Plant P and soil P diagnosis for integrated crop fertilization management

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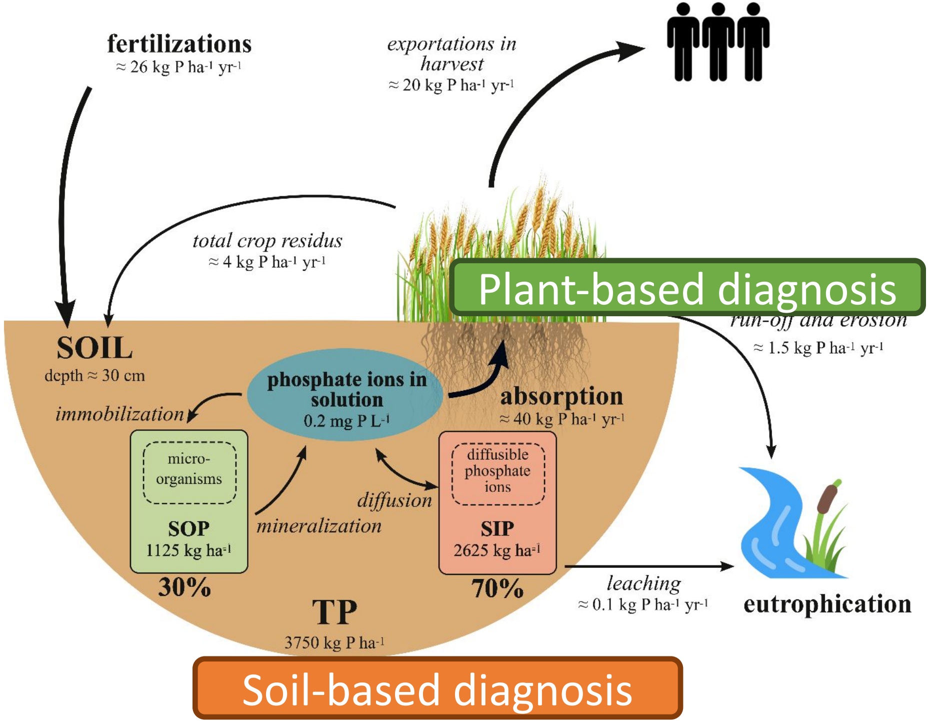
Sustainable management of P fertility in agroecosystems

Two diagnosis methods



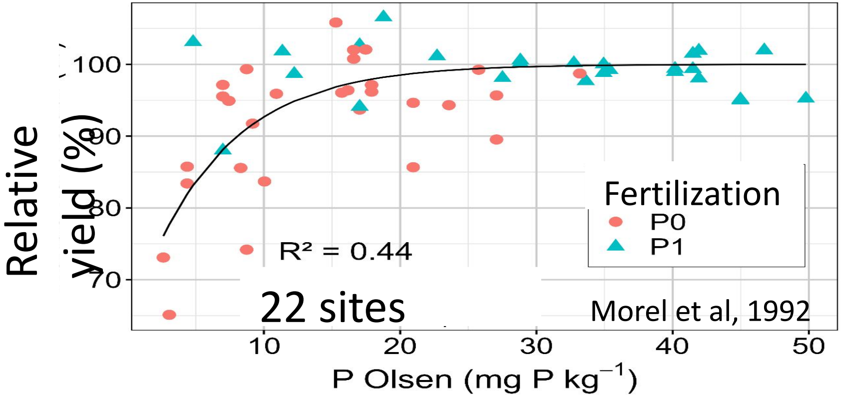
Adapted from Raguet thesis 2023

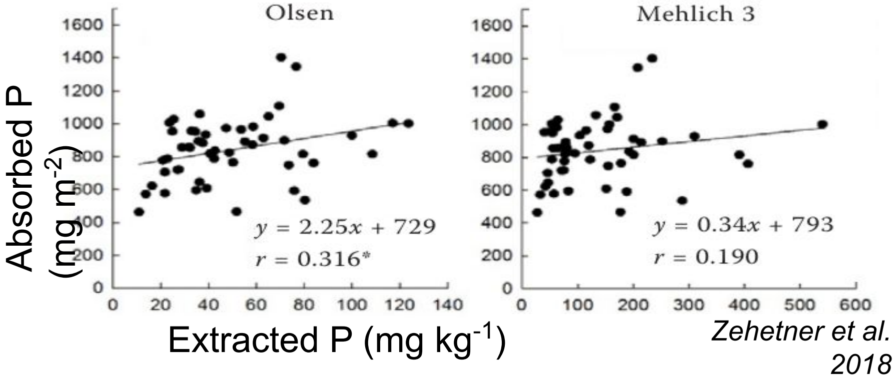
Soil-based diagnosis methods

Plant available soil P is determined by chemical extraction

- Procedures differ widely between countries

Diagnosis is established on relationship between the soil tests and the crop response





Large variability of the relationship between crop yield and extracted soil P: soil, crop, year effects!

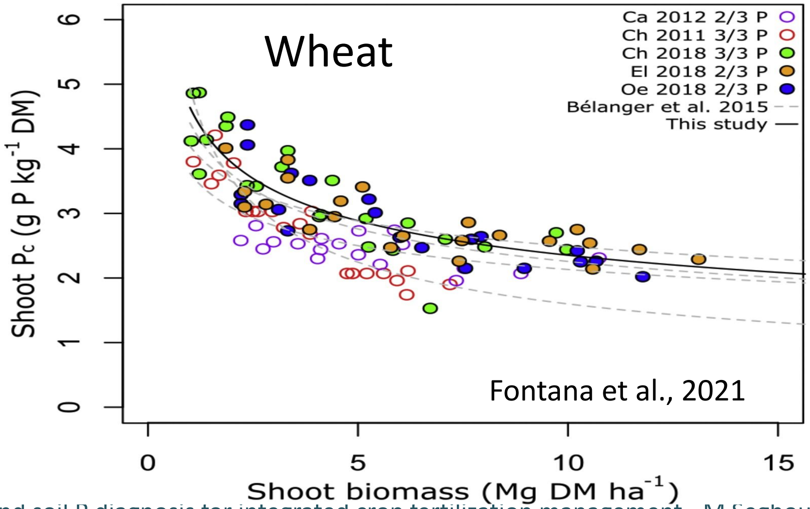
Chemically extracted P and plant P uptake are poorly correlated for several common chemical methods

Plant-based diagnosis methods

Used to evaluate crop P requirements and determine the economically optimum fertilization rates

The concept of critical N dilution curves for diagnosing the N nutrition status has been applied for P

For a non-limiting N supply, the P concentration in shoot biomass (Shoot P_c, g P kg^{-1} DM) of different crops, such as maize, wheat, rapeseed, and potato, decreased with biomass accumulation (W)



Phosphorus Nutrition Index
PNI

Diagnosis

Objectives

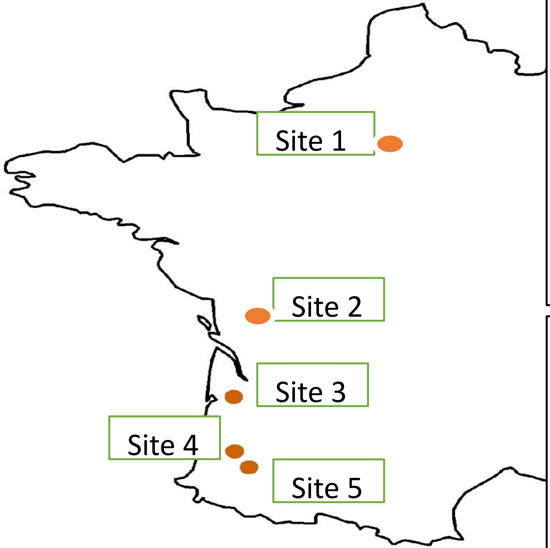
Determine the relationship between the **P nutrition index** based on a critical P dilution of maize (*Zea mays*. L.) and **indicators of the soil P supply** assessed using a process-based approach or the common chemical extraction of the Olsen method.

Incorporate these indicators in the STICS crop growth model to predict crop P uptake and P response

- Determination of critical P dilution of maize
- Determination of the relationship between PNI and soil P indicators
- Analyze N:P interactions effects on plant P status diagnosis
- Development of a P module for STICS model

• Data collection from long-term field experiments on P fertilization

Site	Name and location
1	Folleville (1958-2022)
2	Saint-Felix (Flandrois 1979-2009)
3	Pierroton (1995-2015)
4	Tartas - Carcarès Sainte-Croix (1972-2004)
5	Mant (1975-1992)



3-4 P fert. treatments (superphospahte) : P0 - P1 - P2

Four replications

Maize cultivation

S3-S4-S5 irrigated

~1-2 cropping cycle
5-6 shoot sampling dates

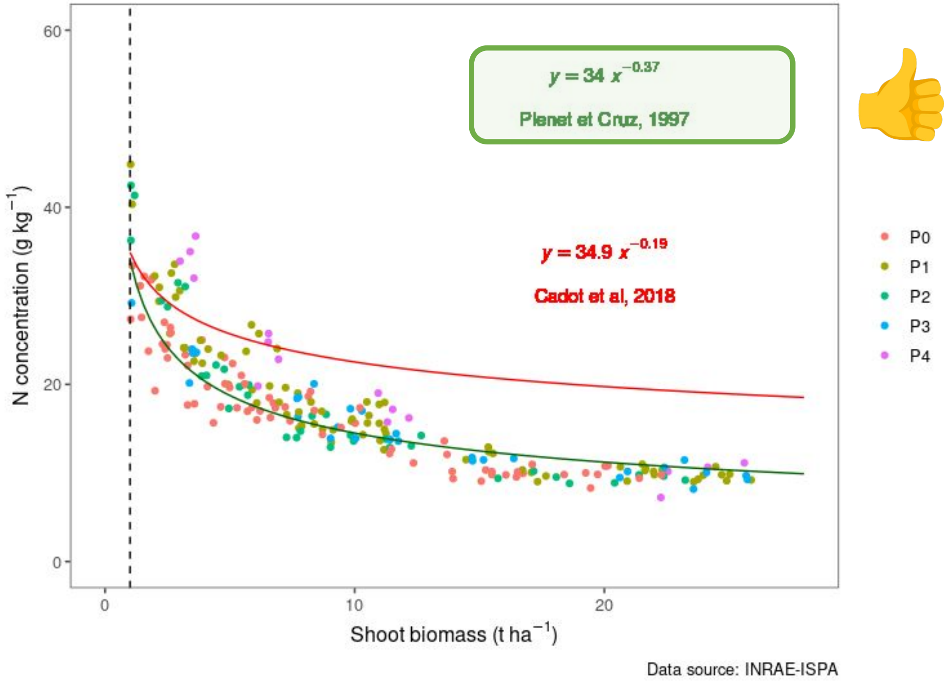
Biomass, N and P content analysis

Soil P availability : Olsen P and process-based assessment

• Determination of N statues

Non-limiting N supply for **all sites** and **all P treatments**

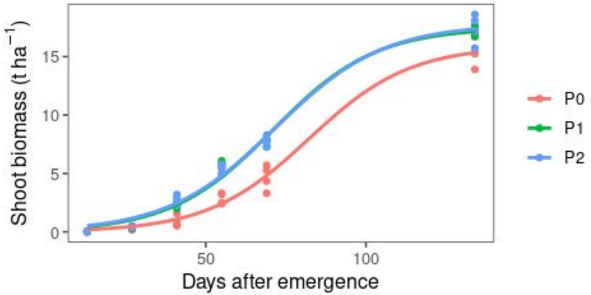
All sites

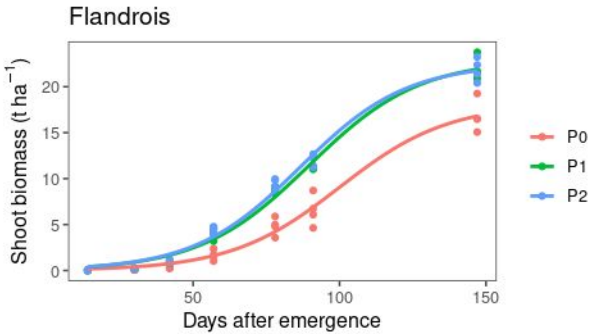


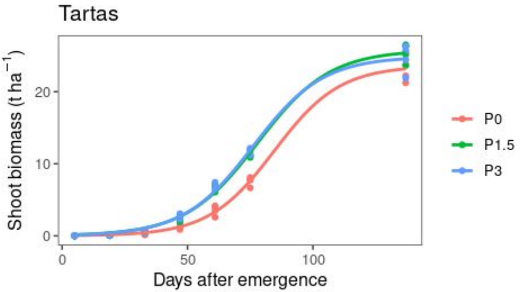
• Growth response to P level

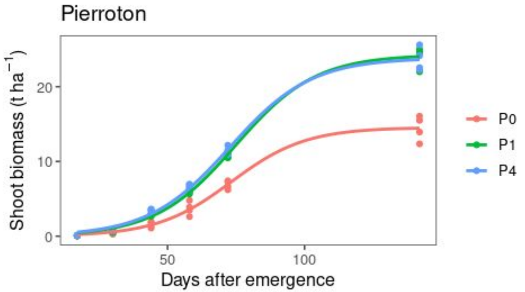
Early growth is strongly reduced in P0 treatment with contrasted responses at maturity

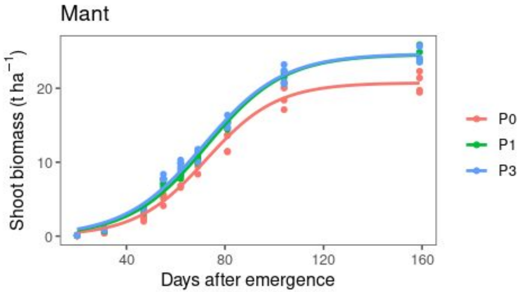
Folleville











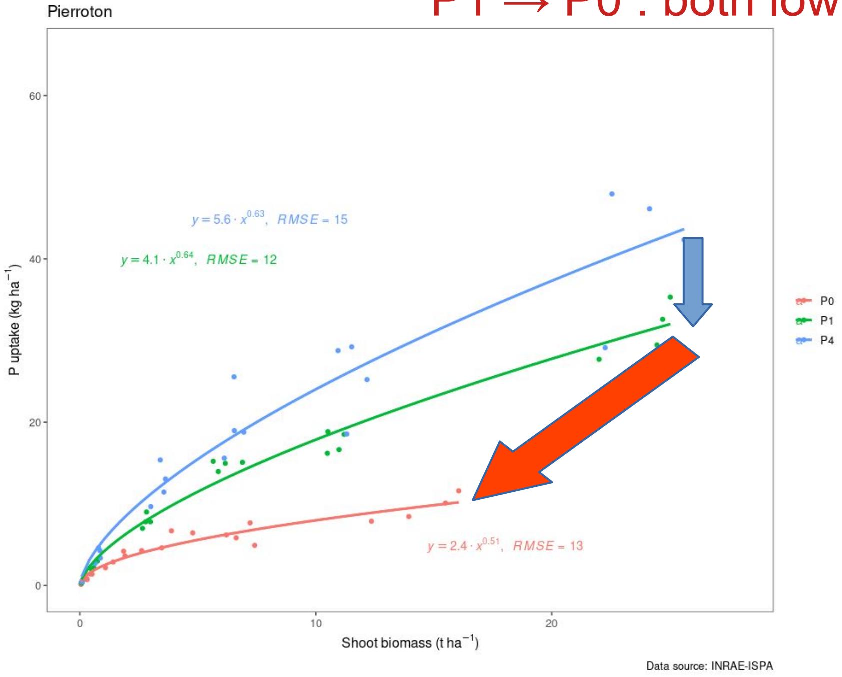
• Relation between P uptake and biomass

P uptake

Ex : Pierroton

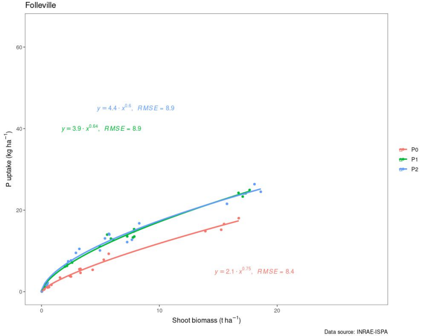
P4→P1 : lower P uptake but almost same W

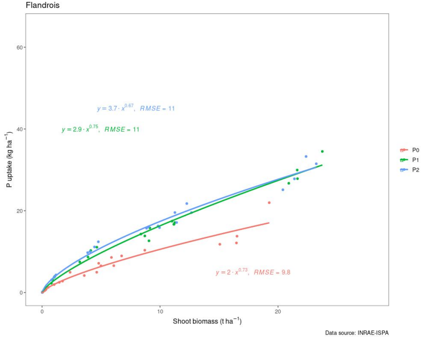
P1 → P0 : both lower P uptake and lower W

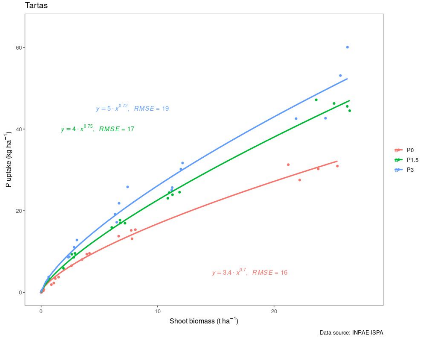


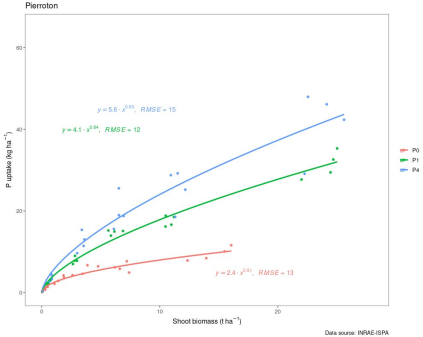
• Relation between P uptake and biomass

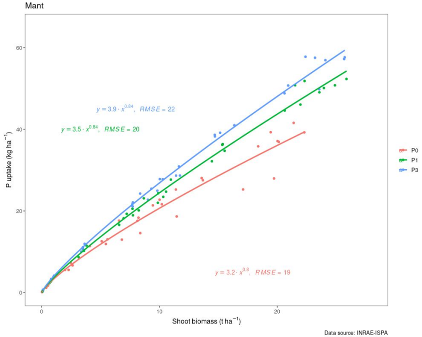
P uptake





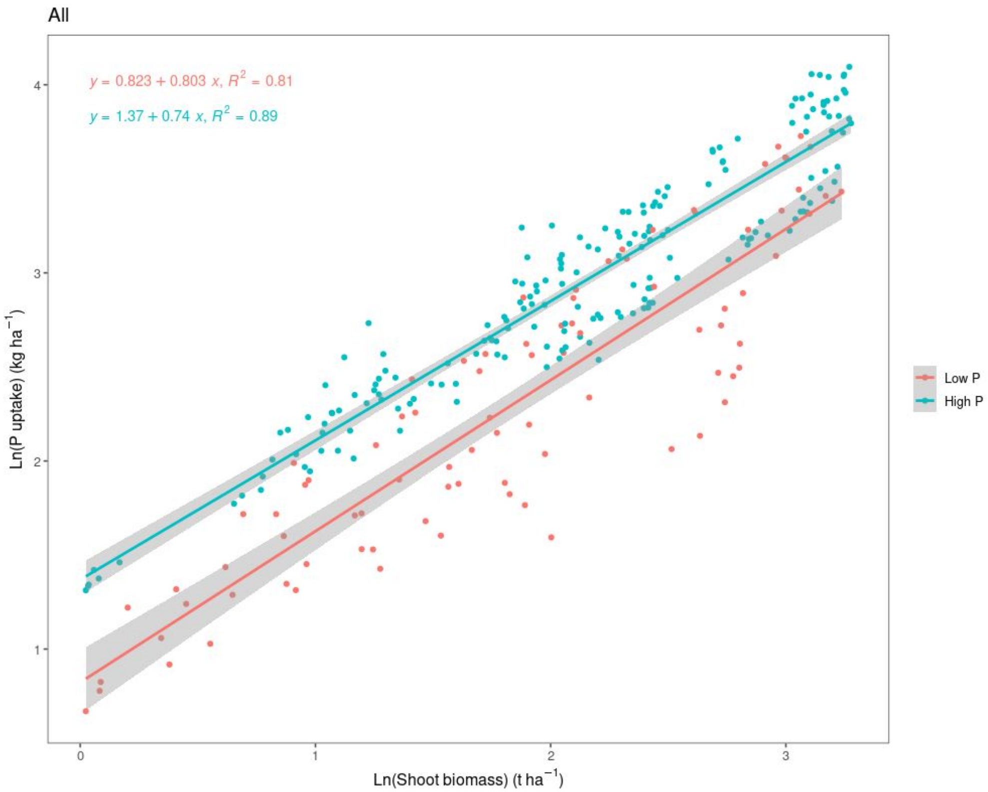






• Relation between P uptake and biomass

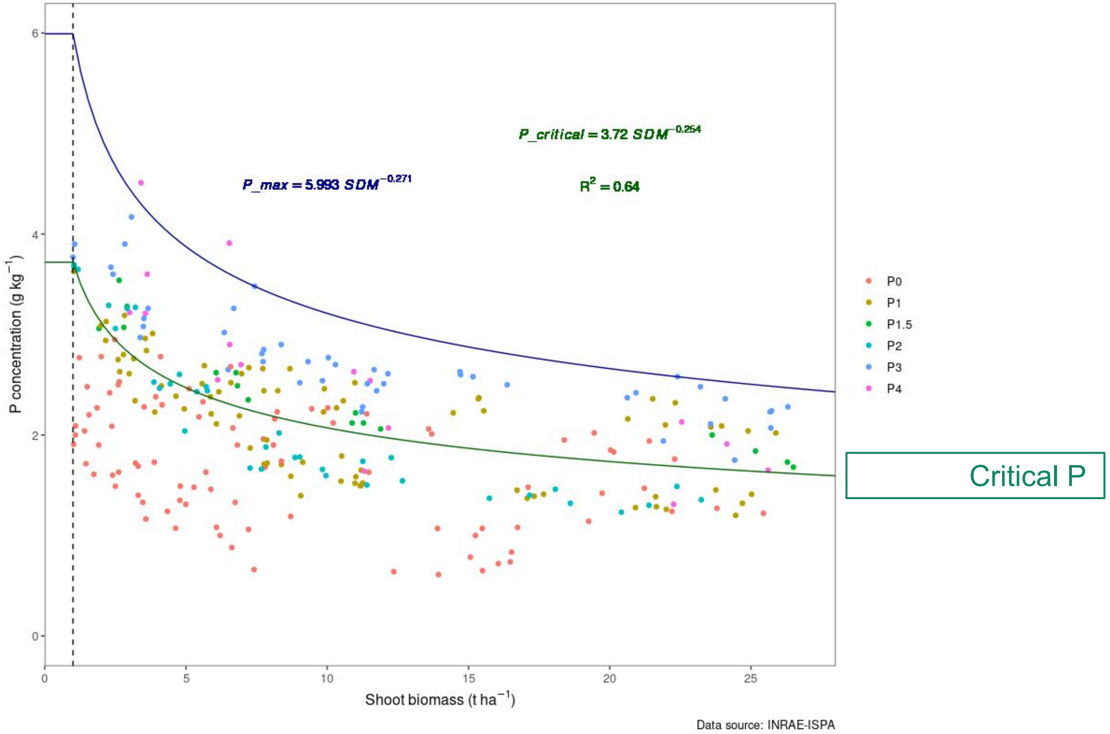
ln(P uptake) vs ln(W) for all sites (Low P = P0, High P ={P1,P2,P3, P4})



• Determination of critical P curves

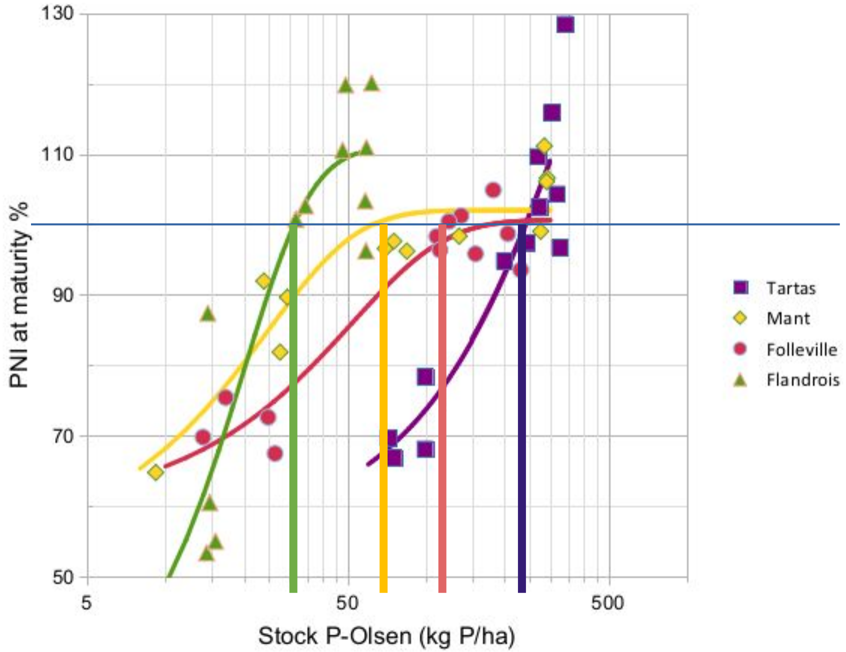
Critical P curves derived from P1 and P1.5 treatments

Max P curve : 99th quantile regression



• Determination of the relationship between PNI and soil P indicators

Stock of P extracted by Olsen's method (ploughed layer)



Logistic equation

$$PNI = \frac{Amax}{1 + (\frac{Amax}{A0} - 1) \times \exp(-k \times X)}$$

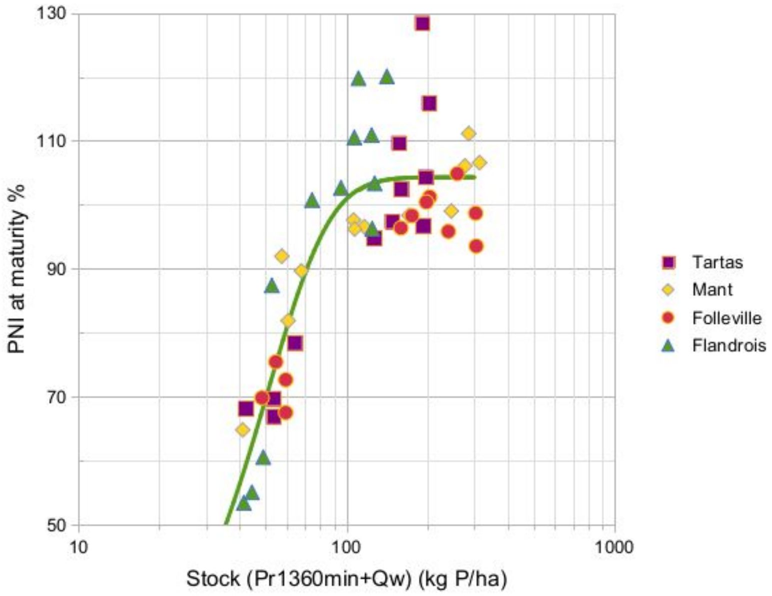
Morel et al. 2021

The response curves varied with soil types

Threshold values are difficult to estimate

• Determination of the relationship between PNI and soil P indicators

Stock of diffusive oPions at the solid-solution interface transfered in about 1 day plus the amount of oPions in soil solution (ploughed layer)



Logistic equation

$$PNI = \frac{Amax}{1 + (\frac{Amax}{A0} - 1) \times \exp(-k \times X)}$$

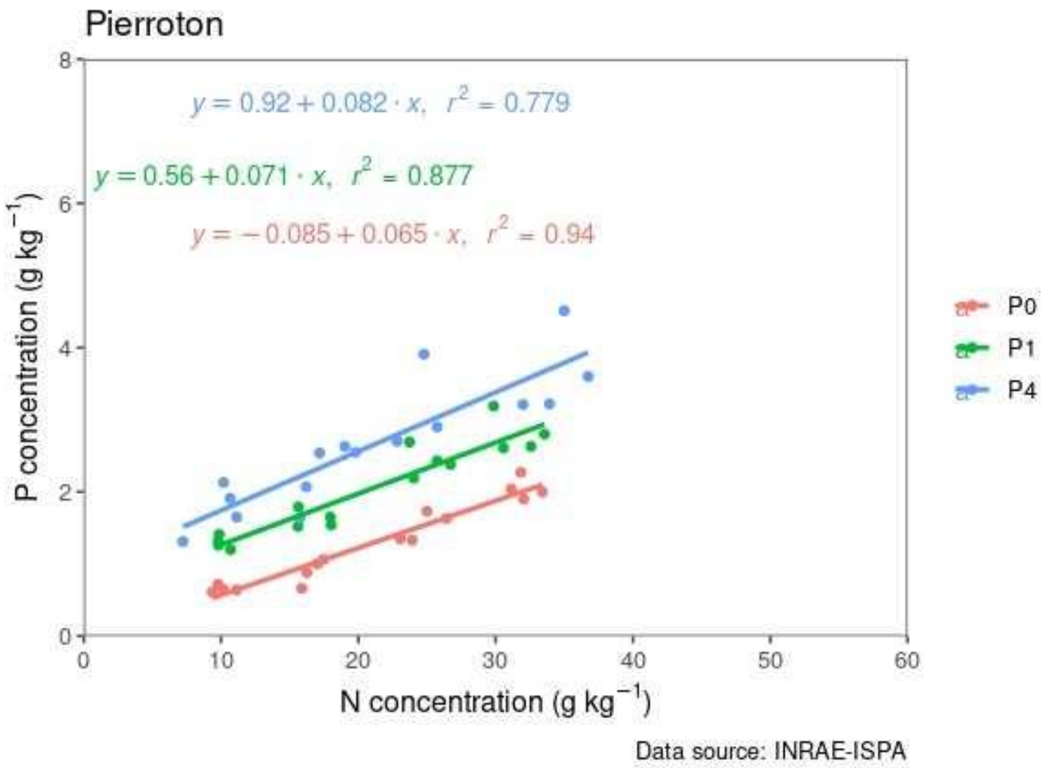
Morel et al. 2021

Unique calibration curve for all sites considering a period of resupplying soil solution oPions about 1 day

This soil- and plant-based methods of diagnosis are both equally effective

Analyze of N:P relationship

The linear P % vs N % relationship depends on the P level

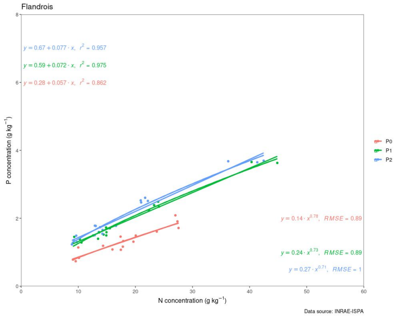


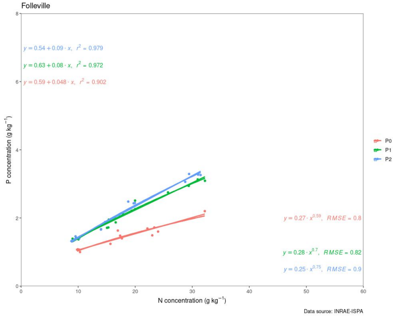
%P vs %N

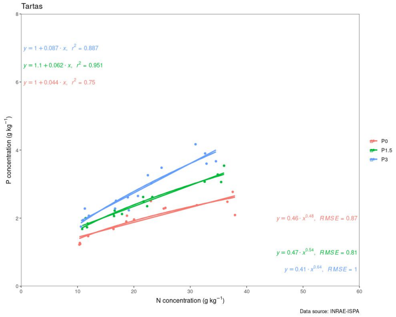
Ex : Pierroton

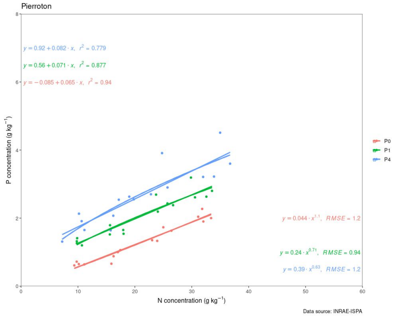
P uptake does not affect N uptake

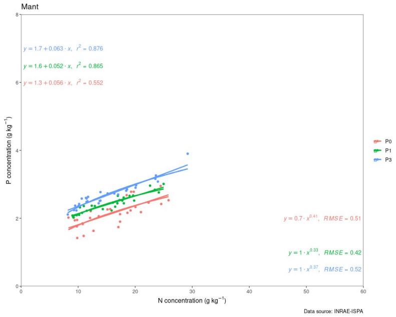
Analyze of N:P relationship











Data collection from TERO trials: Sugar cane (La Réunion)

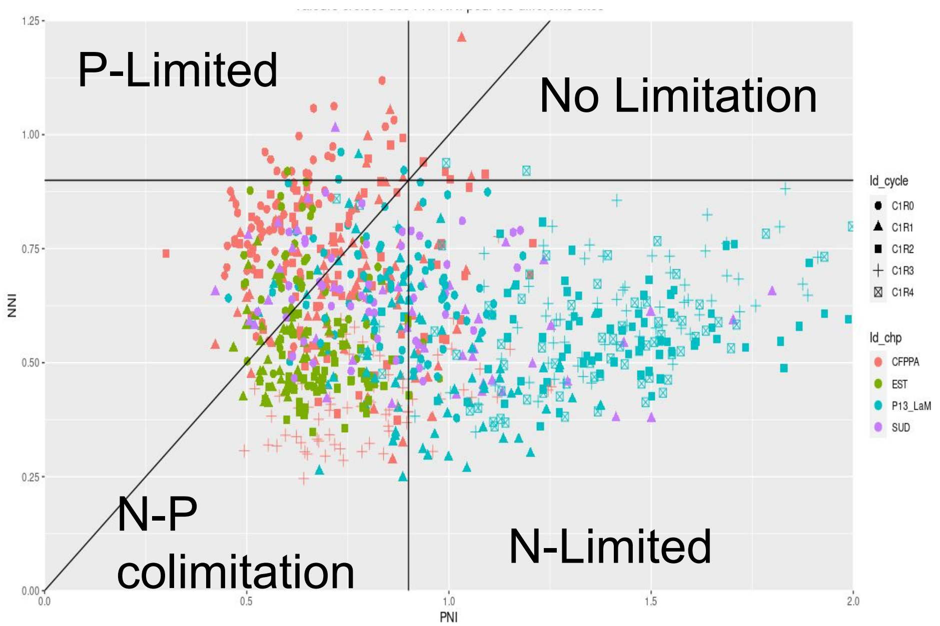
Treatments
Control
Mineral fertilizer
Organic fertilizers :
- sewage farm sludge
- composted sludge
- pig manure and poultry manure

Different N, P, K supplies

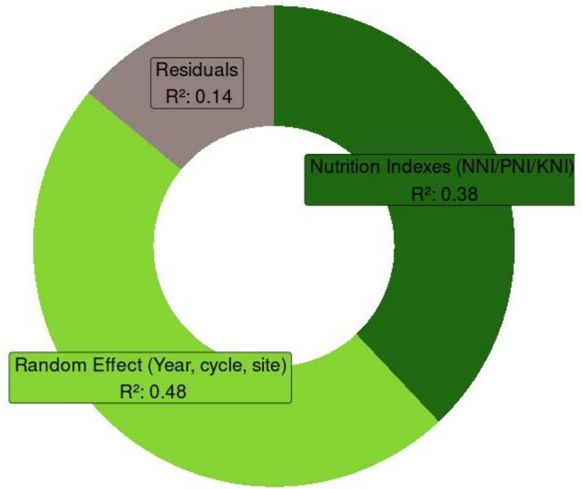
Multi-Site and long-term

Analyze N:P interactions effects on plant P status diagnosis

Identifying situations of N-P co-limitations based on NNI and PNI



Explaining sugarcane yield variability with plant N, P and K status diagnosis at harvest



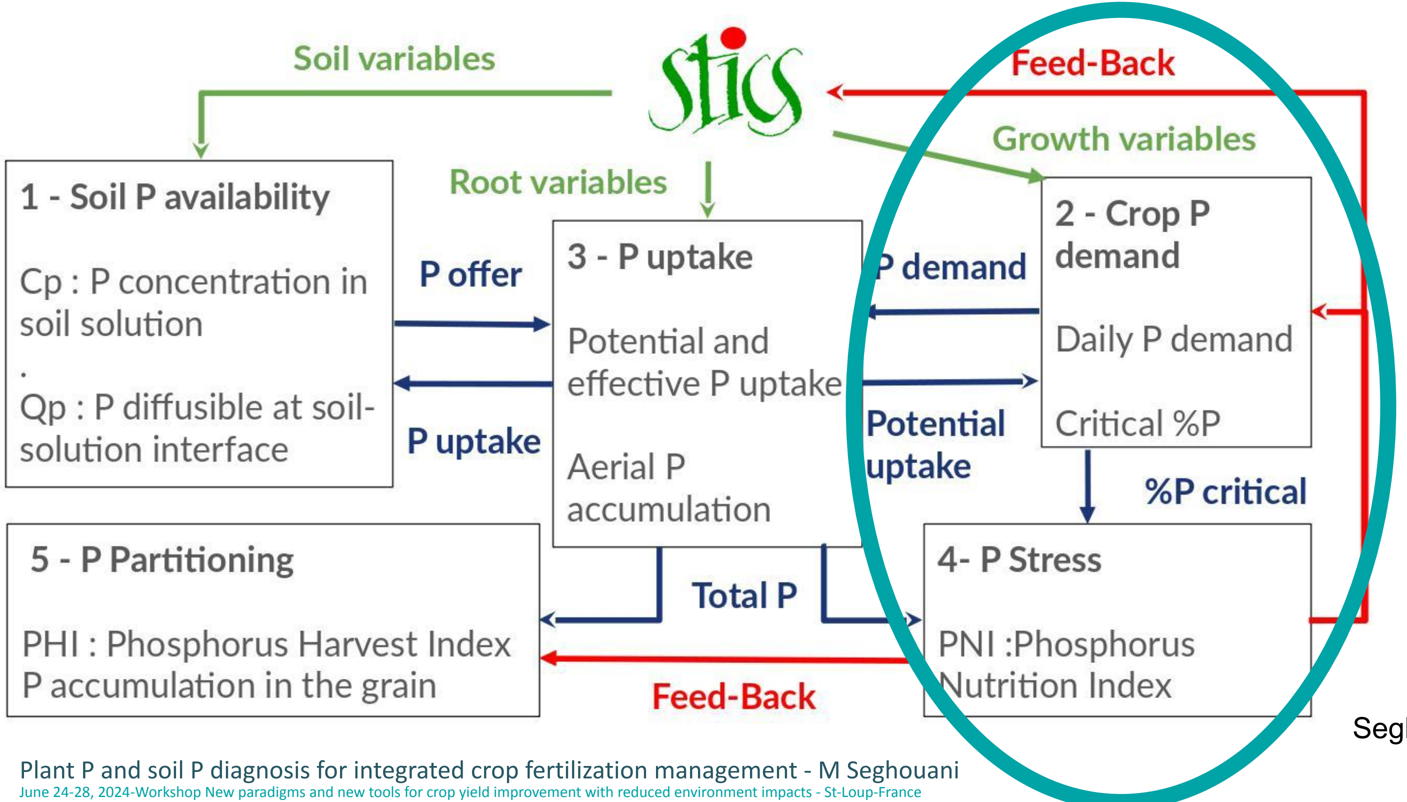
Mixed model :

Yield ~ NNI + PNI + KNI ~ (1|Year) + (1|Site) + (1|Cycle)

Explained 86% of sugarcane yield variability

• Use of P dilution curve to simulate P demand and P status in STICS soil-crop model

STICS-P model structure



Based on P dilution curves

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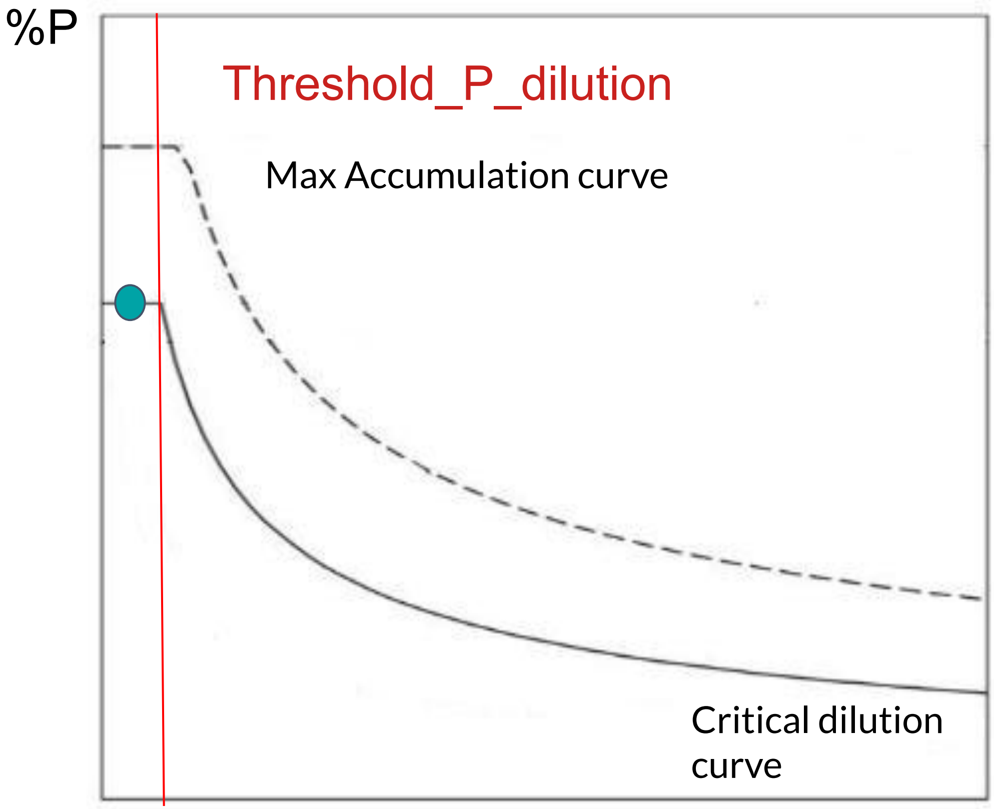
• Use of P dilution curve to simulate P demand and P status in STICS soil-crop model



if (Biomass < Threshold_P_dilution)

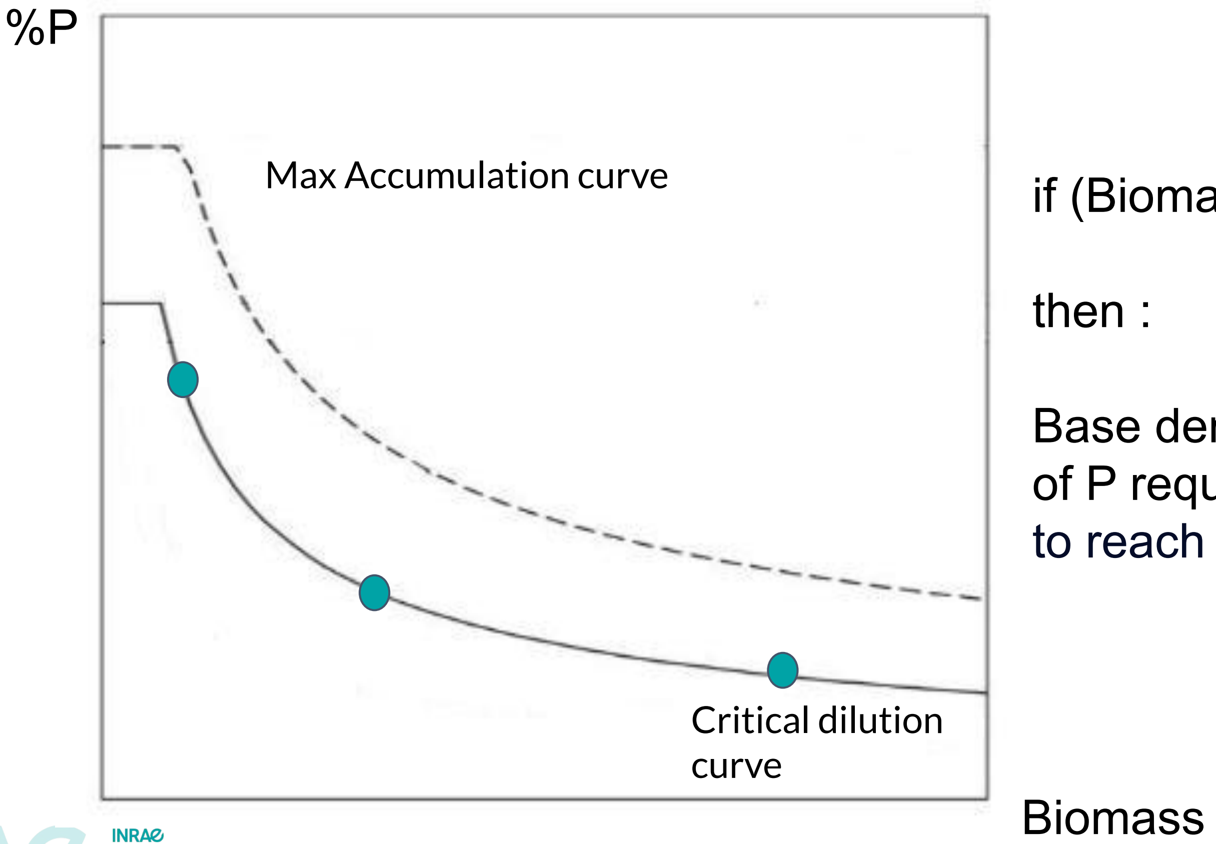
then :

Demand is fix, and

%Pcrit = a parameter of the P dilution curve

Biomass

- **Use of P dilution curve to simulate P demand and P status in STICS soil-crop model**

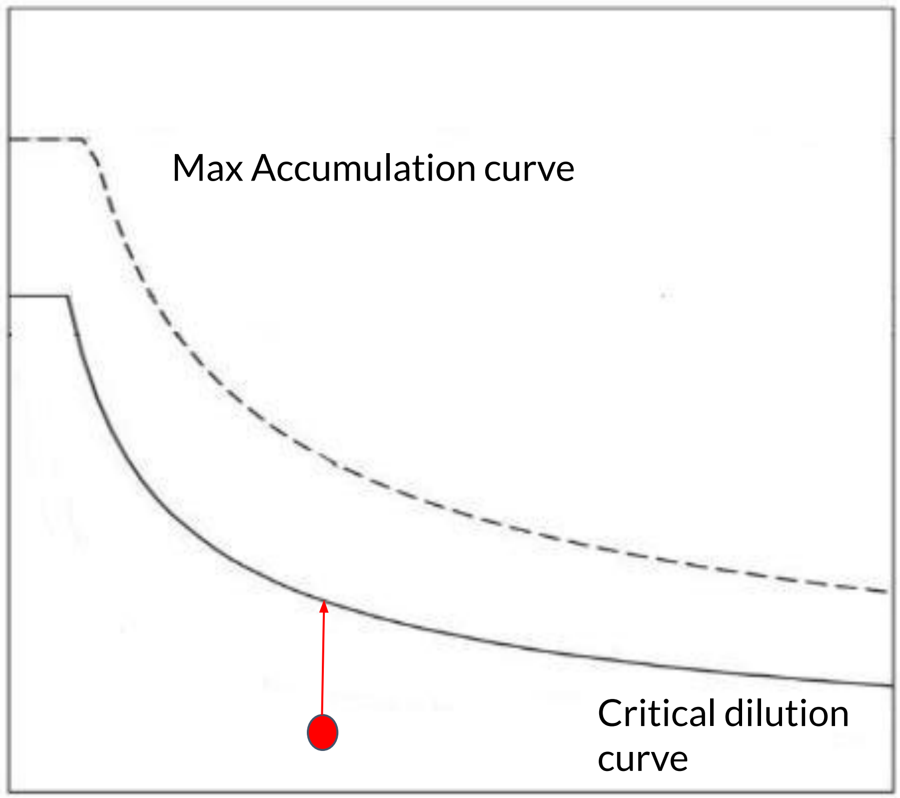


if (Biomass > Threshold_P_dilution)

then :

Base demand equals the quantity of P required to the daily ΔBiomass to reach %Pcrit

• Use of P dilution curve to simulate P demand and P status in STICS soil-crop model

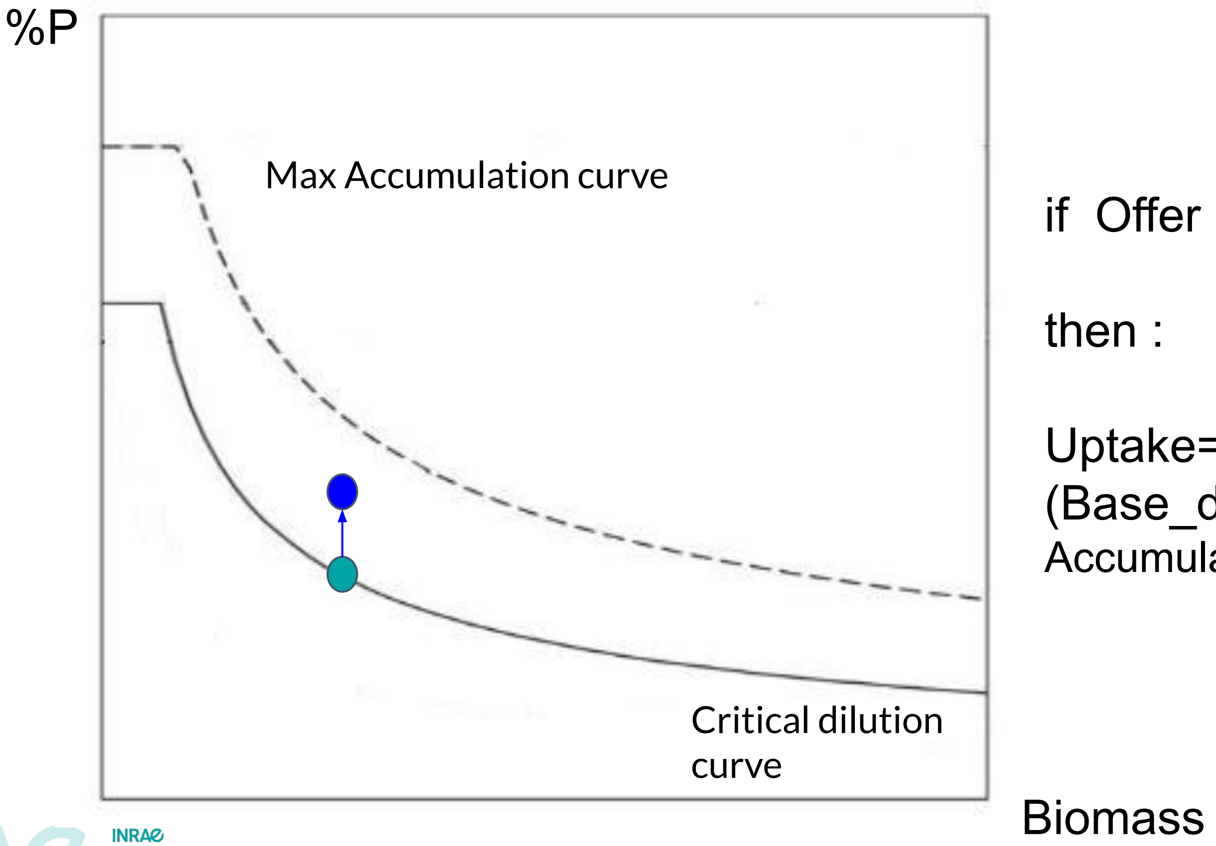


if (%P < %Pcrit)

then :

Demand is equal to the quantity of P required to reach Pcrit

• Use of P dilution curve to simulate P demand and P status in STICS soil-crop model

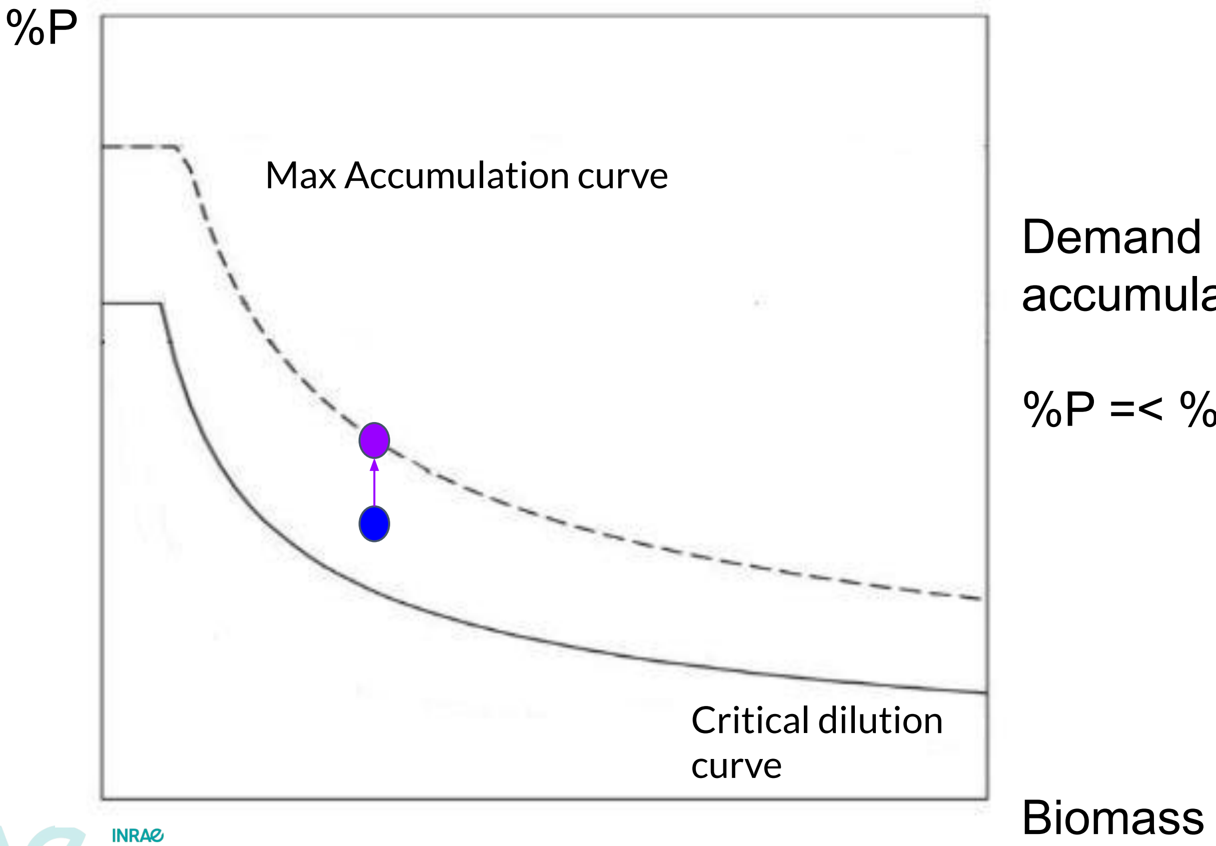


if Offer > Base_demand

then :

Uptake= Base_demand + (Base_demand - Offer) x Accumulation_coef

• Use of P dilution curve to simulate P demand and P status in STICS soil-crop model

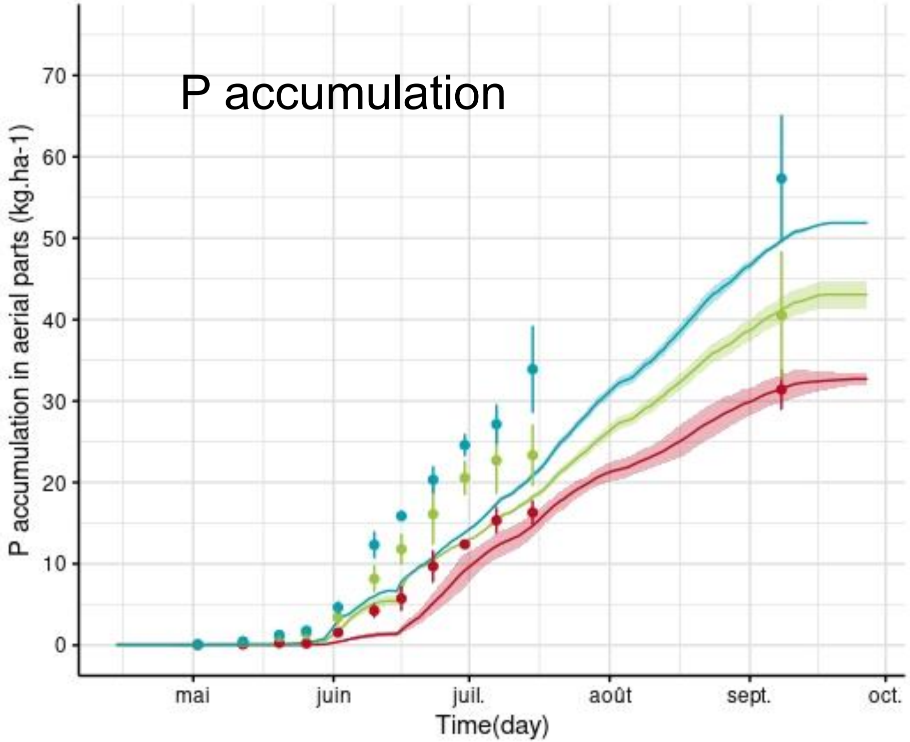


Demand is limited by the crop “max accumulation curve”

%P =< %Pmax

• Use of P dilution curve to simulate P demand and P status in STICS soil-crop model

Outputs : (ex : Tartas 1997)



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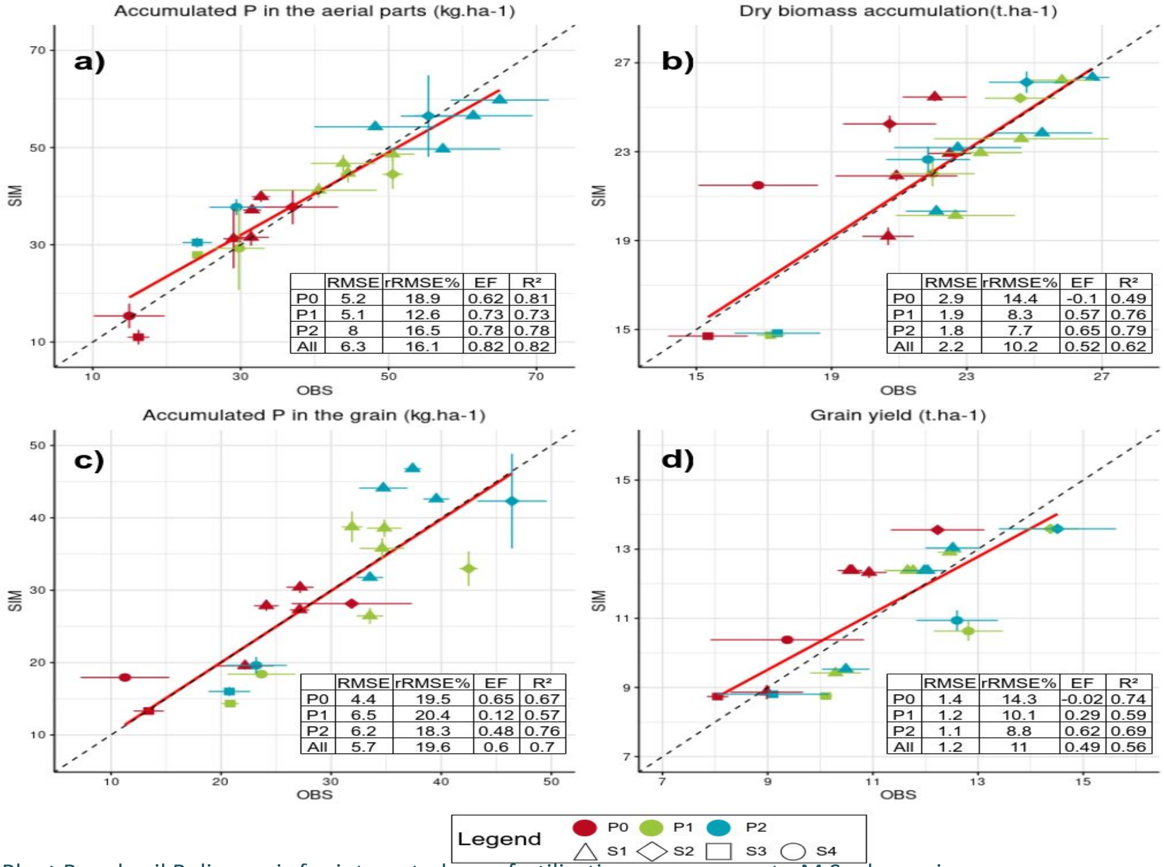
• Use of P dilution curve to simulate P demand and P status in STICS soil-crop model



a) Accumulated P in the aerial parts (kg.ha-1)

	RMSE	rRMSE%	EF	R^2
P0	5.2	18.9	0.62	0.81
P1	5.1	12.6	0.73	0.73
P2	8	16.5	0.78	0.78
All	6.3	16.1	0.82	0.82

b) Dry biomass accumulation(t.ha-1)

	RMSE	rRMSE%	EF	R^2
P0	2.9	14.4	-0.1	0.49
P1	1.9	8.3	0.57	0.76
P2	1.8	7.7	0.65	0.79
All	2.2	10.2	0.52	0.62

c) Accumulated P in the grain (kg.ha-1)

	RMSE	rRMSE%	EF	R^2
P0	4.4	19.5	0.65	0.67
P1	6.5	20.4	0.12	0.57
P2	6.2	18.3	0.48	0.76
All	5.7	19.6	0.6	0.7

d) Grain yield (t.ha-1)

	RMSE	rRMSE%	EF	R^2
P0	1.4	14.3	-0.02	0.74
P1	1.2	10.1	0.29	0.59
P2	1.1	8.8	0.62	0.69
All	1.2	11	0.49	0.56

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• Conclusions

P dilution curves (critical and max accumulation) for maize in France without other limiting factor

-> Need to be test in wider pedoclimatic context

Interest in using dilution curves to study N-P colimitation and reveal NxP interaction

Soil and plant-methods of diagnosis are both equally effective and complementary

Concept are useful to simulate crop growth and response to P

-> Integration of both methods in soil-crop model allow for a more mechanistic representation of the crop nutrition -> Improved simulations -> Test scenarios, build response curves, better understand of crop nutrition.