Ecophyto R&D

Which options to reduce pesticide use?

January 2010

Pesticides at the crossroads of society's concerns and scientific issues

During the past 50 years, the use of pesticides has enabled yields to be significantly increased and production to be better regularised. However, new awareness of the ecological and health impacts of pesticides has made the question of their use a central issue in agriculture and in the environment. This trend has already led to a gradual decrease in their use by some farmers and to changes in relevant government policies. Not only have criteria for pesticide registration been reinforced, there has been a growing demand for evaluation and regulation on their use. At European level, this has resulted in particular in the "Pesticide Package" and in France in the Interministerial Plan for the Reduction of Risks linked to Pesticides (PIRRP) and the Environment Round Table (*Grenelle de l'Environnement*).

Stimulated by this context, and impelled by the need to ensure that agriculture plays a central role in sustainable development, agricultural research has gone beyond investigating alternatives to pesticide use (such as biological control) to focus increasingly on low-input agricultural production methods that require an integrated approach to production systems. This dynamic is widely shared by players in R&D[1] at European level, as testified by the ENDURE Network of Excellence.

Research has also been recruited by governments to clarify the orientations of their policies regarding pesticide use. Thus, in response to a commission from the French Ministers for Agriculture and the Environment, INRA and CEMAGREF (a Public Agricultural and Environmental Research Institute) published a Collective Scientific Expert Report (ESCo) in 2005 that reviewed the most recent data on the conditions of pesticide use in agriculture, and the methods available to reduce this use and limit its environmental consequences. This expert report highlighted the necessity of reducing pesticide use in order to control the resulting environmental contamination. Based on a limited number of examples published in the literature, it also showed how it would be possible to develop cropping systems that could produce satisfactory agronomic results despite a marked reduction in chemical treatments.

Ecophyto R&D: an original study on the feasibility of a reduction in pesticide use

The French Ministers for Agriculture and the Environment consequently commissioned INRA to carry out the Ecophyto R&D study. This was designed to better understand the performance of low-pesticide input systems, to evaluate the potential results of their generalisation in France and design methods for their development and dissemination. Unlike a scientific expert report, this study was intended to exploit not only the academic literature but also all other referenced data available, such as articles in technical journals, trial results and reports, and to supplement them if necessary with input from qualified experts.

In parallel, the Environment Round Table (*Grenelle de l'Environnement)* marked a new step in government decision-making relative to pesticides, and led to development of a plan aimed at achieving a 50% reduction in pesticide use within ten years, "if possible": the Ecophyto 2018 plan. This plan fits in the European framework: the Directive of 21 October 2009, which aims to achieve pesticide use compatible with sustainable development, indeed requires Member States to adopt such national action plans. These plans must target a reduction in the risks and effects of pesticide use on human health and the environment. They must also implement the principles of integrated crop pest management as from 1st January 2014, the purpose being to reduce dependence on pesticide use.

The Ecophyto R&D study was therefore pursued and completed in this context where both French and European policies were strenghtened. Its objectives were refined in the context of the Ecophyto 2018 plan:
- firstly, to generate country-scale scenarios for reduced use based on agronomic, economic and environmental indicators, and to analyse the strategies of stakeholders concerned by the resulting changes in practices, in order to inform decisions regarding potential implementation of this 50% target;
- and secondly, to design a system for the production, management and dissemination of experimental data on low-pesticide cropping systems that will favour their adoption by farmers.

[1] Research & Development

Appropriate organisation guaranteeing the quality, independence and transparency of the study

Particular attention was paid to organisation of the study in order to ensure conditions that would guarantee the optimum quality, independence and transparency of the technical expert report and appropriate interactions with the different stakeholders concerned.

The study strategy was approved and monitored during its implementation by a Management Committee made up of and jointly chaired by representatives from the Ministries commissioning the study.

INRA was in charge of the technical conduct of the study, mobilising some 80 experts from the Institute and from academia, agricultural development agencies and technical experts from the relevant Ministries, who in turn consulted external experts whenever necessary. The experts, chosen for their personal competencies, worked in groups managed by INRA scientists. Eight groups were thus constituted: "Methods", "Cropping systems" ("Arable", "Vegetables", "Grapevines", "Fruit orchards"), "Scenarios", "Player strategies" and "Networks".

Finally, a Steering Committee brought together representatives of all stakeholders: professional organisations, actors in agricultural development, associations, regional government bodies and the Government. This committee met quarterly for updates and debate on progress of the study. The Chairman of this Committee, a personality independent of INRA and the commissioning ministries, ensured general compliance with the duties of each body, with the conditions prevailing for debate and the clarity of the responses provided, and the criticisms and controversies raised by the objectives and content of the study.

Methodological choices

Identification of crop management profiles and the notion of "cut-off" levels used to analyse practices

Pesticides are not a direct means of production but they are used to prevent losses in the context of crop protection strategies associated with yield targets and a series of cultivation practices. For this reason, analysis of the quantities of pesticides employed requires definition of the levels of use that correspond to different crop management profiles. So in the study, profiles involving a change in the plant health protection strategy compared to intensive agriculture were considered as "cut-off levels". In order to evaluate the potential scope for change, they were compared to:
- N0, corresponding to the most intensive use of pesticides under a strategy of systematic plant protection using chemical control. For a given crop and in cases where this strategy is applied, this was the benchmark used by agronomists;
- NA, corresponding to the current situation in France. This was the benchmark used to determine reductions in national scenarios.

The cut-off levels used throughout the Ecophyto R&D study were determined for the four types of cropping systems considered, and then adapted to crop characteristics (annual, perennial, etc.) and the alternative measures available.

The "cut-off" levels studied

Abbre-viation	Level of pesticide use on a farm	Name chosen
NA	Current situation	Current average level
N0	No restrictions on pesticide use	Intensive farming
N1	Restrictions on pesticide use by managing treatments according to intervention thresholds	*"Agriculture raisonnée"*
N2a	N1 + implementation of prophylactic and alternative methods at the (annual) scale of the management plan of <u>one</u> crop in the rotation	Integrated protection
N2c	N1 + implementation of prophylactic and alternative methods at the (multi-annual) scale of the crop sequence	Integrated production
N3	Implementation of organic farming specifications (ban on any treatments using synthetic pesticides)	Organic farming

The Treatment Frequency Index (TFI) as an indicator of pesticide pressure on the environment

The indicator retained to evaluate pesticide pressure was the TFI, which reflects the annual equivalent number of pesticide full doses applied on a crop. For each treatment, it is calculated by adding together the ratios between the dose of product applied and its approved dose. The TFI was thus calculated for each type of product: herbicides, fungicides, insecticides and "other pesticides". This indicator made it possible to evaluate mean pesticide pressures for mainland France, and to compare cropping systems according to their pesticide dependence. On the other hand, it was not possible to integrate information on the toxicities of each product and the risks inherent in their environmental dissemination. Thus Ecophyto R&D was not able to shed any light on the potential environmental or health impacts of changes in practices.

The necessary mobilisation of expert input to consolidate disparate and incomplete data

In terms of knowledge on current crop protection practices, the arable and viticulture sectors benefited from the "Cropping Practices" surveys that had been carried out by the SSP[2] in 2006, producing statistically representative data that provided a robust diagnosis of the situation. Unfortunately, similar reference data were not available for the orchard and field vegetable crop sectors.

The characterisation of the performance of integrated management systems (N2a and N2c), not very widely implemented by farmers at present, was supposed to use experimental data from trials performed by agricultural research or development agencies. An inventory of experimental projects concerned with this "level 2" listed 87 trials for arable crops, 33

[2] Statistics and Foresight Department (*Service de la Statistique et de la Prospective*), French Ministry of Agriculture

for fruit orchards, 9 for viticulture and 36 for vegetable crops. In addition to the unevenness of data on the different crops and cropping conditions covered by these trials, the information produced proved to be dispersed and disparate. Not only was it difficult to apply and exploit because of a lack of common or compatible data management tools, overall there was insufficient information. This inventory revealed that studies on crop protection tended mainly to focus on analytical references, where multiannual evaluations of the consequences of pesticide savings and impacts on economic and environmental results were generally scanty, or even nonexistent. In most cases, the approaches used to study reductions in pesticide use were based either on the reasoning of product use or on their substitution by another technique. So these not very integrative approaches only provide a limited opportunity at present for experiments designed to modify systems and render them less susceptible to pest attack.

This heterogeneity of available reference data meant that work by the "Cropping systems" expert groups proved difficult and complex, as they needed to evaluate the different cut-off levels by determining TFI values, yields, charges and gross margins according to crop-specific zoning, so that scenarios could be constructed for pesticide reductions. So to supplement the survey and trial results available, these working groups found it necessary to call upon expert advice. The experts were asked to evaluate the extrapolation of experimental data, assess the performance of combinations of known "elementary" techniques or design crop rotations adapted to integrated production (level N2c), based on the practices of organic farming. The contribution of expert advice and its associated uncertainties increased in line with the ranking of cut-off levels, from N1 to N2c, even though collective analysis enabled the crossover of expert viewpoints so that the results would be as robust as possible.

A simulation for an average year (2006) with respect to direct agronomic and economic effects

The experts characterised the current situation regarding pesticide use, and evaluated the effects of their reduced use, by retaining 2006 as the baseline year, for which national statistical data on cultivation practices were available. 2006 displayed "average" characteristics in terms of climate, pest pressure and prices, but in fact the choice of a single reference year for most simulations was a limiting factor. It did not allow them to study the effects of climatic, health or economic variations over time, nor the notion of risk and its implications regarding crop protection practices.

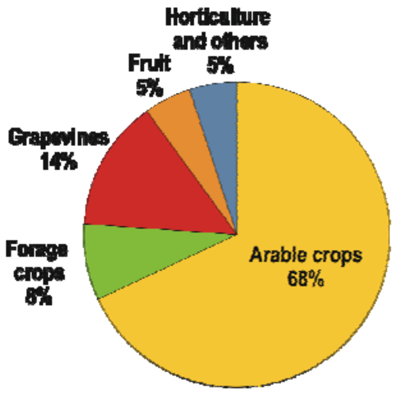
The agronomic and economic effects of a reduction in pesticide use were evaluated by considering the unchanged context. No account was taken of any indirect effects (for example on pest pressure or on the markets for agricultural raw materials), or of the introduction of technological innovations likely to modify the methods used to ensure crop protection. The Ecophyto R&D study should therefore not be considered as a foresight study nor, clearly, as a forecast, regarding the changes anticipated and the rate at which they will occur. Nor are these scenarios of any value at a local or farm level. Their usefulness is national, although based on indicators that must be qualified as somewhat rough and ready.

Based on the data available, pesticide use appears to vary, but potential advances have been identified

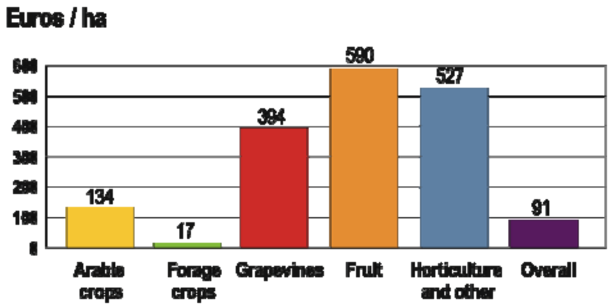
The results of this study throw new light upon the issue of pesticide use and the options that can be envisaged to reduce it. Situations appear to vary considerably, according to the main types of cropping systems considered (arable crops, viticulture, fruit orchards and vegetable crops) and the major regions of mainland France. Differences were observed at several levels, notably pesticide use, the existence, diversification and efficiency of alternative strategies to reduce this use, and the existence and availability of useful data to assess these strategies.

Pesticide use in 2006

According to the Farm Accountancy Data Network (FADN), expenditure on pesticides by professional farmers reached €2.3 billion in France in 2006. Two-thirds of this expenditure went on arable crops (not including field vegetables), 8% on forage crops, 14% on grapevines, 5% on fruit orchards and 5% on horticulture and field vegetables.

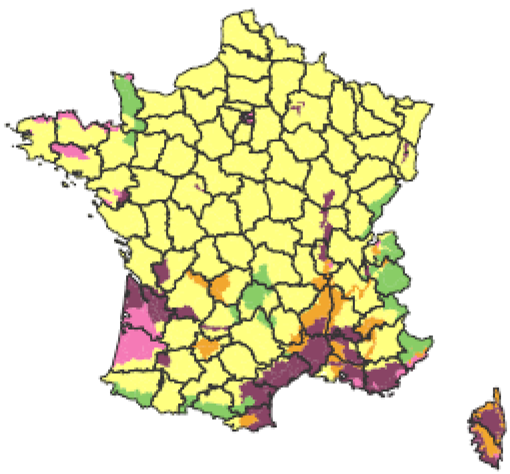


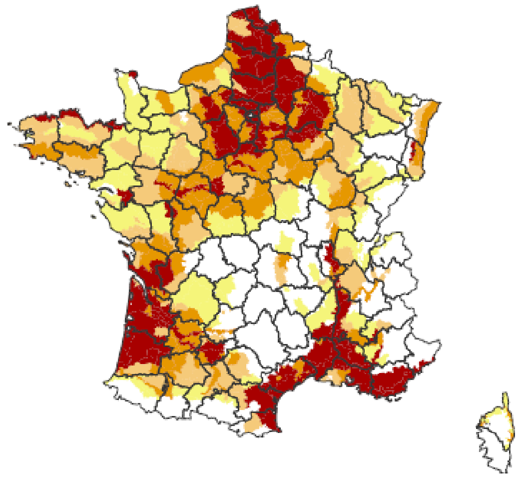
For arable crops, the mean TFI was 3.8 and pesticide expenditure reached €130/hectare; these values corresponded to the costs applicable to wheat. However, pesticide use varied not only according to the crops but also between species (see below).



Spatial analysis of the data confirmed the predominance of arable crops in agricultural expenditure on pesticides in most small agricultural regions of mainland France. However, other crops appeared to be the source of the highest pesticide use at local level. This was the case for all wine-producing areas, and regions specialised in fruit production (notably apples) or horticulture and field vegetables. Major arable regions in northern France were also subject to the greatest pressure. Grassland regions were those with the lowest pesticide pressure.

Breakdown of small farming regions according to the source and level of pesticide pressure (pesticides per hectare)





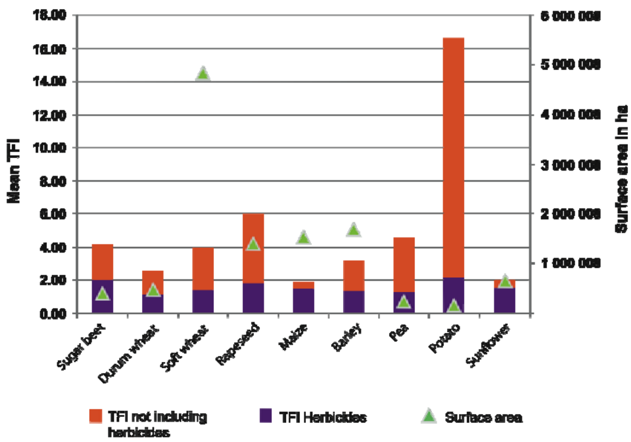
Source: INRA

Leeway available to farming to reduce pesticide use on annual crops

Arable crops accounted for most land and pesticide use (around 75% in 2006, including forage crops). Mean total TFI values ranged from about 2 for maize and sunflower to 16.7 for potato. However, herbicide TFI values were highly comparable.

There seemed to be considerable leeway, although it varied according to species. It was estimated with reference to intensive farming and not compared with the current statistical situation, because insufficient data were available to describe the distribution of different cut-off levels.

Mean pressure of pesticide use (TFI for herbicides and not including herbicides) and cultivated areas (land use in 2006) for the nine arable crops studied



Sources: SSP data for 2006 (TFI) and Agreste 2006 (land areas)

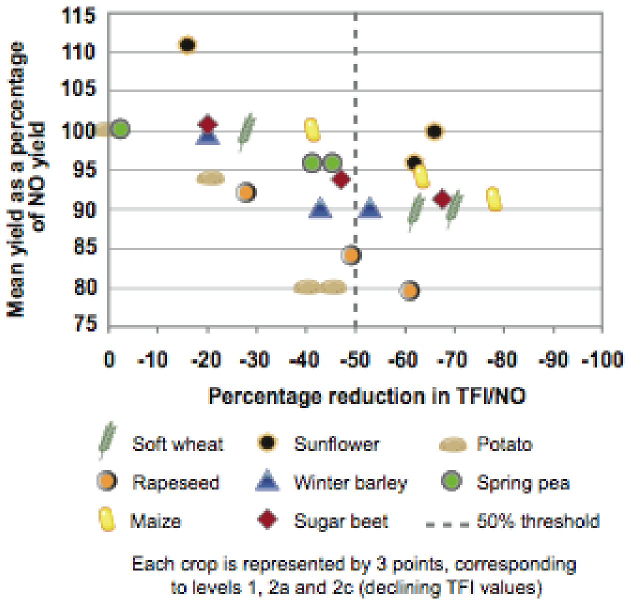
Improved pesticide application management, based on the widespread use of existing decision support tools and field observations (N1), can lead to average reductions in pesticide use of between 3% (pea) and 40% (grain maize), depending on the crops, when compared with intensive management (NO), in most cases without affecting production levels.

Even greater reductions would be possible by going beyond the logic of input optimisation and applying principles of farming management that represent a true "cut-off" in the practices and references employed (N2a and N2c). More or less profound modifications to population characteristics (date and density of sowing, choice of cultivars, etc., for N2a) and also rotations (N2c) make it possible to reduce risks of pest proliferation and weaken their effects on yield and quality. TFI values would be considerably reduced: on average, depending on the crops, from 37% to 62% under N2a, and from 45 to 76% under N2c, when compared with intensive management N0. Herbicide TFI values could only be reduced significantly by adapting crop sequences (N2c). In most crops, the results demonstrated the maintenance or increase of gross margins by comparison with intensive management in the context of 2006 prices. However, levels 2a and 2c raised the question of total production volumes (at a national level) and, more specifically for N2c, that of land use and the organisation of sectors (valorisation of diversification crops introduced into rotations).

Beyond this overall picture, it should be noted that the effects of integrated crop protection management (N2a) or integrated production management (N2c) differed according to crop type. Thus:

- for all cereals, a 50% reduction in the TFI would be achieved under N2c management, except for barley where this occurs as early as N2a;
- for potato and pea, the TFI reduction never reaches 50%, even in the context of N2c management;
- rapeseed and potato were the crops whose yields were the most markedly affected (reductions of 15% and 20%, respectively) by low-input management methods, which is indicative of their high susceptibility to different pests.

Reductions in TFI and associated yield performance
(difference from values under N0 management)
for eight major crops



For **vegetable crops**, the analysis made by the experts was markedly penalised by a lack of statistical data on current practices and the small number of experiments that have actually tested low pesticide cropping systems. This situation is partly due to the great diversity of vegetable species cultivated, their production methods (open fields, cold covered crops, soil-less culture in a greenhouse, etc.) and the different management techniques that are possible.

Experts in the sector considered that, faced with the poor image of pesticides and the lack of approved treatments against certain pests, producers already implement numerous non-chemical methods: the use of resistant cultivars, plastic sheeting on the soil to protect against weeds and various pests, biological protection (mainly under shelter), etc. It was not possible for them to estimate any TFI values, yields and economic indicators for the principal species. Vegetable crops were therefore not included in the scenarios built at the national scale.

Leeway available to farming to reduce pesticide use on perennial crops

There were found to be marked disparities between species (the mean number of treatments being 36 on apples, 20 to 25 on pears and peaches, 10 to 13 on plums and cherries, 5 to 13 on walnuts and 2 to 5 on kiwis) and between regions (e.g. the mean TFI in viticulture ranges from 7 to 10 in Mediterranean regions, from 9 to 15 in Atlantic regions and 11 to 22 in continental regions). Within the cut-off levels, defined by the implementation of one or more measures to reduce pesticide use, the variability of TFI remains high.

In **viticulture**, level 2 (not subdivided) was defined by the implementation of measures other than pesticides to control insects and mites and/or weeds. It was possible to describe the current situation (NA) using data from the "Cropping Practices" survey in terms of a breakdown of different levels in each of the ten main French vineyards. On average, N0 concerned 13% of plots and N1 77%, but the proportions varied between vineyards.

A switch to levels 1, 2 or 3 enabled TFI reductions of 38%, 56% and 51%, respectively, compared with level 0. In the survey, current levels 2 and 3 were associated with lower yields; this probably did not result from harvest losses linked to weaker pest control, but to lower yield targets and an improved control of crop vigour (among other reasons, for prophylactic purposes). The generalisation of integrated production could thus result in quite marked reductions in yield and new balances between the types of wines marketed, thus encouraging higher quality products that would sustain profit margins.

In **fruit orchards**, there appeared to be little leeway, at least in the most studied case of dessert apples. Cut-off levels were defined by the adoption of one (N2a) or several (N2c) alternative measures to control pests (mating disruption) or disease (resistant cultivars). Generalisation of alternative measures to all **apple orchards**, as they are currently applied in commercial orchards, would reduce the overall TFI from 6% (N2a) to 20% (N2c) or even 27% with a total conversion to organic farming (N3), when compared to the current level assimilated to level 1. In practice, these reductions will probably be smaller. Some measures, such as mating disruption, require appropriate orchard configurations (i.e. large size and regular shape). Scab resistant varieties display a risk of being affected by the overcoming of resistance, particularly in the case of massive planting of such varieties which are currently few in number and not well accepted by the market. Greater reductions could however be envisaged if the marketing standards for fruits (visual appearance) were less strict or if producers were able to exploit commercially serious efforts to monitor orchards and thus achieve results closer to those found under experimental conditions, which reach a TFI reduction of 70% under level 2c.

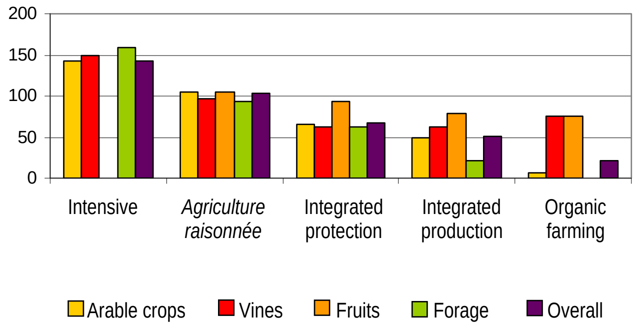
Scenarios at a national scale

Scenarios were constructed by applying the same cut-off level to regions, and then the whole of mainland France. They used the references proposed by the "Cropping systems" expert groups, coupled with information from the Farm Accountancy Data Network, taking advantage of the existence of a good correlation between TFI values and pesticide expenditure per hectare. These scenarios corresponded to technical and economic simulations at the national scale which did not take account of barriers affecting the adoption of certain measures or the behaviour of the different actors of the supply chain faced with risks and innovation.

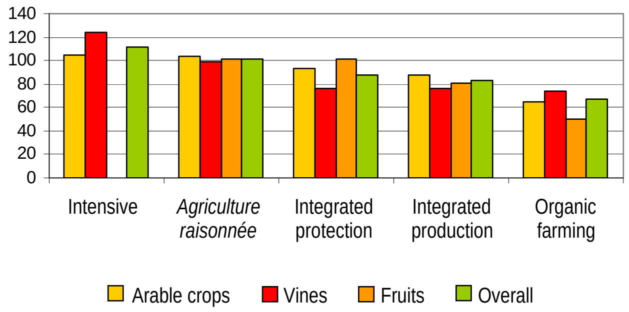
The results demonstrated that the commitment of the Environment Round Table to a 50% reduction of pesticide use from current levels is a difficult target to achieve. During an average year similar to 2006, this could correspond to the results of a simulation under which all French farming would switch to integrated production (N2c): the reduction in pesticide use would then be estimated at 50% in arable crops, 37% in viticulture, 21% in fruit orchards and 100% in grasslands; drops in yield (in value terms) would then be observed, estimated at 12% for arable crops, 24% for viticulture and 19% for fruits (based on 2006 prices).

Evolution of pesticide pressure and production volumes according to cut-off levels

TFI (100 in the current situation)



Production (100 in the current situation)



A target reduction of around 30% in the TFI corresponds to a general switch to integrated protection (N2a). The reduction in pesticide pressure would then be 34% for arable crops, with a 6% drop in yield; in fruit orchards, the reduction in pesticide pressure would be 7% with yields being preserved. Gross margins would be little or not affected by comparison with the current situation in these two production systems. For viticulture, the data do not enable a distinction to be made between the effects of integrated protection and integrated production (see above).

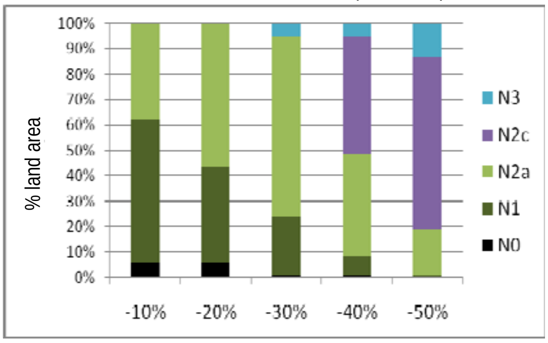
The study did not consider the effects on livestock production of lower pesticide use, but the related land use changes indirectly revealed its possible consequences through a reduction in some forage resources and the development of other crops for livestock feed (alfalfa, pea).

Regarding **arable crops**, a supplementary simulation exercise was carried out to illustrate the usefulness of combining different levels and to estimate the effects of economic incentive mechanisms. This showed that the target of a 40% reduction in pesticide use in this sector could be achieved, but with a drop in yield of around 7%, although profit margins would be maintained (at average prices for 2006) by combining different systems that require more or less pesticide use. Achieving this target would involve abandoning the most intensive practices, a switch from *agriculture raisonnée* to integrated protection and integrated crop management, and a limited expansion of organic farming. At 2007 prices, the maintenance of profit margins would require a less ambitious reduction target of about 35%, thus illustrating the sensitivity of results to annual price levels.

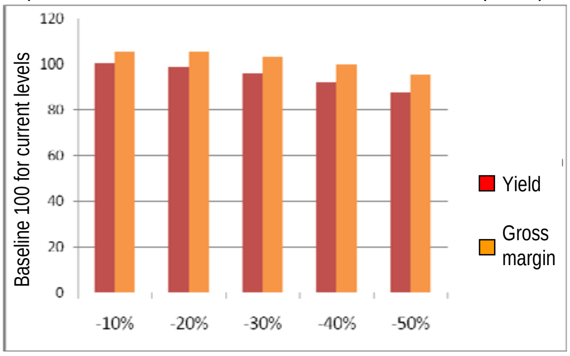
This model also made it possible to calculate the tax and subsidy levels that would allow arable crops to achieve pesticide reduction targets ranging from 10% to 50%. A pesticide taxation system with redistribution of tax revenue to producers would encourage them to reduce their pesticide use while globally compensating them for the reduction in income induced by the tax. However, to achieve reductions of more than 30%, this tax would need to be high: more than 100% of the pesticide price, rising even further when agricultural product prices rose. Thus when used in combination with other instruments (subsidies), lower rates of taxation could be possible.

Our results also suggest the compatibility of pesticide reduction policies with other environmental targets, notably nitrate pollution and energy use. However, this point merits further study through an in-depth analysis of environmental assessments. Nonetheless, compatibility with the development of biofuels (at least those of the first generation) seemed less evident to the experts: their development would imply the maintenance of, or even an increase in, global production, while it would be difficult to achieve a reduction in pesticide use of more than 15 or 20% without lowering yields.

Optimum combination of cut-off levels enabling a reduction in pesticide use (TFI) of between 10% and 50% (abscissa)



Impacts on production and mean national profit margins (baseline of 100 relative to current levels, at 2006 prices)



It should be noted that **a reduction in pesticide use of around one-third** compared with 2006 might be achievable with significant changes of management practices, but without making profound changes to cropping systems. The effects on production levels and gross margins would vary according to production sectors and price levels. For arable crops, which account for the majority of cultivable land and pesticide use, profit margins would be little or not affected at 2006 prices, but a 6% drop in yield would be observed.

Halving pesticide use would suppose a redesign of production systems, with significant effects on yields and gross margins; it would also involve modifications at sector and market levels, and profound, long-term changes. For example, in the arable sector, this target would require more diversified rotations and thus the introduction of new crops into cropping plans: the development of these diversification crops – upon which little value is placed at present – would require considerable adaptation by the different sectors. In fruit orchards, integrated production would involve the replacement of orchards and the planting of disease-resistant cultivars, a necessarily long-term process. In a context of incentives to reduce pesticide use, this orchard renewal might accentuate changes that are already under way; for example, a regression of apple production to the benefit of apricots or walnuts. These changes would not be without effect on the structure of French production and external trade.

The identification of obstacles to the spread of changes in practices

The fact that the available solutions are not more frequently implemented raises the question of the factors that determine producer behaviour: their attitude to risks and expected returns, management of farm resources, information, training and advice, effects of the farming industry and geographical context. The Ecophyto R&D study did not cover all these issues, which would have required a more ambitious analysis, but proposed a pragmatic overview of the checks affecting the dissemination of changes in practices, based on a diagnosis of technical communication and interviews with players in R&D and the agro-industry.

Technical communication on changes to practices leading to lower pesticide use was studied in the context of arable crops and viticulture. It appears to be abundant, but mainly focused on a limited number of alternative practices: the use of decision support systems to manage treatments, the planting of disease-resistant cultivars, the use of mechanical weeding or, under vines, the use of grass cover. The redesign of cropping systems combining several preventive measures in order to markedly reduce pest risks has so far received scant attention. Numerous obstacles to the development of preventive solutions have been advanced by different players: a lack of agronomic reference data and the guarantees of performance that they offer to farmers; the problems encountered when setting up collective organisations at regional level (which are essential to the deployment of some preventive solutions); incompatibility with the demands of food-processing industries which hamper the diversification of crops or varieties. For these reasons, pesticides continue to be considered as the preferred method for pest control; in contrast, the lack of a chemical solution to a disease problem appears to be one of the most powerful driving forces for the development and dissemination of alternative measures.

In this context, there is a need for research and development to generate more knowledge and experimental data on innovative systems, and to make further efforts in genetic selection possible which can exploit new biological mechanisms or which focus on minor species.

In addition to specific obstacles, the experts demonstrated interdependence between the strategies of different players which hampers some changes in practices. For example, diversifying crops to extend rotations simultaneously requires investment by seed breeders in minor species, the development and dissemination of references on the management of these species and access to specific markets; this is difficult as long as regular supplies are not guaranteed. All players organise their strategies according to those adopted by others, and consider that they cannot change if others do not do so. In the short term, only methods to reduce pesticide use that do not question this socio-technical system seem easy to implement.

To favour the dissemination of alternative practices, the study demonstrated the need to act on the whole of this socio-technical system, going beyond encouragement and incentives that target only the farmers. Alongside a revision of the regulations or standards that may prevent changes in practices, government action could contribute to overcoming lock-in. Such action could offer long-term visibility to facilitate the strategic planning of stakeholders, it could support the emergence of new supply chains to further diversify crop species, and it could back efforts to redesign cropping systems and develop collective regional dynamics that involve all players in R&D as well as advisers and farmers.

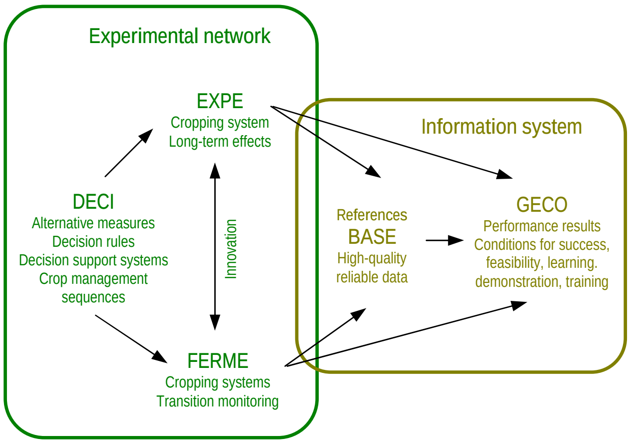
The need for reorganisation to acquire and disseminate reference data on low pesticide cropping systems

The first priority that emerged from the Ecophyto R&D study was the need for a global concept and coordinated organisation: (i) regarding the acquisition of technological and economic data on low-pesticide cropping systems, and (ii) regarding the management of information on these reference data.

The "Networks" expert group proposed an organisational plan that could meet these needs. This proposal combines different spatial and temporal levels (ranging from long-term, local trials on "system" innovations to wide-ranging studies implemented at the farm scale), different types of information and indicators and various levels of innovation and risk. It would involve a coordinated and sustained commitment by research and agricultural development agencies to generate, exploit and disseminate reference data, drawing strength from players in different production sectors and regions, and from networks that are already in existence, e.g. the Joint Technology Network on Innovative Cropping Systems, or the Scientific Interest Groups PICLég (integrated production in vegetable crops) and GC HP2E (arable systems with high economic and environmental performance).

The proposed system comprises five modules organised into two networks:

- an experimentation and demonstration network, involving trials in experimental stations or workshop sites ("EXPE" module), monitoring cropping systems on pilot farms ("FERME") and a system to provide support for targeted research ("DECI");
- an associated information system, comprising the database dedicated to the collection and management of experimental reference data ("BASE") and a module for the management and sharing of knowledge ("GECO").



The pooling of data, the development of models to exploit them, and the design of decision support systems and other tools for agricultural advice appear to constitute functions that are crucial to the future success of an efficient system for the creation and sharing of resources and applicable knowledge for advisers and farmers.

Ecophyto R&D: foundations for the future

Limitations and constraints inherent in the study…

Although the results indicated orders of magnitude that the experts considered to be relatively robust, it is necessary to emphasise the constraints affecting this study and the simplifying hypotheses that were a necessary accompaniment. The technical and economic data available were limited in both quantity and quality, which led the experts to choose a reduced number of indicators and then extrapolate or reconstitute agronomic or economic data.

The study was not able to deal with some essential aspects of a transition towards a target of significant reductions in pesticide use: the direct effects of differences between years in climatic, plant health or economic conditions; the behaviour of those involved when faced with risks and change; medium and long term effects; and the potential "rebound" effects of profound and widespread changes to practices on the evolution of pest populations, national and international markets or the organisation of different sectors. Although the study clarifies the option chosen by the French government for Ecophyto 2018, i.e. a 50% reduction in pesticide use if this is possible, it does not evaluate the possibilities at a ten year horizon. Finally, the impact of changes in practices on health and the environment could not be analysed in the context of this study, apart from an indicator on pesticide pressure.

The study does not take account of innovations in the future and their potential effects on the agronomic, environmental or economic performance of low-pesticide cropping systems.

… but valuable foundations upon which the future can gradually be built

Despite these limitations and constraints, the results of this study constitute an initial analysis of the feasibility of a national strategy for reduced pesticide use, in that it clarified the links between pesticide use, production yields and profit margins, identifying levers that could favour changes in practices and already proposing a plan for the acquisition and dissemination of technical reference data on low-pesticide production systems.

This study, and the interactive relationships between actors that it involved, made possible the assembly and sharing of current knowledge on the agronomic and economic performance of low-pesticide cropping and management systems. It also provided an opportunity for dialogue between all the players involved in this area regarding the levers that could permit change: decision support systems, access to technical references, actions at different levels of a sector or at the regional scale, etc.

The discussion and action framework thus proposed will need to be extended and refined as knowledge is accumulated; it will contribute to an iterative process gradually developing between a political approach (Ecophyto 2018 national plan), improvements in knowledge and its appropriation by the people involved, according to the innovations available but also to the socio-economic framework for action.

And throwing new light on research needs

The study highlighted the need to pursue and reinforce research on the design of innovative cropping systems, using the knowledge and technologies that are available and taking account of ecological interactions within cultivated land and landscapes. Research is also needed on the operation of farms (choice of cropping plans and rotations, notably in terms of resources and markets). The study also demonstrated the crucial role of the issues that determine the agronomic and economic choices made by farmers, individual and collective learning processes, updated advice and the appropriation of knowledge and tools generated by research. Finally, it emphasised the current lack of knowledge on the links between reduction in pesticide use and reduction in their toxic and ecological risks, which remains the ultimate objective.

In conclusion

Because of its originality, and thanks to the investment of all its participants, the Ecophyto R&D study has thus generated numerous results and lessons that can be built upon to prepare the future. It has provided not only the provision of information for public decision-makers and stakeholders regarding plausible scenarios for a reduction in pesticide use, but has also proposed different levers that could be implemented by all players. It will thus encourage greater synergy between agricultural research and agricultural development.

For more information

The following documents can be accessed via the INRA website (www.inra.fr):

- The full Ecophyto R&D study report (9 volumes)
- A synopsis of the study report: Butault J.P., Dedryver C.A., Gary C., Guichard L., Jacquet F., Meynard J.M., Nicot P., Pitrat M., Reau R., Sauphanor B., Savini I., Volay T., 2010. *Ecophyto R&D. Quelles voies pour réduire l'usage des pesticides ?* (90 p.)
- The Scientific Collective Expert Report: *Pesticides, agriculture et environnement. Réduire l'utilisation des pesticides et limiter leurs impacts environnementaux* (2005), and the synopsis of this report: *Pesticides, agriculture and the environment. Reducing the use of pesticides and limiting their environmental impacts* (60 p.).