LEM
Lille Economics Management

IÉSEG
SCHOOL OF MANAGEMENT

Balancing profitability, plant protein production and pesticide reduction in arable farming

Authors:

- *Jean-Philippe Boussemart (LEM-IESEG, Lille, France)*
- *Maé Guinet (UMR Agroécologie INRAE, Dijon, France)*
- *Salomé Kahindo (LEM-IESEG, Lille, France)*
- *Nicolas Munier-Jolain (UMR Agroécologie INRAE, Dijon, France)*
- *Raluca Parvulescu (LEM-IESEG, Lille, France)*

SPECIFICS

Background

The European agricultural sector has undergone changes over time and space.

In the 1960s: focus

Negative impacts on its environmental sustainability

Food sovereignty

Equipment and inputs used.

Biodiversity loss

Degradation of soils

Disappearance of pollinators

Specialization in cereals to the detriment of other crops (**e.g., legumes, rich in protein and with lower environmental effects**)

- ↓ Plant protein
- ↑ Dependency on imports (e.g., soybeans)
- ↓ Decline in agricultural profitability

Negative impacts on its economic and societal sustainability

How to restore the balance of this system, namely, increasing production, preserving the environment, and ensuring farmers' profit(ability)?

Some bibliographic references

The determinants of farm profitability:
Blank et al., 2004,
Davidova et al., 2023,
Kryszak et al., 2021

- Agricultural practices,
- Pedoclimatic conditions
- Productivity,
- Farm characteristics (size, production orientation, organizational structure, …)
- etc.

The benefits of protein-rich crops on the environment:
Magrini et al., 2016

- Nitrogen fixation,
- crop diversification, biodiversity,
- reduction of chemical inputs,
- reduction of greenhouse gases
- etc.

Reduction of pesticides and its impact on production costs:
Jacquet et al., 2011
Boussemart et al., 2016
Lechenet et al., 2017

- Significant reduction in pesticide
- Sustaining crop yields
- No notable substitution effects

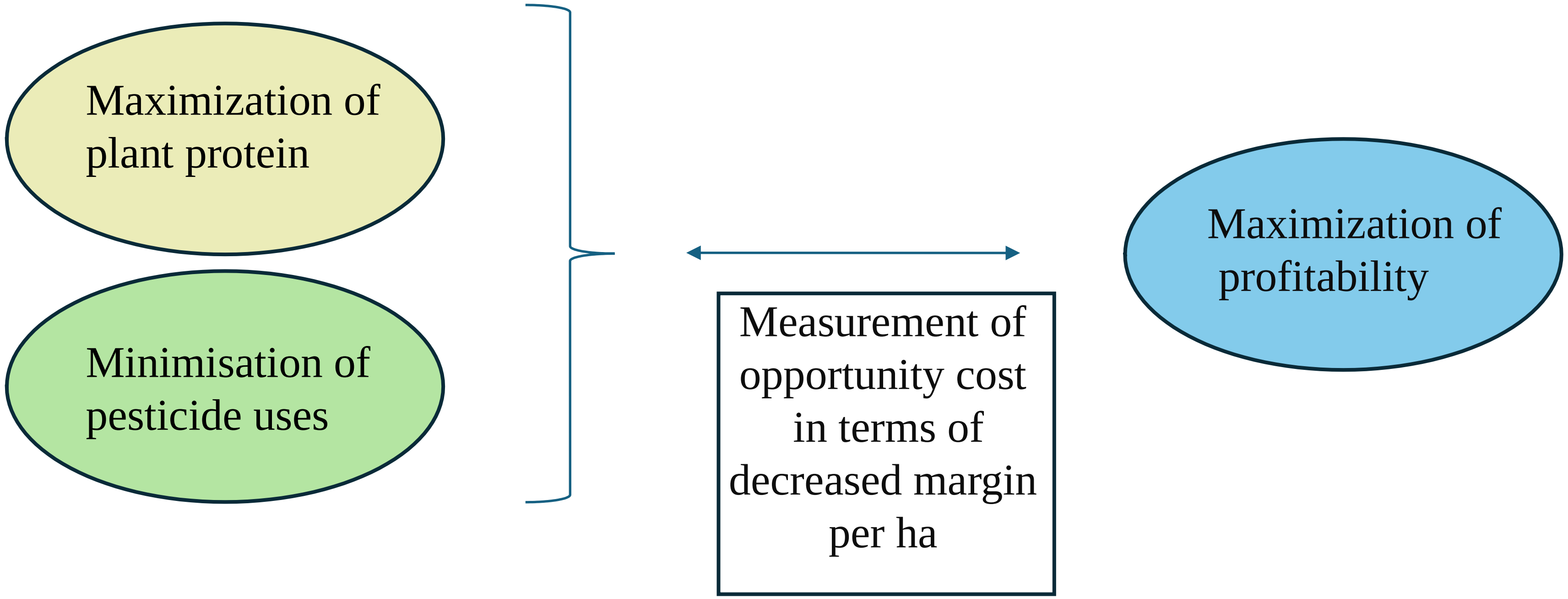
Our contribution: Assessing the potential trade-offs between profitability, protein increase, and pesticide reduction, and their impacts on income, costs, and crop diversity

Presentation Outline

- Methods
- Data
- Results
- Conclusion

I. Methods

Comparison of two scenarios with a third reference scenario



Decomposition of the margin loss on revenue and costs.
Discuss the agricultural practices underlying each scenario.

Correction of potential productive inefficiencies allowing to estimate the production frontier

Different points on the frontier correspond to various possible objectives

Different points on the frontier correspond to various possible objectives

Different points on the frontier correspond to various possible objectives

Max π

Computing the opportunity costs of choosing one objective over the other can only be done along the optimal frontier.

- The farm activity model and the production possibility set

$$T = \{(\mathbf{x}, \mathbf{y}) \in \mathbb{R}^{5\times2} : \mathbf{x} \text{ can produce } \mathbf{y}\}$$

- No free lunch
- Free disposability
- Geometrical convexity

With **x** being the input vector composed of:

- Agricultural land area in ha (AL)
- Other land areas in ha (OS)
- Labor in FTE (L)
- Intermediate consumption in € (IC)
  - Intermediate consumption without pesticides (ICWP) (fertilizer, seeds, energy, etc.)
  - Pesticide cost (P)
- Equipment, Structures, etc. in € (K)

With y being the output vector composed of:

- Quantity of protein produced in kg (y^1)
- Income from other productions in € (R^2)

- Profitability maximization scenario (Max PROF)

Methods

- Profitability, denoted , is defined, for each farm as the ratio of crop revenue to intermediate consumption .

- π^* the optimal level for profitability by adopting the same practices as their benchmark:

:

The objective function to be maximized is multiplicative

Linearization of the objective function by considering its logarithmic form:

- Benchmark estimation using the DEA method with log-linear programming

Log-linear program for the Max PROF scenario

Following Banker & Maindiratta (1986), we suggest employing a piecewise log linear technology.

 applicable to more complex production situations, thereby accommodating local nonconcavity and effectively dealing with a nonconvex production possibility set.

$$\max_{\alpha,\beta,\gamma,\boldsymbol{\mu}} \ [\overline{\alpha} + \overline{\beta} - \overline{\gamma}]$$

$$\sum_n \mu_n \overline{y_n^1} \geq \overline{\alpha} + \overline{y_a^1}$$

$$\sum_n \mu_n \overline{pp_n^1} \geq \overline{\beta} + \overline{pp_a^1}$$

$$\sum_n \mu_n \overline{R_n^2} \geq \overline{R_a^2}$$

$$\sum_n \mu_n \overline{AL_n} \leq \overline{AL_a} \qquad \text{(LP1)}$$

$$\sum_n \mu_n \overline{OS_n} \leq \overline{OS_a}$$

$$\sum_n \mu_n \overline{L_n} \leq \overline{L_a}$$

$$\sum_n \mu_n \overline{IC_n} \leq \overline{\gamma} + \overline{IC_a}$$

$$\sum_n \mu_n \overline{K_n} \leq \overline{K_a}$$

$$\sum_n \mu_n = 1$$

$$\mu_n \geq 0, \forall n \in N$$

Log-linear program for the Max PROT scenario

$$
\begin{aligned}
&\max_{\delta,\boldsymbol{\mu}} \bar{\delta} \\
&\sum_{n=1}^{N} \mu_n \overline{y_n^1} \geq \bar{\delta} + \overline{y_a^1} \\
&\sum_{n=1}^{N} \mu_n \overline{R_n^2} \geq \overline{R_a^2} \\
&\sum_{n=1}^{N} \mu_n \overline{AL_n} \leq \overline{AL_a} \\
&\sum_{n=1}^{N} \mu_n \overline{OS_n} \leq \overline{OS_a} \\
&\sum_{n=1}^{N} \mu_n \overline{L_n} \leq \overline{L_a} \\
&\sum_{n=1}^{N} \mu_n \overline{IC_n} \leq \overline{IC_a} \\
&\sum_{n=1}^{N} \mu_n \overline{K_n} \leq \overline{K_a} \\
&\sum_{n=1}^{N} \mu_n = 1 \\
&\mu_n \geq 0, \forall n \in N
\end{aligned}
\qquad \text{(LP2)}
$$

Log-linear program for the Min PEST scenario

Note that minimizing pesticides is done for the same cultivated area to constrain the optimal solution to be less pesticide-intensive.

$$\min_{\sigma,\boldsymbol{\mu}} \overline{\sigma}$$

$$\sum_{n=1}^{N} \mu_n \overline{R_n^1} \geq \overline{R_a^1}$$

$$\sum_{n=1}^{N} \mu_n \overline{R_n^2} \geq \overline{R_a^2}$$

$$\sum_{n=1}^{N} \mu_n \overline{AL_n} = \overline{AL1_a} \qquad \text{(LP3)}$$

$$\sum_{n=1}^{N} \mu_n \overline{P_n} \leq \overline{\sigma} + \overline{P_a}$$

$$\sum_{n=1}^{N} \mu_n = 1$$

$$\mu_n \geq 0, \forall n \in N$$

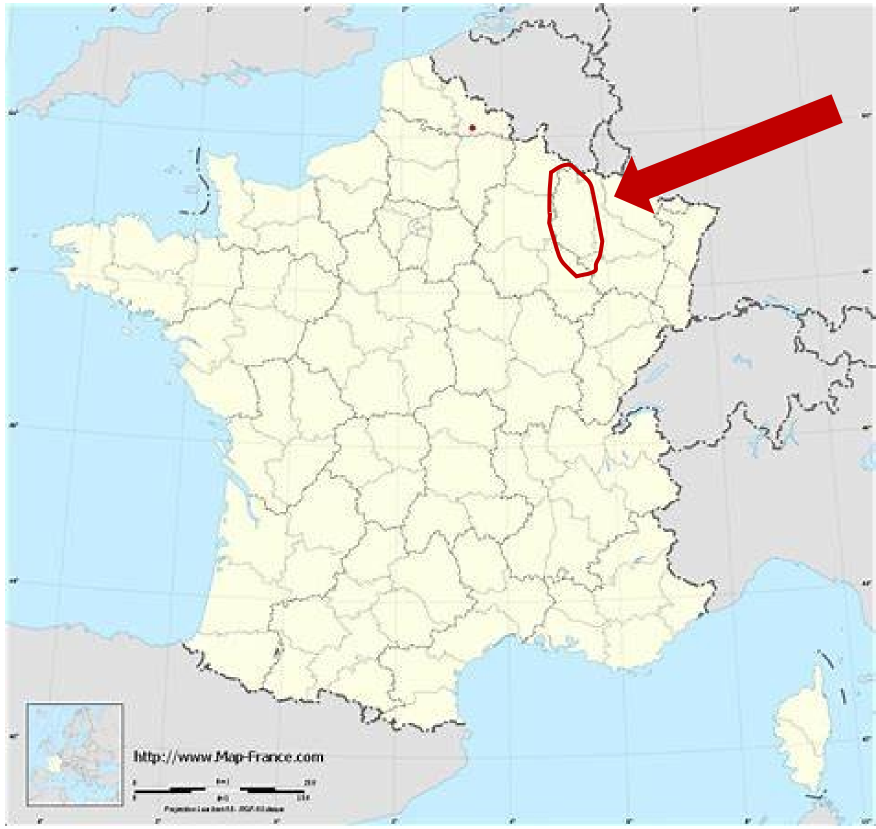
II. Data

Agricultural data from farms in the Meuse region, provided by the "Centre d'Economie Rurale et de Gestion".

Farms specializing in arable crops: wheat, winter barley, spring barley, maize, peas, rapeseed, sunflower, fallow.

- 1991-2017, on average, 107 observations per year and a total of 2900 observations.

The protein content coefficients for each crop are sourced from the Feedipedia information system (https://feedipedia.org).



Estimations are realized on yearly base.
In the following, results are aggregated over the whole period.

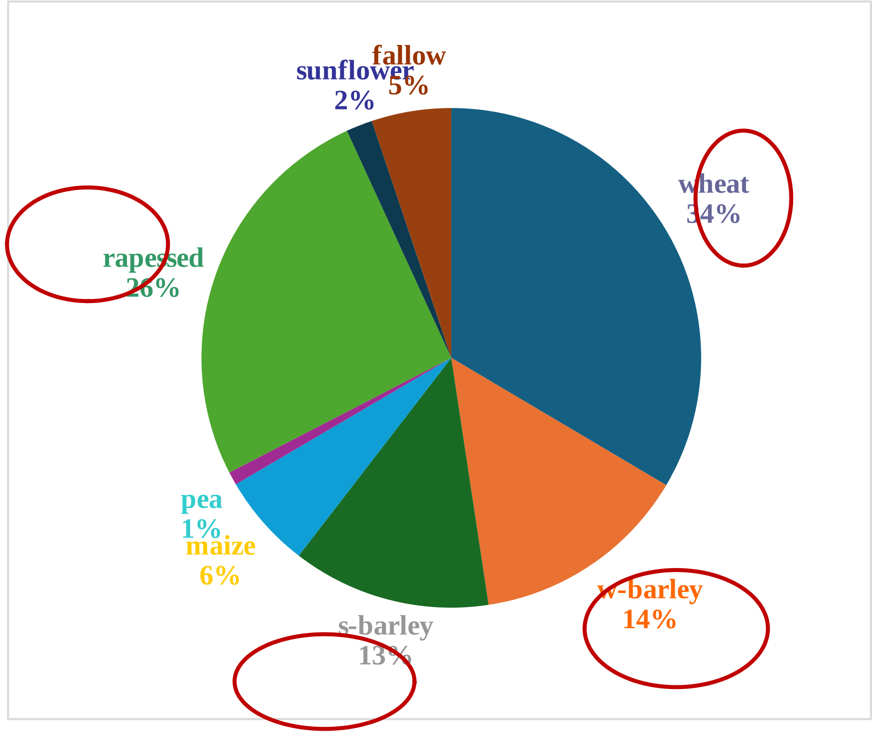
Some descriptive statistics

Data

Table 2. Descriptive statistics for all variables over the period 1991-2017 (per farm and per year)

	Mean	Min	Max	CV
Crop product (€$_{2010}$)	164,795	15,558	972,265	63%
Protein (kg of DM)	111,633	12,747	499,870	57%
Protein price (€$_{2010}$/kg of protein)	1.5	0.9	2.9	22%
Other products (€$_{2010}$)	33,464	0	256,382	91%
Arable land (ha)	176	25	708	54%
Other surfaces (ha)	28	0	183	106%
Labor	1.7	0.2	6.4	52%
Fixed Capital (€$_{2010}$)	62,842	5,776	399,321	63%
Intermediate consumption without pesticides (€$_{2010}$)	61,209	6,610	322,920	61%
Pesticide cost (€$_{2010}$)	28,985	2,484	162,582	64%
Pesticide cost/ha (€$_{2010}$)	165	45	349	27%

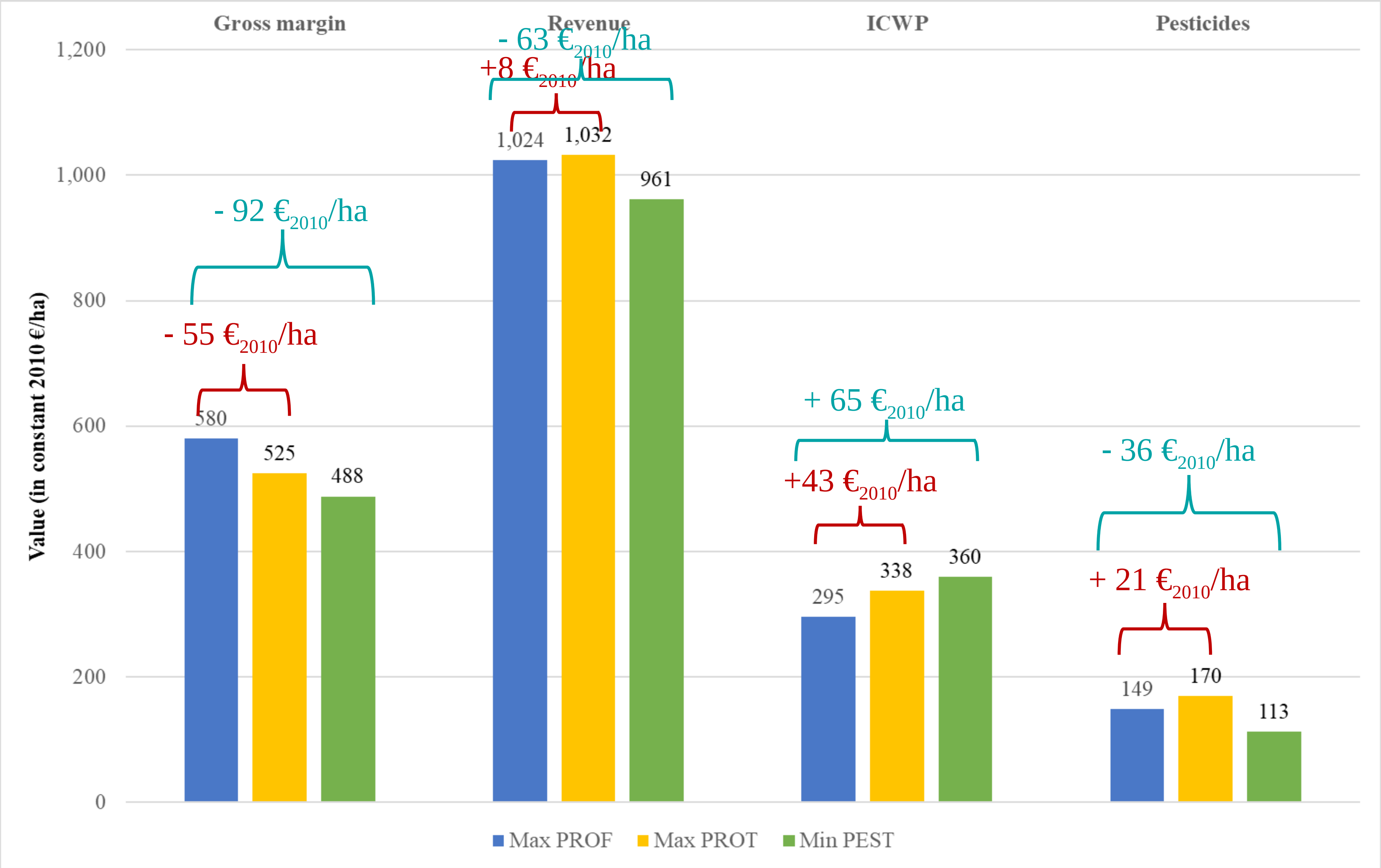
Figure 1. Shares of crops in the total crop agricultural land



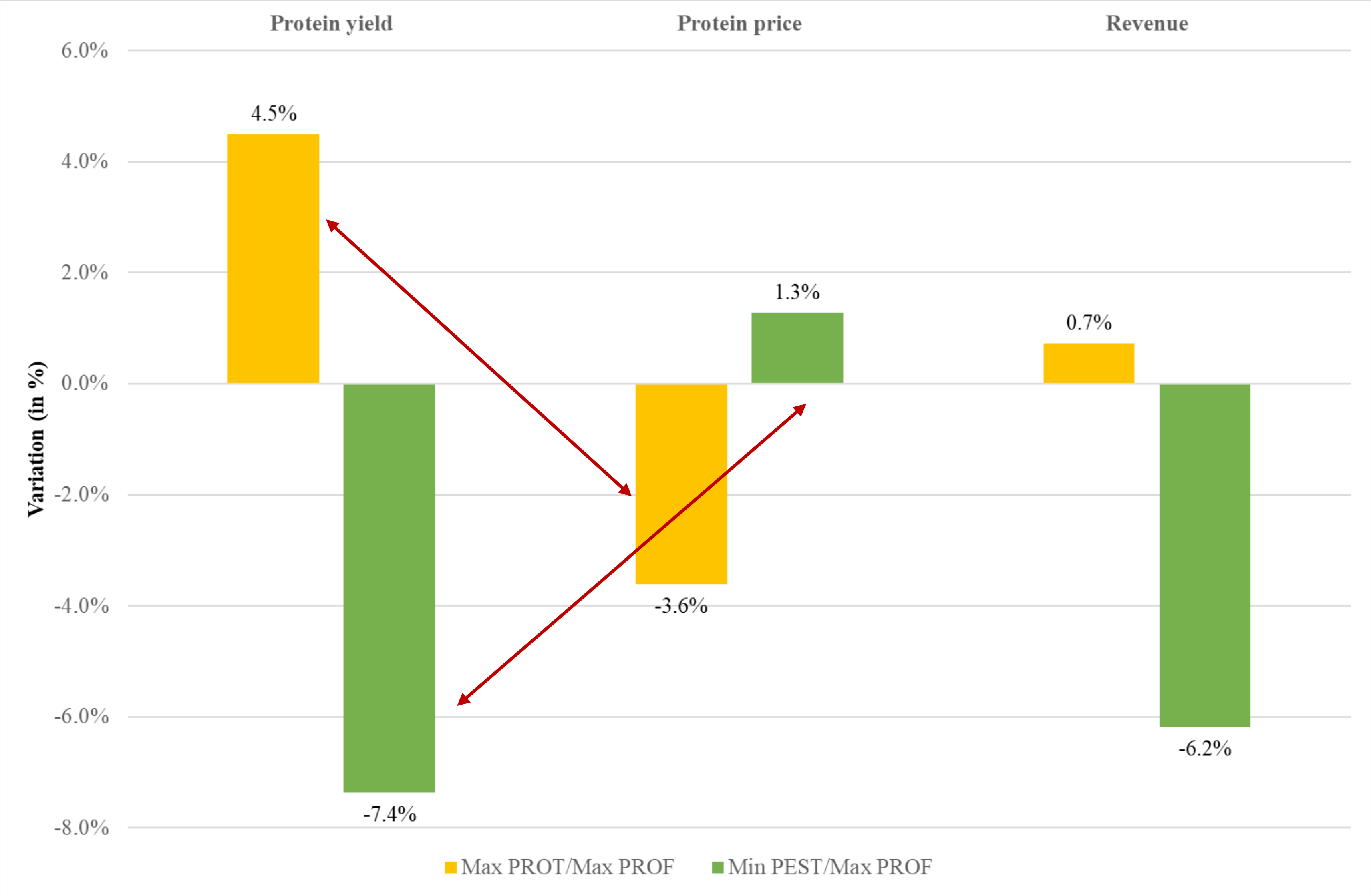
- Average farm size : 176 hectares of arable land,
- Wheat, barley (spring and winter), and rapeseed accounting for 86% of the total.
- Average pesticide use intensity is 165€$_{2010}$ per hectare

III. Results

Opportunity costs of the Max PROT & Min PEST strategies



Variation in the revenue components between the different scenarios (in %)

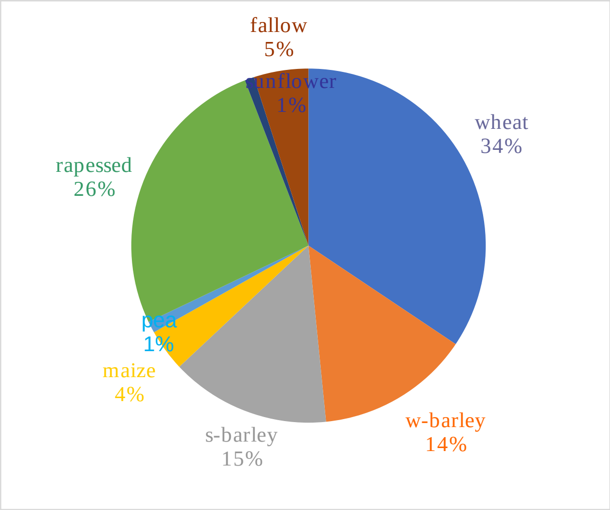


Crop diversification

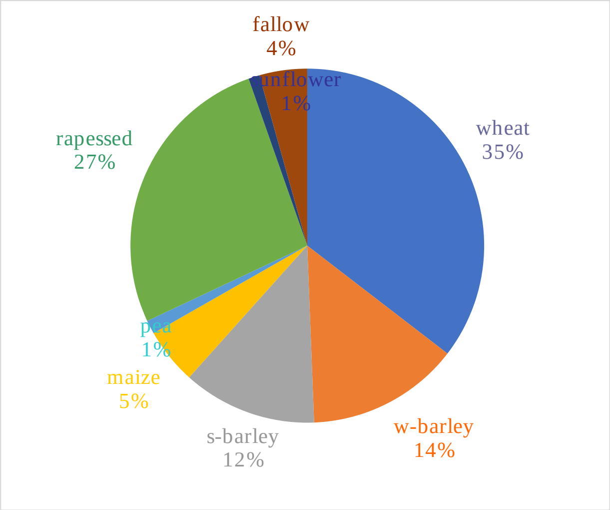
Table 4. HHI index for crop diversification at the global scale over the period 1991-2017

Observed situation	Max PROF	Max PROT	Min PEST
0.222	**0.232**	**0.236**	**0.188**

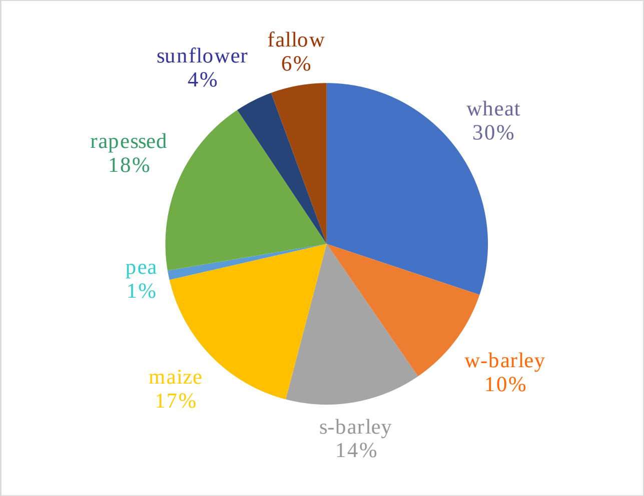
Max PROF



Max PROT



Min PEST



Pesticide minimization versus Profitability maximization

- Decline in cereals (63% 54%)
- Increase in maize (4% 17%)
- Decline in rapeseed (26% 18%)
- Increase in sunflower (1% 4%)

Max PROF ➡ **Max PROT**

⟺ + 1% in protein yields -2.12% in per ha margin

The high level of elasticity suggests that pursuing the productivism strategy can be costly for farmers in terms of losses in gross margin.

⟺ + 1% in protein yields +3,13% in pesticide cost per ha

This high level of elasticity indicates that the goal of increasing protein yields is very demanding in terms of increased pesticide intensity.

Max PROF ⟹ **Min PEST**

⟺ - 1% in pesticide cost per ha -0,66% in per ha margin

⟺ - 1% in pesticide cost -0,31 % in protein yields

Apparently, this relatively low elasticity suggests that pesticide reduction goals could be achievable without excessively compromising producers' margins and yields.

Max PROF ➡ **Min PEST**

Regulation through protein price paid to producer

→ Farmers are indifferent between Max PROF and Min PEST if protein price = 1.70€$_{2010}$ (whereas Max PROF price = 1.53 €$_{2010}$)

⬌ - 1% in pesticide cost per ha +0,45% in protein price

Conclusion

Max production quantities

Often promoted as a means to improve margins, maximizing yields seems to lead to the opposite result when compared to the profitability maximization scenario

A compensation for opportunity costs would be needed, but with which means?

- ✓ **Price increase ?** : consumers can be reluctant to pay more for low quality products
- ✓ **Subsidies ? :** governments may be reluctant due to deficits and potential consumer resistance.

Pesticide reduction policy

Relatively low opportunity cost to farmers and the downstream clients

Various mechanisms are possible within the free market to offset the opportunity costs

- ✓ **Price increase** : consumers are likely to pay a high price for products perceived as high quality
- ✓ **Restructuring of intra-industry negotiations:** for more equity between farmers and downstream partners.

Therefore, it is necessary to consider a drastic reevaluation of large-scale crop systems by exploring new disruptive practices introducing more protein-rich legumes and extending crop rotations, etc.

- Thank you very much for your attention !