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Assessment of the impact of a decrease in pesticide use on wheat production in France using cropping system experiments

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Introduction

Negative impacts of conventional agriculture on the environment are mainly due to the intensive use of inputs, i.e. chemical fertilizers and pesticides (Matson *et al.*, 1997). Organic and low-input cropping systems have both been proposed to reduce these negative impacts (Loyce *et al.*, 2012; McIntyre *et al.*, 2009) but it is important to assess the effects of these alternative systems on crop yield. Two recent meta-analyses showed that the substitution of conventional high-input systems with organic systems would lead to 20-34% of yield losses (de Ponti *et al.*, 2012; Seufert *et al.*, 2012), but these studies did not consider low-input cropping systems. This paper aims at assessing the effect of a reduction of pesticide use on winter wheat potential yield in France. Yield losses due to different levels of pesticide use are estimated from a large set of experimental data from cropping system experiments. The results are used to analyse the consequences of an environmental policy recently adopted in France, aiming at reducing by 50% the pesticide use by 2018 (Plan Ecophyto 2018).

Material and Methods

The intensity of pesticide use was characterized by a synthetic indicator, the Treatment Frequency Indicator (TFI) (Equation 1). TFI was estimated from cropping system experiments carried out in four sites located in different regions in France, between 1995 and 2012 (Dijon, Grignon, Toulouse and Versailles). In each experiment, winter wheat was grown in several cropping systems, differing by their rotation, pesticide use, soil tillage, irrigation and fertilization practices.

The relationship between Grain Yield and TFI was analysed using two different statistical models, Stochastic Frontier Analysis (SFA) and Quantile regressions (QR). SFA was used to estimate a production frontier relating the maximum yield values that could be reached for a large range of TFI (Equation 2). QR was used to relate several Yield quantiles (median, third quartile, percentiles 80, 85, 90 and 95%) to TFI (Equation 3).

(Equation 1) $TFI = \sum_T \frac{AD_T}{RD_T}$; with T the index of pesticide product; AD and RD the per hectare applied and recommended pesticide doses respectively (Pingault *et al.*, 2009).

(Equation 2) $\log(Y_i) = \theta_0 + \theta_1 \log(TFI_i + 0.1) + v_i - u_i$; with i the experimental plot index, Y the grain yield, θ_0 and θ_1 two estimated parameters, v_i the stochastic error term and u_i the technical inefficiency (effect of limiting factors other than TFI).

(Equation 3) $\tau = P[\log(Y) < f(TFI; \beta)]$ with $f(TFI; \beta) = \beta_0 + \beta_1 \ln(TFI)$, τ the quantile of Y ($0 \leq \tau \leq 1$), β the set of estimated parameters.

Results

Measured grain yield and TFI ranged from 1.7 to 10.1 t.ha⁻¹ and from 0 to 10.3 respectively. The shapes of the response functions estimated with the two statistical methods were quite similar. In both cases, grain yield increased in function of TFI, but grain yield increase rates were much smaller for high TFI than for low TFI. Yield values estimated for very low TFI were lower with SFA than with the QR function obtained with $\tau = 0.95$ (Figure 1; Table 1).

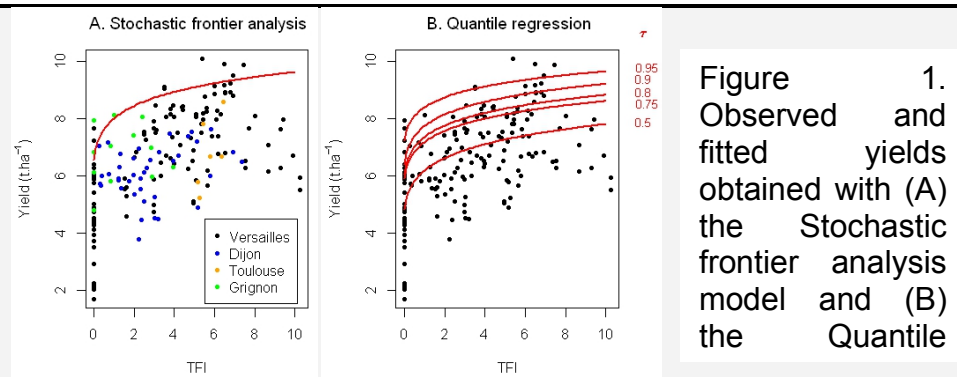


Figure 1. Observed and fitted yields obtained with (A) the Stochastic frontier analysis model and (B) the Quantile

In 2006, the winter wheat production in France was characterized by TFI = 4.1 (Jacquet *et al.*, 2011). If we use this value as a reference, the adoption of zero-pesticide production systems would reduce yield by 2 to 2.4 t·ha⁻¹ according to the SFA model and the QR function for the quantile 0.95 respectively. On the other hand, a 50% reduction of TFI, as required in France by the Plan Ecophyto 2018 (Butault *et al.*, 2010), would reduce yield by about 0.5 t·ha⁻¹ only (Table 1).

Method	50% TFI	TFI = 0
SFA	0.48;5%	2.4;27%
QR (τ=0,95)	0.37;4%	1.9;20%

Table 1. Estimated yield loss in for a 50% TFI reduction and TFI = 0 (current TFI = 4.1 in 2006; Jacquet *et al.* (2011)); in

Discussion

Our results showed that grain yield loss induced by a 50% TFI reduction (less than 0.5 t·ha⁻¹) is much smaller than the one induced by the adoption of zero-pesticide system (about 2 t·ha⁻¹). However, even with this small yield loss, a 50% TFI reduction may not be profitable for farmers; a reduction of 50% of the TFI in France would decrease pesticide costs by about 66 €.ha⁻¹ (Butault *et al.*, 2010) and, with the current wheat prices (more than 200 € per ton), the grain yield loss of 0.5 t·ha⁻¹ induced by a 50% TFI reduction will not be fully compensated by the pesticide cost reduction. If the wheat prices decrease below 130 € per ton, it will then become profitable for farmers to adopt environmental-friendly practices in order to decrease TFI by 50%. This study focused on the effect of pesticide use reduction on potential yield and it will be useful to study the variability of this effect in the future.

References

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