Assessment of the impact of pesticide use decrease on wheat production, using cropping system experiments

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Séminaire Utiliser la Méta-analyse pour l'agriculture et l'élevage
et mieux exploiter les données existantes.

Context

- Negative impacts of agricultural activities on the environment, due to a massive use of inputs

  (Matson *et al.*, 1997)

- Objective in France of the Plan Ecophyto : halving the pesticide use by 2018 (if possible)

- Alternative systems: Organic agriculture, Low-input systems

  => What are their performances?

Objectives

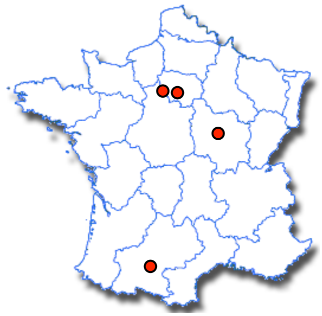
- Estimating yield losses due to a decrease of pesticide use, characterized by theTreatment Frequency Index (TFI), under different pedo-climatic conditions

- Explaining the variability of yield response to TFI

- Case study: Winter Wheat in France

Experimental data (1)

- Four cropping system experiments[1] located in France, between 1995 and 2012



- 178 plots of winter wheat, cropped under a wide range of fertilization practices and pesticide uses

- Yields between 2 and 10 $t.ha^{-1}$

[1]Munier-Jolain *et al*., 2004; Bertrand *et al*., 2005; Debaeke *et al*., 2006

Experimental data[1] (2)

- Winter wheat (WW):
  - TFI: 0 – 10
  - Nitrogen: 0-286 $uN.ha^{-1}$
- Cropping system:
  - 3 – 6 years
  - Preceding crop: Cruciferous sp., WW, Legume, Grass sp.
  - Rotation Tillage: 0 – every year
  - Legumes: 0 to every 2 years

[1]Munier-Jolain *et al*., 2004; Bertrand *et al*., 2005; Debaeke *et al*., 2006

Treatment Frequency Index

- Calculated at field scale for each cropping year
- Based on national recommended doses for each pesticide use (Pingault *et al.*, 2009)

$$TFI = \sum_{T} \frac{\text{Applied\_doses}_{\text{T}}}{\text{Recommended\_doses}_{\text{T}}}$$

with T the pesticide product; the doses are expressed per hectare

Statistical analyses: Potential yields for different TFI values estimated with two methods

- **Quantile regressions[1]:**

$$\tau = P\left[\log(Y) < f(TFI, \beta)\right]$$

with $f(TFI, \beta) = \beta_0 + \beta_1 \log(TFI)$

τ a chosen (high) probability value

β the estimated parameters

[1]Makowski *et al*., 2007; Casagrande *et al*., 2010

Statistical analyses: Potential yields for different TFI values estimated with two methods

- **Stochastic Frontier Analysis[1]:**

$$\log(Y_i) = \theta_0 + \theta_1 \log(TFI_i + 0.1) + v_i - u_i$$

$$Y_i = \exp(\theta_0)(TFI_i + 0.1)^{\theta_1} \exp(v_i)\exp(-u_i)$$

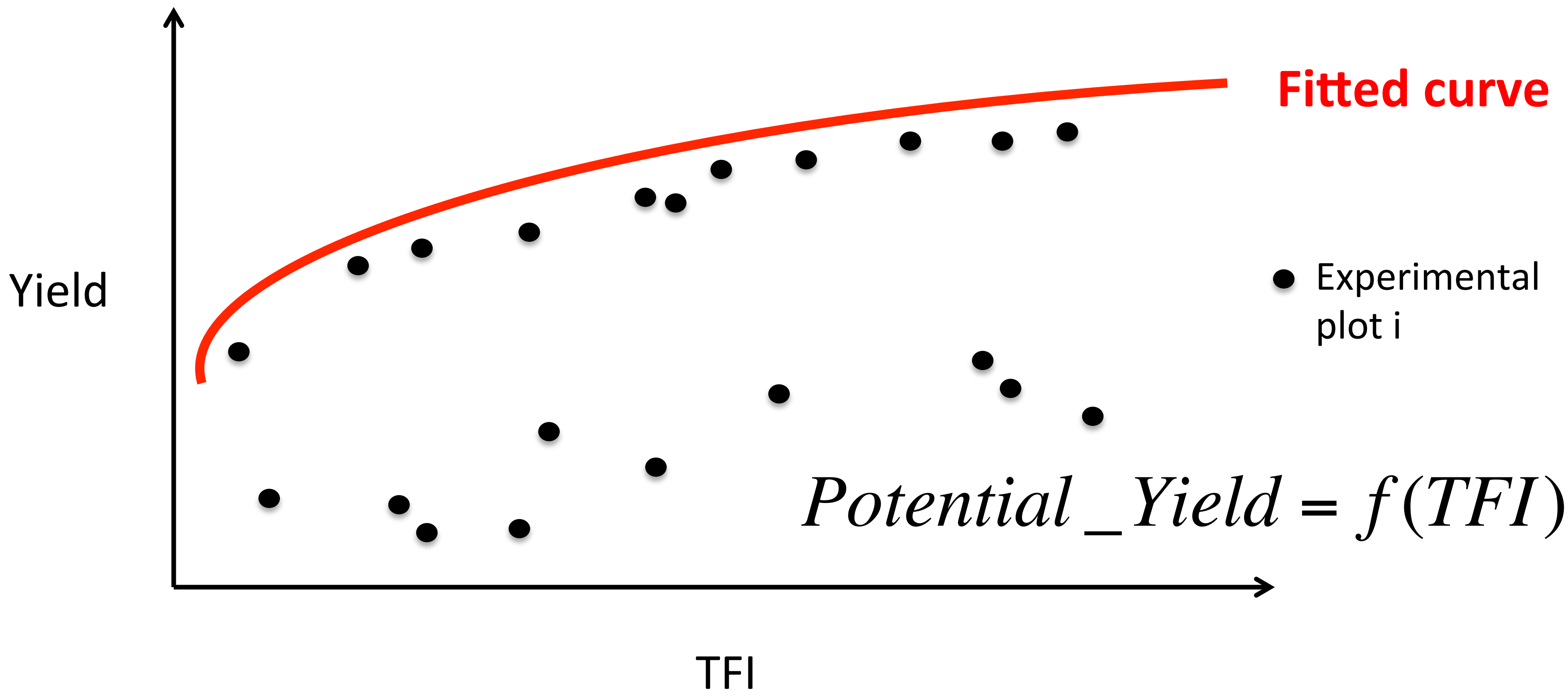
with i the experimental plot,

v_i the stochastic error term : $v_i \sim N(0, \sigma^2)$

u_i the technical inefficiency: $u_i \sim |N(\mu, \sigma_u^2)|$

[1]Battese and Coelli, 1995; Hailu *et al*., 2005

Yield gaps (log curves)



Quantile regression (τ = 0.95)

$$Eff_i = \frac{Yield_i}{Potential\_Yield_i}$$

Stochastic Frontier Analysis

$$Eff_i = \exp(-u_i)$$

Statistical analyses:
Effects of other cropping practices

Random forest[1] relating yield gaps to cropping practices

- 1000 regression trees
- based on binary decision rules
- missing values handled and replaced by mean value of close plots (proximity-based)

⟹ Rank the effects of cropping system characteristics on yield gaps

for four datasets characterized by different TFI values

[1]Breiman, 2001; Philibert *et al.*, 2013

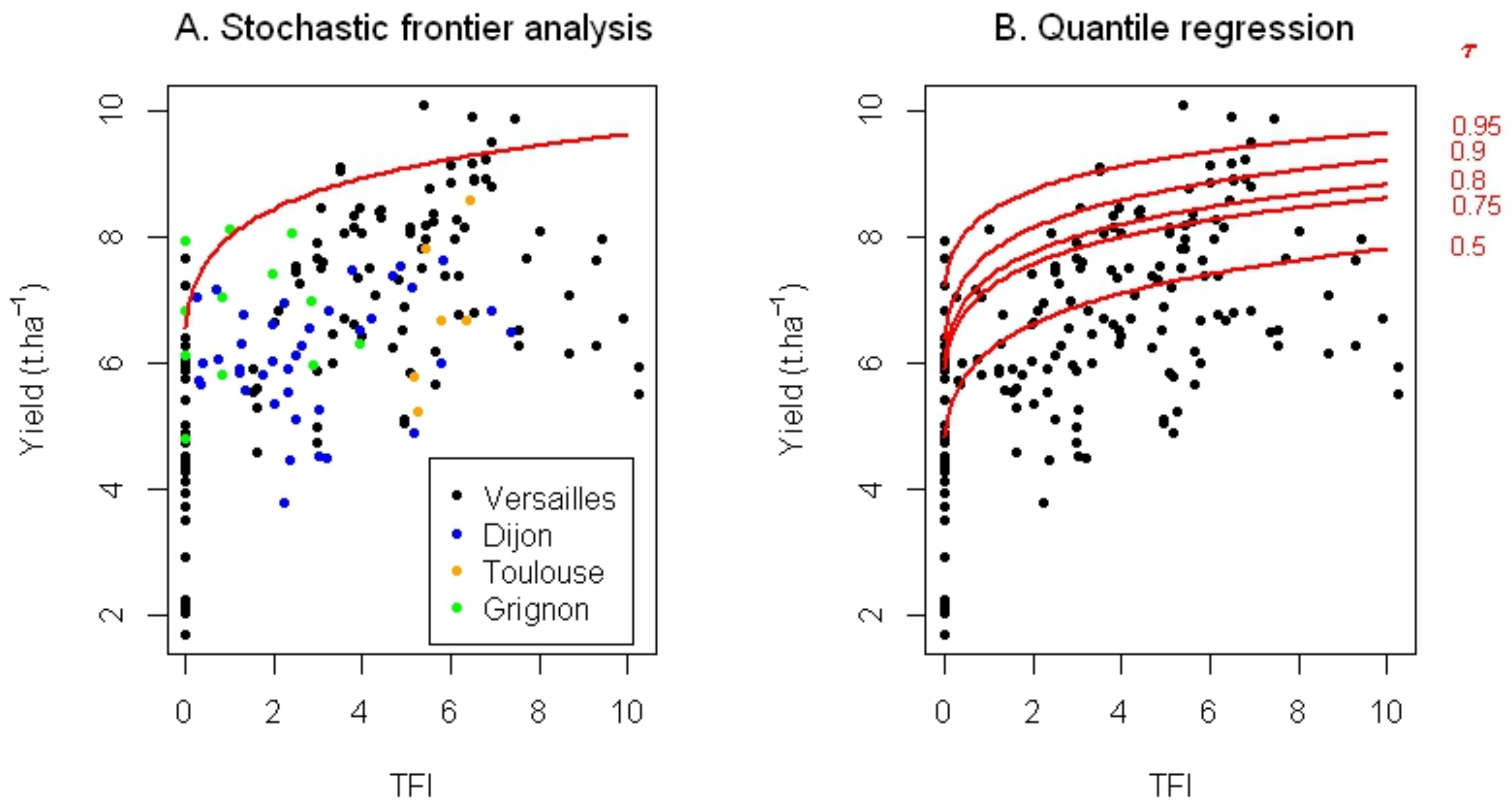
Variables included in Random Forest

Bio-Physical characteristics: Trial, Year

Wheat Fertilization (N, P, K)

System characteristics: Tillage (moulboard plouging frequency), Preceding crop, Rotation length, Frequency of legumes in the rotation

Yield = f(TFI)

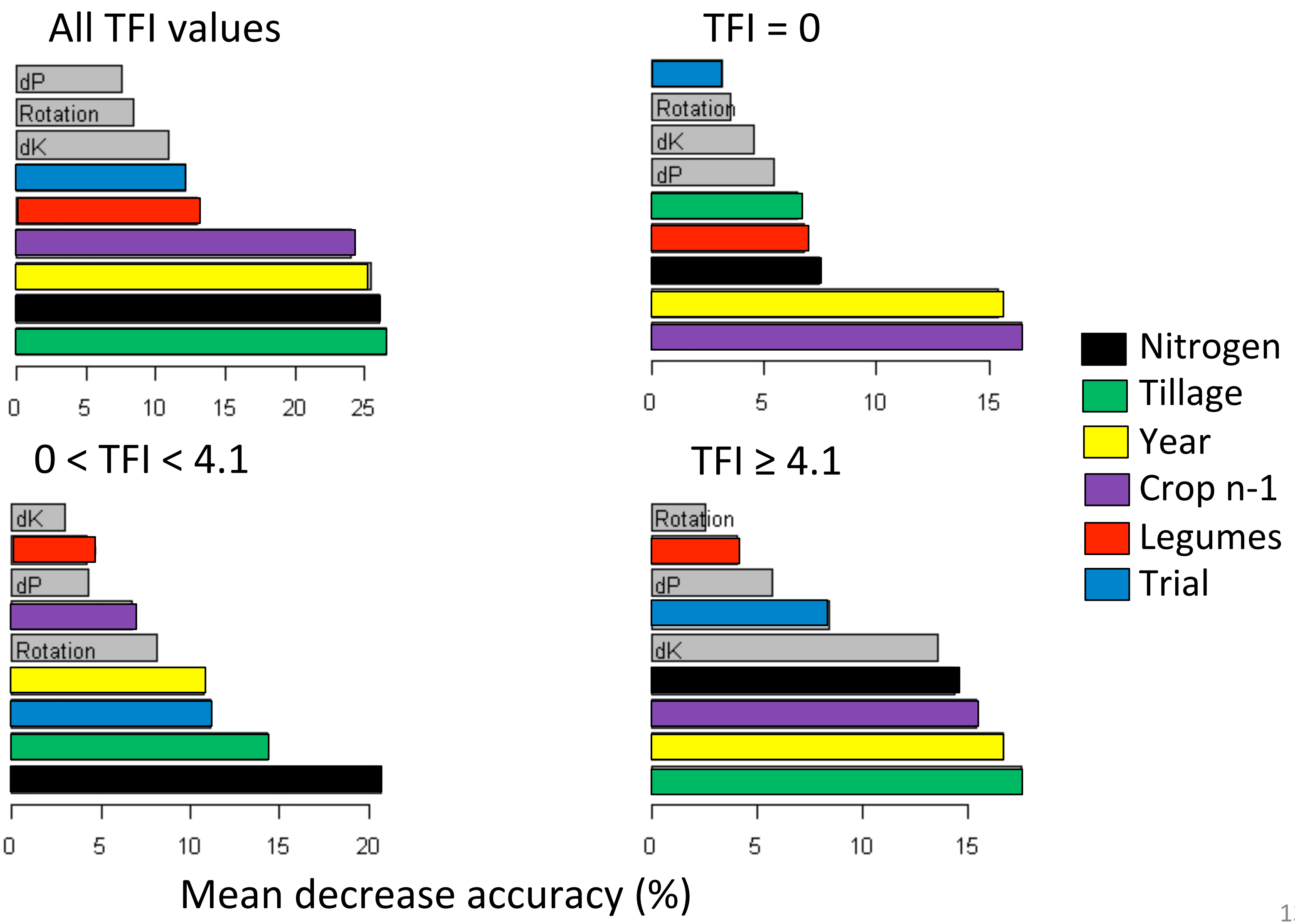


Changing Current TFI (4.1):

- ↘ of 50% : ↘ of 0.5 $t.ha^{-1}$
- TFI = 0 : ↘ of 1.9 – 2.4 $t.ha^{-1}$

Jacquet *et al.*, 2011

Rankings of Random Forest for different TFI ranges (SFA)



Discussion (1)

- Yield loss for a 50% TFI << 0-Pesticide system

- 50% TFI reduction: ↘ 66 €.ha^{-1} (Butault *et al*., 2010)

⇒ Wheat price should be < 130 €.t^{-1} for a zero-economic loss (if no other cropping system modification)

⇒ Today ≈ 200 €.t^{-1}

- Several variables have strong effects on yield gaps

⇒ Year effect >> Location

⇒ Nitrogen & Tillage for systems with pesticides

⇒ Preceding crop for no-pesticide systems

Discussion (2)

- Yield losses for TFI = 0 :

21 and 27 % for QR ($\tau = 0.95$) and SFA resp.

- Meta-analyses at the world scale: 19 and 35 %

(dePonti *et al*., 2012 ; Seufert *et al*., 2012)

Conclusion & perspectives

- Policy design to compensate economic losses

- What about other crops?

=> Hypothesis: lower yield losses for other major crops: corn, soybean (dePonti *et al*., 2012; Seufert *et al*., 2012)

- Upscaling to cropping system and farm scales: careful choice of crops economically efficient despite a strong ↘ of pesticide use

Thank you for your attention

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