N° 2-3/2011 - DECEMBER

RESEARCH IN ECONOMICS AND RURAL SOCIOLOGY

Changes in practices and possibilities for reducing pesticide use An analysis of the arable crop sector in France

In 2008, on the occasion of the "Grenelle de l'Environnement" Conference, France set itself the objective of reducing pesticide use by half within ten years. In order to answer the question of the authorities as to the feasibility of reducing pesticide use in French agriculture and reaching the target fixed by the "Grenelle de l'Environnement", the INRA and the Ministries for Agriculture and Ecology launched the ECOPHYTO R&D project. We show here the results of research carried out within that study.

A significant reduction in pesticide use requires major changes in farming practices. In order to analyse the impacts of such changes in the French arable crop sector, which represents 68% of pesticide use in France, a mathematical programming model was made. It studies the combinations of farming techniques which could achieve various levels of reduction in pesticide use and assesses the impact these changes could have on farm income and production. The results show that a 30% reduction in pesticide use could be achieved by changing the techniques used and without any major fall in production or margin (at 2006 prices). However, the 50% objective would lead to much greater falls in production and would require growth in the use of systems that are currently little used, such as integrated production and organic farming.

An approach integrating available knowledge of alternative technologies into an economic model

Pesticides are not a direct factor of production (such as water or nitrogen) but do directly influence production levels by avoiding production losses caused by climate and pests or diseases. The acknowledgement of this particularity of pesticides as an input that reduces damage has given rise to many studies by economists aiming to ascertain the effects of agricultural inputs in production functions. However, the econometric models which include this dimension use production functions and/or input-demand and product-supply function systems based on the assumption that farmers use a single production technology. This severely limits this type of model when it comes to studying the potential for pesticide use reduction by developing the technologies that are used (Carpentier, 2010). In this case, models based on mathematical programming represent an alternative approach in that they can take account of various technologies, including technologies that have not yet been adopted, and can simulate the effects of large changes to the economic context on production and technical choices. Until now, approaches of that type were applied to analyse the adoption of new techniques on individual farms or in small areas. The originality of our work is to apply this type of model to the whole of French arable crop farming. The main difficulty lay in finding and processing knowledge on technologies that allow a reduction in pesticide use from a variety of different sources (experimental data, reference farm networks, expert knowledge…). The definition of references for the techniques currently used by farmers and for techniques still at the experimental stage was carried out on the basis of expert opinions. Data was aggregated on the basis of the French FADN network and the "Arable crop agricultural practice survey" carried out by the Statistic and Prospective Department of the Ministry for Agriculture.

An inventory of pesticide use in arable farming in France and of potential or existing technologies

An inventory of pesticide use by crop and by region was carried out using the joint data of the "agricultural practice" survey and the French FADN. Fourteen crops or groups of crops were determined covering the whole French cropping plan. A specific regional division was determined for each crop and then data were re-aggregated into 8 regions. For each crop and region, a phytosanitary pressure was calculated in the form of a treatment frequency index (TFI), as were yield and gross margin per hectare (based on product price and expenditure per hectare on seeds, fertilizers, crop-protection products and fuel) and other indicators of potential impact on the environment (energy consumption, nitrogen assessment).

Five technologies ranging from those requiring the most use of pesticides (intensive agriculture, T0) to those using no man-made products (organic agriculture, T4) were determined per crop and region. The T0 technique corresponded to observed practices (on the 30% of plots using the most pesticides for a given production), while techniques T1 to T4 were defined by expert opinion based on many sources of information: scientific knowledge, surveys, farm networks and experiment results. The various technologies were as follows:

- T0: Intensive agriculture. Sub-population of the 30% of the plots with practices consuming the most pesticides.
- T1: Sustainable farm management. Thinking each action through on the basis of observations and beginning treatments when thresholds are reached.
- T2: Agriculture with low use of pesticides. On a given crop, implementation of a strategy relying on a coherent combination of non-chemical control methods and chemical means in order to avoid turning to pesticides. "Rustic wheat" is an example of that strategy.
- T3: Integrated agriculture. The previous techniques plus crop sequences and crop rotations with long cycles to help avoid some of the biological attacks.
- T4: Organic farming.

Except for the intensive technique (by definition) and for organic farming which represents 1% of French arable crops, it was not possible to quantify the precise current weight of these various technologies as a proportion of French production, even though French farmers do use techniques that come close to them.

The first step consisted in comparing the performances of these various technologies. The performances by crop and by region were aggregated for the whole of France on the basis of the regional crop data observed in 2006 and French FADN data. Several limits of the work must be pointed out at this stage: the technologies relating to integrated agriculture (T3) and to organic farming (T4) were constructed using fragile data; the prices were exogenous and did not take account of the impact a fall in production could have on agricultural prices. Finally, the results were mainly based on 2006. Table 1 presents the main results.

Table 1: Results of various techniques at 2006 prices, for whole France, in the arable crop sector

	FTI	Production	Gross Margin
		€/ha	€/ha
Current Level	3.8	891	482
T0	5.4	933	455
T1	4.0	917	498
T2	2.5	834	480
T3	1.9	785	460
T4 Organic farming prices	0.2	581	341
T4 Other product prices	0.2	651	272

Source: Jacquet et al., 2011.

Several remarks can be made:

-On average, the best margins were achieved by sustainable farm management (T1). Compared with intensive farming (T0), for an equivalent yield, it offers savings by making less use of inputs.

- At 2006 prices, the difference in margins between sustainable farm management (T1) and farming with a low-level of inputs (T2) was rather small (it would not be the same with 2007 prices).
- In integrated agriculture (T3), income per hectare decreased compared with the

previous groups, not because of a fall in yield but because of the necessity to introduce less profitable crops (peas, alfalfa and sorghum) into the systems.
- Gross margins were low in organic farming (T4) even when we took account of the higher prices of organic farming products (the last line but one in Table 1).

This first approach which supposes that all French arable-crop production uses one technology or another presents the drawback of not taking account of the various performances of different techniques for different crops and according to regional soil and climate conditions. It only partially answers the question of whether the objectives set by the authorities to reduce pesticide use can be reached.

A mathematical programming model to simulate changes in techniques

In the second stage, a model was built for the whole of France broken down into eight regions. Built by mathematical programming, the model maximized the gross margin per region, subject to soil and cropping pattern constraints. It helped to determine the choices of technique, for each crop and region, which enable the expected levels of pesticide reduction to be achieved, and then simulate the impact of economic incentive measures such as pesticide taxation or subsidies for techniques using little pesticides.

As attention was focused on changes of techniques, the model only addressed the question of changes in crop rotation when they were one of the technological aspects studied. Since T1 and T2 do not require any modification in crop rotations compared with the intensive techniques T0, we maintained the same land areas of the various crops for these technologies as those observed in 2006. On the other hand, for technologies T3 and T4 which rely on changes in the technical approach and in crop rotations (and therefore in cropping patterns), these modifications were taken into account in the model. The model gives the area cultivated for each technique and crop per region and therefore shows the weight of the technique, of crop rotations, production and margins per region and for France as a whole.

The first result was that the optimised situation as defined by the model deviates from the observed situation. On the 2006 price basis, the model gave a solution in which the areas dedicated to intensive techniques (T0) did not represent more than 6% of total areas, against the figure of 30% of the area in the observed data (see table 2). Phytosanitary pressure (TFI) dropped by 9% compared with the initial situation, in spite of a 1% rise in global production and a 5% rise in margins of 26€ per hectare.

Table 2: Comparison of the model results and observed situation (2006 prices)

	Observed	**Model Results**
TFI	**3.79**	**3.44**
Production (€/ha)	891	900
Gross Margin (€/ha)	485	511
% of the cultivated areas		
T0	30 %	6 %
T1		59 %
T2		36 %
T3		
T4	1 %	

Note: The current weights of techniques others than T0 and T4 are not known. The model results cannot be compared with the observed situation.

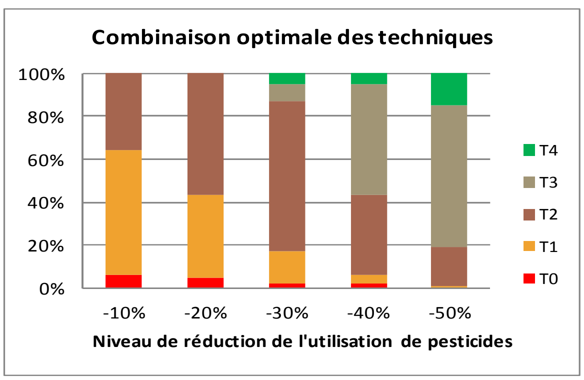
First of all, these results can be explained by the fact that, for most of the crops, the margins obtained by intensive agriculture (T0) are smaller than those with sustainable farm management (T1). Most of the time, sustainable farm management techniques allow yields to be kept to the same level while using a smaller quantity of inputs. This result would therefore not be modified in a context when farm prices were higher than 2006 prices. Furthermore, in the solution in the model, the weight of sustainable farm management (T1) is 59% and the weight of the low-input technique (T2) 36%. The economic interest of reducing inputs (T2) compared to sustainable farm management (T1) depends greatly on farm produce prices, as the reduction in input quantities tends to go hand in hand with a fall in farm yields. Therefore, the respective proportions of the T1 and T2 techniques in the solution of the model depend on the relative prices of farm produces and inputs.

This gap between the model solution and the observed situation raises the question of why the techniques requiring lesser inputs (T1 and T2) are not adopted more widely by farmers. The studies in micro-economics and sociology carried on these aspects propose several sets of hypotheses. Some of them relate to farmers' individual preferences, particularly to their risk aversion, others to learning and training (non-monetary costs linked to the adoption of new techniques) and finally to the guidance and advice available to the farmers; some studies particularly analyse the guidance given by crop-protection firms. The introduction of these hypotheses into the model would show the determinants of adoption of new technologies by farmers more clearly.

Which combination of techniques could reach the objectives of pesticide reduction set for France?

A first potential use of the model consists in gradually introducing a constraint on the desired pesticide use reduction level down to the 50% objective. For each level, the result gives the optimal combination of the techniques corresponding to the various choices, according to the regions and crops.

Figure 1: Technology mixes to reach various levels of pesticide use reduction in French arable crops



Source: Jacquet et al. 2011

This exercise shows that up to a 30% reduction, a substitution between the production technique with low inputs (T2) and sustainable farm management (T1) is enough to reach the objective. Beyond that threshold, it is necessary to have an increase in integrated agriculture (T3) and organic farming (T4), the weights of which must respectively reach 68% and 13% to achieve the objective of a reduction of pesticide use by half (see figure 1). For a 20% reduction objective, the current level of production remains almost constant. On the other hand, it falls by 12% when pesticides are cut by half. Margins hold up better and fall by 5% for the 50% objective (see table 3).

Which economic incentives: tax and/or subsidies?

A second use of the model consists in inducing a substitution between techniques through the introduction of a tax on pesticides which acts by modifying their prices and/or a subsidy for technologies helping to reduce pesticide use.

In a taxation system, tax receipts may be totally redistributed to farmers in an inclusive way (proportionally to the number of hectares farmed). Taking into account low pesticide value in relation to that of the product, the taxation level given by the model proves to be very high: it is 100% to reach a reduction of 30% in pesticides and 180% for an objective of 50% (see table 4). The margins made by the various techniques are affected by that system in different ways. Organic farming is subsidized indirectly since it does not pay any tax but benefits from redistribution.

In terms of production levels, average national gross margin and surface area distribution between various technologies, the overall results are almost equivalent to those previously presented. For instance, for a 50% objective, the gross margin per hectare falls by 30% before redistribution but returns to the same level (-5%) as in the previous exercise after redistribution. The neutrality of this system on overall results must be placed in perspective by the fact that it does not take account of any tax management costs.

Table 3: Effects on margins and production volumes of a combination of techniques allowing a gradual reduction in FTI.

	Situation		Reduction rate in pesticide use				
	Observed	**Optimized**	**-10 %**	**-20 %**	**-30 %**	**-40 %**	**-50 %**
At 2006 prices							
FTI	100	91	90	80	70	60	50
Production	100	101.0	100.8	99.1	96.0	92.5	87.7
Margin	100	105.3	105.3	105.2	103.7	100.3	95.4

Source: Jacquet et al., 2011.

Table 4: Effect of a tax system with inclusive redistribution of tax revenues

	Situation		Reduction rate in pesticide use				
	Observed	**Optimized**	**-10 %**	**-20 %**	**-30 %**	**-40 %**	**-50 %**
Tax rate	0 %	0 %	0 %	16 %	101 %	138 %	182 %
Production	100	101.0	101.0	99.2	95.8	92.7	88.2
Margin before re-distribution	100	105.3	105.3	101.7	84.2	77.4	70.6
Margin after re-distribution	100	105.3	105.3	105.2	103.4	100.1	95.0

Source: Jacquet et al., (2011)

One of the *"Grenelle de l'Environnement"* objectives was also to bring the proportion of organic farming up to 20%. The previous mechanism (taxation with even redistribution) did not specifically encourage that objective, except at very high taxation levels. The model determines the various combinations between taxes and subsidies that can achieve that objective. A subsidy of €140 per hectare for organic farming coupled with a 58% tax achieves the 20% objective of organic farming land (by cutting pesticide use by 40% overall). That objective can also be reached thanks to a subsidy of €180 per hectare coupled with a 38% tax, but in such a case, tax receipts are insufficient to finance the subsidy. The limits of the data on organic farming and the non-consideration of the costs of switching between systems mean that these figures should be taken with caution. However, they do illustrate the idea that a combination of additional public incentives may be judicious in this case.

Cutting pesticide use is possible thanks to ambitious policies and support for farmers

Cutting pesticide use and, more generally, developing cropping systems that allow a better response to sustainable development issues, implies starting by the observation that such progress requires technological leaps involving changes in practices, not only for farmers but also for all the agents downstream and upstream. As regards farmers, there is no technological continuum between conventional agriculture and organic farming, but there are various intermediate technologies the adoption of which can provide a break with existing practices. When looking into the economic assessment of the aggregate impacts of these changes, this requires us to use approaches to modelling that are different from the usual econometric methods.

There are several lessons to be learned from this study. Techniques with low-levels of inputs could help cut pesticide use by about 30%. On the other hand, generalisation of the integrated agriculture and organic farming methods would be necessary to reach a reduction in pesticide use by half, implying much greater changes and, in the present state of knowledge, losses of production volume. Encouraging such changes requires a quite ambitious approach. Our study shows that to be effective, taxes must be set at a sufficiently high level. But we also show that a combination with other economic incentives, in particular with subsidies in favour of economical techniques, can help reduce the amount of the tax to a more acceptable level. It must be kept in mind that to allow the adoption of techniques which are a sharp break with those currently applied by farmers, other dimensions of public policies are essential, particularly in risk management, training and counselling. Finally, because the systems using the least pesticides imply the introduction of changes in cropping rotations, to be economically viable on a large scale they require new outlets for their new output on the market, and therefore changes in the downstream chains for farm produce.

In terms of research paths, this work illustrates the interest of taking account of the diversity of production technologies in the economic models, and calls for economic modelling methods to be developed that can include the agronomic dimensions of input-output connections in the analysis and enhance knowledge of farmer's behaviour when changing their production practices.

Florence Jacquet (corresponding author), INRA, UR1303 ALISS, F-94200 Ivry sur Seine, France. fjacquet@grignon.inra.fr;
Jean-Pierre Butault, INRA, UMR 210 Economie Publique, F-78850 Thiverval-Grignon, France. butault@nancy-engref.inra.fr;
Laurence Guichard, INRA, UMR 211 Agronomie, F-78850 Thiverval-Grignon, France. Laurence.Guichard@grignon.inra.fr

For further information:

Carpentier A. (2010). Economie de la production agricole et régulation de l'utilisation des pesticides. Une synthèse critique de la littérature, Colloque SFER *La réduction des pesticides agricoles, enjeux, modalités et conséquences*, 11-12 mars 2010, Lyon, France, 48 p.

Butault J.P., Delame N., Jacquet F., Rio P., Zardet G., Benoit M., Blogowski A., Bouhsina Z., Carpentier A., Desbois D., Dupraz P., Guichard L., Rousselle J.M., Ruas J.F., Varchavsky M. (2009). Analyse ex ante de scénarios de rupture dans l'utilisation des pesticides, In *Ecophyto R&D. Vers des systèmes de culture économes en pesticides. Volet 1. Tome VI*, 90p. http://www.inra.fr/l_institut/etudes/ecophyto_r_d

Jacquet F., Butault. J.P., Guichard L. (2011). An economic analysis of the possibility of reducing pesticides in French field crops, *Ecological Economics*, 70 (9), 1638-1648.

Publishing unit: Editorial Director: Bertrand Schmitt– Editor: Sophie Drogué (Chief Editor),
Translation and composition: Ariel Gille