZ$

AIC comparison => Model 1

Effect on yield	Signifiacne	Plots (n= 41)
Climate	+++	All
Management zones	++	25
NO3-N	++	27
Interaction MZ – NO3	+	5

Yield difference between MZs by plot



Analysis of HS and LS zones differences

(eq 1) $NRE = \frac{N_{plant}}{N_{fert}}$

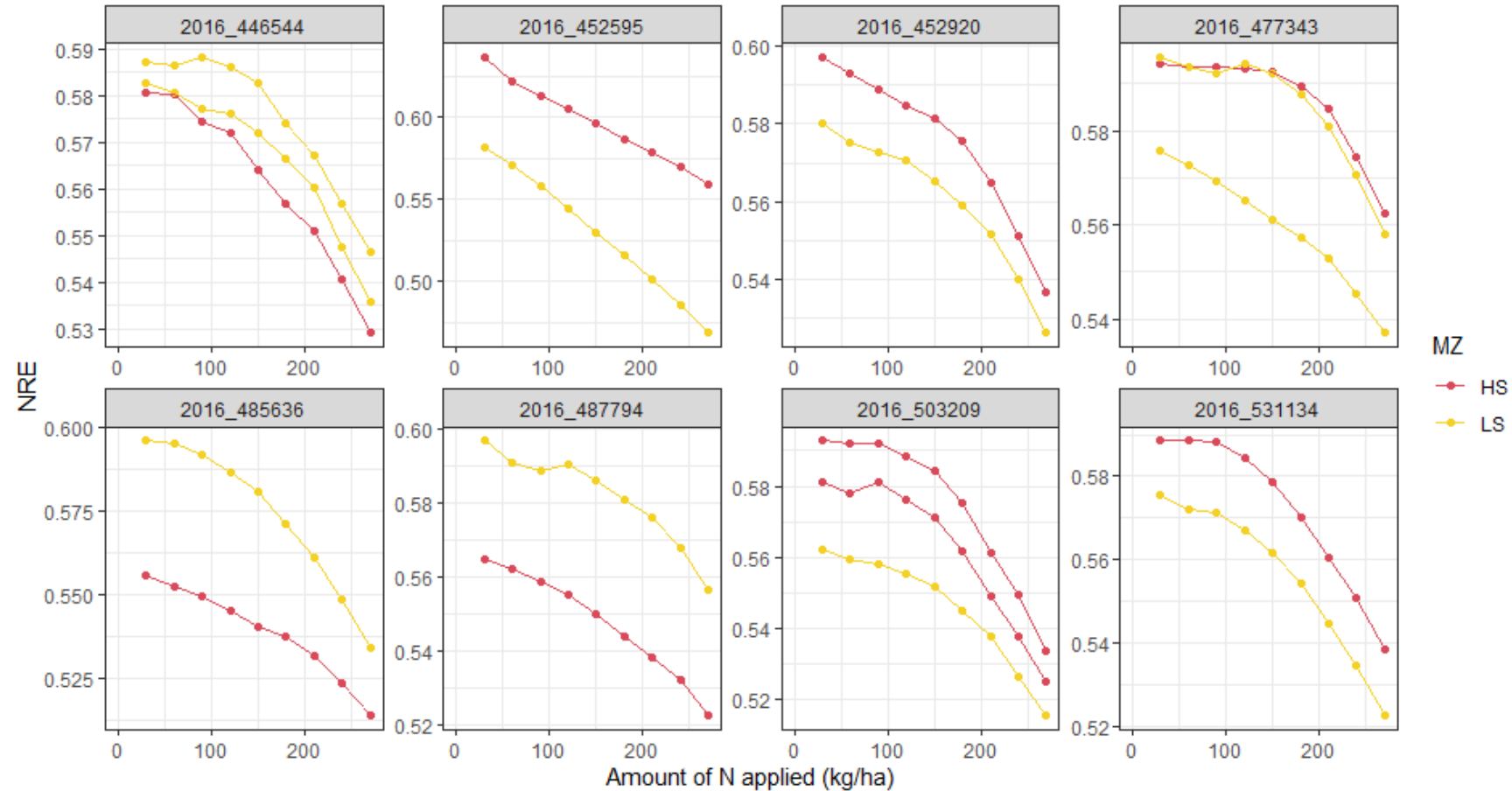
(eq 2) $NU_{pE} = \frac{N_{plant}}{N_{fert} + N_{min}}$

(eq 3) $NU_{tE} = \frac{Yield}{N_{plant}}$

On the 41 plots :

- NRE : 2% to 74%
- NRE difference between HS and LS : 2% to 7%

Mean NRE per Plot vs. amount of N applied in HS and LS zones



Congreves et al. 2021

Analysis of HS and LS zones differences

$$(eq\ 1) \quad NRE = \frac{N\ plant}{Nfert}$$

$$(eq\ 2) \quad NUpE = \frac{N\ plant}{Nfert + Nmin}$$

$$(eq\ 3) \quad NUtE = \frac{Yield}{N\ plant}$$

$$(Mod\ 5) \quad NUE = Nfert \times Year \times MZ$$

$$(Mod\ 6) \quad NUE = Nfert \times Year$$

$$(Mod\ 7) \quad NUE = Nfert \times MZ$$

NUE equation	Best model according to AIC
Eq 1 – NRE	Mod 6
Eq 2 – NUpE	Mod 5
Eq 3 – NUtE	Mod 6

While the model including management zones provided the best fit for NUpE, neither the zone effect nor its interactions were statistically significant.

Congreves et al. 2021



Summary and take home message

1. Potential yield gaps between HS and LS zones are relatively small (most differences ≤ 1 t/ha)
2. Drivers of HS and LS zones are generally weakly related to nitrogen use efficiency
3. These differences require further detailed analysis (e.g., differences in mineralization or sensitivity to climatic variations)
4. Delimitation based on satellite imagery reflects multiple phenomena that, at this stage, do not allow standard N fertilization practices to be adapted to management zones



Limits and perspectives

1. The delineation algorithm always differentiates HS and LS zones independently of yield or NDVI differences.
2. Annual reinitialization is a major limitation for analyzing management zone (MZ) differences.
 1. Common initialization also limits the analysis of MZ differences.
 2. The annual effect is reinforced in the models.
3. Differences in Nitrogen Use Efficiency (NUE) between MZs should be analyzed with varying N fertilizer rates across plant growth stages.
4. Other soil properties should be considered to explain differences between HS and LS zones.



Thank you for your attention