Non classifié/Unclassified **OCDE/GD(97)157**

AGRICULTURE, PESTICIDES ET ENVIRONNEMENT : QUELLES POLITIQUES?
ANNEXES

AGRICULTURE, PESTICIDES AND THE ENVIRONMENT: POLICY OPTIONS
ANNEXES

ORGANISATION DE COOPERATION ET DE DEVELOPPEMENT ECONOMIQUES
ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

Paris

56415

Ce document bilingue contient les annexes au rapport de synthèse “Agriculture, pesticides et environnement : quelles politiques ?”. Il est publié sous la responsabilité du Secrétaire général de l’OCDE.

This bilingual document contains the annexes to the Synthesis Report on “Agriculture, Pesticides and the Environment: Policy Options”. It is published on the responsibility of the Secretary-General of the OECD.

TABLE OF CONTENTS

ANNEX 1

THE ECONOMIC APPROACH TO PESTICIDE POLICY

Professor David Zilberman
University of California
Berkeley, California 94705

TABLE OF CONTENTS

I. Introduction

Synthetic chemical pesticides have been major agricultural inputs since the late 1940s. Growing awareness of their possible negative side effects on human health and the environment has led to a continuous search for policies that will enhance both health and safety and pest control. It has been recognised that pesticide-use patterns are not independent of the regulatory environment in which the agricultural sector operates; consequently, there is a growing need to understand the links between agricultural policies and pesticides use.

This paper relies on the growing literatures on pesticide economics and agricultural policies[1] and provides a review and analysis of alternative policies to control pesticides use and the effects of major types of agricultural policies on pesticide use. Sections II and III will provide background material on the productivity and side effects of pesticides and on the range of direct policies affecting agriculture. The relationships between agricultural policies and pesticides use are described in section IV, and section V analyses pesticide control policies.

II. The Economics And Environmental Health Effects Of Pesticides

Pesticides are "damage control agents," that reduce the difference between the potential output of a production process and the realised output. Inputs such as water, land, and fertilisers interact; and in a world without pests, they would have produced the volume of output that Lichtenberg and Zilberman (1986a) call "potential output." Various pest controls reduce the fraction of output lost to damage caused by insects, fungi, and other pests. Chemical pesticides are part of a large arsenal of weapons used to fight various pests. Cultural practices and biological controls are other means of combating pests. Biotechnology shows much promise in expanding pest control tools and in reducing the need for chemical interventions.

Significant pest control activities are aimed at preserving product quality. In their study on apples, Babcock, Lichtenberg, Zilberman found that quality improvement accounted for about 30 per cent of the benefits from pesticide use. Quality characteristics protected by pesticide use include aesthetic appearance, shelf life, ripeness, etc. Pesticides also play crucial roles in reducing activities beyond the farm gate including storage and transport. A pesticide may have a large array of applications and be used on many crops to address various problems. The productivity of a pesticide may vary significantly across applications, and its value in each case depends on the alternatives available. In many cases, a relatively small percentage of the applied chemicals (say, 20 per cent) account for a significant part of the benefits generated (80 per cent and even more).[2]

Studies document the variability of pesticides and productivity across crops, locations, and seasons (see Carrasco). Pingali and Roger show that productivity gains from pesticides used in rice in Southeast Asia are rather small while Sunding et al. argue that the relative economic impact of banning the

---

1 For more detailed surveys of these literatures, see Chapters 6, 7, and 10 in the recent book by Carlson, Zilberman, and Miranowski.

2 See Sunding et al; Lichtenberg, Parker, and Zilberman; and Zilberman et al.

use of methyl bromide in the United States is very significant. Pimentel and Lehman argue that, on average, the economic benefits from pesticide use are about four times their direct cost to the users. The results of Zilberman et al. and Knutson et al. suggest that consumers, especially low-income ones, benefit economically from the use of pesticides (because of their contribution to the reduction in food prices), while some growers may actually lose because of pesticide use (for example, nonusers whose output price declines because of pesticide use).

Productivity of certain chemicals may decline over time due to the development of resistance. Pesticide application levels have to be adjusted to slow or deter the development of resistance, and that implies in many cases reducing application levels from what it should have been otherwise (Hueth and Regev). When resistance is a regional problem because of pest mobility, individual farmers may overuse pesticides. Efficient pest control in these cases may involve regional co-operation among growers (Rook and Carlson). Pesticides may be also overused by growers in cases where they destroy beneficial organisms (Feder and Regev).[3] The design of an effective pesticides application strategy requires understanding of the ecological system in which the production takes place and, in particular, the relationships between the various species that affect production.

In many situations the effectiveness of pesticide use increases, and its side effects decline if pesticide application is based upon continuous monitoring of pest populations (Carlson and Wetzstein). Headley introduced the notion of economic threshold, the minimal size of pest population that justifies pesticide application economically. Monitoring of pest populations is a major component of integrated pest management (IPM), a pest management approach that relies on multiplicity of tools (biological controls, cultural practices) to address pest problems aiming to limit the use of chemical pesticides. About 50 per cent of California's farmers are engaged in IPM to some extent (Wiebers), and IPM is making headway in the rest of the United States and Europe. Monitoring of pest population is becoming widespread, and in many cases pesticide dealers provide pest population monitoring services to their clients. In some locations, independent pest control consultants have emerged, and they provide both monitoring and counselling of pest treatment.

The use of chemical pesticides may result in food safety, worker safety, environmental quality, and wildlife health risk problems. The environmental or health damage associated with pesticide use is viewed by Spear as a combined outcome of four processes: application, contamination, exposure, and dose response. Thus, suppose a chemical that reaches ground water may cause some human diseases. The number of, say, average sick days lost because of the use of the product reflects the volume of product applied, the percentage of the product that percolates to ground water (contamination), the number and types of people who drink the water (exposure), and the health impacts of various exposure levels (dose/response).

The side effects of pesticides use can be affected by the manner in which pesticides are applied and the extent that safety measures are taken. For example, aerial application of pesticides may generate more than twice the aerial drift generated by ground application (Pimentel and Lehman). Drainage facilities reduce contamination of ground water and surface water by run-off and percolation of pesticides. Protective clothing reduces significantly exposure to hazardous chemical. Medical means can reduce health effects of exposure to toxic chemical materials.

The side effects of pesticides use vary significantly over time and space. In many cases, the environmental damage associated with application of a chemical in a riparian zone is much larger than

---

3 Harper and Zilberman analysed a case where the use of a pesticide to solve one problem (pink bollworm in cotton) destroyed beneficials and initiated a much more severe pest control problem.

application in other areas. Similarly, impacts of the same level of application may be significantly different during a dry period vs. a wet period.[4] The side effects of pesticides use are subject to much randomness and uncertainty. Quantitative policy analysis requires establishing consistent reporting of health risk estimates to allow meaningful comparisons.[5]

III. The Characteristics Of Agriculture And Prevailing Agricultural Policies

The literature on agricultural policies (Tweeten, Gardner) recognised the fast rate of technological change, low income and price elasticities, and high rates of randomness and instability as major features of the agricultural sector. Those features led to situations of excess supplies of agricultural commodities, a decline in the relative prices of agricultural commodities, and decline in the economic well- being of farmers relative to other groups over time. Agricultural policies were aimed to address these issues by supporting and stabilising agricultural prices and controlling supplies.

While the relative importance of the agricultural sector has declined over the years, and the relative situation of farmers has improved in many countries, the major types of agricultural policies have been maintained. The recent trade agreements and growing concerns for government deficits suggest that several agricultural commodity programs are likely to be eliminated or trimmed. Furthermore, it seems that agricultural policies will be modified to achieve environmental policy objectives.

There are several major categories of agricultural policies in most of the developed nations. Policies may vary across crops and agricultural industries. The main categories of policies are:

Price-support policies.--These policies assure farmers a threshold for their output price level. In the short run, these types of policies tend to raise average price and reduce price risk. However, they provide an incentive to extra production and, in the long run, will contribute to the excess supply problem.

Price support/land diversion policies.- These policies assure farmers a minimum price conditional on fallowing certain proportions of their land. These policies aim at reducing supplies while supporting farmers' income. There is strong evidence that the reduction in output supplied as a result of these policies is much less than proportional to the reduction in the land base. Farmers tend to fallow their lower quality lands and increase their input use in response to land diversion policies that lead to higher prices. The increase in output/land ratio associated with these policies is called slippage.

Price stabilisation policies.--These policies subsidise and provide commodity storage. Farmers are allowed to store their grains as long as the price is below a certain threshold and are required to sell their inventories as the price exceeds a higher threshold. Governments may provide low interest loans backed by stored inventory as long as the grain is stored.

Crop insurance.--These policies compensate farmers on crop losses, as yields are below certain threshold levels. Participation in these programs in may countries is voluntary, and farmers may need to pay a premium to join. Typically, these policies are not self- supporting.

Conservation programs.--Farmers enrolled in these programs are paid not to produce on lands that may pose environmental quality problems. These lands typically are highly erodible. These policies

---

4 See Lichtenberg, Zilberman, and Bogen.

5 See Lichtenberg and Zilberman (1988).

typically entail long-term agreement. In some cases enrolment to these program is determined by a bidding mechanism.

Quality and marketing orders.--Quality and marketing standards (including aesthetic and size standards) are determined by producers and imposed by the government. These arrangements are used frequently as supply control mechanisms.

Input subsidies.--Subsidies to inputs in particular water subsidies have been used to induce individuals to expand their irrigated lands, especially when new water projects were established. Similarly, in many regions farmers enjoyed subsidised energy. Farmers may benefit from subsidised water and energy because of restriction on trade in water and the institutional set-up of water agencies (that also provide hydroelectric power) that favour the farm section (see Boggess et al.).

Credit subsidies.--Farmers may obtain special rates and priorities in obtaining credit both for short-term operational purposes and for long-term investment in capital equipment.

Import quotas.--Limitations on volumes imported are used extensively, for example, to protect sugar producers in the United States. These policies provide effective protection to domestic producers and lead to significant increase in their production.

Export supports.--Exports are supported both directly (through subsidies) or indirectly (through promotional policies). Both types of support lead to increased and intensified production in exporting countries and increase production world-wide. Sometimes they lead to reduction in production in importing countries.

These policies alter and shape production patterns and pesticide use and cannot be ignored in pesticide use and regulation analysis. The impacts of policies on pesticide use will be addressed in more detail in the next section.

IV. Government Policies And Pesticide Use

Government intervention in agricultural sectors has a significant impact on patterns and analysis of pesticide use. The procedures that are established to assess pesticide regulations, say, pesticide bans under the assumption of competitive equilibrium, have to be totally modified to address situations where agriculture is regulated. For example, let us consider the impact of introducing a new chemical that affects the supply of agricultural products under two assumptions. First, there is competition and no intervention in the output market; and, second, output price is controlled by the government and producers are assured a minimum level of output price--call it target price. The introduction of the new pesticide is likely to increase the supply of output. Under competition with no intervention, increased supply will lead to lower output price and increased consumption. Consumers will benefit from the fact that they will pay less for their output and consume more. The impact on producers is more ambiguous. They benefit because the cost of production may decline as well as because of the increase in output. On the other hand, the reduction in output price may cause them losses, in particular, when the demand for the product is elastic. Overall, the sum of the impact on consumers and producers is positive and, at least from the output market perspective, society is better off because of the introduction of the new chemical.

Now consider the impact of the introduction of a pesticide that increases supply in the case where producers are assured a target price level. Let us assume also that the target price is greater than the market price, which is determined by the intersection of demand and supply and paid by consumers, and producers receive from the government the difference between the market price and the output price. This difference is called deficiency payment. The introduction of a new technology will increase supply, and producers will produce more. However, producers will consider the target price as their supply price, and their production will be according to the target price and not according to the output price. Therefore, they will produce much higher volumes than under competition. Consumption will be at the competitive level, and the consumer price will be the same as under competition. Thus, consumers benefit from the introduction of the new chemical under regulation. In this case, producers unequivocally benefit from the introduction of the new chemical because they produce more output, their costs are lower, and their price remains the same. Therefore, both consumers and producers are better off; however, another element enters into the social calculation, and this is government expenditures.

The introduction of the new chemical will increase government expenditures for two reasons: (1) output increases and (2) output price declines. And since government has to pay the difference between the target price and output price, overall expenditures increase substantially. In this case, the total sum on consumers, producers, and government may not be positive. The government expenditures may increase so much that the introduction of the new pesticide did not increase the well-being of participants in the market.

Lichtenberg and Zilberman (1986b) followed this type of argumentation to demonstrate that, in the case where prices are supported, an analysis that ignores agricultural commodity programs will tend to overestimate the cost of banning the use of a chemical as well as overestimating the benefits from the introduction of a new chemical. Using U. S. data, they show that sometimes the overestimation of the benefits from the use of the chemical may be as high as 50 or 60 per cent. Thus, it is clear that one has to incorporate the specification of the policies regulating a market whenever one attempts to assess new regulations that affect pesticide use in the market. In particular, if one conducts a cost-benefit analysis under regulation, one has to realise that sometimes the output price does not represent the social value of a marginal unit of output generated by the chemical, and one has to engage in clever analysis to assess the value of a marginal unit of output produced with chemicals. In cases of subsidy and overproduction, it may be that the value of a marginal unit of output to society is negative because this unit of output may not be consumed by producers but stays in government storage, and it only cost the taxpayers and society extra money in storage costs.

When output price is subsidised and production is below the level that would be optimal without intervention, there is likely to be overuse of pesticides even without considering secondary side effects. In many cases, the social value of an additional pesticide unit is negative, taking into account its impact on government expenditures in addition to consumers and producers. In other cases, the market cost of policies that reduce pesticides use may be quite small. There may be overuse of pesticides when output price is supported for another reason. When prices are supported, the producers' uncertainty regarding output price declines, and that may lead them to increase their expenditures on inputs such as pesticides.[6]

The impact of diversion policies, when producers are asked to take some land out of production on pesticide use, is not clear cut. The increase in output price associated with diversion policy would lead to increased use of pesticides on acreages that remain in production, and that will be part of the slippage phenomenon. On the other hand, the total number of acreages in which pesticides are applied has

---

6 Just and Zilberman proved this point conceptually using Sandmo's models for analysing choices under uncertainty.

declined. The actual effect will vary across pesticides and has not been established empirically. On the other hand, it seems plausible that the overall environmental effect associated with pesticide use may decline with diversion policies because in many cases the marginal lands that are taken out of production are low-quality, highly erodible land which may cause environmental quality problems through excess run-off and percolation. There is no doubt that, with land conservation programs, land is taken out of production according to some environmental criteria, and this reduces the damage of chemical use, and improves environmental quality. Babcock, Lakshminarayan, and Wu have shown that in the US, much of the environmentally sensitive areas are concentrated around riparian lands and in other specific locations. Policies that target taking these areas out of production or allocating them to activities that require low use of chemicals and other environmentally endangering materials are highly beneficial.

Commodity programs may cause overproduction and a negative environmental side effect not only because of the increase in output price and reduction in uncertainties they entail but also because of some of the procedures they use for establishing entitlement. Many commodity programs establish base yields and acreage according to past activities, and farmers recognise that their present behaviour affects their future entitlements. Thus, even when output prices are low, a farmer may be engaged in high-intensive production practices in order to preserve his/her yield base. Similarly, farmers may be reluctant to rotate their cropping pattern in order not to lose yield base. Therefore, policies that allow flexibility in production and do not require rigid production patterns for entitlements are more beneficial to the environment than rigid policies that may motivate farmers to engage in activities that may cause more environmental side effects in order to preserve their rights.

Input subsidies and especially water subsidies have a significant effect on pesticide use. First, these subsidies increase land base, thus increasing irrigated land and pesticide use. The increase in production will benefit producers and in many cases pesticide use can be very sound. However, with inexpensive water, farmers may engage in irrigation activities such as flood irrigations that may result in a high degree of deep-percolating water and run-off that would result in significant environmental side effects. Increasing the price of water to reflect its value of marginal product, in particular, enabling farmers to trade in water rights, may present an incentive to adopt modern irrigation technologies, especially drip and sprinkler. This results in less run-off and deep percolating water and thus less environmental side effects of pesticide.[7] The introduction of irrigation increases yields and leads to increased humidity, fungal growth, and entails increased use of agricultural chemicals.

Energy subsidies may actually reduce the use of herbicides because in many cases herbicides are substitutes for tractors used for tillage. However, in many cases cultivation of land by tractors and deep tillage may have a much more severe environmental effect than the use of herbicides. It is not clear from an environmental perspective if it is preferable to allow high energy use, increased air pollution, and soil erosion associated with intensive tillage rather than to use herbicides.

Subsidisation of credit tends to increase the capacity for agricultural production and that increases chemical use. But in many cases added credit enables farmers to engage in capital-intensive activities that may result in improved chemical application and the adoption of modern technologies with high precision, and the increase in precision may reduce drift and pollution runoffs. High-precision technologies increase the productivity of variable inputs and reduce environmental side effects of production. But high-precision agriculture may be highly capital-intensive. In some parts of the world, farmers are switching to higher precision practices for profitability reasons, but that may also have significantly beneficial environmental side effects. Adoption of a high-precision technology is likely to increase as incentives, such as pollution taxes, are introduced.

---

[7] See Dinar and Zilberman for a discussion on the impact of water policy in drainage generation.

Marketing orders and other regulations that have established product quality standards in agriculture increase the use of chemicals that have quality-enhancing effects, such as fungicides or insecticides. As consumers become more interested in tree-ripened foods, there is likely to be an increase in chemical use since ripening fruits and vegetables attract a variety of pests. On the other hand, minimum use of chemicals is becoming a more attractive product characteristic. The establishment and enforcement of standards for organic production and pesticide-free production will be very beneficial. It is clear that some segments of the population will be ready to pay a premium for organic and pesticide-free food, but they would like to be assured that products are indeed what they claim to be. It is also important that the regulatory process is not cumbersome and expensive and that farmers who are engaged in organic and pesticide-free activities get support from extension and public research in order to help them establish viable production practices.

In many cases farmers may receive double subsidies that result in patterns of production that are not viable economically and in many cases are intensive in chemical use. Examples include rice and cotton production in California where growers receive both an output subsidy as well as subsidised water. In the case of cotton, the output subsidy for many years did not amount to much. However, in the case of rice, about 40 per cent of growers' income may come from subsidies.

Policies to support the price of livestock and animal-related activities may have a significant effect on the production levels and pesticide use of field crops. The obvious examples are dairy support policies. Dairy programs lead to excess production of milk, and much of the milk ends up as cheese stored in government facilities. Milk production requires production of feed products such as alfalfa. In some cases in California and other parts of the United States, alfalfa growers are subsidised indirectly through the dairy programs and directly through cheap water. Since alfalfa production is pesticide-intensive, the subsidised and excessive output results in excessive use of pesticide chemicals.

One of the most important elements of government intervention in agriculture is through public research and extensive activities. Public research agencies have recognised over the years their role in providing technologies if they are public goods. Therefore, while the private sector is taking the lead in producing and marketing pesticide chemicals, public researchers were the ones who were promoting biological control, developing strategies of minimum use input, and advising farmers on how to become less dependent on chemicals. Indeed, in many cases, extension specialists have helped to spread pesticide chemicals, but generally they have tended to be more objective than chemical companies and dealers. In many cases they are the ones who recognise some of the environmental side effects of pesticide use and are searching for alternative strategies. Reduction of the public research and extension infrastructure would not lead to reduced pesticide use.

Import quotas lead to misallocation of resources, excessive production of a crop in which a producing country may not have relative advantage, and thus increase the use of pesticides. The case of sugar in the United States provides a good example. Without import restriction, much of the sugar industry in the United States would not have survived. Industries operating in the environmentally sensitive areas, like the Everglades region in Florida and in many other areas, have benefited from the sugar program immensely.

In most cases, the impact of government policy on chemical use is through its impact on production. The wide array of government subsidies that increase agricultural production tends to increase chemical use with this production. Moving to more competitive markets, adopting efficient modes of production, and reducing subsidisation of agriculture will entail less use of chemicals.

V. The Effectiveness And Impacts Of Alternative Pesticide Policies

The draft report of the OECD Pesticide Forum, "Activities to Reduce Pesticide Risks in OECD and Selected FAO Member Countries: Results of a Survey," argues justifiably that, throughout the world, the pesticide regulatory process tends to emphasise the initial registration. Namely, new substances that are considered to be used for pest control are going through an expensive and detailed battery of tests. However, once they pass the test, the extra cost that users pay besides the price of the material is quite limited. Obviously, over time, if there is evidence of side effects, certain types of regulations are enforced.

This type of regulatory process treats the pesticide choice problem as if it were a discrete choice. Namely, the decision is whether to use the chemical or not. In many cases, the pesticide use choice is a continuous choice. How much chemical should be used for a given crop at a given location? The regulatory process, to some extent, answers this question by establishing label dosages. But the dosage on the label does not vary by location, even though it may vary by crop. Over the years, however, if problems arose, the regulations were established to affect the patterns of use. Once environmental or health problems are identified with the use of a certain chemical, it is considered "bad" and is disallowed for use. That may be the case even with a chemical that, when used in small amounts and under controlled conditions, may generate a large volume of good while its environmental side effects may be controllable or insignificant.

The existing regulatory process has not been that bad. It has been able to contain large-scale disasters, and there is much more concern than documented evidence to the actual negative side effects caused by the use of pesticide to human health. However, the existing regulatory process is far from perfect, and one can argue for changes that will improve its performance both in terms of cost as well as health.

The heavy emphasis on initial testing has led to a situation where the costs of introducing new chemicals become extremely high. As a result, we have a chemical industry that is highly concentrated with a small number of firms having relatively significant market power. The ability of new small companies with innovative ideas and concepts to develop new products is curtailed by this heavy cost of regulations. Throughout the agricultural industry, there is a concern for an insufficient number of substitutes for existing chemicals. The lack of substitutes provides a major obstacle in regulating existing chemicals that were found to have some negative side effects. When these chemicals are banned, the cost, because of a lack of substitutes, may be very substantial.

The existing regulatory process is especially problematic when it requires that substantial testing registration be done for every potential use of a new chemical. It makes registration of chemicals for use with crops that have a small volume of operations economically infeasible in many cases. That, in turn, may curtail the development of diversified crops and varieties and will slow the development of agriculture. In the modern economy, agriculture seems to be on a transition process, from producing homogeneous commodities to the production of differentiated products. These products may be varieties that include special nutrients or other types of goods that have special aesthetic or health characteristics. Inability to obtain pest control for the production of these products may be debilitating.

Thus, it seems that key elements in any regulatory reform will be to streamline the initial regulatory process; identify the elements that increase costs without contributing much extra safety; and, in particular, reduce the number of repetitive testing and attempt to identify large groups of commodities that qualify under a given set of testing.

The biggest flaw of the existing regulatory process is that in many cases it does not provide incentives to rationalise and use effective existing chemicals. In many cases, the users only recognise the private cost of using a chemical, and their decision does not take into account the side effects associated with the use of a chemical substance.

Welfare economics suggests that optimal use levels of any input should be at a point where its marginal benefit is equal to the marginal cost. The marginal costs can be divided into private and social costs. Both types of costs may be costs of immediate outcomes or discounted costs of future outcomes. In the case of pesticides, the optimal use can be determined according to:

> value of marginal unit of pesticide in production = price of pesticides + marginal cost in terms of increased resistance + marginal cost in terms of beneficial species + marginal impact on worker safety + marginal impacts on food safety + marginal impact on ground water and environmental quality + marginal impact on wildlife.

The above condition suggests that there may be many difficulties in establishing uniform taxes to provide incentives that will lead to first-best solutions. Many of the external effects associated with pesticide use are local. Problems of resistance may be shared by small numbers of farmers in a given region and have to be addressed locally. They can be addressed by establishing regional pest control boards which are voluntary user-based associations to address open-access problems (see Clark and Carlson). Such an association can either impose taxes or set an agreement on limits for production. The same is true for secondary pest problems. In many cases they apply to only small subregions and should be addressed within such content.

When it comes to the social environmental effects of pesticides, many of them have local characteristics and can be addressed by local solutions. Worker safety problems may vary in severity and in terms of solution between regions. For example, as Lichtenberg, Zilberman, and Bogen have shown, the damage associated with exposure to sprayed chemicals varies between regions that have dry harvest seasons and wet harvest seasons. Furthermore, one can also use protective equipment to address some worker safety problems, and the type of equipment should vary by location depending on weather conditions. Addressing worker safety problems is costly and may affect the labour market; and, again, situations vary across locations in terms of workers' willingness to substitute wage with extra safety. Thus, when it comes to worker safety problems, at least in principle, the optimal solution is not a global one but, rather, one which has to be adjusted by regions. Effectiveness in addressing worker safety problems requires the ability to recognise problems when they exist, educate workers about pesticide risks so they will make informed decisions, and to consider all the feasible policy options including restricting spraying periods, requiring protective clothing, as well some financial incentives to reduce chemical use.

Food safety problems are less local than the other types of pesticide effects, and here more uniform policies are more likely to achieve efficiency. One has to recognise that it may be better to impose a regulation based on residues in the food rather than on pesticide use because the same level of pesticide use may have varying effects on food safety because of differences in processing after post-harvest treatment, handling, etc. Policymakers can establish taxation that is based on pesticide residues or set maximum allowable residue levels. Developing market differentiation schemes based on pest control treatments and residues seems to be a reasonable policy choice because it will allow consumer choice. When such markets are established, growers will get differentiated prices according to the residue level, and that will provide signals to growers when they make their pesticide use choices.

When it comes to environmental side effects of pesticide use, one has to distinguish between global problems and local problems. A residue that affects global environment, for example, use of methyl bromide that may affect the ozone layer, can be addressed by uniform taxes or by trading in chemical use permits on a global level. The problem with such a policy is that the key issue is not the pesticide use level but the pesticide residue level emitted through the atmosphere. One may emit very little methyl bromide or other chemicals to the environment if the application technology is more advanced. Therefore, penalising pesticide use per se is not the solution. The taxes may be dependent on both pesticide and the technology with which the chemical has been used. In order to compute the residue, one needs to know both how much is applied and with what technology, and the tax will be based on the residue. This type of solution is difficult technically and cumbersome; therefore, it seems that the regulators may have to resort to a second-best policy that basically involves providing incentives to reduce the chemical use itself without significant adjustments that are done according to application technologies.

Buchanan and Tullock argued that the use of pollution taxation will encounter several political objections from polluters who will have to pay the taxes and reduce production and, thus, lose substantially from taxation. The introduction of tradable pollution permits, which volume is restricted to a socially derived level, can achieve the same resource allocation outcome as taxation with fewer political objections. Thus, for a global chemical problem, such as the methyl bromide problem, efficient resource allocation may be attained by introducing internationally transferable permits.

When it comes to the local environmental quality problem caused by pesticide use, application technologies as well as the location matter much more than the volume of pesticide applied. Aerial application of pesticides near a body of water may generate much more residue than through the low pressure applicators far away from bodies of water. Therefore, optimality has to be achieved by policies that take into account location and application matters. This may be financial incentives that vary by location and application technologies or some direct control that restricts application levels and options at locations that are sensitive environmentally.

As we have seen, obtaining an optimal chemical use requires a wide variety of intervention that takes into account all aspects that cause heterogeneity among producers. These policies should vary over time as more technological options are available--both in terms of application and identification of environmental situations as well as in terms of pest control. When a new chemical or biological device to address a pest problem is available, then it becomes more economical to restrict the use of existing chemicals further because the opportunity cost declines. Thus, one has to realise that developing new alternatives that will be safer or more effective may be a very important component of an efficient pesticide policy.

The analysis thus far suggests that across-the-board pesticide policies are unlikely to lead to first-best outcomes. Across-the-board taxation of pesticides is a second- or a third-best policy. It will reduce pesticide use and reduce environmental damage associated with pesticide use. It will also provide incentives to conserve pesticides and to use more efficient application technologies. Such technologies generally result in less residue. Thus, a pesticides tax may lead to positive changes in pesticide use and technology, but in most cases it will be inferior to a pesticide residue tax. However, difficulty in observing residues makes pesticide taxation, at least, a technically feasible solution.

One set of financial incentives that are used today in restricting pesticides is liability rules. When users of pesticides are liable for externality damage, they are more careful with the side effects of their operation. Better defined liability rules and improved mechanisms to monitor and enforce them may be the best way to introduce financial incentives to reduce pesticide use. In many cases penalties should be pre-specified according to problems rather than be determined by cost because of the high cost of litigation and the efficiencies they may entail. Furthermore, establishing liability rules may be difficult technically because of the non-point problems that may be associated with chemical use. One may strive for technologies that will allow better identifying sources of pollution in order to establish clear patterns for identification of sources of pesticides. In the meantime, until such technologies are perfected, one may establish some rules to identify liability that will be based on location, pesticide use, and application technology.

Any method that will try to regulate pesticide requires information about application levels, application technologies, and location. Therefore, any regulatory process in the pesticide area requires better data and improved reporting. In some regions, applications of certain pesticides already require reporting. This tendency has to be expanded and, hopefully, in the long run, some agencies will be able to obtain records of all pesticide use levels with exact specifications of location, volume, and application technology. Such reporting will become easier as farmers and farming become more automated, as the use of computers become widespread, and if application is done by professional applicators.

Transferring responsibility for application of pesticides to licensed professionals is one approach to attempt reaching first-best solutions. These professionals will provide both diagnosis and cure to pest problems, be educated and informed about all aspects of pesticide use, and be liable for certain aspects of mismanagement. The emergence of independent pesticide consultants in California and other States in the United States suggests that such approach may be valued in the future, at least in regions with intensive agriculture and good educational infrastructure. The challenge is to develop a profession of pesticide managers that will be cost effective and will not generate new inefficiencies in the system.

VI. Conclusion

Pesticide use levels are affected significantly by government policies. Policies that increase the price received by producers for their output and reduce their risk, as well as input support policies (water and credit subsidies), have tended to increase the intensity of agricultural production and pesticide use. A move towards a freer market is likely to reduce excessive supply and reduce pesticide use to some extent.

Increased competition by itself will not solve much of the problems caused by pesticide use. Pesticide use results in a variety of side effects that affect humans and the environment. Some are global in nature and some are local. Addressing these side effects efficiently requires a mixture of policies. Economic instruments (taxes on chemical use or tradable permits) may be especially effective in reducing volumes of chemicals that may have negative global effects. But addressing local side effects of chemicals (worker safety and environmental damage, resistance and secondary pest problems) may require the use of direct controls on pesticide use and application method (such as protective clothing), establishment of organisations for collective action (such as pesticide user networks that will co-ordinate policies to address resistance problems), and financial incentives.

Pesticide regulations will have to change over time as technology develops. It is important to reduce the cost of introduction of new alternatives to existing chemicals and to provide incentives to the adoption of high-precision application technologies. Furthermore, the development of new technologies to better monitor residues will allow the introduction of financial incentives based on residue levels, which are our real source of concern, rather than pesticide use levels.

BIBLIOGRAPHY

BABCOCK, BRUCE A., P. G. LAKSHMINARAYAN and JUNJIE WU (1995), *The Economic, Environmental, and Fiscal Impacts of Targeted Renewal of Conservation Reserve Program Contracts.* Working Paper 95-WP 120, Center for Agricultural and Rural Development, Iowa State University, Ames.

BABCOCK, BRUCE, ERIK LICHTENBERG and DAVID ZILBERMAN (1992), "Impact of Damage Control and Quality of Output: Estimating Pest Control Effectiveness." *American Journal of Agricultural Economics*, Vol. 74, No. 1 (February), pp. 165-172.

BOGGESS, WILLIAM, RONALD LACEWELL and DAVID ZILBERMAN (1993), "Economics of Water Use in Agriculture." *Agricultural Resources and the Environment.*, edited by Gerald A. Carlson, David Zilberman, and John A. Miranowski. New York: Oxford University Press.

BUCHANAN, J. M. and G. TULLOCK (1975), "Polluters' Profits and Political Response: Direct Control Versus Taxes." *American Economic Review*, Vol. 65, No. 1, pp. 139-147.

CARRASCO-TAUBER, CATALINA (1990), "Pesticide Production: A Survey." *Economic Perspective on Pesticide Use in California.* Working Paper 564, Department of Agricultural and Resource Economics, University of California, Berkeley.

CARLSON, GERALD A., DAVID ZILBERMAN and JOHN A. MIRANOWSKI, editors (1993), *Agricultural and Environmental Resource Economics.* New York: Oxford University Press.

CARLSON, GERALD A. and MICHAEL E. WETZSTEIN (1993), "Pesticides and Pest Management." *Agricultural Resources and the Environment.*, edited by Gerald A. Carlson, David Zilberman, and John A. Miranowski. New York: Oxford University Press.

CLARK, J. S. and G. A. CARLSON (1990), "Econometrically Distinguishing Between Private and Common Property: The Case of Pesticide Resistance." *Journal of Environmental Economics and Management*. Vol. 19, pp. 45-60.

GARDNER, BRUCE L (1988), *The Economics of Agricultural Policies.* New York: Macmillan Publishing Company.

DINAR, ARIEL and DAVID ZILBERMAN, editors (1991), *The Economics and Management of Water and Drainage in Agriculture*. Norwell, Massachusetts: Kluwer Academic Publishers.

FEDER, GERSHON and URI REGEV (1975), "Biological Interactions and Environmental Effects in the Economics of Pest Control." *Journal of Environmental Economics and Management*," Vol. 2, pp. 75-91.

HARPER, CAROLYN R. and DAVID ZILBERMAN (1989), "Pest Externalities from Agricultural Inputs," *American Journal of Agricultural Economics*, Vol. 71, No. 3 (August), pp. 692-702.

HEADLEY, J. C. (1972), "Defining the Economic Threshold." *Pest Control Strategies for the Future.* Agricultural Board, Washington, D. C: National Academy Press, pp. 100-108.

HUETH, DARRELL and URI REGEV (1974), "Optimal Agricultural Pest Management with Increasing Pest Resistance," *American Journal of Agricultural Economics*, Vol. 56, pp. 543-552.

JUST, RICHARD E. and DAVID ZILBERMAN (1988), "The Effects of Agricultural Development Policies on Income Distribution and Technological Change in Agriculture." *Journal of Development Economics*, Vol. 28, pp. 193-216.

KNUTSON, RONALD D., C. ROBERT TAYLOR, JOHN B. PENSON and EDWARD G. SMITH (1990), *Economic Impacts of Reduced Chemical Use.* College Station, Texas: Knutson and Associates.

LICHTENBERG, ERIK and DAVID ZILBERMAN (1986a), "The Econometrics of Damage Control: Why Specification Matters." *American Journal of Agricultural Economics*, Vol. 68, pp. 262-273.

LICHTENBERG, ERIK and DAVID ZILBERMAN (1986b), "The Welfare Economics of Price Supports in U. S. Agriculture." *American Economic Review*, Vol. 76, No. 5 (December), pp. 1135-1141.

LICHTENBERG, ERIK and DAVID ZILBERMAN (1988), "Efficient Regulation of Environmental Health Risks." *Quarterly Journal of Economics*, Vol. CIII (February), pp. 167-178.

LICHTENBERG, ERIK, DAVID ZILBERMAN and KENNETH T. BOGEN (1989), "Regulating Environmental Health Risks under Uncertainty: Groundwater Contamination in California." *Journal of Environmental Economics and Management*, Vol. 17, pp. 22-34.

LICHTENBERG, ERIK, DOUGLAS D. PARKER and DAVID ZILBERMAN (1988), "Marginal Analysis of Welfare Costs of Environmental Policies: The Case of Pesticide Regulation." *American Journal of Agricultural Economics*, Vol. 70, No. 4 (November), pp. 867-874.

PIMENTEL, DAVID and HUGH LEHMAN, editors (1993), *The Pesticide Question: Environment, Economics, and Ethics.* New York: Chapman and Hall.

PINGALI, PRABHU L. and PIERRE A. ROGER (1995), *Impact of Pesticides on Farmer Health and the Rice Environment.* Norwell, Massachusetts: Kluwer Academic Publishers.

ROOK, S. P. and G. A. CARLSON (1985), "Participation in Pest Management Groups." *American Journal of Agricultural Economics*, Vol. 67, pp. 563-566.

SANDMO, A. (1971), "On the Theory of the Competitive Firm under Price Uncertainty." American Economic Review, Vol. 61, pp. 65-73.

SPEAR, ROBERT C. (1991), "Assessing Health Risks in the Presence of Variable Exposure and Uncertain Biological Effects." *The Economics and Management of Water and Drainage in Agriculture*, edited by Ariel Dinar and David Zilberman. Norwell, Massachusetts: Kluwer Academic Publishers.

SUNDING, DAVID, CHERISA YARKIN, DAVID ZILBERMAN, JERRY SIEBERT and ALAN MARCO (1993), "Economic Impacts of Methyl Bromide Cancellation." Working Paper, Department of Agricultural and Resource Economics, University of California at Berkeley.

TWEETEN, LUTHER (1974), *Foundations of Farm Policy*. Lincoln: University of Nebraska Press.

WIEBERS, UWE-CARSTEN (1992), "Economic and Environmental Effects of Pest Management Information and Pesticides: The Case of Processing Tomatoes in California." Ph.D. dissertation, University of Berlin, Department of Agricultural Sciences.

ZILBERMAN, DAVID, ANDREW SCHMITZ, GARY CASTERLINE, ERIK LICHTENBERG and JEROME B. SIEBERT (1991), "The Economics of Pesticide Use and Regulation." *Science*, Vol. 253 (August), pp. 518-522.

ANNEX 2

POLICY CASE STUDY OF AUSTRALIA

Anthony Chisholm
Professor and Head of Agricultural and Resource Economics
La Trobe University,
Dr. Els Wynen

Professor Anthony Chisholm is sole author of the paper with the exception of the section on Australian Pesticide Regulations and Policies, for which the authors are jointly responsible, and the Annex on Reduced Tillage for which Dr. Els Wynen is primarily responsible.

TABLE OF CONTENTS

I. Introduction

Chemical pesticides have been a significant agricultural input in Australia since the late 1940s and their use has increased substantially. Over the last two decades, the rate of increase in expenditure on agricultural chemicals has been greater than any other component of farm costs (see Australian Bureau of Agricultural and Resource Economics, 1995). Application of chemical pesticides has contributed to agriculture's impressive productivity growth, by providing one method of reducing damage from pests and thus reducing the gap between agriculture's realised and potential output.

Australian agriculture is diverse, with a large variety of animal, crop and horticultural products which are affected by a large variety of pests and diseases being produced. Australia faces a greater threat from insect pests than countries in higher latitudes, where cold winters reduce insect populations. The total annual costs to Australian agriculture attributable to insects and weeds have been estimated at $6.4 billion, a little under 30 per cent of the gross value of Australia's agricultural production, with each category of pest contributing roughly equally to losses.[8] Animal pests, including rabbits, wild pigs, wild goats and mice are also a major agricultural pest in Australia, but there are no reliable estimates of the aggregate losses of agricultural production due to animal pests. Estimates of the annual costs of rabbits to Australian agriculture of up to $600 million annually have been made.[9]

The cost of controlling all species of insect pests in Australia is estimated to exceed $1 billion annually, mostly due to chemical expenditure on chemical pesticides. The annual costs of controlling weeds also exceeds $1 billion, but a considerable part of these costs are due to cultivation in addition to herbicide application. No annual estimates of national expenditure on vertebrate pest control are available. However, the expenditure on chemicals to control veterbrate pests would be very small relative to expenditure on chemicals for weed and insect control.

Over the four decades 1950-90, Australian farm output increased 250 per cent. Knowledge flowing from research (R&D) and improved management, were the key resources accounting for this striking increase in output.[10] Annual total factor productivity growth in Australian agriculture over this period was 2.3 per cent (Mullen and Cox, 1995). Australian agriculture, however, remains comparatively land intensive. Whilst Australia recorded the highest rate of growth of land productivity (output per unit of land) of any OECD country over the three decades to 1990, its land productivity remains the lowest in the OECD (Alston et al.)

There is a growing awareness of the possible negative spillover effects of agricultural chemicals on the environment and human health. This has led to a search for safer chemical pesticides and other means of pest control such as biological controls, biotechnology and improved management and cultural practices.

---

8 The estimates of losses to Australian agriculture presented here are derived from data presented in Australia: State of Environment, (Department of the Environment, Sport and Territories, 1996).

9 Kangaroos are also a pest for Australian agriculture. The population of some larger species of kangaroo is now larger than before the advent of agriculture, due to an increased supply of pasture and watering points. In Australia in 1984-85, kangaroos caused estimated losses of $113 million in agricultural production in the commercial culling areas (1.4 per cent of the gross value of agricultural production).

10 For an overview of productivity growth and sustainability issues relating to Australian agriculture, see Chisholm (1992, 1994), Mullen and Cox (1995), and Knopke *et.al.* (1995).

Some indication of the contribution of agricultural chemicals to productivity is given by an estimate that the average return to a dollar invested in pest control in the United States is about $4 in the value of crops saved (Pimentel et al., 1993). Thus, in the United States, an annual investment of about $4 billion dollars in pesticide use is estimated to save around $16 billion in crops. This type of benefit assessment does not include indirect environmental and health costs associated with use of pesticides, nor does it give any indication of marginal benefits.

The indirect environmental and human health costs of pesticide use in the United States have been estimated to be a little over $8 billion annually (Pimentel et al., 1993).[11] This estimate includes about a $3.2 billion cost to agriculture, particularly through destruction of natural pest enemies, build-up of pesticide resistance, non-target crop losses and honeybee and pollination losses. Thus, when both the direct and indirect costs of pesticide use to agriculture are accounted for, the average return to the agricultural sector of a dollar invested in pest control is about $2.2 and the average return to society is about $1.3.

In Australia, depending upon the particular crop or livestock and type of farm chemical, the cost benefit ratio to farmers, has been estimated to vary from 2 to 1 up to 80 to 1 (Prices Surveillance Authority, 1993, p.7).

There are no estimates of the environmental and health costs associated with agricultural chemical use in Australia that are comparable with the above estimates for the United States. However, farm pesticide use in Australia has been linked with the death of fish and other aquatic organisms in many areas such as the Namoi Valley and the Coleambally Irrigation Area in New South Wales (NSW) and the Maroochy River in Queensland (Department of the Environment, Sport and Territories, 1996; CSIRO consultancy report to the NSW Environmental Protection Authority, unpublished, 1996). Eggshell thinning for several species of Australian birds, particularly birds of prey and pelicans has also been linked with pesticides (Olsen et al., 1993). The association between pesticide use and farmers' health is discussed in a later section of the paper.

There are a number of reasons for believing that the environmental and health costs would be substantially less in Australia than in the United States and most other OECD countries. First, the overall level of pesticide use in Australian agriculture is low compared with the United States and most other OECD countries, partly as a result of the low level of protection given to Australian agriculture. Second, Australia is the least densely populated country in the OECD. The OECD average population density is eleven times that of Australia. Despite its low average population density, Australia is one of the most highly urbanised countries in the OECD with 86 per cent of its population living in urban areas in 1990. Comparative figures for some other OECD countries are 74 per cent for the United States, 76 per cent for

---

11 The major indirect costs in order of importance are bird losses, groundwater contamination, cost of pesticide resistance, non-target crop losses and public health impacts. An assessment of the environmental and health costs associated with pesticide use is an enormously difficult task because the impacts are very diverse and often extremely subtle and complex. Many assumptions need to be made and the estimates that have been made should be viewed as providing no more than an order of magnitude estimate of the 'true' costs. It could be argued that even if the above estimates were accurate, they appear to ignore potential environmental benefits. It is generally accepted, for instance, that the key to saving wildlife species is preventing the loss of their habitat. Avery (1995) claims that using synthetic pesticides and fertilizers to attain high-yield farming, has globally saved 10 million square miles of wildlife habitat. He compares this contribution of high-yield farming to saving wildlife habitat, with the 78,000 square miles of land worldwide the Nature Conservancy (one of the few environmental groups that has actually set land aside for wildlife) is administering.

Canada and an average European figure of 73 per cent (Dumsday et al., 1996). A very high proportion of Australians, hence live and work at locations far removed from those where the pesticides are applied.

Third, there is a sense in which environmental resources are not valued as highly in Australia as they are in more densely populated developed countries. The demand for environmental resources, in terms of the "willingness-to pay", in order to save wildlife and environmental amenities is positively correlated with both per capita real incomes and population levels. Countries with lower real per capita incomes and/or smaller populations will, ceteris paribus, have a lower aggregate ability and willingness to pay, and in this sense place a lower value on wildlife and environmental amenities. Let us take, for example, the very high value of over $2 billion annually estimated to be the costs associated with loss of birdlife attributed to pesticide use in the United States (Pimentel et al. op.cit.). One reason for this relatively high value, is that in the higher trophic levels of food chains, birds such as bald eagles, hawks and owls are particularly susceptible to poisonous residues in their food. One instance of this is the bioconcentration of organochlorine insecticides that occurred through food chains (Edwards, 1993). These birds are also rare and often endangered. Consequently, a country such as the United States with a high level of per capita income and a large population, puts a high value on protecting such species. Whilst the author's focus here is solely on 'demand value' for wildlife and environmental amenities, it should be noted on the supply-side that the economic cost of preservation, in terms of the value of other goods and services foregone, is typically also positively correlated with both per capita income and population levels.

Discussions about the social costs and benefits of pesticide use often take place in a super-charged atmosphere. In large part, this is attributable to the uncertainty that often exists about the true health and environmental effects of pesticide use, particularly over the long-run. A state of uncertainty often makes it impossible to show conclusively that some alarmist claims about the extremely harmful effects of using a pesticide are clearly false, or that some reassuring claims about the complete safety of a certain pesticide are clearly exaggerated. Indeed, an environment is created in which both sides of the pesticide debate are tempted to make extreme, but plausible, claims about pesticides. Not surprisingly, this situation has led some scientists and government officials to adopt a defensive stance on issues of pesticide use. However, there are substantial social costs for a society not attempting to fully and openly come to grips with difficult issues like pesticide use. In the context of pesticide use in the United States, Pimentel and Lehman (1993, p. xiii) state:

"A growing number of scientists and government officials have been viewed as primarily concerned with promoting commercial interests rather than protecting public welfare. Indeed, much of the public has lost faith in science and the government."

There have been many calls to reduce the use of agricultural chemicals in Australia because of their perceived negative spillover effects. For instance, both the inquiry into the use of agricultural and veterinary chemicals conducted by the Senate Select Committee (Commonwealth of Australia 1990) and the report of the ESD working group on agriculture (Ecologically Sustainable Development Working Group 1991) recommended that the level of chemical use be reduced.

The primary aims of the paper are first, to identify and evaluate the impact of government agricultural and economic policies on pesticide use and second, to review the existing regulatory structure applying to pesticides and thirdly to consider the potential role for economic instruments.

II. Trends in the Use of Farm Chemicals

Within the Australian farm sector there are two broad market segments for farm chemicals:[12]

(a) plant protection and weed control products such as herbicides, insecticides, nematocides, plant growth regulators and other fumigants; and

(b) animal pest control and associated health care products, including sheep and cattle dips and drenches, to control external and internal parasites, and a range of veterinary products such as vaccines, antibiotics and antibacterials.

About 70 per cent of agricultural chemicals are consumed by the farm sector. The 30 per cent of the value of 'agricultural' chemical production consumed outside the farm sector includes off-farm grain and food storage and associated pest control, home gardening, and local government pesticide use.

Public data on the quantities of pesticides used in Australia, let alone the quantities used by particular agricultural industries and regions is very sparse.[13] AVCARE the institution representing the major agricultural and veterinary chemical manufacturers in Australia, keeps records of the value of farm chemical sales, but keeps no public records of quantities sold.

Data for expenditures on herbicides, fungicides, insecticides and agricultural chemicals for animal health are presented in Figure 1. Between 1975-1994, real expenditure on herbicides, fungicides and insecticides increased about fivefold. The most rapid increase was in herbicide use (sixfold increase) and the major explanation for this is the considerable expansion in minimum tillage in Australia. Data for expenditure on chemicals for animal health were not available until 1979, but the data suggests that the increase in this category is not as great as in the other categories.[14]

Despite the rapid growth in real expenditure on farm chemicals, pesticide use in Australia is generally considered to be low by world standards. Australia's consumption of farm chemicals per unit of agricultural output is significantly lower than in Europe, the United States and Japan (Prices Surveillance Authority, 1993). In 1991 (AVCARE), Australian farmers spent US$ 0.90/ha on farm chemicals compared with US$ 13.2/ha for the United States, US$ 39.7/ha for the United Kingdom, US$ 70.4/ha for France, and US$ 575/ha for Japan. However, these figures are misleading because much of Australian agriculture (in terms of land area) is extensive grazing and broadacre cropping characterised by low-chemical input systems.

In 1992/93 chemicals applied to crops and pastures on broadacre farms in Australia, comprised around 60 per cent of total expenditure on farm chemicals excluding expenditure on animal health products. Australian broadacre farms are classified into wheat and other crops; mixed livestock-crops, sheep, beef, and sheep-beef farms. Dairying, although strictly speaking not a broadacre farm, is included in this category of farm. Broadacre farmers spent around 74 US cents/ha on chemicals applied to crops and pastures and 44 US cents/ha on chemicals used for animal health. Expenditure per hectare on crop and pasture chemicals ranged from around 6 cents for pastoral zone properties to US$ 10.6 for wheat and

---

12 The term farm chemicals is defined to include expenditure on agricultural and animal health chemicals. It excludes expenditure on fertilizer.

13 An exception is a pesticide audit conducted by Rayment and Simpson (1993).

14 The use of broad spectrum insecticides may have decreased due to a move away from calendar spraying (pers. comm. Ben Louden and Philippa Rowland, April 1996). The paucity of hard data, however, highlights the need for a national database on pesticide use in Australia.

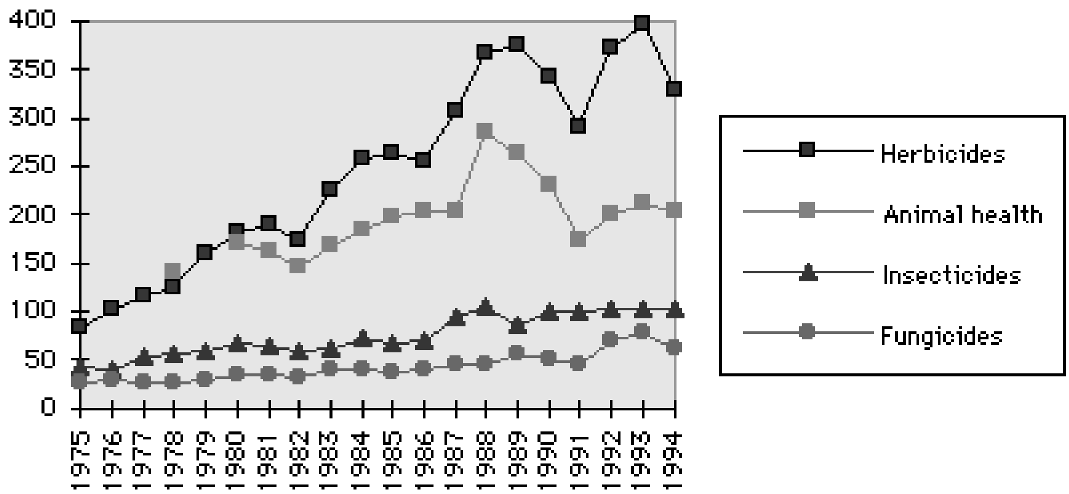
other crop farms. The comparable figure for wheat and other crop farms based on the area cropped only, was US$ 23.0/ha.

Expenditure on farm chemicals as a share of total farm costs in Australian broadacre agriculture in 1991-92, was slightly under 7 per cent, ranging from around 2 per cent on dairy farms to over 12 per cent on wheat and other crops farms.

Non-broadacre farms include horticulture, sugar, cotton, rice and grapes. These farms comprise around only 5 per cent of total farm area in Australia, but probably account for around one third of the total expenditure on herbicides, fungicides and insecticides. The greatest single use of herbicides in the irrigation areas of south-west NSW, for instance, is for the growing of rice (CSIRO, 1996).

The cotton industry accounts for a large share of insecticide use in Australia. "¼ cotton growers have attributed 20 to 50 per cent of their cash costs to the use of chemicals" (Prices Surveillance Authority, p.15).[15]

Figure 1 Real expenditure on pesticides (1987-88 $m)



Source : Dumsday , Edwards & Chisholm (1996), derived from ABARE data

15 The Prices Surveillance Authority and the Trade Practices Commission merged in November, 1995 to form the Australian Competition and Consumer Commission.

III. Structure and Pricing of the Farm Chemicals Industry

In Australia, with a few exceptions, the key ingredients (actives) for farm chemicals, which account for around 55 per cent of an agrichemical's ex-factory price, are developed and manufactured overseas by multinational firms domiciled in the United States, Europe and Japan.

Due to the diverse nature of Australian agriculture, a large number of farm chemicals are used to control weeds, insect and animal pests.[16] Farm chemicals in Australia are usually marketed as well differentiated products and not subjected to strong price competition. The firm structure for farm chemicals supply in Australia mirrors that of the global agrichemical industry. The global industry is dominated by large multinational firms that have a significant degree of market power. The concentrated nature of the global agrichemical industry appears to be primarily due to the large R&D investment (up to $150 million) required to bring a new farm chemical on to the market (Prices Surveillance Authority, 1993). This reflects the high costs and uncertain outcome of assurance procedures required for a farm chemical to satisfy the toxicology, residue and efficiency criteria prior to use. A patent system grants monopoly rights to a firm to exploit a new farm chemical for a fixed period, which enables firms to recover their large R&D expenditures. The issue of efficiency and new pesticide policies is discussed in a later section of the paper.

When firms have considerable market power it would be expected that they would attempt to price discriminate by charging higher prices for a particular farm chemical in those countries and markets that have a lower price elasticity of demand for the product, and conversely. Empirical evidence on international comparisons of prices for farm chemicals supports this theory. Given the generally less intensive nature of Australian agriculture and the lower product prices received by farmers we would expect a more elastic demand (on average) for farm chemicals and correspondingly lower sale prices than prevail in most other developed countries. The empirical evidence presented by the Prices Surveillance Authority (1993) shows that overall the prices paid for chemicals by Australian farmers are low by world standards. Moreover, the identification of a large new market segment with an elastic demand for farm chemicals in the form of minimum tillage, has led to a firm's reducing the price of Roundup by 30 per cent, and more than doubling its sales of the chemical.

One of several exceptions to the generally lower prices paid by Australian farmers for chemicals is Vetrazine which is used to control blowfly strike. The Australian sheep industry requires protection from fly-strike to a greater degree than European countries. This is largely due to the characteristics of the Merino sheep which has folds of skin which increase wool yields, but make the animals more susceptible to fly strike. Consequently, the price elasticity of demand for Vetrazine is likely to be lower in Australia than in other countries and the higher price appears to reflect firms following a policy of charging according to 'what the market will bear.'

Some insight into the generally important influence of the prices of farm chemicals on their levels of usage and farm profits, is provided by the research of Dann et al. (1994). Using ABARE survey data, broad estimates of the private economic costs of an increase in the cost of farm chemicals used in Australian broadacre agriculture are made. The authors provide no information about the model(s) they used to obtain their results. However, they claim that their analysis "takes into account the possibility that decreased chemical use may involve changes in the types of outputs produced, for example as a result of changed rotations. Finally, the analysis allows for substitution between pesticides, fertilisers and other farm inputs." (Dann et al., 1994, p.506).

---

16 There are approximately 4 500 registered agricultural chemical and veterinary products on the Australian market (Prices Surveillance Authority, p.10).

IV. Impact of Government Policies on Pesticide Use

Australian government agricultural and economic policies have often provided incentives, usually unintentionally, that have influenced levels and methods of pesticide use. The agricultural policies of other OECD countries have arguably had a greater impact on Australian agriculture and its associated pesticide use than have Australia's own agricultural policies. These policy issues are addressed in this section of the paper.

Agricultural protection

Australian agriculture may be characterised as an industry that generally receives low levels of protection and that is heavily orientated toward export markets. Changes in the volume of Australia's exports of agricultural commodities are usually assumed to have insignificant impacts on world prices, with the notable exception of wool. The pattern and intensity of rural land use in Australia is thus very dependent upon world agricultural commodity markets and the policies of overseas governments which influence these markets.

Table 1: **Nominal rates of direct assistance to agriculture in industrial countries, 1979 to 1993 (per cent, based on producer subsidy equivalents[a]**

	1979-81	**1982-84**	**1985-87**	**1988-90**	**1991-93**
EC-12	58[b]	50[b]	85	78	90
EFTA	NA	113[c]	180	230	246
Japan	133	170	250	184	187
United States	19	28	56	27	26
Canada	32	41	79	54	53
Australia	10	16	16	9	11
New Zealand	22	37	28	6	6
ALL OECD	**41**	**45**	**79**	**64**	**69**

a The border price plus the per unit producer subsidy equivalent, expressed as a percentage of the border price for each commodity, and averaged across commodities using production valued at border prices as weights. The EC rates include national government assistance as well as that provided by the Community's CAP. EFTA refers to the unweighted average of the national rates of assistance in the five main Member countries.

b EC-10.

c 1979-85

Source: OECD (1994a and earlier issues) as compiled by Anderson (1995)

Anderson (1995) presents data showing a strong positive link between agricultural protection and the use of farm chemicals. Nominal rates of direct assistance to agriculture in industrial countries over the period 1979 to 1993 are shown in Table 1. These data clearly show the low levels of direct assistance given to agriculture in Australia and New Zealand. In Australia, the level of protection to agriculture in 1991-93 is similar to its level in 1979-81. The level of assistance to New Zealand agriculture which was more than double the level of assistance to Australian agriculture over the period 1979-84 has now declined significantly, and is lower than in Australia. In contrast, levels of assistance to agriculture in the European Community (EC) and EFTA have increased substantially.

The most comprehensive picture of the effects of domestic protection for Australian agricultural production and rural incomes, is provided by the ORANI general equilibrium model of the Australian economy (Edwards, 1990). Removal of rural assistance was estimated to reduce agricultural output approximately 3 per cent with 1981-82 rates of assistance.[17] The positive effects on agricultural output of removing protection from the manufacturing sector, are at least 50 per cent greater than the negative effects on output that removal of assistance to agriculture would cause.

While reductions in rates of assistance implemented for rural and manufacturing industries by the Australian Federal Government have made price distortions in product markets a less important cause of inefficiency, some significant incentives for landholders to use resources in ways that do not yield the highest economic returns to the nation, remain. The latest available information from the Industry Commission (1995) shows an average nominal (effective) rate of assistance of 28(92) per cent for milk production, 16(40) per cent for dried vine fruits and 10(26) per cent for wine grapes.[18] The industries receiving this assistance obviously welcome it and governments no doubt see compelling reasons for providing it, but the political and industry benefits come at a cost to the nation in terms of efficient resource use.[19]

As is discussed in a following section of the paper, the above estimates of effective rates of protection do not take the subsidised price of irrigation water into account. Irrigation water is an important input for each of the above protected industries and irrigation and pesticides are complementary inputs in production. The current measures of effective rates of protection therefore underestimate the extent of the inefficient resource allocation cost to the nation.

The highly protected (by Australian standards) dairying industry, is not a pesticide intensive industry. Annual expenditure on pesticides applied to pasture and crop is of the order of only $2.6/ha. The dried vine fruits and wine grapes industries are relatively pesticide intensive industries, but the author is unaware of any quantitative public estimates of expenditures on agricultural chemicals in these rural industries.

The nature of Australia's export orientated agricultural sector, probably has been influenced more by the agricultural policies of overseas countries than by its own domestic policies. The impact of domestic agricultural policies, such as the Common Agricultural Policy (CAP), on depressing and destabilising international trading prices for agricultural commodities is now well documented.[20] Trade liberalisation would lead to a significant expansion of Australian agriculture, particularly in ruminant

---

17 The current rates of rural assistance in Australia are somewhat lower than in 1981-82.

18 With the exception of the small but highly protected tobacco industry, the highest nominal rate of assistance for other agricultural commodities is 5 per cent for sugar.

19 For a more detailed discussion, see Edwards *et al.* (1996a).

20 For an early quantitative empirical study of these impacts see Chisholm and Tyers (1985). For a recent comprehensive study of agricultural protection, see Tyers and Anderson (1992).

meat, wheat, rice and coarse grains and an associated increase in the use of agricultural chemicals. At the same time, trade liberalisation in agricultural commodities would lead to a substantial contraction of agricultural output and the associated intensive use of pesticides in highly protected regions such as the EC.

The simulation work on the impact of the agricultural trade liberalisation in the Uruguay Round of GATT, suggests relatively modest increases on the long run average level of world prices for major agricultural commodities relative to the prices of manufactured goods (Martin and Winters, 1996). The expected increases in world prices for wheat, coarse grains, oil seeds and sugar are likely to cause a modest increase in pesticide use in these sectors of Australian agriculture.

Domestic economic policies

In many respects, domestic macroeconomic and general microeconomic reform policies may have a greater influence on Australian agriculture than domestic agricultural policies. The domestic economic policies have been designed to make Australian industries internationally competitive, and include macroeconomic policies such as deregulation of the exchange rate; microeconomic reforms aimed at reducing industry costs through greater competition, particularly in handling, transport, marketing and other service industries; and trade initiatives such as the pursuit of freer trade at the recently concluded Uruguay Round of GATT and other forums.

On Australian broadacre farms, capital expenditure represented around 25 per cent of total farm expenditure in the late 1970s but, by the early 1990s, this proportion had fallen to around 10 per cent. In contrast, the proportion of expenditure on materials (seed, fodder, fuel, fertilisers and chemicals) on broadacre farms, increased over the same period from around 27 to 35 per cent. This apparent substitution of materials for capital was even greater on crop specialist farms and is associated with a large rise in the use of farm chemicals (Knopke et al., 1995). Over the period 1977-78 to 1993-94, average annual total factor productivity growth was estimated to have been 4.6 per cent on crop specialist farms and 3.2 per cent on mixed crop-livestock farms, compared with less than 2 per cent on livestock specialist farms.

Knopke and Harris (1991) argue that the input substitution that has occurred is partly attributable to changes in relative input prices, most notably the sharp rise in real interest rates and the user cost of capital which occurred in Australia during the 1980s.

Much of the new farm technology in earlier periods was embodied in new plant and equipment. The change in relative input price appears to have provided a strong incentive for the adoption of capital saving farm practices of which the most striking example is the widespread adoption of minimum tillage by crop farmers. An Australian case study of this important technological innovation, which has led to a substantial increase in herbicide use, is provided in Annex 1.

Irrigated agriculture

While subsidies for fertilisers and tax concessions for land clearing - both of which were complementary inputs with pesticides - are long gone, the price of irrigation water continues to be subsidised. Moreover, because of the varying levels of subsidy between the States and the difficulty of quantifying the subsidy, the Industry Commission’s estimates of effective rates of assistance to the agricultural sectors do not take this subsidy into account (pers. comm. Paul Emergy, Feb.1996).

One reason for the difficulty of quantifying the level of subsidy is that much of the headworks and some of the distribution infrastructure associated with irrigation systems represents a sunk cost. A forward-looking marginal cost approach to water pricing which is appropriate for efficiency, does not require irrigators to necessarily pay a price that covers all operating, capital and external environmental costs of water use.

Irrigated agriculture in Australia is a substantial industry accounting for around 25 per cent of the total value of agricultural production and 75 per cent of Australia's total water consumption. Much of Australia's irrigation infrastructure was funded by government as a means of achieving social policy goals such as closer settlement. Irrigated agriculture is thus a much larger industry than it would have been, had its evolution been determined solely on the basis of economic efficiency. Nation-wide, it is estimated that all rice and tobacco crops, more than 90 per cent of the cotton crop, about 70 per cent of vegetables and grapes, 50 per cent of the fruit crops and one-third of the sugar cane crop are grown under irrigation. Irrigation increases crop yields and makes it possible to produce products that could not be commercially produced under dryland agriculture. Irrigated agriculture usually entails increased pesticide use as it leads to increased humidity and associated fungal growth and pest infestation.

Inexpensive water leads farmers to adopt irrigation activities such as flood irrigation, that can have significantly adverse environmental side effects. Flood and furrow irrigation currently account for around 70 per cent of irrigation by area. The potential for polluting waterways through the release of irrigation tail-water is a major concern. The main focus of public attention has been on fish kills believed to be caused by pesticide residues in waterways. Most States have Clean Water Acts whereby it is an offence to discharge pollutants to any water body. These Acts notwithstanding, it appears that authorities in some States do not impose tail-water recycling on farmers.

Even where farmers have reticulated irrigation systems designed to recycle all of their tail-water, there is presumably a question of potential pesticide contamination of waterways via subterranean leaching of pesticides through the soil profile. Major industries of concern are cotton, rice and horticulture. A large number of fish kills have been reported in water bodies in cotton growing regions. There is some speculation as to how many of these fish kills could be attributed to pesticide residues. It is known that fish are particularly sensitive to some pesticides (e.g. Endosulphan).

Policy changes by the States in recent years which involve the introduction of transferable irrigation water entitlements and moves toward high water prices, will provide an incentive for greater adoption of modern drip and sprinkler technologies. The lower run-off and deep-percolating water associated with these technologies will reduce pesticide residues entering surface waterways and groundwater.

Landcare and land conservation[21]

The Commonwealth government established the National Landcare Program to encourage Landcare in the agricultural sector. Activities relating to Landcare have also been targeted through the taxation system by the Landcare tax concessions. Under sections 75B and 75D of the Australian Income Tax Assessment Act (1936), tax concessions are given for investment in soil and water conservation. These concessions reduce the costs of investments in eligible soil and water conservation measures in proportion to an individual farmer's marginal income tax bracket. Their impact overall on farm chemical use is likely to be small. Some farmers, however, may have converted land from land to more soil erosive crops because the private costs of rehabilitation have been lowered by the tax concessions. The more herbicide intensive crop production would result in some increase in farm chemical use.

---

21 The following four sub-sections of the paper draw on Edwards *et al.* (1996b).

A 10 per cent investment allowance was recently introduced for expenditure on fodder and water storage for livestock, water conveyancing and minimum tillage equipment. The benefit from an investment allowance is also tied to a farmer's marginal tax bracket. Minimum-tillage techniques combat soil erosion problems by substituting chemical inputs for mechanical tillage. The investment allowance for minimum tillage equipment thus provides an associated incentive for increased expenditure on herbicides.

Restrictions on clearing of native vegetation

Clearing of native vegetation for agriculture is still being practised in parts of Australia. Over the period 1983-93, it has been estimated that the annual average rate of land clearing for agriculture, was around 570 thousand hectares with well over half of the land clearing occurring in Queensland. It is unclear, however, how much of the relatively large area of land being cleared in Queensland represents regrowth.

Restrictions on the clearing of native vegetation have become politically popular in recent years, especially since the emergence of the 'greenhouse' problem. These restrictions will have caused some reduction in land clearing and the associated demand for herbicides. The longer-run changes in pesticide use will depend on the agricultural uses of the cleared land.

Absence of effective policies to restrict agricultural use near waterways

The riparian zone - embracing river banks, floodplains and wetlands - acts as a crucial buffer between rivers and their catchments. Yet it appears to have been one of the most neglected environments in Australia. Perhaps it has been largely ignored by policy makers because it does not fit neatly into the category of land or water.

The Crown has the rights to the riparian areas of streams, lakes and rivers but seldom exercises those rights in the case of agriculture. It is likely that restriction of cropping and the grazing of animals to within about 30 metres of watercourses would substantially reduce problems such as the movement of pesticides, fertilisers, faeces and sediment to streams. Associated problems of water pollution, algae blooms, and sedimentation of dams and reservoirs would therefore be reduced. These restrictions would not be costless - they would require the installation of fencing and watering points along streams, possibly accompanied by replanting of the riparian areas with indigenous vegetation. These costs should be weighed against the benefits of restrictions.

In most cases it would not be possible for government agencies to manage or police these areas so the problem would have to be 'owned' by adjacent landholders[22]. Under the Resource Management Act 1991, New Zealand has successfully introduced systems for managing riparian areas in several regions, especially in dairying areas where problems of water pollution had become serious. The landholders are assisted in the information, planning and implementation stages of change, and accept responsibility for the control of water quality in their catchment.

It should be recognised that removal of agricultural activities from land in close proximity to waterways, will not necessarily reduce pesticide use levels if weed growth is a problem. Indeed, insofar as

---

22 A number of economists have found that government-owned irrigation systems are less effective than systems owned and monitored by farmers themselves (Ostram 1992). Farmers involved with monitoring, exert strong peer pressure to thwart rule violations which is typically more effective than the monitoring by employees of government irrigation bureaucracies .

grazing animals are a substitute for pesticides in controlling weed levels, pesticide use may increase. In these circumstances, the techniques, timing of application and type(s) of pesticides used are critical.

Rural adjustment scheme/drought assistance

In 1992 drought relief policy was brought under the "exceptional circumstances" provision of the Rural Adjustment Scheme. However, there are some provisions not conducive to conservative management of the land resource. The availability of interest rate subsidies of up to 100 per cent on total debt when special circumstances are declared, encourages higher-risk approaches to stocking and borrowing.

There is evidence (Bob Douglas, pers. comm. 1995) that some aspects of the income taxation system militate against wise stocking policies in the face of an oncoming drought. The use of low nominal values for livestock inventories has the effect of lowering the taxation liabilities of graziers in normal years. However, at the onset of a drought when it may be otherwise prudent, in both economic and environmental terms, to substantially reduce stock numbers, the farmer may discover that if he does so, he will face a large tax liability. The likely impact is increased land degradation and weed growth and an associated increase in pesticide use to control weeds.

A number of other forms of government intervention, such as interest rate subsidies for rural adjustment and income equalisation deposits (IEDs), do not appear to directly influence farm chemical use. However, such policies do increase farm profitability and thus may indirectly increase farm chemical use.

State laws relating to flexibility of pesticide application rates

The laws relating to pesticide application rates in 1989 for each state are shown in Table 2.

Table 2. **Laws relating to rate flexibility in each State**

	VIC	WA	NSW	TAS	SA	QLD
Maximum legal rate?	Yes	Yes	Yes	No[a]	No	Yes
Maximum penalty	$10,000*	$2500	$5000[b] $40000[c]			$2400
Minimum legal rate?	No	No	Yes	No	No	No
Maximum penalty			$5000[b] $40000[c]			
Private advisors flexible?	Yes	Yes	No	Yes	Yes	Yes
Govt. advisors flexible?	No	Yes	No	Yes	Yes	Yes

a Maximum residue limits apply
b Magistrate
c Land and Environment Court
* The maximum penalty for non-compliance by corporations is $20,000.

Source: David Pannell (1989) Plant Protection Quarterly, Vol. 4(3), p.105.

Most state laws relating to pesticide application rates impose regulations on maximum legal rates. NSW is the only state to also regulate minimum legal rates of application. "In New South Wales, farmers are legally prohibited from applying chemical rates less than specified on chemical labels. In some Australian States, advisers and consultants are prohibited from advising farmers to apply chemical rates which are below label rates. It is argued that these laws are not just environmentally unsound but that they can also reduce farmers' profits. Arguments in favour of chemical rate flexibility are presented. It is noted that in the United States, a 1978 amendment to the relevant Act specifically legalised use of sub-label dosages. Similar amendments are needed in the Australian States identified." (Pannell op.cit. p.104).

The current NSW Pesticides Act reflects concerns relating to pest resistance. Farmers can apply pesticides at lower than label rates if they hold a permit. These permits can be obtained providing the Environmental Protection Authority is satisfied that the pesticides will be effective and will not contribute to species resistance. The Environmental Protection Authority is currently reviewing the NSW Pesticides Act, and provision for pesticide use at lower rates, less frequent intervals and lower concentrations is being considered (pers.comm. J. Mallen-Cooper, April, 1996).

Research and development

In the longer run, the structure of incentives for R&D and the related nature of new technology in agriculture has important implications for future pesticide use and the magnitude of adverse environmental effects.[23] Is the current balance in R&D funding between "conventional" agricultural technologies "alternative" "low input" and "green" technologies the appropriate one?

Within the context of conventional agriculture, technologies that facilitate environmental protection may be viewed in several ways. First, reducing pesticides per unit of output could be accomplished by either directly augmenting the productivity of pesticides or augmenting the productivity of other inputs that substitute for pesticides. If there is very high substitutability between new techniques and pesticides, the need for pesticides may be completely eliminated, e.g. pure organic farming. This case is straightforward from an environmental viewpoint, if the new techniques are more profitable than techniques using pesticides they will be adopted and pesticide usage falls unambiguously. The situation is more complicated in the case where technical change diminishes but does not eliminate the need for pesticides. In this instance, new techniques could increase total pesticide usage despite reducing usage at the intensive margin (Abler and Shortle, 1995).

It should be noted that if low input - low output agriculture is adopted only in some regions with suitable bio-physical characteristics and the demand for agricultural products is inelastic, a lower level of output will result in higher agricultural prices. Higher agricultural prices provide an incentive for more intensive use of inputs and expanded output in the other regions practising conventional agriculture. Thus, adverse environmental effects may increase or decrease as a result of low input - low output agriculture replacing conventional agriculture in some regions.

---

23 For more in-depth discussion of agricultural R&D and environmental issues, see Abler and Shortle, 1996 and Chisholm and Hone, 1996.

V. Pesticide Use and Market Failure

Both agricultural pests and pest management resources have special characteristics that create a distinctive and complex class of resource management problems:

- the mobility of many pest types may cause severe open access or common property problems. Property rights to pests are not usually assigned. Consequently, individual farmers may not consider the effects of the impact of their pest management actions on pest populations on neighbouring farms and elsewhere.

- mobility of pesticides via wind currents, water or other media may cause offsite damage to crops, livestock, wildlife flora and fauna and humans.

- there is a risk that farmers acting individually will not take into account the impact of their pesticide use activities on build-up of resistance by pests, just as individual motorists do not consider their contribution to road congestion. The extent of the externality problem associated with pest resistance is greater for highly mobile insect pests than for weeds. However, resistant weed seed can spread via contaminated crop seed.

- the health of farmers and farm workers may be directly affected by pesticide use and consumers of farm products may be adversely affected by pesticide residues.

- research on pest control and information on pest densities and movements, commonly have public good attributes.

Most of the external effects of pesticide use on environmental quality are strongly dependent on the location of applications. A major exception is application of methyl bromide which is a global “public bad” insofar as it causes ozone depletion. The damage to the ozone layer is independent of the location of its use on earth.

The above pest and pesticide problems stem from essentially three types of market failure: externalities; asymmetric/imperfect information; and public good characteristics. In the absence of government action, independent choices by individual producers, consumers and labourers are unlikely to provide the level and form of pest control and safety that society desires.

The major impacts and types of market failure causing sub-optimal uses of pesticides under a laissez faire regime are summarised in Table 3.

A common characteristic of the first three impacts shown in Table 3, relating to spread of pests, is that the acting party generates positive externalities. Thus, under a laissez faire regime too little pest control will be undertaken and the spread of pests will be socially excessive.

The most notable mobile pest in Australia is arguably the rabbit. Legislation recognises the externalities associated with controlling spread of the rabbit and other animal and plant pests. Farmers are legally required to control animal and plant pests classified as being ‘obnoxious’.

Much of Australia’s experience with biological pest control has targeted species with a high capacity to spread from farm to farm and from farm to environment, and conversely. Australia has had mixed success with biological control (Office of the Chief Scientist, Department of the Prime Minister and

Cabinet, 1995). The major successes have been the introduction of Myxomatosis to control rabbits and Cactoblastis to control the prickly pear cactus. There have been several other acceptable outcomes such as the use of insects to control weeds e.g. ragwort, Paterson's curse and boneseed; the use of fungal rusts to control blackberry; and the use of dung beetles to control buffalo flies in northern Australia. Many biological control agents provide only partial control and hence only partial reduction in pesticide use. The introduction of the cane toad to control sugar cane beetles proved to be a spectacular failure as the cane toad itself has since become a major pest in northern Australia. Clearly, biological control of pests is not necessarily a riskless substitute for chemical pesticide use.

Table 3. **Market failure and sub-optimal pest control**[a].

	Description of Impact	Types of Market Failure
1.	Farm-farm pest spread	External cost to farmers
2.	Farm-environment pest spread	External cost to the public
3.	Environment-farm pest spread[b]	information
4.	Pesticide resistance	External cost to farmers. Imperfect information
5.	Destruction of beneficial species	External cost to farmers. Imperfect information
6.	Emergence of secondary pests	External cost to farmers. Imperfect information
7.	Chemical residues in food	External cost to consumers and farmers
8.	Air pollution	External cost to the public and farmers
9.	Chemical residues in surface waterways	External cost to the public
10.	Chemical residues in groundwater	External cost to the public
11.	Worker safety	Imperfect information
12.	Research and extension	Public good nature of research and extension

a This is a modified version of a classification of market failures presented by David Pannell (1994).

b Excessive spread of pests from the environment to farms usually stems from publicly-owned land. This is a form of government failure rather than market failure.

The major impacts of market failures may be divided into impacts on environmental quality, human health and external costs imposed on other farmers. The most common type of market failure is externalities (spillover effects) associated with the application (or lack of application) of pesticides. Externalities are the dominant type of market failure causing impacts 1-10 in Table 3. An externality occurs when an activity undertaken by an individual (firm) has spillover effects on others which are not taken into account by the first party.[24] Negative externalities may also arise from transport and storage of pesticides and disposal of pesticide containers and unused pesticides.

---

24 More precisely, "An externality is present whenever some individual's (say A's) *utility* or *production* relationships include real (that is, non-monetary) variables, whose values are chosen by others (persons

Under optimal resource allocation, a pesticide should be used at the level at which the value of its marginal product is equal to the sum of private costs plus spillover (externality) costs. In principle, the spillover effects that introduce wedges between private and public (social) costs and benefits under a laissez faire system, can be corrected by a government imposed system of price-based incentives. Under a system of Pigovian taxes/subsidies, for example, negative spillover effects of pesticide use would be taxed at rates equal to the marginal damages they cause and positive spillover effects would be subsidised at rates equal to the marginal benefits they generate.

The potential to use economic incentives to attain socially more efficient pesticide use is discussed in a later section of the paper. The following sub-sections briefly consider some general aspects of risk and uncertainty relating to pesticide use and particular aspects of farmers' health and their use of chemical protective equipment.

Risk and uncertainty

Risk has been perceived as an area of considerable importance in the literature on pest control in agriculture. Risk may influence pesticide decision making either because of the risk aversion of producers (or food consumers) or because of its influence on expected profit. For instance, there is evidence that the pesticide dosage which maximises a farmer's expected profit is lower under risk than under certainty. Some agricultural economists have gone so far as to claim that risk reduction is the main motivation for the application of pesticides (Reichelderfer 1980, and Wetzstein 1981).

Some commonly made assertions about the influence of risk in pest control have been challenged (see Pannell, 1991). Pannell's research work leads him to conclude that, "Depending on the balance of forces to increase and decrease pesticide use under risk, in many circumstances the net effect of risk on optimal decision making for pest control may be minimal" p.361.

In particular, Pannell argues that it is important to identify all sources of risk and not confine attention to the most commonly considered sources of risk: uncertainty about pest density and pest mortality. For some sources of uncertainty, such as pest density and yield loss per pest, pesticide application acts to reduce risk. However, Pannell claims that for other sources of uncertainty, such as pesticide damage to crops, pest-free crop yield and output price, pesticide application can increase risk. "Thus the validity of the usual assumption that pesticides reduce risk depends on the relative importance of the different sources of uncertainty." (Pannell op.cit. p.378.)

These research results are clearly very relevant to evaluations of Integrated Pest Management (IPM) programmes.

Farmers' health and their use of chemical protective equipment

The two classes of agrichemical risks to human health commonly referred to in studies of the effects of chemical exposure are the acute and the long-term chronic health risks. Acute agrichemical poisoning results from acute short-term exposure and occurs soon after exposure.

---

corporations, governments) without particular attention to the effects on A's welfare." (Baumol and Oates, 1988)

Chronic health risks are due to small repeated doses of an agrichemical over time. Symptoms of chronic poisoning, such as soft tissue sarcoma and malignant lymphoma, may not become evident for up to 30 years.

In a seminal paper on market failure and chemical use, Brush and Clemes (1995), drawing particularly on New Zealand and to a lesser extent Australian data, present a cost-benefit analysis of the costs of implementing, and the benefits from adopting, safe agrichemical practices. The two main findings of this study are that there is a significant benefit-cost surplus in the use of agrichemical protective equipment; and that there is, however, strong evidence that a substantial proportion of farmers do not comply with the recommended agrichemical equipment requirements.

In Australia, Clarke (1993) states that "No national or state data are available currently to detail the nature and extent of the pesticide exposure problem for those involved in agriculture" (p. 30). However, Brush and Clemes cite a limited case-control study of male patients in the state of Victoria with soft tissue sarcoma or malignant lymphoma by Smith and Christophers (1992). The study found that for Victorian males who had experienced exposure to phenoxy herbicides or chlorophenols for a period of more than 30 days the estimated relative risks[25] were 2.0 for soft tissue sarcoma and 2.7 for malignant lymphoma. Farmers are less likely to suffer from ill health generally than the rest of the population. Thus the relatively high risk among farmers for a few specific work-related cancers is against a background of their being a low risk group for most other diseases (Brush and Clemes).

Two other surveys have investigated the impacts of agrichemical use on users' health in Australian agriculture. The Kondinin Group (1993) survey found that 36 per cent of Australian farm chemical users stated that they had suffered ill effects from using agrichemicals. McMullen et al. (1993) in their study of non-farmer agrichemical users found that 85.7 per cent stated that they had experienced exposure to chemicals at some time, and believed that it had affected their health.

Brush and Clemes conclude in their study that there is strong evidence of a substantial proportion of farmers in Australia and New Zealand not complying with the recommended agrichemical protective equipment requirements.[26] Moreover, their study provides evidence that Australian and New Zealand farmers rate their knowledge of agrichemical practices as being good to excellent, in spite of clear evidence to the contrary. This leads a significant percentage of farmers to underestimate the health risks from exposure to agricultural chemicals, and consequently undervalue the implementation of 'safe' practices. Only 7.8 per cent of Australian livestock farmers, for instance, had been formally trained in the use of farm chemicals, as at January 1994 (McGuffog and Company, 1995). Yet Sutherland (1994) found that 77 per cent of respondents who had undertaken farmer chemical user training in New South Wales, had as a result modified their farm chemical practices and over a half of these indicated they had greatly improved safety measures. Brush and Clemes suggest that there is significant market failure attributable to informational failure by farmers, and that this may warrant making agrichemical application training

25 The relative risk is a measure of the incidence of the disease in a particular category of the population relative to the incidence in the rest of the population.

26 Despite the evidence of non-compliance, a thorough review of the New Zealand agrichemical and occupational safety case law found no instance of any non-compliance case being acted upon under the relevant provisions. The authors are unaware of any comparable review being undertaken in Australia where, under the various state legislation that governs agrichemical and occupational safety, provision is made for considerable penalties for non-compliance.

compulsory for farmers.[27] Furthermore, greater monitoring of agrichemical practices and stricter enforcement of the legislation may also be warranted.

VI. Australia Pesticide Regulations and Policies

Australia does not have a formal policy on pesticide risk reduction. Australia's position is that '¼ Activities such as arbitrary targeted reductions or the setting of levies or taxes against any pesticide or group of pesticides, or moves to harmonise risk evaluation are seen as counter productive to risk reduction principles' (Report of Australian Delegation to the OECD/FAO Workshop on Pesticide Risk Reduction, Uppsala, Sweden, 16-18 October 1995, p.1).

Regulations designed to reduce risks of pesticide use are carried out by an array of organisations at national and state level. The reasons for there being a number of different organisations are primarily historical and constitutional, but are also due to the diversity of Australian agriculture, climate and land type. The central focus of the regulations is improved management of pests and diseases, and more effective use of pesticides, rather than on pesticide use reduction per se or even the targeting of particular groups of pesticides such as the organophosphates.

In 1995, a number of factors led Australia to introduce a National Registration Scheme for agricultural and veterinary chemicals, including community lobbying for a national co-ordinated scheme. The need for a National Registration Scheme was recognised in the report of the Senate Select Committee on Agricultural and Veterinary Chemicals in Australia (July 1990). Importantly, it was also prompted by concerns about the trade implications of pesticide residues, occupational health and safety issues and environmental concerns. The National Registration Scheme was prompted then by a widespread recognised need to rationalise seven different State registration schemes into one.

Prior to the National Registration Scheme, each State operated a registration scheme. Under the National Registration Scheme (operated by the National Registration Authority (NRA), all agricultural and veterinary chemicals have to be registered by the NRA before they can be manufactured, supplied or sold (up to the point of retail sale) in Australia. The registration process of new chemicals involves a standard evaluation of each chemical's safety to humans and the environment. Yet once registered, the controls and conflicts surrounding usage are left to individual State and Territory Governments.

In theory, if new information comes to light which challenges the safety of a chemical the NRA has the power to deregister the chemical, or impose additional restrictions on its use. In practice, there is reason to believe that the NRA is reluctant to deregister chemicals (see, for example, Fritz (1995, p.19), and the Existing Chemicals Review Program below).

The NRA is implementing an Existing Chemicals Review Program (ECRP) which will systematically review the safety of a limited number of chemicals already registered. The Senate Hansard (30 May 1994) records the then Minister for Primary Industries and Energy as saying that the ECRP '¼ is planned to commence in January 1995'. The NRA (News December 1994) announced that it '¼ could handle about 10 to 15 chemicals a year over two to three years' (p.1), and that '¼ the priority list will cover 10-15 chemicals each financial year, with 30-45 chemicals reviewed over three years, and the

[27] There has been increasing participation by Australian farmers in training courses on appropriate chemical use, including the nationally co-ordinated Farm Chemical Users course. In the Goulburn Valley in Victoria, for instance, around 90 per cent of farmers have undergone training (pers. comm. Catherine Hollywell, April 1996).

community will be made aware that the programme will occur at this rate' (p.2). The Gazette of 2nd May 1995, included the ECRP Priority Candidate Review List, consisting of the names of 80 pesticides from which those to be reviewed would be drawn. On 6th June 1995, five chemicals included in the first cycle were listed in the Gazette, all of which had been banned or restricted by a number of Australia's trading partners with one (parathion) being withdrawn in some EU countries in the early 70s.

The Department of Human Services and Health was sufficiently concerned about the rate of progress to note in its Annual Report for 1994-95 (p.27) that the '¼ Existing Chemicals Review Program ¼ was expected to be fully underway by 1994-95 with 13 chemicals assessed by the end of this year. However, procedural delays within the National Registration Authority and the funding cuts it attributed to the rural drought, have delayed the start of assessments until the 1995-96 financial year.'. In August 1995 the NRA News announced that '¼ review of the first five chemicals nears completion ¼' (p.3), though in October 1995 it was announced that the preliminary evaluation is likely to be completed between May and October 1996 (depending on the pesticide), with the review outcome expected to be implemented between August 1996 and April 1997. In summary, instead of having reviewed 10 to 15 pesticides, with another list of 10 to 15 ready by the time of writing this report (according to the Minister's and NRA own estimates), the review of the first five pesticides is expected to be finished by October 1996, with no sign of work on another list as yet.

Under the programme, older chemicals which have been superseded by more effective and less hazardous ones, may be withdrawn from use. Yet in fact, withdrawal is rare and may only have occurred in the case of the partial withdrawal of organochlorines and usually the removal of permits for 2,4,5-T. Australia continues to use a considerable number of chemicals, albeit on a reduced scale, which have been withdrawn, banned or restricted by other national regulatory agencies, including a range of organo-metal herbicides (organic arsenics) and fungicides (organic mercury). Australia permits the use of old pesticides that were 'grandfathered' into the system (accepted on limited data) without requesting full registration data packages at a later date (for example, the herbicide Frenock). This compares with some other countries (for example Sweden and Denmark) which have set limited time frames to re-evaluate all pesticides on the market before a specific date (for example, in Denmark all pesticides registered before 1986 had to be re-evaluated before 1993), and which require re-registration of all pesticides every 5 years (see Wynen 1994a and 1994b).

Under the NRS, the States are responsible for ensuring that pesticides, after retail sale, are used safely and only for the uses for which they are registered. All States, to some degree, have extension and education activities aimed at achieving safe and effective use of pesticides, yet these do not compare favourably with those from overseas.

The States are also responsible for a number of regulatory activities aimed at pesticide risk reduction, including controls on aerial spraying, licensing of commercial pest control operators, investigation of aerial spray drift complaints and the monitoring of pesticide residuals in waterways.

While such regulatory activities are considered the responsibility of the States and Territories, these activities are far from uniform across the country. The licensing of pest control operators is not mandatory in all states, nor are there appropriate and effective controls or investigation of aerial spraying activities or complaints, despite recommendations by the Senate Select Committee on Agricultural and Veterinary Chemicals in Australia (July 1990). The system of investigation of ongoing communities-based complaints has been far from satisfactory.[28] Issues of possible surface water contamination and monitoring have rarely been addressed adequately from the community's point of view. Australia does not have a consistent or co-ordinated programme of environmental monitoring.[29] Contamination of media other than food is only investigated in an ad hoc, often project or issue-based situation.

The Government Departments and Authorities responsible for the above regulatory activities varies between States. In New South Wales, for instance, the Environmental Protection Authority now has the responsibility of administering pesticide regulations and has drafted Licensing Guidelines on Herbicide Use in or Near Waters which, amongst others, sets out the EPA's policy position on whether a licence is required for the application of herbicides. In Victoria, pesticide regulatory powers are divided between the Department of Natural Resources and the Environment and the Environmental Protection Authority. The former, for instance, is responsible for investigating complaints about aerial spray drift, whereas the later is responsible for monitoring pesticide residues in waterways. Penalties vary from State to State. However, few have ever been imposed. There are several reasons for this:

- regulatory agencies are reluctant, or unable, to prosecute offenders because of an absence of environmental standards for a number of commonly used pesticides.[30]

- due to the official culture which prefers persuasion to prosecution, regulatory bodies openly state their reluctance to take on the paperwork involved in prosecutions.

- although the power to impose penalties rests with State bodies, they can only prosecute actions carried out in their own state.

- The variations in State regulations facilitate the ongoing avoidance of prosecutions as contamination of river systems upstream is often not addressed by regulatory authorities downstream. With respect to fish kills, apparently due to excessive pesticides in waterways, successful prosecution of offenders is rare. (pers. comm. Anthony Scott, CSIRO, relating to fish kills in waterways in cotton growing regions).[31]

Australia has a number of residue monitoring programmes to ensure that agricultural produce meets national and international pesticide residue standards. These programmes include:

- The National Residue Survey, conducted by the Department of Primary Industries and Energy's Bureau of Resource Sciences, tests raw food and other agricultural commodities produced in Australia for residues of a wide range of chemicals commonly used in agricultural production. It also tests for residues of heavy metals and other environmental contaminants.

---

28 For instance, a case of direct exposure of school children by aerial spray drift in northern NSW remains unresolved and no action has been taken against the pilot despite over 5 years of recorded complaints. There may be, of course, insufficient *legal* evidence to support a prosecution.

29 Australia has not progressed far on determining the policy relevance of environmental indicators, such as the "pressure-state-response" model adopted by the OECD, in part because of the lack of appropriate ecological models (Chisholm and Dumsday, 1995).

30 Regulators also sometimes face difficulties proceeding to prosecute because of a lack of clear evidence.

31 For a recent comprehensive survey of fish kills and damages to other aquatic organisms in the irrigation areas of South-Western NSW, see Environmental Protection Authority, NSW, 1996.

- Food standards as measured in Maximum Residue Levels can differ between the domestic and export market. However, food rejected on the export market has sometimes been released for domestic consumption in Australia.[32] In addition, until recently, test results of food on the domestic market were often released after the food was consumed.

- The Australian Market Basket Survey, attempts to calculate the intake of residues in the Australian diet. Cooked, or otherwise processed food, that is representative of diets for males and females of various ages is sampled and analysed. Unfortunately, as was noted in the recent Cadmium debate, Australia has no up-to-date dietary information (post-1970s) for specific groups such as adolescents and people of ethnic background.

- The Australian Quarantine and Inspection Service (AQIS) conducts residue testing programmes designed to achieve quality assurance for exported products. AQIS programmes are biased toward detecting critical contaminants such as organochloride and organophosphate residues, particularly in exports of meat, seafoods and dried fruit.[33]

- The National Antibacterial Residue Minimisation Program (NARM) is a joint Commonwealth-State programme designed to detect unacceptable levels of antibacterial residues.

- The States from time to time conduct their own residue surveys which are commonly designed to identify a specific residue problem and facilitate corrective action.

Control of chemical residues in food and fibre

The control of chemical residues in food is vital for Australian agriculture. An ideal incentive structure for controlling chemical residues in Australian food would have several important characteristics

- it would ensure that the pesticide residue standards set by importers in our export markets were clearly met and seen to be met. The response to any infringement of these standards must be swift, efficient and such as to minimise loss of overseas confidence in the quality of Australia's agricultural products.

- the incentive structure should encourage continuous search both overseas and domestically for niche markets ranging from delivery of the high pesticide input 'perfect unblemished red apple' to Japan, to the supply of guaranteed pesticide free organically grown fruit and vegetables to Melbourne's Victoria Market. In other words, the incentive structure confronting farmers, wholesalers and retailers of food should ensure that the wide array of human tastes with respect to pesticide residue status, taste, size and looks of food are catered for. It is particularly important, that consumers can buy with the confidence of knowing that what is stated on the label about, say, the organically grown status of a product, is clear and true. Peoples' attitudes toward risk vary. Even if food containing small amounts of pesticide residues is extremely unlikely to have any impact on human health, it provokes concern in some people as to whether consuming such food would eventually cause serious

32 Minimum Residue Levels and other food quality standards vary between countries and in some instances food may be rejected by an overseas country but meet Australian standards.

33 Recently, the organochloride termiticides has been withdrawn in Australia, with an interim period in the Northern Territory, allowing its restricted use to treat an extremely destructive species of termite whilst alternative methods of control are developed. The only organic mercury farm chemical currently available is for restricted use on sugarcane only (pers. comm. Catherine Hollywell, April 1996).

illness. Other people may not be at all concerned about knowing that the unblemished fruit they eat contains small quantities of pesticides.

Of course, consumers demanding the ‘perfect red apple’ and other niche foods should pay the full health and environmental costs of their production.

Wine grapes

Some agricultural industries are virtually self-regulating. The Australian export wine industry is a notable example. The wine industry is setting standards over and above those set by the Australian registration system for chemicals. A relatively small number of major buyers of Australian wine grapes interact directly with grape growers and a stringent system of pesticide use is enforced. This industry provides a good example of efficient ‘grass roots’ co-operative action to combat a problem.[34] The industry takes advantage of government-provided information of a public good nature on chemical use and integrated pest management. International pressures in particular have pushed wine exporters into setting limits on pesticide use. Some of the importing countries have stringent rules about pesticides residues; in other countries (such as the UK) retailers have started to ask questions about pesticide use, and required tests.

The major buyers of Australian wine grapes developed manuals for chemical use for growers, and required their growers to keep diaries which indicated the details about their spraying activities. These diaries, and samples in the vineyard, are checked randomly. The industry found that growers did not have problems with this approach, as they preferred to restrict pesticide use anyway on the grounds of private health, costs, and for environmental reasons. The fact that everybody had to comply with certain standards meant that competitors did not gain an advantage due to the change. Not all buyers require restrictions on pesticide use. However, as growers often sell to more than one buyer it is estimated that a high percentage of growers comply with the requirements set by the main buyers (Peter Hayes, pers. comm., Feb. 1996).

Residues in grains

The residue status of Australian grains is closely monitored by a number of organisations including the Commonwealth Government’s National Residue Survey and the Australian Wheat Board. The various organisations monitor and report independently which leads to some inevitable duplication of effort and possible waste of resources. However, the current system makes it extremely unlikely that a grain residue problem could ever be concealed in Australia.

Australia’s warm climate provides a favourable environment for insect infestation of stored grain. During the 1970s and 1980s pests were controlled mainly by applying pesticides as the grain was received into bulk storage and Australia’s grain often contained more pesticide residues than did its competitors’ grain. Grain protectants are only one, albeit very important, aspect of the grain residue issue.

---

[34] There is a growing literature providing examples of ‘grass roots’ co-operative actions that have successfully overcome externality-common property problems with minimal government involvement. Indeed, the literature provides a number of examples showing the inefficiency and costliness of traditional government/bureaucratic approaches to these problems, compared with ‘grass roots’ co-operative approaches. A good review that provides an array of real world examples and which discusses the necessary conditions for ‘grass roots’ co-operative approaches to evolve to solve externality/common property problems is provided by Ayers (1995). Wills and Harris (1994) discuss how the best choice between government and private quality assurance will differ between foods and countries importing from Australia for both economic and political reasons.

Other chemicals such as organochlorides and pre-harvest fungicides, may be present in grain as a result of environmental exposure or because they are used in other parts of the production chain.[35] Reforms to the system over the last decade have resulted in major reductions in pesticide residues. For example, the residue status for organophosphates for all Australian grain over the period 1986 to 1994 is shown in Figure 2.

Pressure from export markets for grain with lower level of pesticide residues and the continual emergence of pesticide resistant insect populations have led to the introduction of alternative treatments, such as fumigation with phosphine gas[36], and to a lesser extent carbon dioxide swamping and heat disinfestation.

VII. Efficiency and New Pesticide Policies

Preliminary testing and screening is a necessary part of any system designed to achieve a socially optimal pattern of introduction and use of new pest control agents. If the costs for the introduction of new pest control agents are too high, the level of experimentation and innovation will be too low and growth of food and natural fibre production will be unduly impeded. High registration costs for new pest control agents pose a barrier to the entry of smaller innovative firms which will lead to a highly concentrated agricultural chemical industry, supplying a limited array of high-priced pest control agents. On the other hand, preliminary testing and screening schemes that are too lax will lead to a pattern of development and use of pesticides that causes socially excessive health and environmental damages.

However, Zilberman (1995), argues that policymakers tend to view chemicals as being able to be classified as "good" or "bad". He has strongly criticised this approach in the United States because it has led to extremely high costs for the introduction of new pesticides. "This system of classifying chemicals into good and bad types is an extension of the approach taken by the Federal Drug Authority (FDA) in management of medicines and reflects the basic decision-making mechanism applied by classical statistics. It is an approach that is sub-optimal because the world we live in is full of grey, not black and white. The existing mechanisms reduce innovations for solving pest problems and impede the ability of agriculture to grow" (Zilberman, 1995, p.3). Zilberman suggests that biotechnology (a potential substitute for pesticides) may also encounter unduly heavy regulations that will constrain its potential for innovation.

The current system of pesticide regulation includes an elaborate system of testing and analysis prior to the introduction of new pesticides, some continuing re-evaluation (particularly in response to crisis situations), and regulations relating to application procedures and residue limits. Whilst virtually all pesticides have recommended rates of application, there are very few incentives or regulations related directly to actual use levels. Of course, the requirements and standards of produce buyers, some liability rules for environmental damages attributable to the careless use of pesticides, and educational programmes, all affect farmers' pesticide use levels. However, currently, the main influences on application levels are prices of pesticides, costs of application, price of output, and costs and yields associated with alternative non-chemical methods of pest control.

---

35 During its grain sampling in 1991-92, the NRS detected only 6 cases of organochlorides and 3 cases of pre-harvest fungicides.

36 Fumigation with phosphine gas leaves virtually no residue once the grain has been purged with clean air.

VIII. Economic Instruments and Pesticide Use

"Many noneconomists who are concerned about the environment naturally tend to use command and control mechanisms to address environmental problems, not recognizing the inefficiency of such policies, the political objections that they raise, nor their significant inferiority to financial incentives" (Zilberman et al., 1996, p.16).

In this statement, Zilberman probably overstates the case for economic instruments to address environmental problems. Nevertheless, a major weakness of the existing regulatory system is that in many cases, pesticide users are not provided with an adequate incentive to take into account the spillover effects associated with the use of an agricultural chemical. Users' actions are often based almost solely on the private cost of using a pesticide. Yet, as noted earlier, efficient resource allocation requires that a pesticide should be used at the level at which the value of its marginal product is equal to the sum of private costs plus spillover (externality) costs. Under a system of Pigovian taxes/subsidies, for example, negative spillover effects of pesticide use would be taxed at rates equal to the marginal damages they cause and positive spillover effects would be subsidised at rates equal to the marginal benefits they generate.

A well structured system of Pigovian taxes/subsidies has a number of desirable efficiency characteristics. First, each firm (farm) has an incentive to adopt an individual cost-Minimizing mix of management practices to reduce spillover damages, or increase spillover benefits. Second, each firm will reduce (increase) negative (positive) spillover effects to the point at which marginal damages (benefits) equal marginal costs. The resulting inter-firm pattern of pesticide damage abatement thus provides the aggregate damage abatement at the lowest social cost. Third, a continuous incentive is provided for technical change and for finding innovative low-cost ways of reducing spillover damages from pesticide use.[37] However, computation of the taxes and subsidies that represent the spillover marginal costs and benefits will commonly be very difficult in practice. A number of types of spillover effects may occur simultaneously. Moreover, whilst most spillover effects from pesticide use impose costs on others, some spillovers generate benefits[38] and the magnitude of most spillover effects varies over space and through time.

Pesticide residues in food can be more easily monitored than pesticide residues in the environment. However, valuing the damages to human health for varying levels of pesticide residues in food is as complex and difficult a task as valuing the damages to human health from other types of exposure to pesticides (e.g. aerial spraying) and valuing the damages to the environment. Even if the latter damages could be valued, there is another problem in being able to identify the contribution of each individual source to a perceived pesticide residue problem. The problem is particularly severe for non-point pesticide residue damages such as may occur in waterways.

Most countries in the OECD, including Australia, are signatories of the polluter pays principle, but accurate quantification of optimal taxation for damages from pesticide residues is difficult, to say the least. Realistically, political income distributional reasons, originally outlined by Buchanan and Tullock

---

37 These efficiency characteristics may be classified as intra-source, intersource and dynamic efficiency conditions, respectively. For recent reviews of economic incentives and environmental management see OECD (1994b,c), National Academy of Public Administration (1994), and Chisholm (1995).

38 The spillover benefits of an individual farmer's control of a highly mobile veterbrate pest like the rabbit will usually far exceed any negative spillover effects from fumigation of warrens or laying of chemically poisoned baits.

(1975), will usually prevent policymakers from imposing very high pollution tax rates.[39] Rather, policymakers will tend to favour direct controls and possibly transferable permits as tools for regulating pesticide use. Under a system of transferable pesticide permits an environmental standard for, say, pesticide residues in a regional waterway in a cotton growing area, would be set by policymakers. Free pesticide permits could then be allocated to farmers on the basis of recent historical pesticide use patterns. The effectively fixed individual quota system could then be converted to a transferable quota system by allowing between farm trade in pesticide permits. Free and competitive trading of pesticide permits would ensure that the previously outlined efficiency conditions were met and the environmental standard was attained at the lowest economic cost.

A system of transferable water entitlements (TWEs) currently operates for irrigation water in a number of states in Australia. An innovative system of tradable salt quotas in Australia's Murray-Darling Basin came into force in 1992 (James, 1993). Trades are permitted in terms of salt concentrations, measured in EC (electrical conductivity) units. The participants in the scheme are the States of New South Wales, Victoria and South Australia. Salt credits are tradable between States, but at the present stage of development, the scheme mainly provides an incentive for water catchment and regional government authorities within each State to generate "salt credits" by investing in capital works to reduce salt entering the river system and enhance river flow.

The above schemes represent a major step toward the development of efficient markets, to enable irrigation water to be allocated to those activities providing the highest returns on water inputs.

Whether a transferable permit system or a tax scheme, or a combination of both, is used there is a need to recognise that spillover damages depend upon type of pesticide, method of application and location of application. Pesticides may be divided into categories according to their degree of danger to human health, the environment or both. For a given pesticide some methods of application, such as aerial spraying, generate larger negative spillover effects from spray drift and aircraft noise, than other methods of application. And application of pesticides near towns and cities and in riparian zones clearly generates larger negative spillover effects than in other areas where people and water quality are not threatened. Clearly, pesticide taxes should be higher, or transferable pesticide permits fewer, in urban and riparian environments.

With respect to technique of pesticide application, there is evidence in Australia and overseas that application equipment is commonly inefficient or defective. As a consequence, more pesticide is often used than necessary. A mandatory scheme of regular pesticide equipment testing would be one approach to this problem.[40] More generally, Zilberman et al. (1996) argue that there is great potential for the development and adoption of high-precision application technology in the application of pesticides and other farm inputs. These techniques would be firstly more efficient in terms of productivity because of greater utilisation of the input applied, and secondly, their impact on the environment is more benign. Drip technology systems for applying irrigation water is a good example of a precision technology. It is also relevant to pesticide use insofar as the more common practice of flood irrigation is a vehicle for

---

39 The distributional incidence of a pesticide tax will depend particularly on the price elasticity of demand for food and the elasticity of substitution between pesticides and other methods of pest control. If, for instance, price demand and substitutability between pesticides and other pest control methods are both very inelastic, a pesticide tax would lead to a substantial increase in food prices. That is to say, the incidence of a pesticide tax would be mainly on consumers. On the other hand, if the price elasticity of demand for food is high, the incidence of a pesticide tax would be largely on producers.

40 In the Farm Chemical Users courses in Australia, calibration of pesticide equipment has recently been made a core competency requirement.

transporting pesticides into waterways. High monitoring costs of non-point environmental damages caused by pesticide use will commonly make the method of application of a pesticide or a complementary input an appropriate incentive target.

The adoption of high-precision technologies that have benign effects on human health and the environment could be encouraged by policymakers and 'cruder' technologies that have harmful impacts on the environment or human health could be taxed. Conceivably, there could be a self-financing scheme in which the tax revenues collected from farmers using the 'crude' technology were used to subsidise farmers applying the high-precision technology.[41] Another approach to pesticide use would be to restrict the application of at least some pesticides to licensed professionals. This approach was first suggested in Australia by Longworth and Rudd (1975). Professional pesticide users would be educated in all aspects of pesticide use and could both diagnose and provide solutions to farmers pest problems.

Professional pest advisers would have the potential to contribute particularly to approaches to pest problems like Integrated Pest Management (IPM). IPM, as practised in Australia, utilises notions of precision technology together with close monitoring of pest populations and use of preventative spraying when defined thresholds are reached. Interestingly, adoption of IPM may in some situations lead to increased, but privately more efficient pesticide use. Few studies have attempted to evaluate the effects of IPM on the environment. It appears that the spillover effects associated with IPM may be positive or negative depending on the circumstances.[42] Another approach to introducing price-based incentives is through the establishment of liability rules (Sunding and Zilberman, 1994).

IX. Special Section: Reduced Tillage and Increased Pesticide Use

Background

Farm management practices in the past contributed to soil degradation on large tracts of agricultural lands in Australia in the form of fertility decline, loss of soil structure, and wind and water erosion. Practices included long fallows (where the soil was left bare for periods up to 15 months); extensive cultivation; stubble burning; relatively high cropping intensities; and clearing of vegetation which could have served as wind breaks. When the effect on the soil was realised solutions to these problems included a change in rotation by increasing the proportion of pasture; including nitrogen fixing plants in the pastures; and decreasing the fallow period.

With the advance of large scale availability of herbicides, a technology was developed to cut down on practices which degraded agricultural land by allowing a reduction in number of cultivations previously undertaken to manage weeds. The technology of minimum tillage (MT), zero till (ZT) and direct drill (DD) came to Australia from England in the 1960s. Commercial use in Australia started in the early 1970s.

---

41 One of the major advantages of Pigovian type taxes is that not only do they correct market failures, but also they raise government revenue. Other methods of taxation typically generate deadweight efficiency losses. Findlay and Jones (1982), for instance, estimate that the marginal excess burden of income taxation in Australia is likely to fall between 23 and 65 per cent. If we take the lower bound of 23 per cent, this implies that the social return required from giving a $1 subsidy to farmers adopting precision technology would need to be at least $1.23 if the subsidy was financed from income tax revenues.

42 For a recent overview of IPM in the State of Victoria, see Parigi and Malcolm (1996).

MT and ZT refer to the situation where few or no cultivations, respectively, are carried out. DD involves the drilling of crop seeds into the soil, without first removing the weeds by cultivations. The method of managing the weeds depends on the area, with its particular climatic and soil characteristics. It can include a chemical application in the spring/summer to prevent seed setting of weeds ('spraytopping') before planting takes place in autumn. Usually it includes a herbicide application at the time of planting. With the development of selective post-emergent herbicides farmers became more flexible in the use of the method, as they could manage weeds after planting.

The effects of DD are usually reported together with the effects of another technique: that of stubble retention (SR) of a crop on the soil, instead of burning it, which was the usual practice. These new technologies together, meant that with similar cropping, an improvement of soil structure and decreased risk of erosion was possible, by retaining more organic matter on top of the soil and a decrease in the soil being exposed to rain and wind. Indeed, intensification of cropping could occur without the severe consequences in the form of soil degradation experienced in earlier years. While reduced tillage can reduce costs and soil degradation, it increases pesticide use and the resulting negative effects on public health and the environment.

Scale of adoption

Originally, the acceptance of DD and MT/ZT was slow (see Table 1), especially in the eastern states. It was only with the development of a selective post-emergent herbicide, and the increase in fuel prices in the latter half of the 1970s, that the technology started to become more attractive to farmers more generally. The relatively high profitability of cropping, as compared with livestock production, is said to have contributed to the adoption of the technology (Poole 1987, p.25), although this situation was reversed from the mid 1980s.

Table A1. **Area under direct drill by year and State ('000 hectares**)

		SA	**Vic**	**NSW***	**Total**
1971	21	na	na	na	21
1972	24	na	na	na	24
1973	57	na	na	na	57
1974	140	2	na	na	142
1975	46	1	na	na	47
1976	45	2	<1	na	47
1977	51	5	<1	<1	56
1978	80	na	na	4	84
1979	160	55	25	20	260
1980	250	88	24	50	412
1981	1000	125	125	100	1350
1982	1680	125	86	280	2171
1983	2340	168	171	400	3079
1993	3397	2397	1121	1874	8699
per cent of area	61	62	53	45	52

Sources: 1971-1983 Pratley and Rowell (1987, p.18); 1983-1993 ABS: minimum, reduced and zero tillage.
* Figures for NSW are for Southern NSW only (winter-dominant rainfall); Na = not available.

The adoption of DD was particularly noticeable in Western Australia (see Table 1). Pratley and Rowell (1987) argue that, apart from the (sandy) soils in the west being more suitable than the heavier soils in the eastern states, the traditional sowing methods in the west closely resemble to the practice of minimum tillage. In addition, in-crop infestations of annual grass weeds could be fought more easily in Western Australia than in the east (due to climatic differences). With the release of post-emergent herbicides, adoption of DD became more attractive in the east. However, Kirkgaard (1995) proposes that the slow adoption of DD could well be accounted because it provides no yield advantage over traditional cultivation methods.

In 1983 a national survey by the 'National Farmer', a rural newspaper, reported that nearly half the farmers were using or considering the use of DD (Conacher and Conacher 1986, p.20). Steed, Ellington and Pratley estimated in 1993, that 30 per cent of farmers in South-east Australia routinely used DD. The Australian Bureau of Statistics (ABS) estimates of approximately the same time are somewhat higher, with MT/ZT practised on 45 per cent or more of the cropped area in all mainland states except Queensland (just under one third). The increase over the previous ten-year period is almost threefold, with the slowest growth in Western Australia (due to initial high figures).

In the early 1990s a survey was conducted in six shires (local government areas) in New South Wales (Vanclay and Glyde 1994). Although 74 per cent of farmers said to practise minimum or reduced tillage operations, only 2 per cent did not cultivate at all, while 90 per cent cultivated twice or more.

An officer of the Department of Land and Water Conservation (DLWC) in Central New South Wales (NSW), involved with MT/ZT and DD, provides the following estimates for regional developments (Ian Packer, DLWC Cowra, personal communication, December 1995):

- in Central NSW the DD has been adopted by 2 to 5 per cent of farmers in Parkes / Bland, 20 per cent in Cowra, and 80 per cent in Young;
- in Northern New South Wales (with summer rainfall and a tradition of long fallows) the adoption of DD was estimated to be between 10 to 20 per cent of farmers, and MT at 80 per cent on a regular basis;
- the estimate for Southern NSW is 60 to 70 percent of farmers using DD on a regular basis on between 20 to 30 per cent of their crops.

Pesticide use

Total real agricultural pesticide expenditure has grown almost five-fold in the last 20 years; of which herbicides have always been the main category of pesticide expenditure, rising from over half to almost three quarters of the total with real expenditure on herbicides increasing almost six-fold.

Also the composition of crops has changed. Total area under crop excluding wheat increased by approximately 50 per cent over the last twenty years. Area in cotton increased fastest (almost eight-fold since 1975-76). However, starting from a low base it is still insignificant in total acreage, though not in pesticide use. To give some idea about the order of pesticide use in cotton, budgets for irrigated cotton in NSW (which comprises approximately 90 per cent of cotton) show a 3 to 13-fold increase in herbicide use over irrigated grain and pulses, and an 8 to 23-fold increase in insecticide use (material plus application) (Patrick 1995). Equivalent dryland crops compare as similar to 9 times the herbicide use and 30 to 40 times insecticide use. However, the general picture is that the increase in pesticide, and in particular herbicide, use was not due to an expansion of area planted.

Consequences of adoption of minimum tillage and direct drilling

When cultivations are replaced by pesticide applications, labour, fuel and depreciation costs will decrease, while pesticide costs will increase. This is the case not only for herbicides, but also for other biocides, as a result of the change in practice. Examples are as follows (Cornish and Pratley 1987, p.17):

- due to the year-long availability of feed, an increase in certain insect pests (such as the red-legged earthmite (RLEM; *Halotedeus destructor*) is reported, resulting in increased insecticide use;

- previously annual ryegrass (*Lolium rigidum*) in the crop was controlled by pasture management (preventing the weed to set seed by mechanical means). However, spray-topping (preventing seed-set with applying paraquat at flowering) was introduced in later years;

- the availability of post-emergent herbicides from the early 1980s made DD more acceptable in those places where spray-topping was not successful.

Other changes involve a higher level of nutrient mineralisation (Robson and Taylor 1987), with consequences for fertiliser applications; phyto-toxic effect of herbicides on the crop, where crop yield decreases due to the application of pesticides; limitations on subsequent crops, due to sensitivity to the pesticide sprayed for a previous crop; and the occurrence of diseases, especially root diseases such as *Rhizoctonia*.

The effects on soil quality involve (Steed, Ellington and Pratley (1993)) a slow down in soil degradation and an improvement in physical, biological and chemical state of soil. Also improvements in infiltration rate, depth of wetting, and run-off time have been observed. Finally, there can be decreases in sediment in run-off and bulk density; as well as increases in water retention capability.

However, these results incorporate a change towards stubble retention rather than the change in cultivation pattern *per se* (DD). The change towards stubble retention explained a large part of the positive change in soil quality. As stubble retention is possible without adopting DD methods, linking the two technologies is not relevant in connection with showing the case for DD. For example, under organic management (where DD is not practised, at least not in combination with herbicide use), stubble retention takes place more frequently than under conventional farm management (see Wynen 1989). Kirkegaard (1995) finds that no yield advantages are related to the change to DD, at least not at this level.

Because reduced cultivations and stubble retention improve soil quality, adoption of these technologies allows more intensive cropping and cropping in more marginal areas (see, for example, Hamblin and Kyneur 1993, p.61), without incurring the same soil degradation as in the past. Both these practices (increased cropping intensity and expansion into marginal areas) can have a negative effect on average yield trends.

Increased risk of herbicide resistance is an aspect which is of concern more to some than others. Especially farmers and weed researchers tend to think that it could well develop into a major problem. Those involved in research and extension related to farm productivity and soil conservation (such as state departments of agriculture, CSIRO and the state departments of water and land conservation) often seem to be more optimistic about the prospects. A large part of their expectations are based on assumptions that new pesticides can be found, and that other mechanical means (such as adaptation of machinery such that it can screen out weed seeds) will be developed. Cullen *et al.* (1995) estimate that, in Western Australia, herbicide resistant weeds occur over 500 000 ha or 10 per cent of the cropping area.

Large scale weed resistance to herbicides was acknowledged in Australia by the Kondinin Group (a group considered to consist of progressive farmers). Sixty per cent of farmers surveyed reported 'less than successful results with herbicides in their spraying program' (p.22). In their publication of February 1992, attention was focused on herbicide resistance. Solutions can be summarised as follows (Farming Ahead 1992, p.30):

- reducing cropping intensity;
- rotational manipulation;
- cultivation without cropping (stimulating seed germination in the pasture phase or before cropping), followed by actions to prevent the weeds going to seed, such as use of non-selective knockdown herbicides, spraytopping, grazing and cultivation;
- manipulation of planting date and seeding rates;
- inclusion of crops and varieties competitive in the early growth stages;
- adaptation of equipment which allows weed seed to be separated from the crop, and collected in a separate container.

Using more pesticides might also imply more problems with the marketing of the produce, in the form of pesticide residues on products. Even if no pesticide residues can be detected, some consumers consider the production process in their decision making. Preference is sometimes given to products considered to be produced in more environmentally-friendly systems.

More worrisome might be the health and environmental effects of the increased pesticide use. Cross (personal communication, March 1996, Rural Projects Officer, Albury Community Health Centre, Southern New South Wales) reports that the number one concern of people screened through the heart health assessment days (over 500) is farm based chemicals. This issue will therefore be addressed as a priority of the program in 1996. Brush and Clemes (1996) report results from other surveys. The one especially relevant to this study is the survey by the Kondinin Group, which mentioned that '...36 per cent of Australian farm chemical users indicated that at some stage they had suffered ill effects from using agricultural products'.

In financial terms, the practice of reduced tillage was calculated as not having any effect on the gross margin. Yields were similar, and the extra herbicide cost were found to be offset by the reduced cultivation cost (Land and Water Care Program 1995).

Concerning environmental costs, few data are available on pesticides in the environment. Those available are mainly on water in irrigated areas. Bowmer *et al.* (1992) found high levels of several pesticides (chlorpyrifos and molinate) in rice floodwater in Southern New South Wales. Similarly, Korth et al. report levels of several pesticides (molinate, atrazine, malathion and chlorpyrifos) exceeding water quality guidelines in drainage and surface water in Southern New South Wales. Cooper (1995) reported that the results of pesticide monitoring in the Central and North West Regions in New South Wales in

1994-95 were closely related to the drought, when many cotton-growing areas got no, or minimum, water allocations. Drinking water guidelines of chlorpyrifos and profenofos were exceeded. In the years 1992-1995 between 50 and 89 percent of samples exceeded the ANZECC aquatic ecosystem guidelines for endosulfan. Moderate to high concentrations of atrazine were a common occurrence in most areas.

Conclusions

The availability of new technology for crop and pasture establishment — minimum tillage (MT), zero till (ZT) and direct drilling (DD) — in Australia since the 1970s has led to the adoption of this technology at different rates in different states. This led to a dramatic increase in expenditure on herbicide use in Australia in general, and in Western Australia in particular.

It is often claimed that the technology stems soil deterioration in cropping areas. However, wheat yield trends in Australia over the last 40 years are low as compared to its competitors. Short rotations are seen as part of the problem (Hamblin and Kyneur 1993). Though this might be brought about mainly by financial factors such as relative product prices, the availability of a technology which slows down soil erosion is likely to influence rotation decisions. Expansion into areas which would have suffered unacceptable soil deterioration with previous weed management techniques are also seen to have occurred with the help of DD.

Several private and public costs and benefits were pointed out. The difference between the opinions of some farmers and researchers on the one hand, and those of most other researchers and extension personnel on the other hand, are presumably related to differences in costs and benefits to the different sectors. As farmers experience herbicide resistance and health problems, some research and extension organisations have only recently paid attention to issues such as increased water pollution. These long-term social and environmental costs, however, could well make the difference between the acceptance or rejection of reduced tillage in combination with increased pesticide use.

X. Concluding Comments

Australian agriculture is diverse, with a large variety of animal, crop and horticultural products being affected by a large variety of pests and diseases. Total annual costs to Australian agriculture attributable to insects and weeds, have been estimated at nearly 30 per cent of the gross value of agricultural production.

Over the last two decades, expenditure on agricultural chemical usage has been one of the most rapidly growing components of farm costs in Australia. Annual real farm expenditure on herbicides, for instance, has grown dramatically. In contrast, herbicide usage in the United States has decreased (Zilberman, et al., 1991). These facts in themselves should not be a cause for concern, but they do raise questions.

The important questions are, why has expenditure on agricultural chemicals increased so substantially in Australia, and is there any evidence that the level and pattern of agricultural chemical usage in Australia, is not socially optimal? It is also of some interest to ask how pesticide intensive Australian agricultural production is, compared with other countries. It is difficult to satisfactorily answer the latter question because of a lack of public data on the quantities of agricultural chemicals used by each of Australia’s rural industries, particularly the rural sectors which are known to be the most pesticide intensive. There is a strong need for a quantitative national database on pesticide use in Australia.

The major reason for the substantial increase in herbicide usage in Australia, has been the growth of minimum tillage. This is a 'new' technology which provides the potential for lower cost establishment of crops and pasture, and which also reduces erosion. Herbicides are essentially substituted for traditional cultivation methods as a means of controlling weed growth. Minimum tillage techniques are also less capital intensive than traditional cultivation methods and it is of interest to note that rapid adoption of minimum tillage coincided with a period of high real interest rates and thus high user costs of capital. It is not possible at present to quantify the negative spillover costs of the increased pesticide use associated with minimum tillage. Weed resistance related to minimum tillage has become a significant problem, particularly in Western Australia.

There is a strong positive link between the level of protection given to agriculture and the level of agricultural chemical usage. The level of protection given to Australian agriculture is very low by world standards. Indeed, the agricultural policies of overseas countries, particularly through the CAP, are likely to have greater influence on the nature and profitability of Australian agriculture, through depressing and destabilising world agricultural prices, than do domestic agricultural policies.

Complete global trade liberalisation in agricultural products would lead to a substantial contraction of agricultural output and pesticide use in the highly protected countries and regions, and an expansion of agricultural output and an associated increase in pesticide use in Australia. However, the free-trade level of pesticide use in Australia, would be much lower than current levels of pesticide use in the EU and EFTA. From an economic efficiency perspective, it is ironical that in the EU and EFTA, the net marginal value of national agricultural output is negative, even without taking into account the spillover health and environmental costs of pesticide use. The recently completed Uruguay Round of the GATT provides one small step toward a more liberalised global agricultural trade.

Whilst the overall level of protection to Australian agriculture is low, some industries receive relatively high levels of assistance, most notably dairying, dried vine fruits and wine grapes. These rural sectors are also significant users of subsidised irrigation water. Irrigation water and pesticides are complementary inputs and low priced irrigation water induces greater water and pesticide use and greater spillover health and environmental damages. Moreover, irrigation water subsidies reduce the adoption rate of high-precision technologies like drip irrigation which are more environmentally benign than flood and furrow irrigation.

Horticultural, sugar, cotton and rice farms are also large users of subsidised irrigation water. These farms, together with wine grape farms, comprise around only 5 per cent of total farm area in Australia, but probably account for around one-third of the total expenditure on herbicides, fungicides and insecticides.

The global agrichemical industry, upon which Australia depends, is dominated by multinational firms that have a significant degree of market power. Overall, the prices paid for chemicals by Australian farmers appear to be low by world standards. This is consistent with the view that agrichemical firms adopt price discrimination practices. That is to say, the lower prices for farm chemicals in Australia imply that price elasticities of input demand for most farm chemicals in Australia are relatively high. Given the lower product prices received by Australian farmers and the generally less intensive nature of Australian agriculture, compared with other OECD countries, a more elastic input demand for most farm chemicals would be expected.

Product prices and agrichemical input prices are very important determinants of levels of farm chemical use. Compared with most other OECD countries, the substantially lower product prices received by Australian farmers exert a larger influence on reducing levels of farm chemicals usage than lower chemical input prices have on increasing farm chemical use.

Achieving optimal pesticide use is one of the most challenging resource management problems because of the wide array of types of potential market failure. In particular, a number of spillover effects (externalities) may occur simultaneously and affect the environment or human health. Moreover, whilst most are negative spillover effects some types of pest control spillover effects confer positive benefits on others. In the case of one of Australia's worst pests, the rabbit, the positive spillover effects of an individual's control activities will usually dominate any negative spillover effects.

There is also the difficult issue of a society attaining the optimal mix and dynamic path of technological innovation and development of new pesticides and other means of pest control (e.g. biological practices, biotechnological and cultural and management practices). The current system of pesticide regulations includes an elaborate system of testing and analysis prior to the introduction of new pesticides, some continuing re-evaluation (particularly in response to crisis situations), and regulations relating to application procedures and residue limits. Whilst virtually all pesticides have recommended rates of application, there are very few incentives or regulations related directly to levels and methods of use. The main influences on application methods and levels are prices of pesticides, costs of application, price of output and costs of alternative non-chemical methods of pest control.

Just as preliminary testing and screening schemes that are too lax are sub-optimal, it needs to be recognised that registration costs which are too great for new pest control agents pose a barrier to the entry of smaller innovative firms which will lead to a highly concentrated agricultural chemical industry, supplying a limited array of high-priced pest control agents.

Australian primary producers have a very strong incentive to meet pesticide residue standards on export markets. For most commodities there is now a stringent and very effective set of regulations to achieve this goal. Grains and wine grapes are two groups of primary commodities that have particularly effective systems. In the case of wine grapes, the structure of the industry is such that co-operative arrangements between growers and a small number of large buyers have evolved with minimal government action to provide a very efficient means of meeting strict pesticide residue standards for Australian wine on export markets, Very low pesticide residue status is also efficiently achieved in the grain industry, but by a more centralised bureaucratic approach.

Estimates of health and environmental costs of pesticide usage in the United States suggest that each dollar of investment in pesticides generates in the order of $2 negative spillover costs to other parties. The total negative spillover costs of pesticide usage in the United States is estimated to be $8 billion annually. There are no comparable estimates of the cost of health and environmental damages in Australia, but they are almost certainly less than in the United States.

In recent years there has been increasing participation by Australian farmers in educational and training courses on appropriate chemical use. Nevertheless, a recent study concluded that there is a significant benefit-cost surplus in the use of agrichemical protective equipment, but that there is strong evidence that a substantial proportion of farmers in Australia and New Zealand are not complying with recommended agrichemical protective equipment requirements. Moreover, Australian and New Zealand farmers were found to rate their knowledge of agrichemical practices as being good to excellent, in spite of clear evidence to the contrary.

In spite of the evidence that farmers rate their knowledge of agrichemical practices highly, increasing use is being made by farmers of private and public professional pesticide agents in some sectors of Australian agriculture, such as the cotton industry.

In Australia, like most countries, control of environmental damage caused by pesticide use is much more problematic than achieving appropriate pesticide residue standards in food. Commonly environmental damages are of a non-point type, such as the presence of pesticides in waterways and this makes measurement, monitoring and enforcement difficult.

It is possible to design economic instruments and 'grass roots' co-operative type institutions for pesticide use that are more efficient than existing command and control mechanisms. The goal should be to develop incentive structures for agrichemical usage that effectively remove any wedges between private and social marginal costs and benefits. Policies which simply set targets for overall reduction of agrichemicals are likely to be an inefficient instrument for achieving socially optimal farm chemical usage. There is, for instance, great potential for the development and adoption of high-precision application technology in the application of pesticides and other farm inputs, such as irrigation water. Incentive structures need to be designed to encourage the adoption of high-precision technologies that have benign effects on the environment and human health and which discourage the use of cruder technologies that have harmful spillover effects. A significant challenge to successful policy development and implementation will be to better educate biologists in economic reasoning and to better educate economists about biological and ecological systems.

BIBLIOGRAPHY

ABLER, D. G. and J. S. SHORTLE (1995), 'Technology as an Agricultural Pollution Control Policy,' *American Journal of Agricultural Economics*, 77(1): pp. 20-29.

ABLER, D. G. and J. S. SHORTLE (1996), 'Environmental Aspects of Agricultural Technology,' Global Agricultural Science Policy for the Twenty-first Century, Conference Proceedings of Invited Papers, The Conference Secretariat of Global Agricultural Science Policy for the Twenty-first Century, Melbourne, Australia, pp. 203-225.

ALSTON, J. M., J. A. CHALFANT and P. G. PARDEY (1993), 'Structural Adjustment in OECD Agriculture: Government Policies and Technical Change.' Paper prepared for the Quantitative Analysis and Special Studies Division of the OECD's Directorate for Food, Agriculture and Fisheries, Paris.

ANDERSON, K. (1995), 'On Measuring the Extent of Agricultural Policy Intervention: A review of the PSE and related indicators,' Policy Discussion Paper No. 5, Department of Economics and Centre for International Economic Studies, University of Adelaide.

AUSTRALIAN BUREAU OF AGRICULTURAL AND RESOURCE ECONOMICS (ABARE) (1995), Australian Commodity Statistics Canberra.

AVERY, D. T. (1995), 'Saving the Planet with Pesticides and Plastic,' Hudson Institute, Indianapolis, Indiana.

AYERS, J. (1995), 'Grass Roots Collective Action,' Presidential address to the Western Agricultural Economics Association, Annual Meeting, Tucson, United States, August.

BAUMOL, W. J. and W. E. OATES (1988), 'The Theory of Environmental Policy,' Cambridge University Press, Cambridge.

BUCHANAN, J. M. and G. TULLOCK (1975), 'Polluters' Profits and Political Response: Direct Controls Versus Taxes,' *American Economic Review*, 65: pp. 139-147.

BRUSH, G. J. and M. D. CLEMES (1995), 'Market Failure and Chemical Use,' *Review of Marketing and Agricultural Economics*, 63(3): pp. 394-407.

CHISHOLM, A. H. (1992), 'Australian Agriculture: A Sustainability Story,' *Australian Journal of Economics*, 37, (1): pp. 1-21.

CHISHOLM, A. H. (1995), 'Economic Incentives and Environmental Management,' Opening Plenary Paper Proceedings of the New Zealand Agricultural Economics Society Annual Conference, Blenheim, New Zealand, 30 June to 1 July, pp. 1-43.

CHISHOLM, A. H. (1994), ‘Land Use Choices in a Changing World,’ *Land Degradation and Rehabilitation*, 5: pp. 153-178.

CHISHOLM, A. H. and R. G. DUMSDAY (1995), “Environmental Indicators and Land Resources Policy: An Australian Perspective,” in S. S. Batie (ed.) Developing Indicators for Environmental Sustainability: The Nuts and Bolts. Proceedings of the Resource Policy Consortium Symposium, Special Report (SR) 89, pp. 69-98, Washington, D.C., June 1995.

CHISHOLM, A. H. and P. HONE (1996), ‘Long Lived Resource Quality and Resource Policy,’ Global Agricultural Science Policy for the Twenty-first Century, Conference Proceedings of Invited Papers, The Conference Secretariat of Global Agricultural Science Policy for the Twenty-first Century, Melbourne, Australia, pp. 227-262.

CHISHOLM, A. H. and R. TYERS (1985), ‘Agricultural Protection and Market Insulation Policies: Application of a Dynamic Multisectoral Model,’ In Piggott, J. and Walley, J. (eds), *New Developments in Applied General Equilibrium Analysis*, Cambridge University Press, pp. 189-220.

CLARKE, L. (1993), ‘Profile of Farm Health and Safety: A Preliminary Report,’ In AAHU (1993), *Farmsafe Australia Yearbook*, Australian Agricultural Health Unit, Moree, NSW, pp. 23-34.

COCKS, D. (1992), ‘*Use with Care: Managing Australia’s Natural Resources in the Twenty First Century,’* New South Wales University Press.

COMMONWEALTH OF AUSTRALIA (1990), Report of the Senate Select Committee on Agricultural and Veterinary Chemicals in Australia Senate Publication Unit, Canberra.

COMMONWEALTH OF AUSTRALIA (1992), *National Strategy for Ecologically Sustainable Development*, AGPS, Canberra.

CONACHER, J. and CONACHER, A. (1986), Herbicides in Agriculture: Minimum Tillage, Science and Society, Geowest 22, Department of Geography, University of Western Australia.

CORNISH, P. and PRATLEY, J. (1987), Tillage - New Directions in Australian Agriculture, Inkata Press, Melbourne.

CSIRO (1996). ‘Agricultural Pesticides in the Irrigation Areas of South-Western NSW,’ CSIRO consultancy report to the NSW Environment Protection Authority (unpublished).

CULLEN, J., LONSDALE, W., AULD, B., HODGKINSON, K. and HYNES, H. (1995), 'Vegetation management and the impact of weeds' in P. M. S. a. E. Council (eds.), Sustaining the Agricultural Resource Base, AGPS, Commonwealth of Australia, Canberra, (pp. 90).

DANN, T., V. TULPULE and E. TOUSSAINT (1994), ‘Agricultural Chemicals: their use in Australian agriculture,’ *Australian Commodities*, 1(4). Australian Bureau of Agricultural and Resource Economics (ABARE).

DAVIES (1993), mimeo

DEPARTMENT OF THE ENVIRONMENT, SPORT AND TERRITORIES (1996), Australia: State of the Environment.

DEPARTMENT OF HUMAN SERVICES AND HEALTH (1995). Annual Report 1994-95, Australian Government Publishing Service, Canberra.

DUMSDAY, R. G., G. W. EDWARDS and A. H. CHISHOLM (1996), 'Environmental Constraints to Australian Agriculture,' In Allan N. Rae and Anton D. Meister (eds), Environmental Constraints to Pacific Rim Agriculture, Centre for Agricultural Policy Studies, School of Applied and International Economics, Massey University, Palmerston North, New Zealand (forthcoming).

EDWARDS, C.A. (1993), 'The Impact of Pesticides on the Environment,' In David Pimentel and Hugh Lehman (eds) The Pesticide Question, Chapman & Hall, Ch.2, pp. 13-46.

EDWARDS, G. (1990), 'Agricultural Protectionism in Australia: What has Been Done and Why,' In Fred H. Sanderson (ed.), Agricultural Protectionism, Resources for the Future, Ch.5, pp. 219-267.

EDWARDS, G., R. G. DUMSDAY and A. H. CHISHOLM (1996a), 'Efficient Use of Australia's Land and Water,' *Search*, 27(6): pp. 188-191.

EDWARDS, G, R. G. DUMSDAY and A. H. CHISHOLM (1996b), 'Australia's Land and Water: Policies that Ensure they are Used Efficiently,' *Search*, 27(7): pp. 205-208.

FARMING AHEAD (1992, 'Herbicide Resistance', Farming Ahead, pp. 22-33.

FINDLAY, C. C. and R. L. JONES (1982), 'The Marginal Cost of Australian Income Taxation,' *Economic Record*, 58: pp. 253-266.

GAZETTE (1995), Existing Chemicals Review Program (ECRP), Commonwealth of Australia, 2 May.

GAZETTE (1995), Existing Chemicals Review Program, Commonwealth of Australia, 6 June.

HAMBLIN, A. and KYNEUR, G. (1993), Trends in Wheat Yield and Soil Fertility in Australia, Bureau of Resource Sciences, Canberra.

INDUSTRY COMMISSION (1994-95), Annual Report, Commonwealth of Australia.

JAMES, D. (1993), Using Economic Instruments for Meeting Environmental Objectives: Australia's Experience, Environmental Economics Research Paper No.1., Department of the Environment, Sport and Territories, Canberra.

KIRKEGAARD, J. (1995), 'A review of trends in wheat yield responses to conservation cropping in Australia', Australian Journal of Experimental Agriculture (35), pp. 835-48.

KNOPKE, P. and J. HARRIS (1991), 'Changes in Input Use on Australian Farms,' *Agriculture and Resources Quarterly*, 3(2): pp. 230-40.

KNOPKE, P., L. STRAPPAZZON and J. MULLEN (1995), 'Productivity Growth: Total Factor Productivity on Australian Broadacre Farms,' Australian Commodities, Vol.2 No.4, pp. 486-497.

KONDININ GROUP (1993), Report of Personal Protective Equipment Survey Results from a National Agricultural Survey, quoted in Kondinin Group (1993). 'Cover Up Tactics for Farmers,' *Farming Ahead* 19. The Kondinin Group, Perth, pp. 27-43.

LAND AND WATER CARE PROGRAM (undated), Research for profitable and sustainable cropping, CSIRO Institute of Plant Production and Processing.

LONGWORTH, J. W. and D. RUDD (1975), 'Plant Pesticide Economics with Special Reference to Cotton Insecticides,' *The Australian Journal of Agricultural Economics*, Vol.19, No.3, pp. 210-227.

MARTIN, W. and L. A. WINTERS (1996), 'An Economic Assessment of the Uruguay Round Agreement on Agriculture,' Invited Paper for the 40th Annual Conference of the Australian Agricultural and Resource Economics Society, Melbourne, February.

MCGUFFOG AND COMPANY (1995). National Survey of Farmers-Container Management Practices in Australia, Unpublished Research Report, Avcare Container Management Strategy, National Association for Crop Protection and Animal Health, Sydney, Australia.

MCMULLEN, B. et al. (1993), *Pesticide Exposure in Horticultural Industries in Central, South East and South West NSW 1992-93*, Agricultural Health Unit with Central West Public Health Unit and Workcover Authority of NSW, Australian Agricultural Health Unit, Moree, NSW, Australia.

MULLEN, J. D. and T. L. COX (1995), 'The Returns from Research in Australian Broadacre Agriculture,' *Australian Journal of Agricultural Economics*, Vol. 39, No. 2, pp. 105-28.

NATIONAL ACADEMY OF PUBLIC ADMINISTRATION (1994), 'The Environment Goes to Market,' The Implementation of Economic Incentives for Pollution Control. NAPA, Washington, D.C.

NEWS (1994), 'Chemicals review achieves a steady response,' National Registration Authority, Canberra, 4.

NEWS (1994), 'How public consultation changed the Existing Chemicals Review Program' National Registration Authority, Canberra, 4.

NRA NEWS (1995), 'First five chemicals nominated for review', National Registration Authority, Canberra, Vol.2, No.2.

NRA NEWS (1995), 'Timetable for Review', National Registration Authority, Canberra, Vol.2, No.3.

OECD (1994a and earlier issues), *Agricultural Policies, Markets and Trade: Monitoring and Outlook*, Paris.

OECD (1994b), *Integrating Environment and Economics: The Role of Economic Instruments*, Paris.

OECD (1994c), *Applying Economic Instruments to Environmental Policies in OECD and Dynamic Non-Member Economies*, Paris.

OECD (1995), Activities to Reduce Pesticide Risks in OECD and Selected FAO Member Countries: Results of a Survey, Paris.

OLSEN, P., FULLER, P. and T. G. MARPLES (1993), 'Pesticide-Related Eggshell Thinning in Australian Raptors,' Emu, 93, pp. 1-11.

OFFICE OF THE CHIEF SCIENTIST, Department of the Prime Minister and Cabinet (1995), Sustaining the Agricultural Resource Base. A Paper prepared by an independent working group for consideration by the Prime Minister's Science and Engineering Council at its Twelfth Meeting, 23rd June, 1995, Canberra, AGPS.

OSTRAM, E. (1992), 'The Rudiments of a Theory of the Origins, Survival and Performance of Common-Property Institutions', In D. W. Bromley (ed.), Making the Commons Work, Institute for Contemporary Studies, pp. 293-318.

PANNELL, D. J. (1989), 'Economics and the Law Relating to Flexibility of Chemical Rates,' *Plant Protection Quarterly*, Vol. 4(3) pp. 104-106.

PANNELL, D. J. (1991), 'Pests and Pesticides, Risk and Risk Aversion,' *Agricultural Economics*, 5: pp. 361-383.

PANNELL, D. J. (1994), 'Economic Justifications for Government Involvement in Weed Management: A Catalogue of Market Failures,' *Plant Protection Quarterly*, Vol. 9 (4).

PARIGI, P. and W. MALCOLM (1996), 'On Assessing Some of the Net Effects of IPM,' Contributed Paper presented to the Fortieth Australian Agricultural and Resource Economics Conference, Melbourne, February.

PATRICK, I. (1995), Summer Crop - Budget Handbook, Agdex 100/10, NSW Agriculture.

PIMENTEL, D., H. ACQUAY, M. BILTONEN, P. RICE, M. SILVA, J. NELSON, V. LIPNER, S. GIORDANO, A. HOROWITZ and M. D'AMORE (1993), 'Assessment of Environmental and Economic Impacts of Pesticide Use,' In David Pimentel, Hugh Lehman (eds), The Pesticide Question, Chapman & Hall, Ch. 3, pp. 47-84.

POOLE, M. (1987), 'Tillage practices for crop production in summer rainfall areas' in P. Cornish and J. Pratley (eds.), Tillage - New Directions in Australian Agriculture, Inkata Press, Melbourne, pp. 24-47.

PRATLEY, J. and ROWELL, D. (1987), 'From the first fleet - Evolution of Australian farming systems' in P. Cornish and J. Pratley (eds.), Tillage - New Directions in Australian Agriculture, Inkata Press, Melbourne, pp. 2-23.

PRICES SURVEILLANCE AUTHORITY, Australia, (1993), Inquiry into the Prices of Farm Chemicals, PSA Report #49

RAYMENT, G. E. and B. W. SIMPSON (1993), 'Pesticide Audit,' Queensland Department of Primary Industries Report to the Condamine-Balonne Water Committee.

REICHELDERFER, K. H. (1980), ‘Economics of Integrated Pest Management: Discussion,’ *American Journal of Agricultural Economics*, 62: pp. 1012-1013.

ROBSON, A. and TAYLOR, A. (1987), 'The effect of tillage on the chemical fertility of soil' in P. Cornish and J. Pratley (eds.), Tillage - New Directions in Australian Agriculture, Inkata Press, Melbourne, pp. 284-307.

SENATE HANSARD (1994), ‘Chemicals’, 30 May.

SHORT, K. (1994), ‘Quick Poison, Slow Poison: Pesticide Risk in the Lucky Country.’ Southwood Press, Sydney.

SMITH, J. G. and A. J. CHRISTOPHERS (1992), ‘Phenoxy Herbicides and Chlorophenols: A Case Control Study on Soft Tissue Sarcoma and Malignant Lymphoma,’ *British Journal of Cancer*, (65)pp. 442-48.

STEED, G., ELLINGTON, A. and PRATLEY, J. (1993), 'Conservation tillage in the Southeastern Australian wheat-sheep belt' in M. Carter (eds.), Conservation Tillage in Temperate Agroecosystems, CRC Press, Boca Raton, Florida, pp. 231-51.

SUNDING, D. and D. ZILBERMAN (1994), ‘Strict Liability Rules for Pesticide Damage,’ Department of Agricultural and Resource Economics, University of California, Berkeley.

SUTHERLAND, R. (1994), *An Evaluation of the Suitability and Effectiveness of the National Farm Chemical User Training Program in New South Wales*, CSIRO Division of Wool Technology, Ryde, NSW.

TYERS, R. and K. ANDERSON (1992), ‘Disarray in World Food Markets: A Quantitative Assessment,’ Cambridge: Cambridge University Press.

VANCLAY, F. and GLYDE, S. (1994), Land degradation and Land Management in Central NSW - Farmers' knowledge, opinion and practice, Charles Sturt University, Wagga Wagga.

WETZSTEIN, M. E. (1981), ‘Pest Information Markets and Integrated Pest Management,’ *Southern Journal of Agricultural Economics*, 13: pp. 79-83.

WILLS, L. and J. HARRIS (1994), ‘Government versus Private Quality Assurance for Australian Food Exports,’ *Australian Journal of Agricultural Economics*, 38(1), pp. 77-92.

WYNEN, E. (1989), Sustainable and Conventional Agriculture: An Economic Analysis of Australian Cereal-Livestock Farming. PhD, School of Economics, La Trobe University, Bundoora.

WYNEN, E. and G. EDWARDS (1990), ‘Towards a Comparison of Chemical-Free and Conventional Farming in Australia,’ *The Australian Journal of Agricultural Economics*, Vol. 34, No. 1, pp. 39-55.

WYNEN, E. (1994a), ‘Agriculture and the Pesticide Reduction Scheme in Sweden,’ Eco Landuse Systems, Canberra.

WYNEN, E. (1994b), ‘Agriculture and the Pesticide Reduction Scheme in Denmark,’ Eco Landuse Systems, Canberra.

ZILBERMAN, D. KHANNA, M. and L. LIPPER (1996), ‘Economics of Sustainable Agriculture,’ Opening Plenary Paper presented to the Fortieth Australian and Agricultural Resource Economics Society Conference, Melbourne, February.

ZILBERMAN, D. (1995) ‘Financial Incentives and Pesticide Use,’ University of California, Berkeley, mimeo.

ZILBERMAN, D., A. SCHMITZ, G. CASTERLINE, E. LICKTENBERG and J. B. SIEBERT, (1991), ‘The Economics of Pesticide Use and Regulation,’ *Science*, Vol. 253, (August 2), pp. 518-522.

ANNEXE 3

ETUDE DE CAS DE LA FRANCE

A. Carpentier and P. Rainelli
Institut National de la Recherche Agronomique
Rennes Centre
65, rue de St-Brieuc 35042 Rennes Cedex

TABLE DES MATIERES

I. L'utilisation des produits phytosanitaires en France

La répartition des produits phytosanitaires consommés en France selon les grandes familles figure dans le tableau 1, les données étant exprimées en tonnage. La France, deuxième pays dans le monde après les Etats-Unis quant à la consommation de pesticides, dispose de 912 substances répertoriées correspondent à 8 883 spécialités homologuées pour plus de 2 600 usages différents (Grivault, 1995). En tonnage, la majeure part de ces substances est composée des fongicides (60 pour cent). Mais parmi ceux-ci plus de la moitié sont à base de cuivre et de soufre. En valeur, les fongicides représentent moins de 40 pour cent suivis de très près par les herbicides avec 37,5 pour cent de la consommation (Auber et My, 1995).

Tableau n° 1.
Consommation française des pesticides par familles de produits
(tonnes en 1993)

Herbicides = 25 982 t (28,9 %)		**Fongicides = 54 254 t (60,4 %)**	
Benzonitrites	620	Carbamates	10 422
Composés phénoliques	826	Dérivés du benzène	670
Amides	3 225	Dicarboximides	444
Carbonnates	969	Amines-amides	6 814
Aryloxyacides	3 182	Inhibiteurs de stérols	2 351
Diazines	1 237	Cuivre	13 222
Toluidines	1 468	Souffre	17 909
Triazines	3 017	Fongicides divers	2 422
Urées substituées	4 271		
Sulfonylurées	31		
Dérivés picoliniques	282		
Herbicides divers	6 854		
Insecticides = 5 408 t (6,0 %)		**Divers 4 172 t (4,7 %)**	
Carbonnates	1 417	Nénaticides	1 268
Organohalogènes	1 431	Rodenticides	1
Organophosphorés	1 320	Molluscicides	33
Pyréthroïdes	121	Autres	2 870
Insecticides divers	899		
Acaricides divers	220	**TOTAL =**	**89 816 t**

Source: ARPSAH, 1995.

Par rapport au marché mondial, la France se différencie assez fortement en raison du poids particulier des fongicides comme l'indique le tableau 2. En 1987 ces derniers représentent 20 pour cent des consommations mondiales contre 33 pour cent à la même époque en France. Cette spécificité a deux causes : le poids du vignoble d'une part, et le niveau de développement des systèmes de grande culture d'autre part.

Pour ce qui concerne la vigne, qui avec près de 1 million d'ha et surtout 17,2 pour cent des livraisons agricoles en 1995 (SCEES - INSEE, 1995), constitue un secteur d'importance, il y a une forte utilisation de produits phytosanitaires. En effet, le raisin étant un fruit humide, et les ceps de vigne ayant un couvert végétal limité la maîtrise des parasites fongiques (mildiou et brotytis) et des mauvaises herbes est essentielle. Ceci explique que la vigne représente 5,2 pour cent du marché national pour les seuls fongicides et 12,4, pour l'ensemble des pesticides.

Environ 30 pour cent de la surface agricole française étant destinés à la production de céréales en France, on comprend que les fongicides de céréales aient représenté 21 pour cent du marché national des pesticides en 1986. Mais la part très importante des fongicides dans le total des produits phytosanitaires servant aux céréales (près de la moitié en 1986) provient du niveau d'intensification atteint en France. Le cas de la culture du blé d'hiver illustre bien cet état de fait.

Tableau 2.

Parts de marché des pesticides en France pour différentes cultures (1986) et, en France et dans le monde pour l'ensemble de l'agriculture (1987).

	Parts de marché par cultures des pesticides en France en 1986 (%)				
	Herbicides	Fongicides	Insecticides	Autres	Total pesticides
Céréales	11.0	21.0	2.6	9.4	44.0
Maïs	6.0	0.6	3.1	-	9.7
Vigne	2.8	5.2	1.4	3.0	12.4
Betterave sucrière	3.3	0.7	1.7	-	5.7
Tournesol	3.0	-	1.0	0.2	4.2
Colza	2.4	1.2	0.7	0.2	4.5
Vergers	0.4	1.2	1.3	0.2	3.1
Pomme de terre	0.3	0.4	0.2	0.6	2.0
	Parts de marché des différents pesticides en 1987 pour l'agriculture française et l'agriculture mondiale (%)				
Agriculture française	42	33	17	7.8	100
Agriculture mondiale	43	20	31	6.0	100

Sources: Brouwer et la. (1994) et Assouline (1989).

En effet, les techniques de production de nos jours sont caractérisées par (Meynard, 1991) : des densités de semis élevés, l'utilisation de cultivars très productifs, l'utilisation massive d'engrais (voire de l'irrigation) et l'avancée des dates de semis. Ces pratiques permettent la recherche de l'efficacité photosynthétique maximale permise par la culture considérée. Cependant, la protection des cultures devient un élément crucial pour le développement et la croissance de la culture dans ce contexte. En effet, l'avancement des dates de semis accroît la durée de la photosynthèse mais expose la culture aux levées automnales d'adventices, au piétin verse et aux attaques de pucerons d'automne. De même, l'augmentation de la densité des semis accroît l'efficacité d'interception des rayonnements solaires mais favorise le développement de maladies cryptogamiques (piétin verse, oïdium,...). De plus, l'utilisation de ces pratiques permet une fréquence rapide du retour du blé dans les rotations culturales mises en oeuvre sur les parcelles, c'est-à-dire une forte spécialisation des exploitations dans cette culture. Cette spécialisation aggrave aussi les risques d'infestation car elles permettent le développement des populations des parasites du blé durant plusieurs années. La viabilité de la conduite intensive des cultures de blé d'hiver dépend donc, de manière prépondérante, de la maîtrise des déprédateurs, et en particulier des maladies fongiques. Ce besoin est actuellement satisfait par l'utilisation de pesticides chimiques, tout au moins dans une très large mesure. Une même logique a conduit à l'utilisation de pratiques culturales intensives pour l'ensemble des grandes cultures et cultures industrielles. Ces dernières (i.e. céréales incluses) représentent à elles seules plus de 70 pour cent du marché français des pesticides, et plus de 72 pour cent de celui des fongicides en 1986.

Le tableau n°3 permet d'apprécier tant en valeur absolue, qu'en pourcentage du produit ou du résultat d'exploitation, le montant des dépenses en produits phytosanitaires selon l'orientation des exploitations. Il s'agit de données provenant du Réseau d'Informatique Comptable Agricole et qui concernent donc les seules exploitations professionnelles (Bonny et Carles, 1993).

Tableau 3.
Importance des dépenses de produits phytosanitaires dans le résultat économique des exploitations françaises en 1990 et pour diverses orientations technico-économiques

	Orientation technico-économique des exploitations					
	Céré-ales	Grandes Cultures	Maraî-chage	Vin de qualité	Autre viticul-ture	Fruits
Dépenses de pesticides (*ff90/ha)*	781	903	4 027	2 045	1 313	2 510
Part des dépenses de pesticides dans le produit brut d'exploitation (*%*)	12.3	10.1	5.0	1.8	2.7	3.4
Part des dépenses de pesticides dans le résultat d'exploitation *(%)*	45.4	39.1	13.0	8.0	13.8	18.0

Source: Bonny et Carles (1993).

Les cultures spéciales apparaissent comme les plus consommatrices de pesticides. Les exploitations spécialisées dans la production de légumes, de fruits, de vins de qualité et autres produits de la viticulture dépensent respectivement 4027, 2510, 2045 et 1313FF par hectare cultivé pour les pesticides en 1990, contre "seulement" 903 et 781FF pour les exploitations spécialisés en grandes cultures et en céréales. Les problèmes posés par l'utilisation des pesticides peuvent donc être aigus dans les bassins de production des cultures spéciales (e.g. la Gironde pour la vigne de qualité ou le Nord-Finistère pour le maraîchage). Ils concernent cependant des surfaces assez limitées. En revanche, les quantités de pesticides utilisées en grandes cultures et en cultures industrielles sont beaucoup plus importantes mais concernent une très grande superficie. Dans ce cas, les pollutions liées à l'utilisation des pesticides sont plus diffuses mais peuvent être à l'origine de problèmes liés à l'accumulation des résidus de ces intrants (dans les nappes phréatiques en particulier) ou à la chronicité de la leur présence.

Les dépenses de pesticides pèsent nettement plus dans le revenu des exploitations spécialisées en céréales et en grandes cultures. Ces dépenses représentent respectivement 45.4 et 39.1 pour cent du résultat de ces exploitations (respectivement 12,3 et 10,1 pour cent du produit brut d'exploitation) contre seulement 8.0 ou 13.0 pour cent du résultat (respectivement 1,8 ou 5,0 pour cent du produit brut d'exploitation) des exploitations produisant des vins de qualité ou des légumes. Cependant, quelle que soit la culture concernée, le coût (rapporté à l'hectare ou au produit brut d'exploitation) de la protection des cultures est, en France, l'un des plus élevé au niveau de l'UE (Brouwer et al. 1994).

Ces différences peuvent être en partie expliquées par deux types de facteurs. Le premier est d'ordre biologique et agronomique. Les productions spéciales sont généralement des fruits, légumes, bulbes ou racines relativement humides. En outre, elles sont en général concentrées sur de petites surfaces voire sous serre. Dès lors, les infestations fongiques, virales ou bactériologiques ainsi que les attaques de ravageurs peuvent être à l'origine de dégâts très importants dans un laps de temps très courts. Dans ce contexte, les traitements préventifs peuvent être justifiés pour limiter les risques des déprédations. De plus, ces cultures sont souvent reconduites d'une année sur les mêmes parcelles ou des parcelles proches. Ce qui favorise le développement de déprédateurs statiques tels (e.g. les nématodes) qu'il convient de combattre. Ceci explique par exemple l'utilisation très importante de nématicides par l'agriculture néerlandaise, l'une des plus spécialisées dans l'horticulture, le maraîchage et la production de pommes de terre (Oskam et al. 1992). La vigne, en tant que culture pérenne, est aussi protégée à l'aide de nématicides.

Le second facteur concerne les effets des pesticides sur la qualité des produits agricoles. Ces effets semblent très importants dans le cas des fruits et légumes. Un produit ayant de bonnes qualités esthétiques peut être vendu sur un marché de frais. Un produit piqué ou légèrement déformé ne pourra être aisément vendu que sur le marché des produits destinés à la transformation, marché beaucoup moins rémunérateur[43]. Ce problème a été étudié dans le cas de la production de pommes en Caroline du Nord par Babcock et al. (1992). Dans ce contexte, Starbird (1994) montre que le renforcement des normes sanitaires sur les produits frais peut être à l'origine d'un accroissement significatif de l'utilisation des pesticides par les agriculteurs. Ces effets liés à la qualité des produits agricoles semblent aussi importants pour ce qui concerne la viticulture de qualité. En effet, les producteurs de vins de qualité sont contraints par des rendements plafonds.

L'existence de cette contrainte législative tendrait à prouver que les quantités importantes de pesticides utilisées par ces viticulteurs ne sont pas uniquement destinées à accroître la quantité de raisins produite mais aussi, et peut-être surtout, à protéger les qualités sanitaires, technologiques et organoleptiques de ces produits. Ce point rejoint d’ailleurs le premier évoqué dans la mesure où l’utilisation de pesticides peut améliorer les qualités sanitaires des biens agricoles sensibles aux moisissures ou à tout autre attaque altérant certaines des caractéristiques des biens agricoles. Ces contraintes semblent particulièrement importantes lors des opérations de stockage pour des cultures spéciales. En effet, les produits humides, tels que les fruits ou les légumes frais, sont plus difficiles à stocker que les produits secs, tels que les grains de céréales et ce en raison de problèmes fongiques. En revanche, il convient de noter que la présence de mauvaises herbes en quantités importantes déprécie de manière significative les lots de céréales destinés à la transformation industrielle.

II. Les effets des pesticides sur les écosystèmes

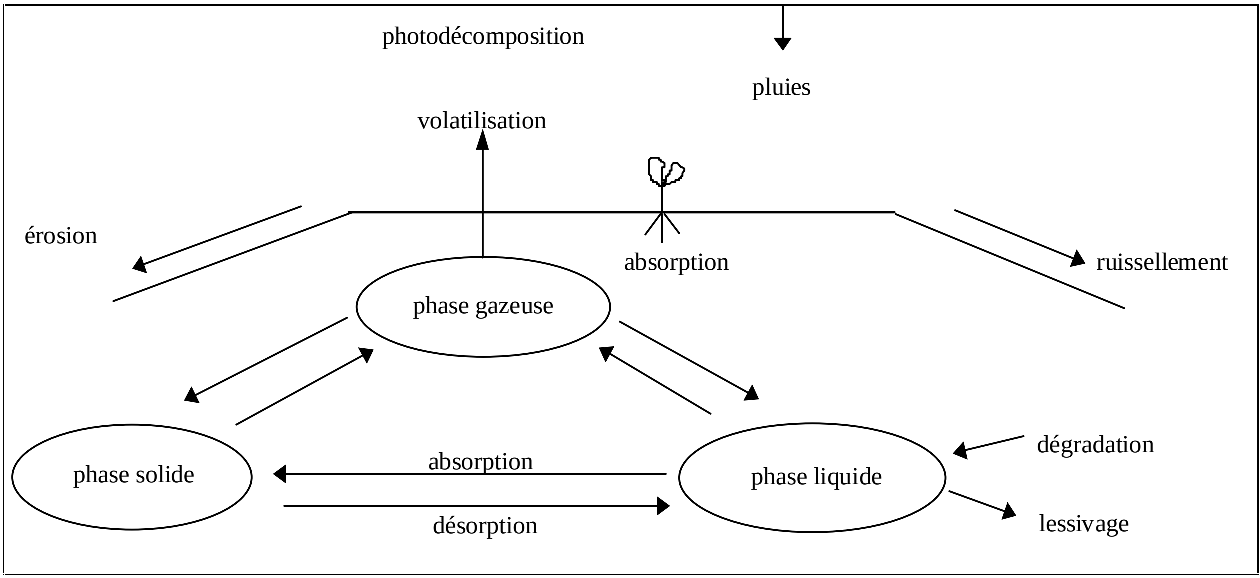
II.1 Pesticides et les bassins versants

L'action des pesticides sur les écosystèmes dépend en première instance des relations entre systèmes de production et conditions locales, tant agro-pédologiques que physiques. Cela signifie que concrètement les phénomènes doivent être appréhendés au niveau des bassins versants.

43 Il est à noter que les préoccupations d'ordre esthétique sont une des sources d'explication potentielles de la taille relativement limitée des marchés biologiques de produits frais en France.

Le devenir des pesticides dans l'environnement dépend du contexte géologique et pédologique, ainsi que des conditions météorologiques. Comme l'indique le schéma n° 1 une substance épandue va subir une certaine volatilisation avec possibilité de décomposition sous l'action du rayonnement solaire. Les quantités mises en cause sont importantes puisqu'elles représentent entre 25 et 40 pour cent du total faisant l'objet d'applications (Faasen, 1995). Il en résulte une forte dispersion et l'on constate ainsi que la pluie à Paris contient un certain nombre de produits phytosanitaires provenant de traitements effectués à plusieurs dizaines de Km (Chevreuil et Garmouna, 1993).

Schéma 1.
Devenir des pesticides une fois épandu



Source: DELMAS, 1995.

Les molécules provenant directement des traitements, ou indirectement, par les pluies, vont se fixer plus ou moins sur les constituants du sol par absorption, le processus inverse pouvant se produire ultérieurement. Ce qui n'est pas absorbé peut être dégradé ou bien absorbé par les cultures. On sait que la matière organique du sol joue un rôle important dans ces phénomènes d'absorption. Mais interviennent aussi tous les phénomènes d'érosion et de ruissellement lesquels dépendent étroitement des pluies et de l'infiltrabilité des sols. Ainsi le caractère spatio-temporel de la contamination d'origine agricole dépend-il des caractéristiques propres des bassins versants, que ce soit à l'échelle des bassins de quelques ha ou de km^2, ou pour les systèmes intégrateurs des réseaux des grands fleuves.

La connaissance des caractéristiques de ces grands bassins versants est nécessaire si l'on souhaite relier les pratiques agricoles dans une zone précise avec les conséquences locales mais aussi avec la biogéosphère compte-tenu de la rémanence des produits et de leur transport sur de longues distances.

Pour ce qui est de la rémanence le tableau n° 4 indique pour quelques grands types d'insecticides le temps nécessaire à une disparition dans le sol de 70 pour cent et de 95 pour cent . De ce point de vue la mise au point de nouvelles molécules se traduit par de sensibles progrès en matière de sécurité.

Tableau n°4.
Rémanence dans le sol de quelques insecticides temps nécessaire à leur disparition aux taux de 70% et 95%

	70 %	95 %
DDT	4 ans	30 ans
Dieldrine	5 ans	25 ans
Lindane	3 ans	10 ans
Heptachlore	2 ans	3 ans
Aldrine	2 ans	3 ans
Endosulfan	2 mois	2 ans
Carbofuran	4 mois	6 mois
Malathion	1 mois	2 mois

Source: IFEN, 1994.

En ce qui concerne les transports à longue distance, des estimations ont été effectuées dans les estuaires de la Seine, des Abers Benoît et Benouic et dans le delta du Rhône montrant que d'importantes quantités de substances actives sont transportées par les grands fleuves en provenance des cultures à proximité des affluents (cf. tableau n° 5).

Tableau n° 5.
Estimation des quantités de triazines à l'estuaire de 2 grands fleuves et de 2 fleuves côtiers

Kg/an	Rhône 1994-1995	Seine 1992	Seine 1993	Aber Benoît 1993-1994	Aber Benouic 1993-1994
Atrazine	5 809	1 367	21 641	4	3
Reséthylatrazine	3 119	nd	nd	3	2
Simazine	2 058	831	1 543	1,5	1
Terbuthylazine	3 315	nd	nd	nd	nd

Source: Tronczynski et al., 1995.

Le tableau 5 fait ressortir l'importance des apports de triazines dans les grands bassins versants et notamment celui du Rhône par rapport à la Seine. Or ce dernier a une couverture végétale où le maïs est nettement supérieur à ce que l'on trouve dans le bassin du Rhône. Cela signifie l'existence de mécanismes de transfert différents. Cet écart peut être mis en évidence en présentant le potentiel de transfert des triazines en flux annuel normalisé par rapport à la surface du bassin versant, ou de manière plus rigoureuse, par rapport à la surface des cultures concernées par l'emploi de ces pesticides. C'est à dire les céréales, et le maïs (cf. tableau 6). Les données du tableau 5 font ressortir que pour la même dose d'atrazine utilisée pour désherber le maïs le potentiel de transfert se trouve 6 à 10 fois plus élevé dans le cas du Rhône que dans celui de la Seine. Il en résulte obligatoirement des conséquences pour le milieu aquatique, estuarien et maritime bien plus significative pour l'ensemble Rhône-Méditerranée que pour l'ensemble Seine-Manche.

Tableau 6.
Potentiel de transfert de l'atrazine dans les bassins versants de la Seine et du Rhône en flux annuel normalisé (g/ha)

Flux normalisé par rapport à la surface	Bassin de la Seine	Bassin du Rhône
- du bassin versant entier	0,20 - 0,33	0,61
- agricole utilisée	0,25 - 0,42	4,0
- en cultures céréalières	0,59 - 0,99	12,0
- en maïs	3,1 - 5,2	30,0

Source: Tronczynski et al., 1995. Les deux valeurs pour la Seine correspondent aux chiffres pour les années 1992 et 1993 respectivement.

II.2 Les perturbations des écosystèmes

La perturbation d'un écosystème s'analyse dans le cadre de la relation dose-réponse. Quand il s'agit de voir les effets des produits phytosanitaires sur les milieux naturels, on se heurte à un ensemble de difficultés à la fois d'ordre méthodologique et d'ordre pratique.

D'un point de vue méthodologique pour voir comment les milieux naturels réagissent à une altération, il faut prendre en compte deux éléments de base : l'état initial et la durée de recouvrement. Pour cette dernière les écologistes se basent parfois sur trois paramètres synthétiques : le nombre d'espèces caractérisant la richesse de l'écosystème, l'abondance ou la densité, et enfin la biomasse. A la suite d'une perturbation on enregistre en général une baisse simultanée de ces 3 paramètres, suivie d'une évolution divergente en raison du développement d'espèces opportunistes, moins intéressantes, occupant les espaces vides. Ce n'est qu'au bout d'un temps plus ou moins long que l'on va retrouver un équilibre proche de la situation initiale, à condition qu'il n'y ait pas eu d'effets irréversibles.

Graphiquement la mesure de cette perturbation s'appréhende en se référant à un écosystème produisant un flux de services S_6 dans des conditions normales, et qui soumis au temps T_5 à un déversement accidentel de pesticides ne retrouve son état initial qu'en T_2, T_3 ou T_4. Cette différence dans le délai de recouvrement tient à l'intervention humaine importante pour T_2, faible pour T_3 et inexistante pour T_4 qui correspond à une restauration naturelle (Mazzotta et al., 1994). Le schéma n° 2 montre que sans intervention humaine le montant des pertes est égal à la somme des aires A + B + C + D. En cas de dommages irréversibles cette aire tendrait vers l'infini.

Schéma 2.
Evaluation des pertes d'un écosystème ayant subi une forte altération

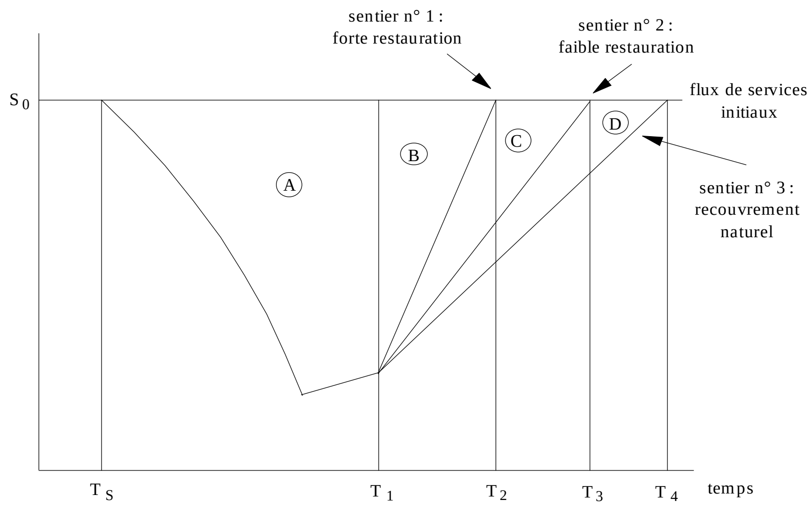


Schéma simplifié des modes de restauration d'un écosystème

Mais l'appréciation des pertes subies par un écosystème est délicate en l'absence à la fois d'état zéro (le flux de services initial) et de suivi régulier du recouvrement. Par ailleurs, il n'y a pas que les pollutions accidentelles, puisque, comme on l'a vu, la durée de vie de certaines molécules est très grande. En l'absence d'évaluations précises il est possible de donner quelques indications sur les conséquences des produits phytosanitaires sur les écosystèmes terrestres, les écosystèmes aquatiques et les écosystèmes marins.

Pour le milieu terrestre, en France, après de simples observations ponctuelles concernant les effets nocifs sur la faune sauvage, une enquête nationale annuelle de mortalités anormales du gibier a été mise en place en 1972. Cette enquête a mis en évidence la sensibilité du petit gibier aux insecticides et notamment aux inhibiteurs de la cholinestérase, et aux appâts toxiques (Mallet, 1990). Il apparaît toutefois que la sensibilité varie considérablement selon les molécules et selon les espèces. Ainsi, par rapport au rat, l'insecticide carbofuran est 20 fois plus toxique pour la perdrix grise et le zirame est 18 fois plus toxique pour la perdrix rouge. Mais on a aussi la situation inverse de moindre sensibilité des espèces sauvages par rapport au rat. Tel est le cas du canard 10 fois moins sensible au thiofanox et 20 fois moins au lindane.

On a aussi constaté des accidents sur lièvres à la suite d'épandages d'appâts granulés molluscicides pour lutter contre les limaces, ou sur sangliers et rapaces dus à la consommation de grains-appâts destinés à la lutte contre les campagnols des champs. Mais tous ces résultats ont un caractère ponctuel et ne permettent pas de connaître les effets sur les populations sauvages. Il faut dire que cela nécessiterait la mise en place de dispositifs complexes avec un suivi assez long afin de prendre en compte les fluctuations naturelles.

Pour les écosystèmes aquatiques classiquement on teste leur sensibilité aux produits phytosanitaires sur des algues (daphnées) et des poissons (truite et carpe). Mais la littérature montre que les macrocrustacés font partie des groupes les plus touchés par les diverses substances actives. Des auteurs ont montré l'impact des pesticides sur des populations d'insectes qui, affaiblis, ne peuvent plus résister au courant et deviennent dérivantes. Il en résulte une modification de la relation prédateur-proie causant des perturbations biocénotiques non négligeables pour les communautés benthiques (Ode-Walter et Guéguen, 1995).

Mais des macrophytes comme le faux-roseau, les renoncules et d'autres espèces montrent aussi des contaminations non négligeables de 10 à 200 µg/kg de matière fraîche. Dans le faux-roseau on constate une accumulation de lindane dans les racines et de l'atrazine dans les parties aériennes qui se chlorosent (Giovanni et Haury, 1995). Cela conduit à penser que certaines plantes aquatiques pourraient constituer des bio-indicateurs fiables.

Des études en Bretagne sur des anguilles, des chevaines et des gardons ont montré que 70 pour cent des échantillons étaient contaminés soit par l'atrazine, soit par le lindane, ou les deux. Chez l'anguille la bioaccumulation varie de 1 à 7,9 mg/Kg de matière grasse, tandis que les chevaines ou gardons ont des concentrations de 0,3 à 1,0 mg/Kg de matière grasse (Giovanni et Haury, 1995). En général les adultes accumulent plus souvent les deux molécules que les juvéniles, surtout dans le foie et les organes génitaux. Les oeufs et alevins de salmonidés et de cyprinidés se révèlent très sensibles notamment au dinoterbe et au carbendazime.

Pour les eaux marines et estuariennes, malgré un temps de séjour assez long et une énorme dilution on constate des contaminations d'une certaine ampleur. Comme l'indique le tableau n° 5 les estuaires des grands fleuves, et notamment celui du Rhône, connaissent des contaminations que l'on ne peut négliger. Les concentrations en herbicides atteignent au moment des traitements entre 200 et 1 000 µg/l en amont des estuaires. En zone de mélange des eaux douces et marines les chiffres se situent dans la fourchette 40 à 400 µg/l. En zone côtière on constate des valeurs inférieures à 50 µg/l (Tronczynski et al., 1995).

En milieu maritime le suivi des pollutions est effectué à partir d'organismes "sentinelles" comme les huîtres et les moules. Bien qu'il soit interdit en France depuis 1973, le DDT apparaît de manière significative. Les concentrations les plus importantes apparaissent dans le Bassin d'Arcachon et sur le Languedoc-Roussillon. En microgrammes par kg de matière sèche les valeurs maximales s'élèvent à 250 et 450 selon les lieux (IFEN, 1994).

III. Les pesticides et la santé humaine

Dans un premier point nous envisageons les risques des pesticides pour l'homme à travers les conséquences plus ou moins connues concernant la santé. Le deuxième point traite de la situation française en terme de qualité des eaux et de résidus dans les produits agricoles.

III.1 Les risques concernant la santé humaine

Les produits phytosanitaires génèrent des résidus, qu’il s’agisse des pesticides non transformés, de leurs métabolites, de leurs produits de dégradation ou de réaction, que l’on retrouve dans les aliments et l’eau de boisson. Ainsi lors du traitement pour rendre l’eau potable on fait parfois appel à des procédés d’oxydation. Il apparaît à l’usage que ces dégradations sont incomplètes conduisant pour l’atrazine et la simazine à la formation d’autres triazines. Si pour ces deux molécules on a un abattement de 75 pour cent cela se traduit pour le total des triazines à une réduction de seulement 36 pour cent (Seux, 1995). Les effets de ces résidus sur la santé humaine dépendent de leur persistance et de leur toxicité. Dans ce cadre la relation dose-réponse permet une évaluation du risque.

Pour les effets aigus et chroniques on se réfère à la DL 50 établie à partir de petits mammifères (souris, rats, cobayes) puisque a DL 50 est la dose qui tue 50 pour cent de la population soumise à l'essai dans un délai de 14 jours seulement. Mais, le vrai problème est l'identification des dangers liés à une exposition répétée. Ceci conduit à mettre l'accent sur la dynamique à long terme des processus et la rémanence des molécules. Les impacts sur la population pour des expositions répétées dans le temps dépendent des propriétés mutagènes, tératogènes et cancérogènes des substances. Des pesticides comme le DDT, le 2,4,5 T, le diméthoate, le méthy-paration... ont des effets mutagènes intervenant sur le développement du foetus et de l'embryon. Ils ont également des conséquences sur la fonction de reproduction provoquant une baisse de fécondité et une augmentation des avortements (Periquet et de Saint Blanquat, 1991).

L'activité carcinogène de nombreux pesticides a pu être démontrée chez l'homme et un certain nombre d'organismes, en particulier l'académie des sciences américaines (NRC, 1987), en a dressé la liste. La synthèse des études de morbidité conduit à des conclusions nuancées, dans la mesure où un lien peut être établi entre utilisation ou fabrication de pesticides et apparition de cancers particuliers (ECPA, 1992). Certes les premières études suédoises établissant une relation significative entre le développement de sarcomes des tissus mous et exposition à des herbicides dérivés de l'acide phénoxy-acétique n'ont pas pu être confirmées aussi nettement dans d'autres contextes. Par contre l'exposition à cette même famille d'herbicides entraîne un accroissement du risque d'apparition de lymphomes malins. On note une plus forte occurence de leucémie à myéloïde chez les agriculteurs. Il y a aussi des indices sur l'accroissement de risque attribuable aux pesticides dans la déclaration de cancers touchant l'appareil digestif, les voies urinaires et le foie ; mais en l'absence de données empiriques plus complètes, il convient d'être prudent (ECPA, 1992 ; Pluygers et Sadowska, 1994).

Les effets cancérogènes des pesticides ont fait l'objet d'une synthèse par le Centre International de Recherche sur le Cancer (IARC, 1991) classant les produits en fonction d'une évaluation de la fréquence des tumeurs malignes basée sur des observations sur des espèces animales et éventuellement sur l'homme. Cinq groupes sont retenus : groupe I, l'agent est cancérogène ; groupe IIa l'agent l'est probablement ; groupe IIb, l'agent l'est peut-être ; groupe III, l'agent ne peut pas être classé quant à sa cancérogénécité ; groupe IV, I'agent n'est probablement pas cancérogène. L'Agence pour la Protection de l'Environnement des Etats-Unis a suivi une démarche analogue faisant porter ses investigations sur un nombre de produits nettement plus important. Combinant les résultats des deux listes on obtient un total de 22 composés probablement cancérogènes (Pluygers et Sadowska, 1994).

L'identification des dangers étant effectuée reste à estimer la probabilité de survenue de ces dangers, ne serait-ce que pour définir des niveaux de doses « virtuellement sûrs » servant à établir des normes d'exposition. Cette dose virtuellement sûre en matière de cancer est celle qui entraîne au plus un supplément de risque d'un millionième par rapport au « bruit de fond », et ce pour une exposition durant la vie entière. Cette dose est déterminée par l'approche toxicologique ou de manière probabiliste.

Dans l'approche toxicologique on part des résultats obtenus par expérimentation animale pour définir le niveau de dose le plus élevé sans effet pathologique. Ce chiffre exprimé en mg/Kg de poids corporel est ensuite extrapolé à l'homme mais affecté d'un facteur de sécurité. Le résultat auquel on arrive est la DJA ou Dose Journalière Admissible. Le mode opératoire peut être précisé à l'aide de l'exemple de la simazine (Seux, 1995).

Au titre de l'approche probabiliste on peut citer le calcul théorique effectué par l'Académie Nationale des Sciences des Etats-Unis. Pour cela elle est partie de la DJA concernant les aliments couramment ingérés. En supposant que sur 70 ans de vie on se nourrisse de produits atteignant la DJA il en résulterait un accroissement de 6/1 000 de l'incidence du cancer, soit plus d'un million de cas sur 70 ans. Certes, il s'agit de conditions limites, mais il faut rappeler les risques de synergie lorsqu'on a des cocktails de pesticides. Cet exercice a toutefois l'avantage de mettre l'accent sur la chronicité, élément non pris en compte dans les études de toxicologie traditionnelles. L'Organisation Mondiale de la Santé (OMS) a procédé de la même manière pour l'alachlore produit pour lequel les données expérimentales ne permettent pas d'affirmer qu'il soit génotoxique. Toutefois la mutagénécité d'un de ses métabolites a été démontrée. Par ailleurs, les résultats de deux études ont montré que l'alachlore provoquait chez le rat des tumeurs du cornet nasal, de l'estomac et de la thyroïde (Seux, 1996). Compte-tenu des effets, surtout sur le cornet nasal, l'OMS a défini la valeur guide de 2 µg/l dans l'eau alimentaire qui correspond à un risque additionnel de cancer sur la vie entière de 10^{-6}.

Les résultats les plus probants sont quand même ceux provenant d'études épidémiologiques conduites sur des populations humaines. Il n'y a pas en France de travaux aussi conséquents qu'aux Etats-Unis, notamment dans les grands états agricoles tels l'Iowa, Kansas, Minnesota, Nebraska ... où l'on a systématiquement cherché à mesurer le risque des agriculteurs aux pesticides. Un recensement, probablement incomplet, fournit quelques éléments d'appréciation, et donne un état des travaux en cours.

En matière de résultats pour une forme assez rare de leucémie, puisqu'elle ne constitue que 2 pour cent de l'ensemble de cette affectation, on a montré que les agriculteurs français étaient particulièrement touchés (Clavel et al., 1995). Dans une enquête épidémiologique sur 291 cas de leucémie à tricholeucocytes diagnostiqués entre 1980 et 1990 ont été comparés à une population témoin de 541 personnes. Il apparaît que les agriculteurs ont un risque d'apparition de cette maladie deux fois plus élevé, du fait de leur exposition aux produits de traitement. Sans que les choses soient claires, il semble aussi que la présence de bovins et d'ovins sur l'exploitation joue également un rôle.

Pour expliquer le rôle des animaux on a évoqué la possibilité de transmission d'un virus animal provoquant la leucémie, mais sans preuve formelle. Mais on sait que les soins aux animaux peuvent nécessiter le recours aux pesticides. On a montré que les traitements prophylactiques des moutons, qui conduisent à les plonger 1 à 3 fois par an dans des solutions à base d'organophosphorés pouvaient conduire à des troubles neuropsychologiques par simple contact (Stephens et al., 1995).

Parmi les travaux en cours on retiendra ceux du Centre Hospitalier Universitaire de Caen qui tente de mesurer auprès de l'ensemble de la population agricole du département du Calvados le degré d'exposition aux pesticides à partir d'enquêtes postales. Avec un taux de retour de 25 pour cent cette équipe dispose de 6 530 dossiers qu'elle compare ensuite systématiquement aux données du registre général des tumeurs départemental afin d'évaluer le risque des agriculteurs. Ultérieurement des entrevues sur place seront effectuées ainsi que des analyses sanguines et d'urine.

Dans un autre domaine, des recherches sont entreprises pour déterminer l'impact des produits phytosanitaires, à partir des chaînes alimentaires sur la reproduction. En effet, certaines molécules auraient des caractéristiques proches des hormones femelles et pourraient interférer avec l'action des hormones naturelles mâles perturbant ainsi les fonctions reproductrices masculines, et ce de la vie foetale à l'âge adulte. Les recherches sont conduites en laboratoire sur la fonction des organes génitaux chez l'embryon, et sur le terrain auprès de viticulteurs. Une grande enquête épidémiologique lancée à l'échelle européenne est en cours, et concerne pour la France les viticulteurs alsaciens.

III.2 Qualité des eaux et importance des résidus dans les produits agricoles

L'état des grands systèmes aquifères est connu de manière fragmentaire compte-tenu du coût élevé des analyses (de 700 FF à 2 700 FF par analyse selon les familles de produits phytosanitaires). Dès le début des années 80, l'analyse de 76 forages du Haut-Rhin servant à l'alimentation en eau potable montrait la présence de lindane (60 µg/l), de DDT (50 µg/l) et de triazines (400 µg/l).

Des analyses entreprises en 1983 dans le département voisin du Bas-Rhin sur 34 forages ont montré l'absence de contamination. Mais ces mêmes forages ont fourni des résultats positifs deux années plus tard montrant la présence de lindane. La nappe des calcaires de Beauce s'est également révélée dès les années 1980 contaminée par un certain nombre de molécules comme l'indique le tableau n° 7.

Tableau n° 7.
Concentrations maximales en divers pesticides dans la nappe des calcaires de Beauce dans les années 80

Heptachlore époxyde	119 µg/l
DDE pp'	258 µg/l
Lindane	11 µg/l
Parathion	413 µg/l
Composés phosphorés	354 µg/l
Atrazine	794 µg/l
Composés soufrés	9 367 µg/l

Source: Belamie et Giroud, 1986.

Des analyses effectuées début des années 90 ont mis en évidence la contamination des aquifères libres vulnérables de la Beauce ainsi que des forages situés en nappe alluviale ou en relation hydrogéologique avec les eaux superficielles. La teneur en atrazines peut dépasser les 2 µg/l dans certaines situations.

En ce qui concerne les eaux superficielles dès 1978 en Seine et Marne des teneurs d'atrazine de 0,15 à 0,60 µg/l ont été relevées au printemps (Bellamie et Giroud, 1986). Avec la systématisation des recherches de pesticides après le décret du 3 janvier 1989 on dispose d'informations plus précises même si les analyses sont limitées en fonction du débit journalier.

La prédominance des eaux superficielles dans la ressource en eau potable de la Bretagne, celles-ci constituant 80 pour cent du total, a conduit à la mise en place d'un important programme de surveillance, surtout depuis 1990. En plus du contrôle sanitaire des eaux brutes et des eaux distribuées effectué au niveau des prises d'eau, 10 rivières bretonnes font l'objet d'un suivi plus ou moins fréquent complété par des études ponctuelles. Dans ces conditions on dispose d'un ensemble cohérent d'informations. Celles-ci sont d'autant plus significatives que la Bretagne avec 6 pour cent de la Surface Agricole Utilisée nationale ne consomme que 4 pour cent environ des produits phytosanitaires. Contrairement aux nitrates, on est donc dans un contexte à priori moins défavorable. Notons toutefois, du fait de la prépondérance des cultures de céréales et de maïs, une utilisation conséquente d'herbicides par rapport à la moyenne nationale.

Globalement la contamination des eaux brutes superficielles est préoccupante sachant que 90 pour cent des prises d'eau révèlent des teneurs ponctuelles ou chroniques d'atrazine supérieures à 0,1 µg/l. Dans 25 pour cent des cas on constate même des pointes à plus de 2 µg/l (Louis, 1995). Outre les triazines plusieurs autres familles apparaissent à des concentrations comparables, mais avec une moindre fréquence. Cela conduit parfois à la présence simultanée de 10 molécules dont chacune dépasse 0,1 µg/l et à un cumul de substances actives de l'ordre de 30 µg/l (Guiho, 1995). Par ailleurs certaines substances actives, comme l'atrazine, peuvent se retrouver dans l'eau des rivières plusieurs mois après qu'elles aient été épandues. Il résulte de tout cela que les 2/3 des prises d'eau bretonnes présentent un risque de contamination par les pesticides (Louis, 1995).

Fait plus préoccupant des résidus de buturon, de la famille des urées substituées, qui est un produit non homologué en France, ont été relevés dans deux rivières dont une dans le Finistère à 1,1 µg/l. L'origine de ce produit n'a pu être déterminée (Guiho, 1995). Cela signifie que des utilisateurs importent frauduleusement certains produits phytosanitaires dont les effets ont été jugés trop néfastes.
Dans la Dose Journalière Admissible (DJA) de pesticides il n'y a pas que l'eau de boisson à intervenir, les aliments constituent une source de résidus qui peut dans certains cas correspondre à 90 pour cent de ce que l'on admet. Il est donc essentiel de connaître la situation dans ce domaine cela d'un point de vue santé humaine, mais aussi dans des perspectives commerciales sachant que la présence de certains résidus peut intervenir comme restriction aux échanges. Le cas de la vigne est assez exemplaire de ce point de vue.

En 1990 des arrivages de vins français ont été bloqués aux Etats-Unis en raison de l'existence de résidus de procymidone, un fongicide non autorisé dans ce pays. Cela a conduit à rechercher de manière plus systématique les matières actives que l'on pouvait trouver dans les raisins, d'où une série d'enquêtes sur les vendanges de 1990, 1991 et 1992 des principales régions viticoles. Au total un millier d'analyses a été réalisé dont 727 sur les raisins et 274 dans les vins (Lugier et Riffiod, 1994).

Pour les raisins il est apparu que les Limites Maximales de Résidus, ou LMR, telles qu'elles sont fixées par la législation française, étaient respectées dans 96 pour cent des cas avec 44 pour cent des échantillons indemnes de tout résidu compte-tenu du seuil de détermination. Les substances responsables du dépassement sont les dithiocarbonnates, l'oxadixyl, le flufenoxuron et le fenoxycarbe. C'est surtout le premier type de produit qui est responsable à cause des traitements dans les 2 mois avant la vendange pour lutter contre le botrytis. Le flufenoxuron pose quant à lui des problèmes du fait de sa rémanence (plus de 70 jours) tandis que les autres substances sont repérées quand les applications ont lieu dans les 2 semaines précédant la récolte.

Pour ce qui est du vin, comme il n'y a pas de LMR pour les produits transformés on ne peut pas parler de dépassement des normes, mais simplement de présence de certains résidus.
Les problèmes touchant aux vergers sont différents car la présence de parasites, ou la nécessité de conserver les fruits conduisent à des traitements importants. Ainsi pour les pommiers la tavelure et le carpocapse sont des parasites obligeant à traiter souvent et avec des produits comme les dithiocarbonnates, à forte rémanence. Un suivi sur 3 années d'une centaine d'arboriculteurs de Corrèze adhérents d'une coopérative fruitière a permis à l'aide de 4 494 analyses de dresser un tableau précis de la situation locale. En termes de LMR 99,55 pour cent des résultats sont conformes, l'essentiel des dépassements étant dus aux dithiocarbonnates (Juillard-Condat et al, 1994). Toutefois cette enquête incite à être plus vigilant encore sur les traitements avant la récolte destinés à lutter contre les maladies de conservation.

Pour les pêches et les abricots ce problème de conservation est crucial et l'on a même un traitement 2 jours avant la récolte afin de contrôler les Monilia, principaux agents de pourriture des fruits à noyaux. La pratique courante avec 3 applications entre un mois et 2 à 5 jours avant la récolte entraîne des taux de résidus de 0,2 à 0,3 µg/kg pour le carbendazine et 0,4 à 0,5 µg/kg pour l'iprodione dans le cas des pêches. Dans le cas des abricots les teneurs en iprodione peuvent atteindre 2,30 µg/kg (Lafuste, 1994). Même si au regard de la législation française les niveaux de résidus ne sont jamais excessifs, les teneurs en carbendazine peuvent poser problème pour des exportations vers l'Allemagne.

Les cultures légumières enfin ont la particularité d'être consommées directement, et compte-tenu de leur diversité de ne pas être considérées comme des marchés intéressants pour l'industrie phytopharmaceutique. Ce dernier point est important. En effet, la réglementation française (arrêté du 15 juillet 1985) impose aux producteurs de n'utiliser que des produits homologués ou ayant une autorisation provisoire de vente. Dans ces conditions on n'a pas sur les 47 cultures légumières les produits homologués correspondant aux besoins. D'où des essais pour déterminer les résidus présents du fait des pratiques mises en oeuvre (Reulet, 1994). Près de 2 500 analyses sur plus d'une douzaine de cultures ont été effectuées montrant des dépassements très peu nombreux par rapport aux normes françaises. Mais si l'on se réfère aux normes européennes les dépassements deviennent significatifs (20,2 pour cent pour les tomates et 10,1 pour cent pour les fraises). Ce décalage tient à l'existence de normes européennes très strictes dans certains cas, parfois proches des seuils de détection, et aussi à une mauvaise maîtrise des agriculteurs utilisant des produits non homologués et donc ignorant les doses à utiliser et les délais avant récolte.

IV. Soutien des prix et intensification

Dans un secteur aussi fortement administré que l'agriculture il est évident que les politiques mises en oeuvre ont eu des effets sensibles quant à l'emploi des intrants d'origine industrielle, et notamment des pesticides. Un premier point est consacré à l'analyse à la fois d'un point de vue théorique et empirique, quant aux relations entre mesures de soutien des prix et recours aux pesticides.

La relation entre soutien des prix et intensification se fait essentiellement à travers le foncier. Ceci est analysé à partir d'une présentation graphique faisant l'objet d'une première section. Une seconde section montre sur une base purement descriptive comment la production céréalière française s'est développée en ayant recours à la fois aux pesticides et aux engrais. Une troisième section donne quelques éléments d'explication sur la complémentarité entre ces deux intrants.

IV.1 Soutien des prix et intensification : le rôle du foncier

Après la seconde guerre mondiale la relance et la modernisation de l'agriculture française figurent au rang des impératifs nationaux. Il s'agit de liquider la pénurie alimentaire tout en dégageant la main d'oeuvre nécessaire à la reconstruction et à la relance de l'activité industrielle. D'où la mise en place d'une politique agricole très volontariste et l'émergence de ce que l'on a appelé l'idéologie moderniste aussi bien dans les milieux gouvernementaux et professionnels agricoles, que dans l'appareil de développement. Simultanément il s'agit d'assurer un revenu décent aux agriculteurs.

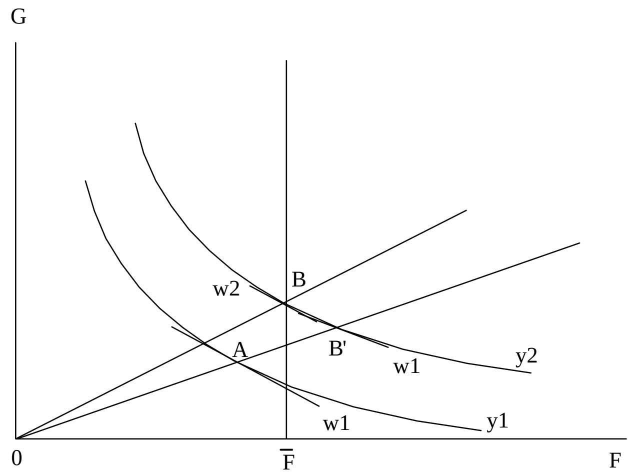
La mise en oeuvre de cette politique s'est faite au moyen d'un ensemble de mesures concernant l'organisation des marchés, l'aide à l'investissement privé, la mise en place d'un puissant outil de recherche, développement, de grands travaux d'aménagement ... Mais du point de vue qui nous intéresse c'est le soutien des prix des produits agricoles, inauguré avant - guerre pour le blé, élargi après et repris dans la Politique Agricole Commune, qui a eu un rôle prépondérant. Cette mesure en effet a accéléré l'intensification du processus de production, ce phénomène étant entendu comme l'accroissement du rapport entre l'un des facteurs de production et les autres. Du fait des particularités de la technologie agricole, le facteur-clé par rapport aux questions d'environnement, est le foncier.

Pour préciser les mécanismes à l'oeuvre on peut partir d'une fonction de production simplifiée à deux facteurs, le foncier F et un agrégat G qui regroupe l'ensemble des autres facteurs (T, le travail ; K, le capital ; et C les consommations intermédiaires). D'où la représentation dans un espace à deux dimensions des possibilités de produire Y avec diverses combinaisons de F et G, (cf. figure 1; Mahé et Rainelli, 1987).

La hausse du prix des produits agricoles, hausse en valeur absolue, ou bien hausse relative du fait d'un progrès technique neutre au sens de Hicks, conduit à un déplacement de Y_1 vers Y_2. Au rapport de prix entre G et W de w_1 correspond pour le niveau Y_1 le point A. Mais si le passage de Y_1 à Y_2 se heurte à une limitation dans la disponibilité en terre (contrainte $\overline{F}$) on quitte la droite OA pour OB du fait de la hausse du prix du foncier. De manière mécanique on a une application de G par hectare qui augmente.

Cette intensification relève d'un processus global de type ricardien. Toutefois, les décisions de politique agricole peuvent aussi jouer. Tel est le cas avec la réforme de la Politique Agricole Commune (PAC) avec le gel des terres. Cette mesure revient bien à durcir la contrainte foncière $\overline{F}$ au niveau des exploitants.

Figure 1.
Effet de la contrainte foncière sur l'intensification de l'agriculture



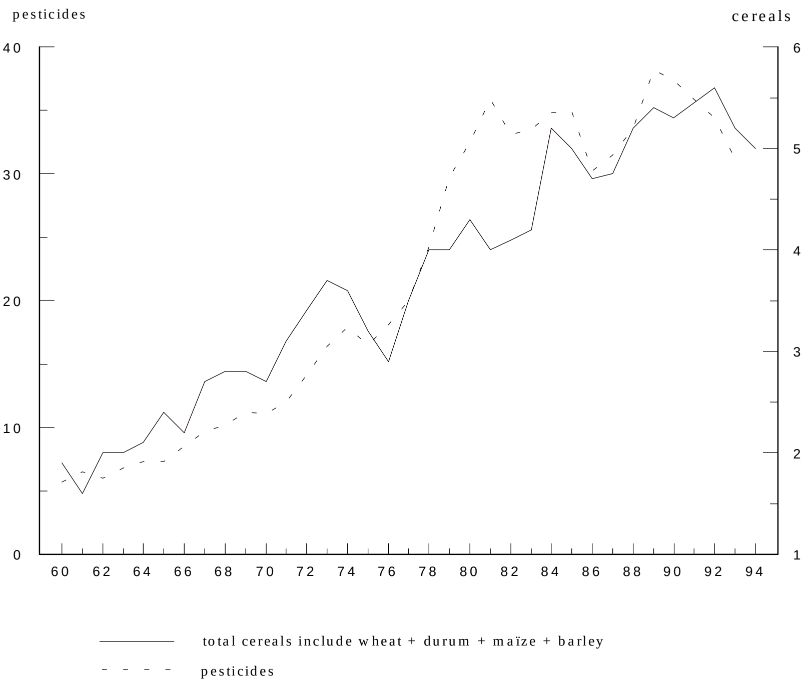
Par commodité on a raisonné avec l'agrégat G comprenant tous les facteurs de production autres que la terre, comme si il y avait une stricte complémentarité entre les intrants, et avec un progrès technique neutre. Or, il y a au cours du temps substitution entre capital et consommations intermédiaires d'une part, et travail d'autre part en raison d'un biais factoriel négatif pour le travail. Celui-ci a été mis en évidence aux Etats-Unis pour la culture du blé (Weaver, 1978). Ce type de résultat se retrouve aussi en France à partir de résultats obtenus dans des analyses utilisant des données par département (Bonnieux, 1987).

Outre ce biais factoriel défavorisant le recours au travail, il y a une évolution des rapports de prix favorisant l'emploi du capital et des consommations intermédiaires au détriment du travail. Ainsi entre 1970 et 1990 capital et consommations intermédiaires s'accroissent en volume dans la proportion d'environ 2/3 alors que les actifs agricoles voient leur nombre divisé par 2. Durant cette période le facteur foncier connaît une légère décroissance.

IV.2 Développement de la production céréalière et pesticides et engrais

Comme on l'a vu précédemment dans le tableau 2 l'ensemble céréales-maïs représente plus de la moitié de la consommation des pesticides. A ce titre, il est intéressant de voir les relations au cours du temps entre production céréalière et consommation de produits phytosanitaires, toutes utilisations confondues. La figure 2 exprime sur un même graphique l'évolution en volume de ces deux éléments (céréales en tonnage, pesticides en francs constants) de 1960 à 1993. Le parallélisme entre les deux courbes est tout à fait probant (r^2 = 0,90). Il est à noter que la relation est légèrement moins bonne lorsqu'on compare la production en t et les pesticides en t - 1 (r^2 = 0,88).

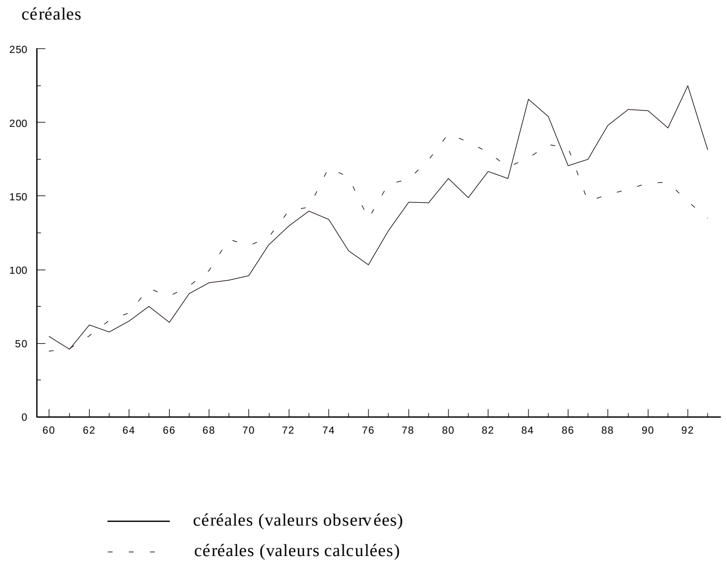
Figure 2.
Evolution France entière de la production céréalière (en tonnage)
et de la consommation de pesticides (en millions de F constants) de 1960 à 1993.



La même présentation mettant en parallèle production céréalière et consommation d'engrais, ces deux éléments exprimés en tonnage, met en évidence le même type de relation (cf. figure 3). Toutefois c'est avec un décalage (production en t, engrais en t - 1) que l'on a un meilleur ajustement (r^2 de 0,65 contre un r^2 DE 0,60 sans décalage). On remarque aussi un résultat moins bon par rapport à ceux des pesticides.

Figure 3.

Evolution France entière de la production céréalière en t et de la consommation d'engrais en t - 1 de 1960 à 1993.



Ces résultats assez significatifs au niveau national ne présentent pas la même qualité statistique au niveau régional. Ainsi pour la région Centre, qui concentre une part appréciable de la production céréalière nationale, les meilleurs r^2 sont 0,73 avec les pesticides et 0,42 pour les engrais. Les essais effectués pour les régions viticoles reliant dans un cas vin de qualité et produits phytosanitaires et dans l'ordre vins d'appellation courante et produits phytosanitaires, ne sont pas révélés probants.

Il apparaît ainsi clairement que la production céréalière s'est développée en s'appuyant sur l'emploi massif d'engrais et de pesticides. Réciproquement le fléchissement de la production début des années 90 se retrouve au niveau de l'emploi dis intrants d'origine industrielle. Une analyse plus fine basée sur un échantillon cylindré d'exploitations céréalières issues du Réseau d'Information Comptable Agricole (RICA) sur la période 1987-1990 permet d'affiner cette observation (cf. tableau n° 8).

L'observation du prix réel de la production de grandes cultures montre une évolution à la baisse sur la période 1987-1990 liée au gel des prix de soutien européens. Parallèlement, le prix des pesticides, et dans une moindre mesure, celui des autres intrants connaît un fléchissement. La réduction des prix agricoles entraîne une baisse de la production et de la demande dérivée d'intrants. Cette contraction de la demande est à l'origine de la baisse du prix réel des facteurs variables.

Tableau n°8.
Evolution du prix à la production et du prix des intrants pour un panel d'exploitations céréalières de 1987 à 1990

	1987	1988	1989	1990	période 1987 - 1990
Prix des grandes cultures	1	0,93	0,92	0,87	0,94
Prix des pesticides	1	0,99	0,91	0,94	0,96
Prix des engrais	1	1,02	0,97	0,97	0,99
Prix des autres intrants variables	1	1,01	0,98	0,98	0,99

Source: Carpentier, 1995, p. 152.

IV.3 Le caractère coopérant des engrais et des pesticides

A partir des exploitations céréalières du RICA on a établi une matrice des corrélations empiriques entre surface cultivée, produit à l'hectare et facteurs variables (tableau n° 9). Cette matrice montre que le produit à l'hectare est positivement et significativement lié aux quantités d'intrants utilisés, et en particulier aux pesticides. Le tableau n° 9 met aussi en évidence les relations entre les différents facteurs variables. Les quantités de ces facteurs sont positivement corrélées deux à deux. La liaison positive entre engrais et pesticides appuie les observations globales des figures 2 et 3 et montre les effets aggravants des techniques de production intensive sur le risque phytosanitaire.

L'étroite relation entre intensification et recours aux facteurs variables, principalement engrais et pesticides s'explique par le fait que les produits phytosanitaires sont des intrants coopérant en espérance avec les autres facteurs de production. Cette opération est envisagée au sens de Rader, à savoir que deux facteurs coopèrent si l'utilisation de l'un augmente la productivité marginale espérée de l'autre. Cette complémentarité tient à des considérations agronomiques.

En effet, les techniques d'intensification mises en oeuvre en France ont permis d'atteindre des rendements assez proches des maxima théoriques. Le recours à l'irrigation et à l'utilisation massive d'engrais ont fait sauter les verrous nutritionnels limitant la croissance des cultures. Cela s'est accompagné de l'utilisation de semences plus productives. Mais ce faisant il y a eu augmentation des risques phytosanitaires car les variétés les plus productives en mobilisant toute leur énergie pour croître perdent en capacité de défense. De même, l'avancement des dates de semis, pour augmenter la durée de photosynthèse, expose en contre-partie les cultures plus longtemps aux attaques des déprédateurs. L'augmentation des densités, qui permet de mieux bénéficier du rayonnement solaire, favorise en revanche les maladies cryptogamiques.

Tableau n°9.

Matrice des corrélations empiriques (et des risques de 1ère espèce du rejet de l'hypothèse de non corrélation) calculée sur le panel des exploitations céréalières du RICA.

	Surface cultivée	Produit à l'ha	Pesticides	Engrais
Produit / ha	0,03 (0,14)			
Pesticides	0,16 (0,00)	0,51 (0,00)		
Engrais	- 0,11 (0,00)	0,34 (0,00)	0,25 (0,00)	
Autres intrants variables	- 0,25 (0,00)	0,33 (0,00)	0,25 (0,00)	0,27 (0,00)

Source: Carpentier, 1995, p. 153.

Ainsi le caractère coopérant en espérance des pesticides avec les autres intrants, principalement les engrais, provient de deux éléments. D'une part, les produits phytosanitaires servent à protéger un rendement potentiel qui dépend positivement de l'utilisation des intrants directement productifs, ce qui est évident pour les carburants qui sont nécessaires aux traitements. D'autre part, l'utilisation massive de ces intrants directement productifs traduit un accroissement du niveau d'intensification et par conséquent entraîne une augmentation des dégâts potentiels dus aux attaques des ennemis des cultures. Ces relations peuvent être mises en évidence et testées à partir de l'estimation économétrique de fonctions de production (Carpentier, 1995).

V. Le cadre législatif et ses répercussions

La présente section est axée sur la législation française visant les produits phytosanitaires qui désormais prend pleinement en compte la reglementation communitaire. Plutôt que d'analyser les aspects juridiques en eux-mêmes elle s'attache à étudier l'incidence que cette legislation exerce sur la demande de denrées agricoles et sur le marché des pesticides.

Après une présentation générale du cadre législatif en place en France on envisagera de manière sommaire ses répercussions pour ce qui concerne la demande de produits agricoles et le marché des produits phytosanitaires.

V.1 La législation des produits antiparasitaires

L'élément central de la réglementation française est la loi du 2 novembre 1943 sur le contrôle des produits antiparasitaires à usage agricole. Cette loi, plusieurs fois complétée et élargie, impose une procédure d'homologation à ces produits pour qu'ils puissent être distribués. Malgré les évolutions au cours du temps les principes originels sont toujours les mêmes à savoir :
- le contrôle de la mise en marché des produits phytosanitaires par une procédure d'homologation,
- le contrôle de la présence de résidus dans les biens alimentaires et l'eau,
- le contrôle des fraudes quant aux conditions d'utilisation des produits par les agriculteurs.

Toutefois, il convient de noter que l'objet de la loi porte sur la mise en marché des produits laissant de côté leur utilisation, même si les autorisations délivrées font état des conditions d'application. Ces autorisations passent par la vérification de l'efficacité des molécules par rapport aux ennemis des cultures visés, par rapport à leur sélectivité et leur innocuité pour l'homme et l'environnement (Doussau, 1995). Pour cela, les firmes doivent établir des dossiers sur les aspects techniques, toxicologiques et écotoxicologiques qui sont examinés par divers instances. Il s'agit :

- de la commission d'étude de la toxicité composée de représentants de l'administration, la profession, la recherche, l'enseignement, du secteur médical de l'écologie et biologie... qui émet un avis en précisant les conditions d'emploi,
- du comité d'homologation formé de représentants de l'administration, qui après avis de l'INRA et de la Commission des toxiques propose l'autorisation provisoire de vente (4 à 6 ans au plan), l'homologation, le refus ou le retrait,
- de la commission des produits antiparasitaires où s'effectue la concertation entre les diverses parties prenantes de la phytopharmacie quant à la bonne application de la loi,
- de la commission d'étude de l'utilisation des produits issus du génie biomoléculaire dont les avis consultatifs sont transmis à la commission d'étude de la toxicité.

La création du Marché Unique s'est traduite par la directive 91/414 harmonisant la mise en marché des produits phytosanitaires dans les Etats-membres. Le décret du 5 mai 1994 l'a transposée dans le droit français sans qu'il ait été nécessaire de modifier la loi du 2 novembre 1943. Il y a simplement renforcement sur trois aspects :

- l'obligation pour qu'une substance active soit autorisée de figurer sur une liste communautaire dite "liste positive" ce qui conduit au réexamen sur 12 ans de toutes les substances actives existantes :
- la nécessité pour une firme de constituer des dossiers d'efficacité et de toxicité en suivant un schéma défini officiellement, et non plus en se contentant de protocoles d'essais rigoureux. Seuls sont pris en compte à présent les résultats d'essais effectués par des services officiels ou agréés.
- la fixation d'une limite maximale de résidus prévisible dans l'eau de 0,1 µg/l. Une dérogation autorisant la vente si cette limite est dépassée, est possible, mais pour une durée de 5 ans seulement et avec obligation de surveillance sachant que l'on doit rester en dessous des normes de l'OMS.

Par ailleurs, la législation française a été durcie pour que les utilisateurs de produits phytosanitaires soient mieux informés. D'où la loi entrée en vigueur au 1er janvier 1996 soumettant les distributeurs et les entreprises prestataires à la nécessité d'un agrément lié à la présence de personnes qualifiées. Enfin, la France prévoit, pour pallier la disposition des contrôles aux frontières de renforcer le dispositif de contrôle de la conformité des produits végétaux et animaux (Doussau, 1995). Ceci est justifié par l'introduction de spécialités non autorisées à la vente en France (cf. présence de buturon dans les eaux bretonnes !).

V.2 Les effets du cadre législatif sur la demande de biens agricoles et sur le marché des pesticides

Il est important de souligner en premier lieu les effets de la législation en vigueur sur la qualité des produits agricoles et, par voie de conséquence, sur la demande de ces biens. Etant donné qu'ils ne sont traités que pendant la durée d'une campagne, les produits agricoles ne peuvent, contrairement à l'environnement (et les sources d'eau potable en particulier), accumuler des quantités importantes de pesticides dès que les agriculteurs respectent les "bonnes pratiques agricoles". Dans ce contexte, la procédure d'homologation (et les mesures de contrôle des pratiques des agriculteurs) s'avère relativement fiable. Cet aspect est important dans la mesure où cette assurance d'innocuité est une garantie de qualité des produits agricoles auprès des consommateurs et de l'industrie agro-alimentaire. Il est particulièrement important dans les cas où l'utilisation de pesticides permet d'éviter des problèmes sanitaires (e.g. présence de bactéries ou de champignons microscopiques toxiques), ou simplement qualitatifs difficilement perceptibles à l'acquisition des produits (e.g. éclosion d'oeufs présents sur le produit lors de l'achat). Cet aspect a été souligné par Brouwer et al. (1994) dans le cas des produits horticoles notamment.

On a estimé dans les années 80 que le délai existant entre la première formulation d'une molécule et sa mise en vente était d'environ 5 ans. Cette période correspond au temps nécessaire à la mise au point du produit et des dossiers nécessaires à son homologation. Dans ce conteste, le point d'équilibre financier d'un produit phytosanitaire se situerait aux environs de 13 ans à partir de sa première formulation, c'est-à-dire 7 ans avant qu'il ne passe dans le domaine public (My 1991). Le renforcement des contraintes environnementales constaté à l'heure actuelle vise à inciter les industriels de la phytopharmacie à proposer des produits de plus en plus inoffensifs vis-à-vis de l'environnement.

Concrètement, ces mesures contraignent les industriels à conduire des tests d'innocuité de leurs molécules sur un nombre d'espèces animales et végétales de plus en plus important. Elles tendent donc à accroître les coûts et le temps nécessaires à la constitution du dossier toxicologique des matières actives.
Cet impact des contraintes législatives s'est traduit aux Etats-Unis par une augmentation très nette du délai entre la découverte d'une matière active et sa mise en marché. Avant le renforcement de la réglementation en 1982 ce délai était de 7 ans. Il est ensuite passé en 1987 à 11 ans en moyenne pour l'industrie phytopharmaceutique américaine (Ollinger et al., 1994). En France, on constate de la même manière un accroissement permanent du coût de mise au point des nouvelles spécialités. En 1995, le montant de l'investissement était chiffré à 875 millions de F contre 200 millions environ vingt ans avant. Les études liées à la constitution du dossier de toxicologie et d'écotoxicologie sont responsables pour une large part de cette envolée des coûts (Auber et My, 1995).

L'accroissement des coûts de mise au point d'une molécule homologuée incite les firmes à se spécialiser vers les pesticides dont la taille du marché potentiel est importante, c'est-à-dire vers les pesticides des cultures majeures telles que le soja et le maïs pour le marché américain (Ollinger et al. 1994). Cette évolution pourrait avoir des conséquences importantes pour les secteurs de production des cultures mineures par rapport à la taille de leur marché phytosanitaire. En particulier, les cultures maraîchères ou fruitières, très diverses par nature pâtissent de cette stratégie des firmes phytosanitaires comme on l'a vu précédemment dans la première partie. Par ailleurs, cet accroissement des coûts de production des pesticides homologués est aussi une des principales causes de la concentration du secteur phytopharmaceutique mondial. En effet, les industriels de la phytopharmacie demeurant sur le marché se sont agrandies à la suite de croissances externes afin d'être à même d'investir suffisamment en recherches et développement pour élaborer des produits commercialisables (Byé et Monétari 1991). On estime que les firmes phytosanitaires investissent 10 pour cent de leur chiffre d'affaire en recherche et développement (Auber et My, 1995). Cette évolution de la structure de l'offre pourrait elle aussi avoir des conséquences importantes. En effet, l'évolution du marché mondial des produits phytosanitaires pourrait être soumis aux choix stratégiques d'un nombre très limité de firmes.

La mise en place d'un cadre législatif de plus en plus contraignant pour la qualité des produits phytosanitaires commercialisés ne peut à elle seule résoudre le problème des nuisances des pesticides sur l'environnement. Si ce problème est analysé sous l'angle des responsabilités des différentes parties (Segerson, 1990), on remarque que ces mesures sont fondées sur le principe selon lequel la responsabilité des dommages causés à l'environnement est entièrement imputable au pesticide. Aussi, elle joue un rôle important du côté de l'offre des produits, en incitant les fabricants à proposer des produits de plus en plus "propres" vis-à-vis de l'environnement.

Cette logique se heurte principalement à l'obstacle constitué par la nature même des produits phytosanitaires. Ceux-ci sont des produits nécessairement toxiques. Aussi, la solution qui consiste à rechercher des pesticides à dégradation de plus en plus rapide ne peut être que partielle puisque le produit doit être suffisamment stable pour atteindre et détruire ou inhiber l'agressivité des populations-cibles. La solution qui consiste à rechercher des pesticides de plus en plus sélectifs ne peut être, elle aussi, que partielle. Comme cela a été vu précédemment, l'accroissement des coûts d'homologation tend à concentrer les efforts de recherche des firmes vers des pesticides dont le marché est potentiellement important. Dans ce contexte, les seuls pesticides sélectifs intéressants pour les firmes phytopharmaceutiques ne peuvent être destinés qu'aux cultures majeures[44]. Enfin, malgré les progrès réalisés récemment dans ce domaine, il subsiste une grande incertitude sur le devenir, les mouvements et les effets potentiels des pesticides dans l'environnement. Etant fondées sur l'utilisation des connaissances scientifiques disponibles, les procédures d'homologation des pesticides sont partiellement pris au dépourvu vis-à-vis de cette incertitude.

Ces limites ont, de notre point de vue deux implications essentielles en termes de politique. La première est que la recherche et l'adoption par les agriculteurs de substituts aux pesticides chimiques, voire de technologies de production agricole moins dépendante en matière de protection des cultures, est nécessaire. Or force est de constater que si les recherches menées dans ce domaine sont déjà nombreuses, leur utilisation par les agriculteurs demeure encore limitée (Byé et al. 1991). La seconde est que l'application du principe de précaution justifie la mise en place de mesures de restrictions portant sur les quantités de pesticides utilisées et non plus seulement sur la qualité de ces produits, étant donné que cette dernière demeure incertaine dans l'état actuel des connaissances. Nous étudions dans la sous-section suivante les effets marchands potentiels de telles mesures.

---

44 D'autre part, les résistances posent un réel problème à l'industrie phytosanitaire pour la recherche de produits sélectifs. En effet, un pesticide sélectif s'expose à des phénomènes de résistance car une souche de déprédateur acquiert une résistance par mutation génétique. Or un pesticide pour être sélectif ne doit agir que sur les phénomènes biochimiques les plus caractéristiques de l'espèce concernée. Il suffit donc que la partie des gênes qui commandent ces caractéristiques mute pour que la souche acquière une résistance.

VI. Conclusion

L'état des lieux a permis de prendre la mesure de l'impact des pesticides sur les écosystèmes terrestres, aquatiques et maritimes, même si la connaissance des perturbations est fragmentaire. Concernant les effets sur la santé humaine, qui sont beaucoup plus préoccupants, le manque d'informations présente un caractère dramatique, même si les normes européennes très strictes pour l'eau de boisson et les aliments, présentent des garanties. Le développement d'études épidémiologiques afin de mesurer les risques cancérogènes des principales molécules utilisées est une urgence.

Dans ces conditions, la mise en oeuvre de politiques visant à réduire le recours aux produits phytosanitaires relève au minimum du simple principe de précaution. Contrairement à certains pays d'Europe du Nord, la France a fondé sa démarche sur le principe selon lequel il est plus efficace de convaincre que de contraindre (Larguier, 1994). Cela a conduit à une définition plus précise des bonnes pratiques agricoles. Il faut rappeler ici que l'expression "bonne pratiques agricoles se réfère uniquement au respect scrupuleux des prescriptions concernant l'utilisation d'un produit, que cette utilisation soit raisonnée ou non.

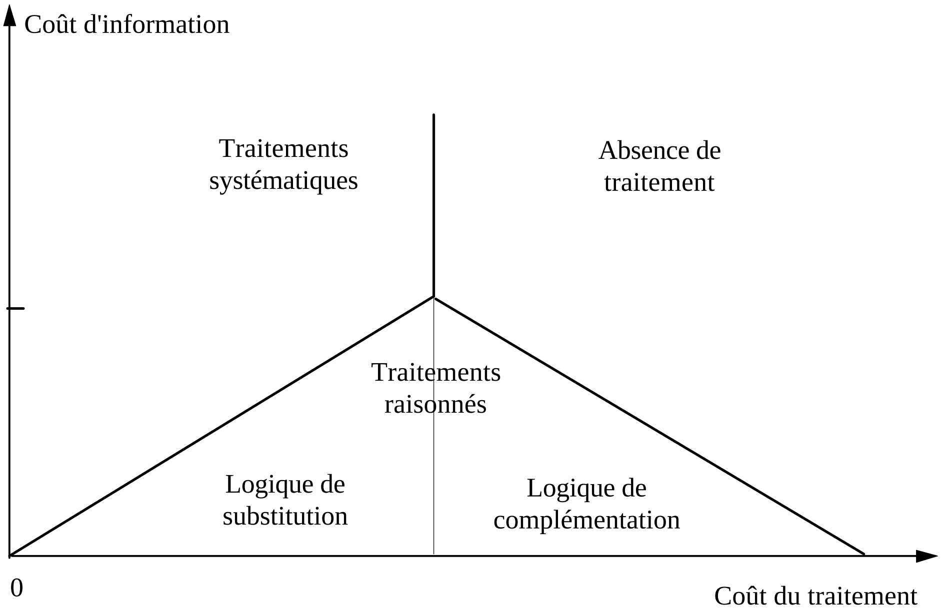
Concrètement l'état intervient, outre la mise en oeuvre des directives européennes, par des mesures de restriction d'emploi avec réduction de la dose homologuée (dose réduite à 1 350 g/ha pour le lindane et 1 500 g/ha pour l'atrazine), l'interdiction d'emploi pour certains types de traitements, l'allongement du délai de traitement avant la récolte... Au niveau départemental, les représentants de l'Etat peuvent aussi intervenir par le biais d'arrêtés préfectoraux permettant d'interdire ou de restreindre localement l'usage de certains produits phytosanitaires.

Au-delà, la mise en oeuvre d'une utilisation raisonnée des pesticides passe par une meilleure prise en compte du comportement des producteurs, et notamment de son attitude face au risque. Un exploitant ayant peu d'aversion au risque acceptera de ne pas traiter en pariant sur des rendements acceptables en moyenne, mais aléatoires. Faisant l'économie des produits phytosanitaires, il peut espérer une marge élevée. Par contre, celui qui a une attitude plus frileuse cherchera à avoir des rendements plus surs avec en contre-partie une marge moyenne amputée par les coûts de traitement.

Dans les faits on montre que les céréaliers français ont une nette aversion au risque. Celle-ci a été estimée à partir d'une prime marginale de risque pour l'ensemble engrais-pesticides, facteurs coopérants comme on l'a vu. Cette prime, qui est négative pour les pesticides équivaut à 12,5 pour cent du prix propre de l'intrant (Carpentier, 1995). Cela signifie que les agriculteurs ajustent leurs achats de produits phytosanitaires "comme s'ils payaient ce facteur à un niveau inférieur de 12,5 pour cent du prix réel de marché".

La mise en oeuvre de conduites raisonnées passe par la prise en compte de cette aversion au risque. Elle passe aussi par un recours systématique à l'information. En effet, compte tenu de l'état sanitaire des parcelles et des risques d'infestation, l'agriculteur va savoir s'il faut ou non traiter. Cela revient à dire qu'il y a une possibilité de substitution entre pesticides et acquisition d'information. Comme il n'existe pas en France de firmes vendant aux exploitants du conseil personnalisé, le coût de cette information peut être assimilé en première approximation au temps consacré par l'exploitant à l'obtention des renseignements utiles et à la maîtrise des outils techniques de base (logiciels de prévision, ou de simulation, connaissance des symptômes d'infestation, ...). On voit qu'il y a un temps de travail correspondant à l'amélioration du capital humain, et un temps consacré aux observations de terrain.

Figure 8.
Relations entre pesticides et information, et comportement des agriculteurs



Par rapport aux diverses conduites possibles, l'agriculteur peut donc soit ne pas traiter du tout, soit traiter systématiquement, soit avoir une pratique raisonnée sur la base d'une information de qualité. A partir de ces éléments on peut proposer un schéma (cf. figure 8) où ces trois possibilités sont comparées. (Carpentier et Vermersch, 1994). On y voit bien les relations existants entre coût de traitement et coût de l'information. Quand le prix des pesticides est faible, tandis que l'information revient cher, l'agriculteur a intérêt à traiter systématiquement. Lorsqu'on a un coût élevé à la fois pour les produits phytosanitaires et pour l'information, il y a une forte incitation à ne pas traiter du tout. Le rôle de l'information, comme l'indique le triangle de la figure 8 répond à une logique de substitution si cela évite les traitements, ou à une logique de complémentation si cela conduit à un recours plus mesuré aux pesticides.

Sur le terrain, la comparaison des résultats de l'enquête "pratiques culturales" de 1994 à celle de 1986, montre pour le blé tendre une généralisation du contrôle des parasites par les produits phytosanitaires, mais avec un emploi plus rationnel (Mazières et Rodes, 1995). Ainsi, en 1994 les 2/3 des surfaces ont 2 traitements ou plus de désherbants qu'en 1986. Pour les fongicides 80 pour cent de la surface reçoit 2 traitements contre moins des 2/3 en 1986. Pour les insecticides la croissance est plus marquée encore. Mais aujourd'hui un agriculteur sur deux parcourt son exploitation avant de décider un traitement et un sur trois tient compte des conseils prodigués dans les revues professionnelles.

Toutefois, on voit bien que l'effort de protection de l'environnement à l'égard des produits phytosanitaires, nécessite par ailleurs la disposition d'incateurs de vulnérabilité des zones en fonction de leurs caractéristiques générales, du type de culture et des pratiques agricoles. L'élaboration de ces indicateurs pourrait se traduire par des documents cartographiques permettant une action à la source au niveau des types de molécules à éviter ou des applications. Des éléments plus détaillés sont présentés en annexe.

VII. Annexe: Elaboration d'indicateurs pour la définition de zones présentant des risques à l'utilisation des pesticides

Il est relativement aisé de définir les milieux terrestres, aquatiques ou maritimes présentant une grande sensibilité aux produits phytosanitaires. Des indicateurs écotoxicologiques basés sur les daphnées, les truites, les macrophytes ou diverses associations de plantes ou d'animaux existent. Le problème réside dans la mise au point de systèmes suffisamment sensibles et représentatifs des milieux que l'on souhaite protéger, et peu onéreux. Mais la plupart du temps, ces pollutions sont exogènes aux milieux sensibles et il importe plutôt de disposer d'indicateurs fiables établis au niveau de bassins versants suffisamment vastes pour caractériser ces apports et assurer également l'approvisionnement en eau potable. C'est dans cette perspective que nous présentons ici deux approches susceptibles d'aboutir à des cartographies opérationnelles.

L'approche basée sur la méthode Hollis

Pour Hollis (Hollis, 1991) on peut prédire la pollution des eaux en pesticides en se basant sur 3 paramètres : la vulnérabilité des sols, les caractéristiques des molécules et les données climatologiques.

La vulnérabilité des sols

Selon que l'on a à faire à des aquifères ou des eaux de surface, les éléments pris en compte diffèrent. Dans le premier cas, on tient compte de la profondeur de l'aquifère ou de la couche saisonnièrement saturée, de la présence ou non d'un écoulement en dérivation vers un substrat perméable et du type prédominant d'écoulement insaturé. Pour les eaux de surface, la vulnérabilité dépend des caractéristiques de l'écoulement et de la proportion de pluie atteignant un cours d'eau dans un laps de temps donné. Ces éléments sont traduis par deux paramètres : le SPR (Standard Percentage Runoff) et le BFI (Base Flow Index). Qu'il s'agisse d'aquifères ou d'eaux de surface, il convient également de tenir compte de la teneur en matière organique qui a un rôle très important de rétention des pesticides par absorption. Ce rôle est prépondérant pour les horizons de surface tandis qu'en profondeur, ce sont plutôt les composés minéraux qui importent. En général, on retient 3 classes : peu de matière organique (1,1 pour cent de carbone organique), une quantité moyenne (2,5 pour cent), une forte quantité (4,7 à 7 pour cent).

Les caractéristiques des molécules

Les facteurs en relation avec la molécule sont la mobilité et la persistance. La mobilité moyenne d'une molécule est appréciée à l'aide du Koc qui reflète l'absorption par la biomasse du sol et la précipitation, ce que l'on appelle sorption. Hollis définit 5 classes de mobilité, de non-mobile à très mobile. La persistance indique l'évolution de la concentration du produit sous l'effet des processus de dégradation ou de dissipation. En faisant l'hypothèse que la vitesse de dégradation est proportionnelle à la concentration, la persistance dans le sol s'exprime sous forme de demi-vie, ou temps nécessaire à la dégradation de la moitié du produit appliqué. On retient A classes : de impersistant (moins de 5 jours) à très persistant (plus de 60 jours).

Les données climatologiques

La première donnée est la température qui détermine le niveau d'activité microbienne dans le sol et donc la demi-vie des pesticides. De nombreuses caractéristiques des événements pluvieux interviennent en modifiant la manière dont l'eau migre dans le sol vers des zones où la possibilité de dégradation de la molécule est réduite. De manière synthétique, on retient la durée qui sépare l'application du produit et la première plus significative. Pour évaluer la pollution des aquifères, Hollis propose un modèle donnant le facteur d'atténuation qui est la proportion de pesticides qui, appliquée sur un champ, se retrouve dans les eaux souterraines. Par référence à la norme de 0,1 mg/l, on peut ainsi déterminer s'il y a ou non risque. De la même manière, on va prédire la concentration de pesticides appliquée que l'on retrouve dans les cours d'eau et cela en fonction du moment d'arrivée de la première vraie pluie.

L'approche SIRIS (Système d'Intégration des Risques par Interaction des Scores)

La méthode de Hollis qui à déjà fait l'objet d'essais en Grande-Bretagne se révèle assez complexe à mettre en oeuvre et donc à systématiser sur de larges zones. En effet, on voit qu'il faut rassembler un grand nombre de données physiques, dont certaines très détaillées, telles celles concernant la vulnérabilité des sols et d'informations précises quant aux molécules utilisées et les quantités appliquées. Afin d'avoir des indicateurs d'une lecture aisée et suffisamment généraux, il convient d'élaborer des cartes susceptibles d'être générées plus ou moins automatiquement à partir de bases de données existantes ou à compléter. Tel est l'objet de l'approche SIRIS (Système d'Intégration des Risques par Interaction des Scores). Sur le fond, SIRIS est une méthode d'aide à la décision faisant appel au jugement d'experts afin de hiérarchiser les risques comparés de chaque substance (Vaillant, 1995). Les experts ont à se prononcer quant à la liste de critères à prendre en compte, à la définition des classes et leur importance respective. Le risque est défini en référence à la possibilité d'exposition d'une part et la gravité des effets d'autre part.

Un essai d'application a été conduit sur la Bretagne en considérant le risque de mise en mouvement des produits phytosanitaires vers les eaux de surface par ruissellement (Simon, 1995). Ont été retenus les facteurs en relation avec :

- le sol: matière organique, profondeur, état de la surface.
- les caractéristiques du bassin versant: pente, forme, longueur.
- les précipitations: intensité, durée entre la première pluie significative et l'application, volume de l'averse.
- la zone d'application : occupation du sol (part des cultures désherbées comme le maïs), existence de courts-circuits, importance des zones saturées.

Ces diverses informations étant couplées avec un modèle numérique de terrain, permet d’élaborer une grille de pénalité par bassin versant.

BIBLIOGRAPHIE

ARPSAH (1995), (Association Régionale des Pays de la Loire pour la Promotion de la Santé par l'Amélioration de l'hygiène) : les produits phytosanitaires, la santé et l'environnement. 46 p.

AUBER D., MY J. (1995), Marché phytosanitaire 1994 : La tendance s'inverse. Phytoma la défense des végétaux n° 473, Juin 1995.

BABCOCK B.A., LICHTENBERG E., ZILBERMAN P. (1992),. Impact of damage control and quality of output : estimating pest control effectiveness. American Journal of Agricultural Economics 74 (1): 163 - 172.

BELLAMIE R., GIROUD S. (1990), Les pollutions liées à l'utilisation des pesticides. Perspectives Agricoles n° 146: 52 - 56.

BONNIEUX F. (1988), Spécialisation régionale et efficacité de l'agriculture. Cahiers d'Economie et Sociologie Rurales n° 8: 5 - 26.

BONNY S., CARLES R. (1993), Perspective de l'évolution de l'emploi des engrais et des phytosanitaires dans l'agriculture française. Cahiers d'Economie et Sociologie Rurales (26): 29 - 62.

BROUWER F. (1995), Pesticides in the European Union-Policy measures to control environmental impacts from agriculture. Concerted Action AIR 3, Workshop on pesticides. Wageningen August 24-27.

BROUWER F.M., TERLUIN I.J. and GODESCHALK H. (1994), Pesticides in the EU. Agricultural Economics Research Institute (LEI-DLO), The Hague, 154 p.

BYE P. et MONETARI J.-C. (1991), L'environnement industriel. In BYE P. DESCOINS C. et DESHAYES A. (Editeurs), 1991. pp. 23 - 42.

BYE P., DESCOINS C. et DESHAYES A., (Ed) (1991), Phytosanitaires, Protection des plants, Biopesticides. INRA, Versailles, 200 p.

CARPENTIER A. (1995), La gestion du risque phytosanitaire par les agriculteurs dans les systèmes de production intensive: une approche économétrique. Thèse de doctorat de l'EHESS, EHESS, Paris, 434 p.

CARPENTIER A., VERMERSCH D. (1994), La nouvelle PAC pourra-t-elle réduire l'intensification ? INRA Sciences Sociales n° 23. Mars - Mai 1994.

CHEVREUIL M., GARMOUNA M. (1993), Occurrence of triazines in the atmospheric fallout on the catchment of the River Marne (France). Chemosphere 27 (9): 1605 -1608.

CLAVEL J., MANDEREAU L., CORDIER S., LE GOASTER C., HEMON D., CONSI F., FLANDRIN G. (1995), Hairy Cell Leukemia, occupation and smoking. British Journal of Haematology 91: 154-161.

DELMAS A.B. (1995), Suivi du transfert d'atrazine vers la nappe et modélisation exemple du polder du Mont Saint Michel. Qualité des eaux et produits phytosanitaires. Colloque Qualité des Eaux et Produits Phytosanitaires : Rennes, 27 Nov. 1995.

DOUSSAU A. (1995), Homologation française des produits antiparasitaires. Colloque Qualité des Eaux et Produits Phytosanitaires : Rennes, 27 Nov. 1995.

ECPA (European Crop Protection Association) (1992), Health effects in man from long-term exposure to pesticides.

FAASEN R. (1995), Agricultural pesticide use.... a threat to the European environment ? European Water Pollution Control (5) 2: 34-40.

GIOVANNI R., HAURY J. (1995), Pesticides et milieu aquatique Colloque Qualité des Eaux et Produits Phytosanitaires : Rennes, 27 Nov. 1995.

GRIVAULT G. (1995), Les produits phytosanitaires : une vaste gamme de substances, un marché en constante évolution, des utilisations variées. Colloque Qualité des Eaux et Produits Phytosanitaires: Rennes, 27 Nov. 1995.

GUIHO M. (1995), Les réseaux de surveillance : résultats, évolution. Colloque Qualité des Eaux et Produits Phytosanitaires. Rennes, 27 Nov. 1995.

HOLLIS J.M. (1991), Mapping the vulnerability of aquifers and surface waters to pesticide contamination at the national/regional scale. In Pesticides in soil and water. Ed. A. Walker BCPC. Monograph 47. Lavenham Press, 1992: 165 -174.

IFEN (Institut Français de l'Environnement) (1994), L'environnement en France, édition 1994-1995. Dunod, Paris.

JUILLARD-CONDAT L., COURTEIX M., LAFON J-P. (1994), Résidus de pesticides sur pommes et optimisation des interventions au verger. BTI (Bulletin Technique d'Information). Juillet-Décembre 1994: 82 - 87.

LAFUSTE J.P. (1994), Protection contre les maladies de conservation des pêches et abricots BTI (Bulletin Technique d'Information). Juillet-Décembre 1994: 88 - 92.

LARGUIER M. (1994), Eléments de la politique française pour la protection de l’environnement à l’égard des produits phytosanitaires. BTI 17-18-19 Juillet. Décembre 1994: 6-11.

LOUIS D. (1995), Pesticides et traitement des eaux de surface pour la production d'eau alimentaire en Bretagne. Evaluation de la situation actuelle et prospective. Colloque : Qualité des eaux et produits phytosanitaires. Rennes, 27 Nov. 1995.

LUGIER J.P., RIFFIOD G. (1994), Les raisins et le vin sont-ils pollués ? Résultats d'une enquête de la sous-direction de la protection des végétaux BTI (Bulletin Technique d'Information) Juillet, Décembre 1994 : 97-108.

MAHE L., RAINELLI P. (1987), Impact des pratiques et des politiques agricoles sur l'environnement. Cahiers d'Economie et Sociologie Rurales n° 4: 9-31.

MALLET C. (1990), La faune sauvage et les produits agrochimiques. Perspectives Agricoles (146): 65-67.

MAZIERES C., RODES V. (1995), Résultats de l'enquête "pratiques culturales" 1994 - SCEES Ministère de l'Agriculture. Données n° 83. Octobre 1995.

MAZZOTTA M., OPALUCH J., GRIGALUNAS T. (1994), Natural resource damage assessment : The role of resource restoration. Natural Resources Journal (34) 1: 53-178.

MEYNARD J.M. (1991), Pesticides et itinéraires techniques in Bye P., Descoins L., Deshayes A. (1991): 85 -100.

MY J. (1991), La recherche de l'industrie phytosanitaire : perspectives in Byé P., Descoins C. et Deshayes A. (1991): 101 - 106.

NRC (National Research Council) (1987), Regulating pesticides in food. National Academy Press, Washington DC.

ODE-WALTER H., GUEGUEN A. (1995), Evolution des macroinvertébrés benthiques des cours d'eau bretons. Effets des produits phytosanitaires. Colloque Qualité des Eaux et Produits Phytosanitaires: Rennes, 27 Nov. 1995.

OLLINGER M., ASPELIN A. and SHIELDS M. (1994), Regulation and New Pesticide Product Size in the U.S. Pesticide Industry. Contribution to the Annual Meeting of the American Economics Association, 7-10 August, San Diego, California.

PERIQUET A., de SAINT BLANQUAT G. (1991), Les pesticides dans l'alimentation humaine. La Revue du Praticien, Nutrition et Diététique (11): 977-984.

PLUYGERS E., SADOWSKA A. (1994), Pesticides et cancer humain. Aves, La Louvière, Belgique.

REULET Ph. (1994), Les résidus en cultures légumières : une situation assainie par la règlementation BTI (Bulletin Technique d'Information). Juillet - Décembre 1994: 93-96.

SCEES - INSEE (1995), Les comptes prévisionnels de l'agriculture française pour 1995. Etudes n° 33 Novembre 1995.

SEGERSON K. (1990), Liability for groundwater contamination from pesticides. Journal of Environmental Economics and Management 19 (3): 227-243.

SEUX R. (1995), Prévention des risques pour le consommateur liés aux résidus de phytosanitaires et procédés de traitement adaptés pour la production d'eau alimentaire ; Colloque Qualité des Eaux et Produits Phytosanitaires: Rennes, 27 Nov. 1995.

SIMON F. (1995), Analyse des facteurs de risque de transferts de pesticides dans les paysage. Etablissement d'une hiérarchie de ces risques. Mémoire de fin d'études ENSA. Rennes, Sept. 1995 46 p.

STARBIRD S.A. (1994), The effect of quality assurance policies for processing tomatoes on the demand for pesticides. Journal of Agricultural and Resource Economics 19 (1): 78-88.

STEPHENS R., SPURGEON A., CALVERT I, BEACH J., LEVY L., BERRY H., HARRINGTON J. (1995), Neuropsychological effects of long-term exposure to organophosphates in sheep dip. The Lancet vol 345. May 6: 1 135 - 1 140.

TRONCZYNSKI J., MOISAN K., MUNSCHY C. (1995), Biogéochimie et flux des produits phytosanitaires en zones estuariennes et cotières en France. Colloque Qualité des Eaux et Produits Phytosanitaires: Rennes, 27 Nov. 1995.

VAILLANT M. et al. (1995), A multicriteria estimation of the environmental risk of chemicals with the SIRIS method. Toxicology modelling vol. 1 N° 1: 57 - 72.

WEAVER R. (1978), Measurement of allocative biases of production control policies. Southern Journal of Agricultural Economies. Déc. 1978.

ANNEX 4

POLICY CASE STUDY OF ITALY

Liliana Cori
via Farini 21
40124 Bologna
Italy

TABLE OF CONTENTS

I. Overview of Italian Agriculture

At present, primary agriculture in Italy accounts for 2.7 per cent of GDP (or 46 000 billion lira in 1994). Fundamental changes have occurred in Italian agriculture over the last few decades (see table 1). From 1971 to 1989 cropland area decreased by 6.8 per cent, or 1 400 000 hectares (ISTAT 1991). Even more striking, from 1990 to 1993, the number of farmers and total farm area fell by 6.6 per cent and 4.1 per cent. The greatest loss has been among small farms. In Italy small farms (with an average of 1.5 hectares per farm) account for more than 75 per cent of the farms, but only 20 per cent of total utilised area. It is also noteworthy that 30 per cent of the farm population are older than 65 years; and only 12.7 per cent of farmers consider farming as their main activity. The education of the farm population is also very low: 51 per cent of labour force in agriculture has no more than an elementary school education, a further 12 per cent has no qualification at all (INEA, 1995).

Table 1. **Agriculture area and employment in agriculture**

Year	Population (millions)	Percentage working in agriculture	Hectares of cultivated land *
1965	52.6	25.8	20 438 000
1975	55.4	15.3	17 527 000
1985	57.1	11.1	17 090 000
1990	57.7	8.9	16 850 000

* The total area of Italy is 29,454,000 hectares

Source: Cannata G., Merlo M., 1994.

Similar to other European countries after the Second World War, Italian agriculture experienced a far-reaching shift towards a new agricultural model based on mechanisation, use of chemicals and high-yielding selected varieties of seeds and plants. The Italian situation is, however, somewhat unique. The presence of many small farmers hindered the concentration and rationalisation of production. Additionally, a geographical differentiation strengthened in the '60s, with a wealthy agricultural sector developing in the Northern plains of the Po valley and in a few big landholders in the Centre and South. Elsewhere, a myriad of small farmers was active, hardly producing surplus for sale on the local marketplace. At present only 20 per cent of farms (around 200 000 in the country) produce goods for the market, accounting for 80 per cent of total marketed volume.

Pesticide use in Italy is marked by a steady increase until 1988, followed by a remarkable decrease in use (17.9 per cent reduction from 1988 until 1993).

Table 2. **Pesticide use in Italy, 1981-1993**

YEAR	FUNGICIDES	INSECTICIDES	HERBICIDES	ACARICIDES, FUMIGANTS, POISON BAIT, RODENTICIDES	OTHERS	TOTAL
1981	121 252	31 283	22 111	14 237	9 130	198 015
1982	96 536	29 851	24 810	13 600	9 747	174 546
1983	82 003	33 187	26 055	14 045	8 715	164 007
1984	84 529	36 402	28 284	15 731	9 478	174 426
1985	85 126	34 401	28 525	12 948	5 838	166 839
1986	93 734	33 489	29 777	14 446	9 146	180 594
1987	114 684	32 987	31 338	14 595	6 261	199 867
1988	116 081	36 643	31 109	15 379	9 950	209 165
1989	105 608	35 914	28 766	15 320	9 753	195 363
1990	106 120	34 619	26 671	16 270	8 827	192 508
1991	89 575	33 188	25 954	15 225	8 367	172 309
1992	94 611	32 607	22 464	13 113	7 372	170 167
1993	94 839	33 749	24 468	13 230	5 375	171 662

Source: ISTAT

Fruit, vegetables and vine growing are the most pesticide-intensive agricultural activities in Italy. Vegetables, fruit and vines account for about 30 per cent of arable land area, and about 54 per cent of total pesticides. In contrast, cereals account for about 63 per cent of arable land area, but only 26 per cent of total pesticide consumption.

II. Environmental Problems Linked with Pesticide Use in Italy

Concern about environmental pollution and related health consequences arose in Italy in the mid 1980's, after some major cases of water pollution by chemicals, leading to bans on water consumption. But before this, the pesticide pollution problem was largely unknown to the general public. The problem was mentioned neither in the first report by the Environment Minister in April 1986, nor in a 1986 report of a major environmental association about water pollution.

In 1986, after the implementation of EEC Directive 80/778, which imposed limits to chemical compounds present in drinking water, widespread herbicide pollution was 'discovered' in large areas of Northern and Central Italy. This is generally known as the 'atrazine emergency', because atrazine (an herbicide used on corn and sorghum cultivation) was the most widely detected, controversial and best known pesticide involved. In order to deal with the emergency, federal authorities (Ministry of Health) decided to 'derogate' from the limits given by the EEC Directive, and allowed consumption of water containing pesticides at levels above the EC limits. Some estimates indicate that around 300 000 people have used water above the EEC limits (Cori, Faustini, and Settimi, 1993).

Other environmental consequences of pesticide use in Italy are:

- resistance to pesticides
- reduction of beneficial organisms
- growth of pest population resulting from the use of pesticides (such as the fruit-tree red spider mite as a consequence of use of pirethroids)
- damage to non-target fauna and vegetation (such as the very negative impact of the use of fenoxicarb on silkworm breeding in the Northern part of Italy, completely obliterating silk production during years 1989-1990)
- effect on the ozone layer of the use of methyl bromide, a fumigant (Sicilia is the single territory with the highest use of methyl bromide in the world. A law on ozone layer protection passed in 1993 imposed a ban on methyl bromide production, import and use, effective as of 31st December 1999. No measures have been taken this far, to enact this law, and a further delay, or worse, abrogation, is very likely in the future)
- risks to human health problems for agricultural workers and the general population, especially when using pesticides with potential long-term toxicity.

The presence of chlorinated pesticides in different environmental sectors has been recently examined by Galassi et al. (1994). The presence of chlorinated pesticides in recent years doesn't seem to reach levels that are hazardous for the environment, considering quality criteria proposed by EEC for water life. However, scattered local situations show an unacceptable level of contamination, e.g. in the rivers of the Calabria Region.

IRSA (Water Research Institute of the National Research Institute) carried out an investigation in 1987 to check the presence, among other pollutants, of atrazine, simazine and molinate (see Galassi and Guzzella, 1990). The research was made on water supplies of the towns of Torino, Ferrara, Chioggia (Venezia), Dalmine (Bergamo) and Mortara (Pavia), in surface and ground water, before and after cleansing in purification plants. The whole range of herbicides under scrutiny was detected at different levels in the different areas, sometimes exceeding EEC Directive limits for a single pesticide in water for human consumption (0,1 micrograms), though seldom exceeding the limit for more than one pesticide (0,5 micrograms).

In 1988 presence of pesticide residues in drinking water was found to be above EEC limits in 303 Municipalities in Northern Italy (Piemonte, Lombardia, Veneto, Emilia-Romagna). Pesticides presence in groundwater was also recorded in the same area.

Following the ban on atrazine, the levels of atrazine detected in surface waters of the Po River in Pontelagoscuro (Ferrara) dropped, whereas the increase in sales of alachlor corresponds to an increase in levels of alachlor detected in the same area. Other herbicides were found, that are substitutes of atrazine in corn cultivation, such terbuthylazine and metolachlor. A case of ground water contamination by alachlor was already detected in 1990.

The effects of residues of pesticides in the environment, in drinking water and food on the population are difficult to record, except in cases of high toxicity. Epidemiological studies can only record evidence of possible carcinogenic, teratogenic, and mutagenic pesticides on a long-term. In spite of some evidence of the existence of local situations of high risk, pesticide risk for human health is not considered as a nationally relevant issue. The 1995 report of the European Centre for Environment and Health of the World Health Organisation (WHO) on "Health and Environment: the Italian situation" doesn't even mention pesticides among the risks for the population.

With reference to the presence of residues in food, a good set of data is available for the last years, mainly a consequence of the activities of the main consumer and environmental associations. The systematised data record a common presence of residues, within and above the allowed levels.

III. Pesticide Management and Control

The Italian government has never adopted a mandate for a pesticide reduction policy. However, the Ministry of Agriculture (MRAAR) introduced a general program for pesticide use reduction in 1987, containing some procedures for pesticide risk reduction. The results were, according to many experts, discouraging at a national level, but the Program did not include evaluation and monitoring, making it difficult to assess its effectiveness.

The National Program was implemented though funding to Regional governments, and lasted until 1991. The declared purpose of the program was to reduce the use of pesticides through:

- control of pesticide use, on field and for food storage;
- use of alternative methods to control pests;
- reorientation of pesticides' production towards more environment-friendly pesticides;
- promotion of the image of hygienic quality for national food products.

Regional governments were responsible for the promotion of co-ordinated actions, in particular for the setting up of a scientific body for advice and research, monitoring of pesticides' residues and control of pesticides' use. Funds allocated under this program totalled 215 billion lira, and were used for: technical assistance, information and training (150 billion), research and monitoring (40 billion), and training and qualification of advisors (25 billion).

The Ministry of Agriculture is also in charge of phytosanitary protection. It, therefore, has competence on pesticides' use to protect cultivation and to improve production; and it grants approval for exports (e.g. export of flowers and plants), guaranteeing the phytosanitary conditions of products.

The Ministry of Health is in charge of risk reduction activities regarding pesticides and all the procedures linked with approval of new pesticides, bans, limitations, production, distribution, as well as control of sale, use, and of residues in food and in freshwater for human consumption. Local health authorities are in charge of delivering training courses for the concession of licenses to buy pesticides.

The Ministry of Health has developed several measures aimed at:

- reviewing authorisations for pesticide use;
- classifying the toxicology potential of pesticides according to the EEC regulations;
- banning or severely restricting use of targeted pesticide;
- updating pesticides' residues limits.

The *Ministry of Environment* was only established in 1986, and agriculture is not on the top of its agenda. In the Ministry's second 3-year Program for environmental protection, the five priority areas are: waterway management, urban waste disposal, management of areas with high environmental risk, development and improvement of protected areas, and employment in depressed areas in the South. The Ministry of Environment had little or no responsibility related to pesticides until 1995, when the Ministry was given the following competencies:

- definition of conditions for applying experimental tests in open field and for authorised institutions;
- participation in the panel of expert giving permission for the above mentioned experiments;
- participation in the National Expert Advisory Committee, following all their activities (evaluation of old and new pesticides' documentation and drafting of evaluations, evaluation of proposals for limitation in use of pesticides or their ban, evaluation of pesticides according to the EU review program);
- definition of criteria for setting of sensitive and protected areas, where pesticide use will be limited or banned;
- definition of technical procedures for the disposal of pesticides and packaging;
- participation in the preparation of annual programs for pesticide control;
- definition - in agreement with the National Agency for the Environment Protection (ANPA) - of programs on a 3-year basis, for the control of environment and health effects of pesticides. ANPA is in charge of the co-ordination of control activities, data collection, drafting of proposals for precautionary measures. ANPA is also responsible for the provision of advice about experimental use of unauthorised pesticides;
- appointment of one representative and five experts for the evaluation activities of the National Expert Advisory Committee.

Other relevant pesticide management activities in Italy include a law passed in 1968 which provides the obligation for people that buy pesticides falling within toxicity classes I and II to have a license. Such license is granted after a test, during which the applicant must prove of having knowledge of legislation, correct use, storage, precaution for using pesticides. Licensed subjects are usually farmers, not necessarily the users on field, but responsible for their use. Only 500 thousand licenses to buy pesticides are presently in force (around 1 every 5 farm) in Italy. The license often was, and it still is, too easy to obtain, and this fact generates doubts about its efficacy a mean of control or information on risks associated with pesticides' use. Such doubts are further corroborated by the very low perception farmers have about human and environmental risks associated with pesticide use.[45]

Extension programs providing technical advice on pesticide use are traditionally delivered by producers' representatives. Distribution of pesticides in Italy is done via co-operatives (18 per cent), Provincial Agrarian Consortia (30 per cent) and in shops or direct sale (52 per cent). The organisation of independent public advisory and assistance services in the agriculture sector is very recent. Only in 1994, and with EU support, had all Italian Regions passed a law setting specific provisions for technical services and assistance in agriculture. Through the Program "Development of agricultural extension" 760 extension workers were trained in 1993-1994 in the Southern Regions. The figure for the country as a whole was of 1 589, only 45 per cent of the number foreseen by the National Program. All these factors can explain a behaviour in the use of pesticides that can be defined, until recently year, as excessive, lacking a complete knowledge of all the possible negative effects on people and the environment.

The CAP reform and the implementation of related measures are also relevant for pesticide management and are re-designing the landscape of agriculture in Italy. In the first period of set-aside (1988-1992), following Regulation 1094/88, more than 700 000 hectares were withdrawn from production, a relatively large amount compared to other European countries. Most of the set-aside (10-20 per cent) land was in the South of the country. In the Northern part of the country, where more than 40 per cent of production is concentrated, the percentage is 1-2 per cent. No reduction of surplus cereal production has been observed as a result of the set-aside policy. The areas eligible for set-aside benefits have been hilly areas, where yield is already low. This is particularly the case in the Southern Regions, where wheat cultivation prevails, and set-aside substituted the traditional rotation. There is, therefore, no evidence that the set-aside policy has reduced the environmental impact of agriculture, and the balance of costs and benefits in this first phase of set-aside program is probably negative (INEA, 1993).

Results are quite fragmented for the first year of application of the new set-aside system (introduced with Regulation 1765/92). Around 206 000 set-aside hectares are mainly concentrated in the Central and Northern Regions (63 per cent). The new program has been more effective in decreasing cereal production, but it has apparently been even less effective for environment protection. For instance, rules of application for Italy envisage mandatory ploughing by the 15th of May, a provision that can generate serious problems associated with soil erosion, nitrate leaching and destruction of animal habitat (INEA, 1993). Cost of the new set-aside system is also significant: 1 125 billion lira, 569 of which come from the National budget.

Also relevant is the application at the national and regional level of EU Regulation 2078/92 (the agri-environment regulation). Data made available by the EU show that the regulation has been mainly used in Italy to control pollution by chemicals: 70 per cent of the resources in Italy are allocated for measures aimed at pesticide reductions and organic farming. Support for organic farming is greatest. But, it is interesting to observe that the area (16 000 hectares) covered by Regulation 2078/92 is well below the actual area of organic farming in Italy.

---

45 This is proven by several inquiries, by the declaration of farmers representatives, by the permanent conflict between environmentalists and the farmers' world in general, emerging during discussion, meeting, in public declarations.

Table 3. **Program costs per hectare, Emilia-Romagna Region (1994/95): IPM Regional Program, and 2078/92 EEC Regulation**

MEASURE	FUNDS	HECTARES	FUNDS / HECTARE
IPM Regional Program	3 000 000 000 liras	50 540	59 359 liras
2078/92 (Pesticides reduction)	4 992 997 ECU, or 9 985 994 000 liras	17 639	566 131 liras

Source: Prepared by the author and Dr. C. Malavolta, Regional Agriculture Administration, Emilia-Romagna Region.

It is possible to compare the annual cost of the regional Emilia-Romagna integrated pest management (IPM) program, and the cost for implementation of EU 2078/92 in this region. Considering an annual expense of 3 billion lira for the Emilia-Romagna Regional IPM program, the expense per hectare is 60 000 lira. In contrast, the expense per hectare in Italy for implementing measures under the EU agri-environment regulation (2078/92) that reduce pesticide use cost ECU 283 000 for the year 94-95, or liras 566 000 per hectare. *If both the IPM Program and the EU agri-environment measure have the same result of enhancing environmental quality, then the regional IPM Program is more cost effective by an order of magnitude.*

Currently, research at the Institute of Agrarian Economy of the University of Bologna is assessing the costs and environmental impacts of applying Regulation 2078/92 in Emilia-Romagna Region. The research will be concluded in 1996.[46]

IV. Regional Policies

Italy is divided into 20 Regions with local administrations. Agricultural activity is very differentiated over these Regions given large variation in geography and climate. Many of the Regions have introduced their own activities to reduce agricultural pesticide risks, most of them involving integrated pest management (IPM). An example is the Emilia-Romagna Regional IPM Program.

Romagna, the eastern part of Emilia-Romagna Region, is one of the most 'industrialised' agriculture areas in the country, with intensive fruit cultivation. Here a regional pesticide program is co-ordinated by the regional Agriculture Department, with a technical-scientific body in charge of advise and control. All the major institutions of the region working on phytosanitary research, including Universities, were involved in the project, thus enabling an effective gathering and distribution of know-how and data.

Advisers offer direct assistance to farms for fruit and vine growing cultivation protection and in general for farm practice and management (apple, vine and peach are among the most important crops in terms of pesticide consumption). The main purpose is farmer's education. Direct assistance is complemented with the publication of a weekly bulletin, disseminated through newspapers, phone, radio, and posters. Meetings for small groups of farmers are also organised.

46 The title of the research is "*Un modello di contabilità ambientale per il monitoraggio territoriale delle attività agricole*" (An environmental accounting model to monitor agriculture activities), co-ordinated by Prof. Gallerani, Institute of Agrarian Economy, University of Bologna.

An important goal was that of improving knowledge of alternative techniques. This resulted in a marked reduction of the difference between the overall quantity of pesticides used and the number of treatments among 'traditional' farms and farms applying IPM techniques. Additionally, the presence of an 'independent' technical advisor is likely to have contributed to the rationalisation of pesticide use in the area. According to farmers, the most significant result during the project was the saving of money consequential to the reduction of pesticide use. The presence of the adviser is crucial, as the monitoring of pest presence is considered quite difficult and time-consuming by farmers. Particular attention is paid to the market and to the quality improvement of marketed. An agreement with a research laboratory was signed to analyse and certificate products.

Figure 1**. Administrative map of Italy**

Table 4. **Input-output analysis of apple cultivation in the Emilia-Romagna Region**

	traditional	IPM	organic
Inputs			
hours of labour	576.65	560.69	478.36
hours of machines	166.41	122.54	120.06
chemical fertilisers (100 kg)	5.74	2.94	
organic fertilisers (100 kg)	6.36	57.13	291.79
pesticides, kg.	186.86	134.67	128.29
° fungicides	78.90	47.28	126.07
° insecticides	95.06	77.39	2.22
° acaricides	9.42	5.58	
° herbicides	3.39	1.92	
° others	0.09	2.50	
Energy input			
GJ/ha	48.32	31.65	23.97
MJ/100 kg output	120.08	96.30	93.57
Economic results (1,000 liras)			
Gross production	9.526	10.368	18.158
expenses for pesticides and fertilisers	1.891	1.312	1.427
° organic	211	396	1.427
gross margin			
° per hectare	7.635	8,600.0	14.566
° per 100 kg output	21	26	57

Source: INEA, April 1995.

An analysis of pesticide use in the cultivation of three major fruit trees in the Emilia-Romagna Region shows the benefits of integrated pest management. Based on the author's communication with the Emilia-Romagna Regional Agriculture Administration, the reduction in pesticide use and cost of pesticides in production using IPM techniques in the Region range from 17-35 per cent and 23-42 per cent respectively. Similar results have been found by INEA, the National Institute of Agrarian Economy (1995). INEA estimates further show that gross production using IPM or organic farming methods is greater than that using traditional methods, thus implying a large net economic benefit (see Table 4).

The wide acceptance and the dissemination of IPM techniques and the market expansion for high quality food demonstrate the feasibility and the positive attitude of farmers towards new practices. It can be underlined that, in any place where pesticide reduction policies are implemented on a long term basis and with clear objectives farmers evidently gain advantage and economic benefits.

V. The Role of Different Stakeholders

It is very difficult to evaluate the impact of government laws and actions to reduce pesticide risk because a large number of factors affect the pesticide market and use in Italy. Among others, these factors include the role of the general public, chemical producers, retailers, and agro-industry.

The general public

The Italian population has always been quite sensitive during the last decade to the issue of pollution from pesticides and poisoning. A referendum was held in Italy in 1990 on pesticide use and the need for a pesticide reduction policy, after the "atrazine emergency". The discussion about the referendum showed wide support by citizens to the development of sustainable agriculture techniques. The referendum wasn't valid, as the voter percentage was not sufficient, but the fact remains that 18 million people voted in favour of a pesticide reduction.

Agrochemical producers

Italian pesticides and fertilisers producers are associated with Agrofarma, covering 95 per cent of the National market. The role of industry in reducing pesticide use was crucial in the second half of 80's, through research and development of new pesticides, effective at very low doses compared with previous products and through improvement of more efficient technologies for pesticide application. In 1994, new products accounted for 70 per cent of the value and 53 per cent of weight of pesticide active ingredients.

Health and environmental risk prevention is presented as a major commitment of the pesticide industry. Agrofarma presented a Code of Conduct for its associated firms in May 1994. The voluntary regulation includes a commitment to abide to the Ethical Code of the Association of Italian Chemical Producers, and the FAO Code of Conduct with respect to research and development, production, transport, and storage of pesticides.

Retailers

Another stakeholder playing a key role in pesticide reduction in Italy is the retail sector. The case of Coop supermarket chain will be illustrated here. However, the same pattern linking sale and farm practice is presently applied by other chains. Coop holds about a 10 per cent share of the Italian supermarket sector, selling 5 500 000 tonnes of fresh food every year. The Coop Consumers' Association ensures adherence to consumers' needs and demands. Coop gathered 1 000 000 signatures on a petition calling for a new law to limit and control pesticide use in 1993. In the meantime, Coop supermarkets began to sell fresh food produced using IPM techniques (labelled as *Prodotti con amore* - Produced with love), guaranteed by Coop as containing no more than a 50 per cent of the maximum residue limit permitted by law for pesticides in food.

Coop signs direct contracts with producers, giving technical advise and "production protocols", listing the type of pesticides permitted for each cultivation. In late 1993, Coop decided to phase out the use of 17 pesticides from "production protocols", that were suspected of being carcinogenic for humans by the US Environmental Protection Agency. Production of "Prodotti con amore" fresh fruit and vegetables increased from 6 400 tonnes sold in 1988 to 72 000 tonnes in 1994 and 92 000 in 1995. ‘Prodotti con amore’ products now represent a high percentage of the total volume of agricultural production in Italy.

Agro-industry

There are also examples of a commitment of the agro-industry to sustainable farm practice and reduced pesticide use. Eridania Beghin-Say is one of the biggest agroindustrial groups in the world, producing sugar and derivates, starch and derivates, oil, seasonings, spices, vegetables proteins and lecitines. In 1994 the firm published a report aimed at improving production and reducing use of inputs (the report is entitled "Eridania for sustainable agriculture").

The agricultural sectors studied are sugar beet and soybean cultivated in rotation with corn. It was shown that significant reductions in pesticide use and production cost could be attained using low input, IPM techniques. If these techniques were applied to all sugar beet production in Italy, it is estimated that it would be possible to achieve a reduction of 1 715 tonnes of herbicides (58 per cent of present use) and 324 tonnes of fungicides (22 per cent of present use). Similar reduction for soya beans is estimated at 650 tonnes of herbicides (43 per cent of present use).

VI. Conclusions

This paper analyses the policies developed in Italy regarding pesticide use and identifies links between policies' implementation and the state of environment. The actual consequences of policies are difficult to identify given the many different factors determining pesticide use: a direct and simple correlation between governmental policies and pesticide reduction can not in most instances be established.

Problems

- A crucial problem is the availability of coherent data for evaluation. Data collected at the local level are essential for evaluating the effect of policy changes; data at national level need to be collected on a long term basis, according to the international groups working on the same issue (e.g. OECD, EU), allowing comparability. A more systematic program of monitoring and data gathering should be implemented to help guide policy and policy evaluation. And existing data should be made more readily available to the public and researchers.
- Environmental pollution is not adequately or regularly monitored in Italy.
- None of the laws approved in Italy include procedures for monitoring policy effectiveness in terms of costs or environmental impact.

Lessons learned

- Policies developed by the competent Ministries in Italy, and specifically directed to limit pesticide use, were approved in a period when other elements were influencing farm practice and farmers' attitude towards chemical use. All the elements for a change were already in place. Government policies may be interpreted as an additional source of change. This additional change was limited by the fact that government policies were not introduced and implemented in a co-ordinated fashion.
- Farmers are sensitive to price changes. This means, as it actually happened in Italy, that as pesticide prices rise, they will be more careful using pesticides.

- However, the application of taxes or the implementations of the Polluter-Pays Principle would be very difficult. Farmers would refuse to bear the costs of such a measure. It would be more appropriate for a single pesticide, when a risk has been proven, and where an alternative is available.

- So far, the Polluter-Pays Principle has not been applied in Italy, and could not be enforceable, within Regulation 414/92, as it could violate the "free circulation" of pesticide products within EU territory.

- The experience of the Emilia-Romagna Region shows that a program developed at the regional level, involving research institutions and other stakeholders, is a powerful opportunity for long term pesticide reduction. Direct technical assistance coupled with a high degree of responsibility of farmers, and the possibility to sell on a selected market are crucial elements to develop a coherent program.

- The role of indirect change of behaviour is also a relevant issue. When a long lasting program demonstrates its feasibility, even those farmers not initially involved in the IPM program begin to change behaviour and experiment with new pesticides, thereby benefiting the whole area where IPM is applied.

- Local level monitoring is possible and necessary to collect coherent and reliable information, and to improve a Program during the course of its implementation.

- Considering the importance of the issues, it's extremely important that, facing uncertainty, policy makers work to build stronger structures and useful sets of data for a complete and rational solution to pesticide problems. The Precautionary Principle would imply that a pesticide be suspended when it's suspected of negative effects either on health or environment. A competent body would be necessary to quickly evaluate evidence of such effects in the country and at the European level.

Opportunities for improving pesticide policy

- The present re-organisation of the Agriculture Ministry and the organisation of a National Agency for Environmental Protection give the possibility of building simple structures to effectively work on pesticide risk reduction in agriculture.

- The existing laws in Italy, if applied and properly monitored, provide the necessary structure to put in place effective pesticide controls.

- There are many opportunities to further work toward pesticide risk reduction, in connection with all the initiatives already developed in the country by: regional governments, the private sector (retailers, farmers' association, agro-industry, pesticide manufacturers), research institutes, universities, etc.

- EU activities such as the agri-environment regulation and the set-aside program could be used more effectively and better monitored to increase environmental benefits.

BIBLIOGRAPHY

AA VV (1993), L'agricoltura dell'Emilia-Romagna una regione in Europa, Regione Emilia-Romagna, collana Studi e Ricerche, Bologna.

AA VV (1994), Quaderni di igiene pubblica e veterinaria, Regione Toscana, Dipartimento Sicurezza Sociale, Firenze.

AA VV (1995), La produzione integrata in Europa, visibilità e regolamentazione. Atti del convegno, Regione Emilia-Romagna, 25 settembre, Bologna.

AA VV (1995), La valorizzazione delle produzioni integrate emiliano romagnole supp "Agricoltura", n. 4, Regione Emilia-Romagna, aprile, Bologna.

AA VV (1995), L'agricoltura e l'Europa, in "Agricoltura", Regione Emilia-Romagna, dicembre, Bologna.

AA VV (1995), Lotta integrata in Emilia-Romagna supp di "Agricoltura", n. 3, Regione Emilia-Romagna, marzo, Bologna.

AA VV (1990), Tecnologie a minore impatto ambientale per una valorizzazione qualitativa dell'agricoltura CESTAAT, Roma.

AA VV (1990), Rapporto sull'agricoltura italiana '89. Confagricoltura, Roma.

AA VV (1991), Lotta Integrata supp. "Agricoltura", Regione Emilia-Romagna, aprile, Bologna.

AA VV (1991), Tutela della qualità ambientale e agricoltura nell'area del parco del delta del Po. Amministrazione Provinciale di Ferrara, Ferrrara.

AA VV (1991), La qualità delle acque del fiume Po negli anni '90. IRSA, CNR, Roma.

AA VV (1992), Epidemiologia per la salute, Rivista, Osservatorio Epidemiologico, Comune di Bologna, n. 10, settembre.

AGROFARMA (1990), Gli antiparassitari e l'agricoltura, Agrofarma, Milano.

AGROFARMA (1992), Il mercato dei fitofarmaci. Andamento e rilevazioni. Agrofarma, Milano.

AGROFARMA (1994), Codice di autodisciplina per le imprese aderenti. Agrofarma, maggio, Milano.

AGROFARMA (1995), I fitofarmaci nell'agricoltura, dati economici, andamento e proiezioni. Agrofarma, Milano.

AGRONOMICA (1994), Eridania per l'Agricoltura Sostenibile, Eridania Béhin-Say, Bologna.

ARIANO, E., GAIARDI, S. (1995), Esposizioni occupazionali a fitofarmaci: produzione e formulazione, colture in pieno campo. Atti Seminario ISS “Epidemiologia della patologia da antiparassitari”, 11-15 dicembre, Roma.

ASSESSORATO AGRICOLTURA E FORESTAZIONE, REGIONE PIEMONTE (1992), Il programma regionale di difesa integrata delle colture, Regione Piemonte, Torino.

AUDINO, R., SILANO, V., TIGANI, F. (1995), I prodotti fitosanitari in agricoltura e nell’ambiente, Pirola, Milano.

BENFENATI, E. (1993), Inquinamento idrico nel milanese: considerazioni sulla natura del fenomeno e sui suoi riflessi tossicologici, in “Ambiente, risorse, salute”, n. 21, ottobre, Padova.

CALABRETTA, C., NUCIFORA, A. (1985), Considerazioni sulla possibilità di lotta biologica e integrata contro Liriomyza trifolii (Burgess) (Diptera Agromizidae) su gerbera in coltura protetta. Atti XIV Congr. Naz. Ital. Ent., pp 807-813.

CAMONI, I., et al. (1989), Residui di pesticidi in campioni alimentari (anni 1986-1987), Istituto Superiore di Sanità, Rapporti ISTISAN, Roma.

CAMONI, I., et al. (1990), Residui di pesticidi in campioni alimentari (anno 1988), Istituto Superiore di Sanità, Rapporti ISTISAN, Roma.

CAMONI, I., et al. (1991), Residui di pesticidi in campioni alimentari. Anno 1989. Prima parte, Istituto Superiore di Sanità, Rapporti ISTISAN, Roma.

CANDITI, D. (1995), Misure agroambientali, un decollo a metà in “Terra e vita”, n. 29.

CANNATA, G., MERIO, M. (1994), Interazione fra agricoltuta e ambiente in Italia, Il Mulino, INEA Ricerche, Bologna.

CELLI, G., PORRINI, C. (1991), L’ape, un efficace bioindicatore dei pesticidi in “Le scienze”, n. 274, Milano.

CORI, L., FAUSTINI, A., SETTIMI, L. (1993), “The pesticide case in Italy” in “Communicating Health and Environmental Risks in Europe”, World Health Organisation, European Office. (not yet published).

CORI, L., TRIOLO, L. (1994), Riduzione ed eliminazoine dell’utilizzo di bromuro di metile in Italia in “Ambiente”, giugno, Roma.

DONNA, A., BETTA, P.G., ROBUTTI, F., et al. (1984), Ovarian mesotelial tumors and herbicides: a case control study. In “Carcinogenesis”, n. 5, pp. 941-942.

DONNA, A., CROSIGNANI, P., ROBUTTI, F., et al. (1989), Triazine herbicides and ovarian epithelial neoplasms. In “Scand. J. Work Environ. Health”, n. 15, pp. 47-53.

FANFANI, R., GALIZZI, G. (1994), Il sistema agro-alimentare dell’Emilia-Romagna, rapporto 1993, Franco Angeli.

FANFANI, R., GALIZZI, G. (1995), Il sistema agro-alimentare dell'Emilia-Romagna, rapporto 1994, Franco Angeli.

FAUSTINI, A., ARPAIA, F., PAGLIARELLA, P., et al. (1992), Monitoraggio delle colinesterasi in lavoratori agricoli e commercianti esposti ad esteri fosforici et carbammati. in "Med. Lav.", n. 83, pp. 135-145.

FINUOLA, R. (1995), La spesa pubbica in agricoltura. Il Mulino, INEA studi e Ricerche, Bologna.

FUNARI, E., et al. (1991), Il rischio della contaminizione delle risorse idropotabili da erbicidi. La situazione in Italia. Istituto Superiore di Sanità, Rapporti ISTISAN, Roma.

GALASSI, S., GUZZELLA, L. (1990), Erbicidi e esteri fosforici in acque di superficie e di falda destinate al consumo umano, "Acqua Aria", n. 3, marzo.

GALASSI, S., MINGAZZINI, M., BATTEGAZZORE, M. (1993), The use of biological methods for pesticide monitoring. "The Science of the Total Environment", n. 132, pp. 399-414, Amsterdam.

GALASSI, S., PROVINI, A., GUZZELLA, L., DE PAOLIS, A. (1994), I pesticidi clorurati constituiscono ancora un problema in Italia? Atti Site, settembre.

GALASSI, S., VAILATI, G., GENESI, M. (1994), Alachlor e atrazina: due erbicidi a confronto, "Inquinamento" n. 8, settembre.

GALLERANI, V., CAGGIATI, P., ORI, M., VIAGGI, D., ZANNI, G. (1993), La lotta integrata in Emilia-Romagna, Edizioni CUSL, Bologna.

GALLONI, G., TAROLO, C., DONNHAUSER, C. (1995), Agricoltura e ambiente, Pirola, Milano.

GIAREL, C. (1995), Erbicidi e fungicidi alla foce del Po e nell'alto Adriatico, tesi University of Milano, Biological Sciences, Milano.

INEA (1992), L'agricoltura italiana conta 1992, INEA, Roma.

INEA (1993), Dodici anni di agricoltura in Italia 1980-1991, Il Mulino, Bologna.

INEA (1993), Annuario dell'agricoltura italiana, vol. XLVI, 1992, Il Mulino, Bologna.

INEA (1993), Italian Agriculture in figures, 1992, INEA, Roma.

INEA (1994), Annuario dell'agricoltura italiana, vol. XLVII, 1993, Il Mulino, Bologna.

INEA (1995), Rapporti fra agricoltura e ambiente: un confronto fra tecniche a differente intensità di impatto di alcune importanti attività agricole. INEA, aprile, Roma.

INEA (1995), Annuario dell'agricoltura italiana, vol. XLVIII, 1994, Il Mulino, Bologna.

INEA (1995), L'agricoltura italiana conta 1995, INEA, Roma.

INEA (1995), Italian agriculture in figures 1993, INEA, settembre, Roma.

ISTAT (1991), Statistiche ambientali, vol. 2, ISTAT, Roma.

ISTAT (1991), Statistiche dell'agricoltura, zootecnia e mezzi di produzione, anni 1989-1990, ISTAT, Collana d'informazione, n. 47, Roma.

ISTAT (1992), Statistiche dell'agricoltura, zootecnia e mezzi di produzione, anno 1989, ISTAT, annuario n. 37, Roma.

ISTAT (1993), Statistiche dell'agricoltura, zootecnia e mezzi di produzione, anno 1990, ISTAT, annuario n. 38, Roma.

ISTAT (1995), Statistiche dell'agricoltura, anni 1992-1993-1994, ISTAT, collana d'informazione n. 4, Roma.

ISTAT (1995), Statistiche dell'agricoltura, zootecnia e mezzi di produzione, anno 1993, ISTAT, annuario n. 41, Roma.

ISTAT (1995), Rapporto annuale. La situazione del paese, 1994, ISTAT, Roma.

ISTAT (1995), Le regioni in cifre, 1995, ISTAT, Roma.

LEGAMBIENTE (1992), Ambiente Italia 1992, Vallecchi, Firenze.

MALAVOLTA, C. (1995), The Application of Integrated Production on Apple and Pear in Italy. Atti Convegno "III Encontro Nacional de Proteccao Integrada", dicembre, Lisbona.

MALAVOLTA, C., MAZZINI, F. (1993), La produzione integrata in "Agricoltura", Regione Emilia-Romagna, marzo.

MAZZINI, F., ZAGHI, C. (1989), Quali, quanti, dove? Proviamo a capire. in "Agricoltura", Regione Emilia-Romagna, febbraio, Bologna.

MINISTERO DELL'AGRICOLTURA E DELLE FORESTE (1987), Piano nazionale di lotta fitopatologica integrata, MAF, Roma.

MINISTERO DELL'AGRICOLTURA E DELLE FORESTE (1990), Le proposte del MAF sui problemi nell'uso dei fitofarmaci. Ismea, Roma.

MINISTERO DELL'AGRICOLTURA E DELLE FORESTE (1992), Progetto Agricoltura, una via italiana al futuro dell'agricoltura. Ismea, Roma.

MINISTERO DELL'AMBIENTE (1992), Relazione sullo stato. Ministero dell'Ambiente, Roma.

MONTANARI M. (1995), 2078, Primo bilancio con luci ed ombre. In "Agricolltura", Regione Emilia-Romagna, agosto, Bologna.

NOMISMA (1992), Rapporto 1992 sull'agricoltura italiana. Il Mulino, Bologna.

NOMISMA (1994), Rapporto 1994 sull'agricoltura italiana. Il Mulino, Bologna.

ORGANISATION MONDIALE DE LA SANTÉ (1991), L'utilisation des pesticiides en agriculture et ses conséquences pour la santé publique. OMS, PNUD, Genève.

ORGANIZZAZIONE MONDIALE DELLA SANITÀ, Centro Europeo Ambiente e Salute (1995), Salute e Ambiente in Italia. OMS, Roma.

OSSERVATORIO AGROAMBIENTALE (1990), Alcuni dati sull'utilizzo di antiparassitari in Provincia di Forli. Osservatorio Agroambientale, Cesena.

OSSERVATORIO AGROAMBIENTALE (1991), Utilizzo di antiparassitari e fertilizzanti nella Provincia di Forli-Cesena, Monitoraggio Agroambientale. Osservatorio Agroambientale, Cesena.

OSSERVATORIO AGROAMBIENTALE (1995), Esperienze di valutazione degli agroecosistemi. Atti del seminario. Osservatorio Agroambientale, Cesena.

PARISINI, F. (1993), Garanzia in Tavola in "Consumatori", n. 11, dicembre.

PERONE PACIFICO, C. (1993), L'agricoltura italiana nei nuovi scenari comunitari. Il Mulino, INEA Studi e Ricerche, Bologna.

PIMENTEL, D. (1982), "Pests and Their Control" in N. Bushan Mandava "Handbook of Natural Pesticides: Methods", CRC Press, Boca Raton.

PORRINI, C. (1991), I pesticidi in provincia di Forli, 8 anni di monitoraggio con le api. Atti del Convegno "Vivere il territorio", in "Vita della Provincia", 12 dicembre, Forli.

POVELLATO, A., ZEZZA, A., BLASI, G. (1995), L'agricoltura italiana e l'ambiente attraverso i piani del regolamento 2078/92 in "L'informatore agrario", n. 31.

POVELLATO, A., ZEZZA, A., BLASI, G. (1995), L'agricoltura italiana e l'ambiente attraverso I piani del regolamento 2078/92 in "L'informatore agrario", n. 31, Roma.

RAVAGLIA, C. (1995), Tra agricoltura e ambiente l'equilibrio è difficile in "Agricoltura", Regione Emilia-Romagna, giugno-luglio, Bologna.

REGIONE EMILIA-ROMAGNA (1990), "Come", Regione Emilia-Romagna, n. 5-6, ottobre-dicembre, Bologna.

REGIONE EMILIA-ROMAGNA, SEDI (1994), Rischi ambientali, alimentari e occupazionali. Regione Emilia-Romagna/Sedi, Dossier n. 20, Bologna.

SCHIPANI, T., MALAVOLTA, C. (1995), L'assistenza tecnica alle coltivazioni in "Agricoltura", Regione Emilia-Romagna, giugno-luglio, Bologna.

SNOP (1991), XI Convegno Nazionale Progretto Agricoltura, Atti del Convegno.

SNOP (1992), XII Convegno Nazionale Progretto Agricoltura, Atti del Convegno.

SNOP (1993), XIII Convegno Nazionale Progretto Agricoltura, Atti del Convegno.

SNOP (1994), XIV Convegno Nazionale Progretto Agricoltura, Atti del Convegno.

STOLFI, N., TRIOLO, L. (1995), Interazioni tra agricoltura, inquinamento e ambiente in alcune regioni italiane. ENEA, CIA, Roma.

STROPPA, M; (1993), Metodi e strumenti di integrazione fra agricoltura e ambiente, Assessorato Agricoltura Provincia di Verona, Verona.

TECNAGRO (1991), L'impiego dei prodotti chimici in agricoltura, Tecnagro, Roma.

ANNEX 5

POLICY CASE STUDY OF JAPAN

Toshihiro KAJIWARA
Japan Plant Protection Association

TABLE OF CONTENTS

I. Overview of Japanese Agriculture

Characteristics of Japanese Agriculture

Limited cultivated land

Japan has a land area of 377 800 km^2 and a population of about 124 million. The land area of Japan is smaller than California, USA and 70 per cent of the land area is mountainous. The area of land available for cultivation is only 13.6 per cent of the total land area, 5 124 000 ha. Cultivated land per person is only 0.04 ha. When compared with other developed countries, the scale of Japanese agriculture is very small.

Intensive agriculture

To meet domestic demand for food on the limited arable land available, the utilisation rate of arable land is extremely high as shown in Fig. 1. This means Japanese agriculture is extremely intensive from the viewpoint of land utilisation.

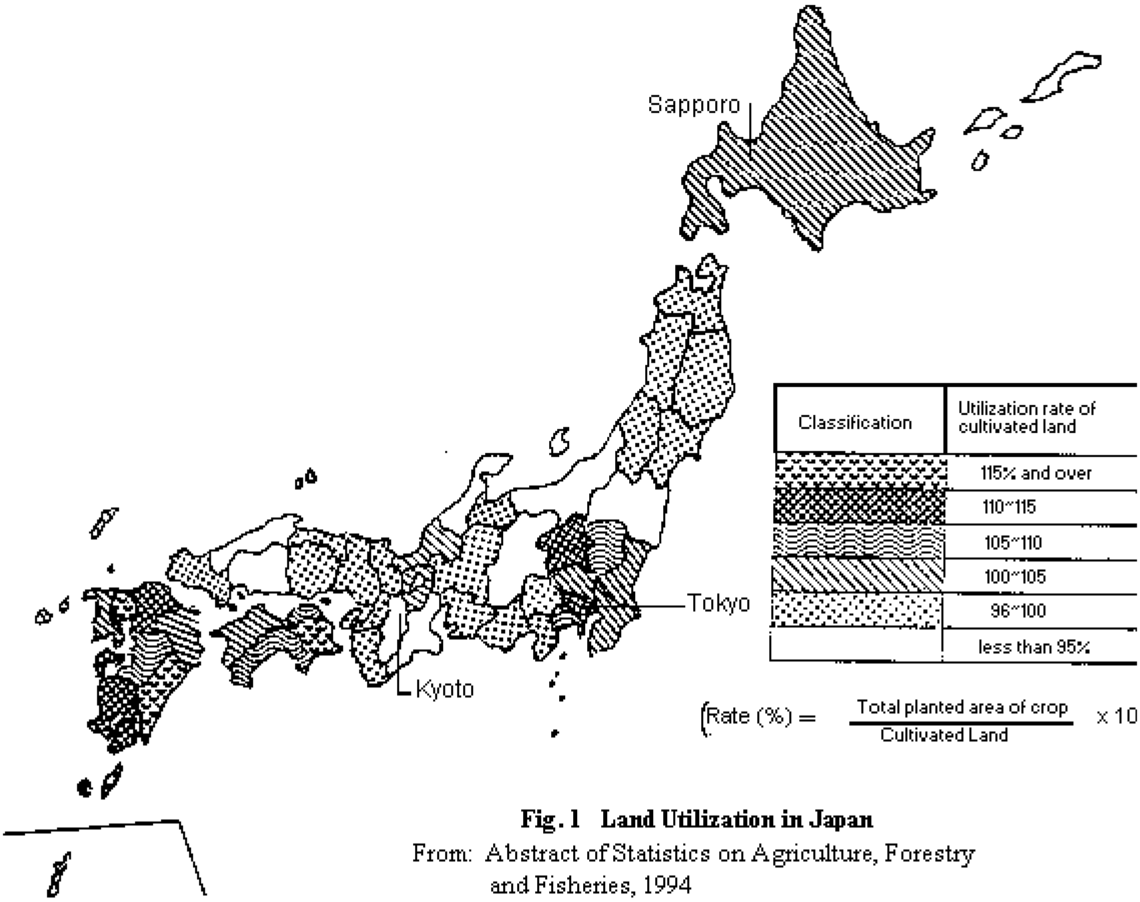


Fig. 1 Land Utilization in Japan
From: Abstract of Statistics on Agriculture, Forestry and Fisheries, 1994

Rice cultivation

As indicated in Fig. 2 in terms of the utilisation pattern of cultivated land, more than half of cultivated land is occupied by rice paddy fields. Japan belongs to the Asian monsoon region, so its climatic conditions are suitable for rice cultivation. As a consequence of this background, Japanese people have utilised rice as the staple food from ancient times. Summary statistics on rice cultivation is shown in Table 1.

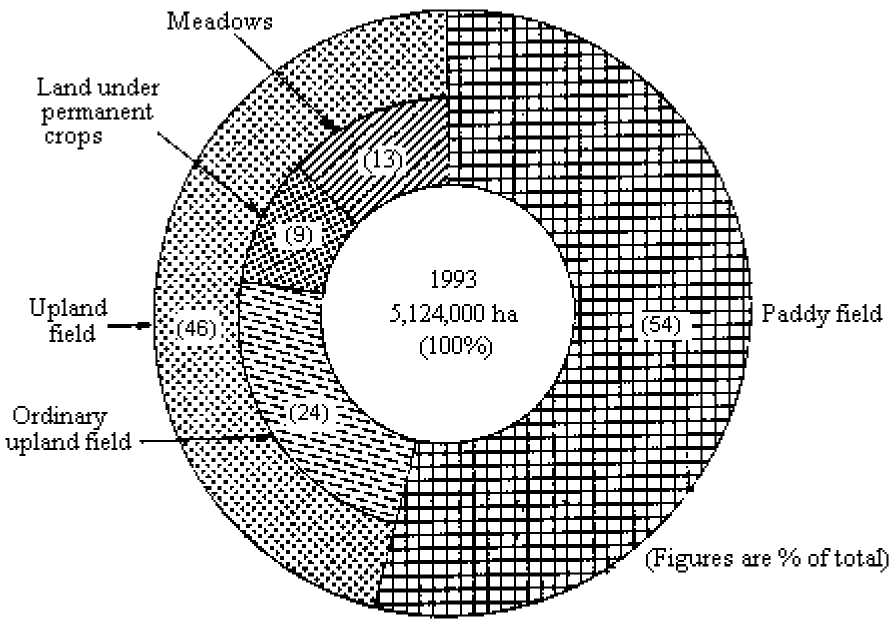


Fig. 2 Cultivated Land in Japan and Its Use
From: Abstract of Statistics on Agriculture, Forestry and Fisheries, 1994

Historical overview of Japanese agricultural policies

Before World War II

Because of the above mentioned characteristics of Japanese agriculture, the agricultural policies of successive Japanese governments, not only the modern government since the start of the Meiji period (from 1868), but also the Bakufu in the Edo era (the Tokugawa shogunate), have concentrated on how to produce enough rice to meet the national demand.

Land reclamation for rice cultivation, improvement of irrigation and drainage infrastructure, promotion of agricultural research including variety breeding, cultural practices, methods of fertiliser application and control methods for diseases and insect pests, etc., have all been promoted by government. Despite such public sector support, Johnston and Josling (1990) note that

"government interventions during the Meiji period did not distort relative prices. In addition to avoiding the costs associated with allocative inefficiency resulting from underpricing and preferential allocation of

Table 1. **Overviews of rice cultivation in Japan**

Year	Cultivated land (ha)	Planted area of rice (ha)	Total production of rice (t)	Rice yield per unit (kg/ha)	Number of farm households	Number of rice farm households (1 000)	Price of rice (yen/60kg)	Imports of rice (1 000t)	Planted area of rice per farm household	Gross income by rice cultivation (yen/10a)	Gross income per rice farm household (1 000 yen)
	A	B	C	D	E	F	G	H	I	J	K
1925	6 017 000	2 992 000	8 717 000	2 910	5 548 599			699			
1930	5 867 000	3 079 000	9 790 000	3 180	5 599 670			170			
1935	6 008 000	3 044 000	8 414 000	2 760	5 610 607			10			
1940	6 027 000	3 004 000	8 955 000	2 980	5 479 571			1 245			
1945	5 301 000	2 798 000	5 823 000	2 080				150			
1947	5 242 000	2 811 000	8 746 000	3 110	5 909 227			2.8			
1950	5 048 000	2 877 000	9 412 000	3 270	6 176 419		2 540	692.6			
1955	5 140 000	3 045 000	12 073 000	3 960	6 042 945		4 064	1 290.9		21 390	
1957	6 044 000	3 075 000	11 188 000	3 640			4 129	432.2		20 019	
1960	6 071 000	3 124 000	12 539 000	4 010	6 056 630		4 162	218.5		22 060	
1965	6 004 000	3 123 000	12 181 000	3 900	5 664 763	4 886	6 538	1 072.2	0.639	34 744	222
1970	5 796 000	2 836 000	12 528 000	4 420	5 402 190	4 505	8 272	15.7	0.629	43 102	271
1975	5 572 000	2 719 000	13 085 000	4 810	4 953 071	4 157	15 570	25.7	0.654	91 534	599
1980	5 461 000	2 350 000	9 692 000	4 120	4 661 384	3 841	17 674	21.5	0.612	73 885	452
1985	5 379 000	2 318 000	11 613 000	5 010	4 376 013	3 560	18 668	14.8	0.651	81 363	530
1990	5 243 000	2 055 000	10 463 000	5 090	3 834 732	3 166	16 500	11.1	0.649	69 796	453
1995	5 038 000	2 106 000	10 719 000	5 090	3 437 569	2 855	16 392		0.738		

* I = B ÷ F
* K = I x 10 x J

capital and foreign exchange, longer term decisions about research priorities, which shape a country's pattern of technological change, were not distorted by inappropriate price signals."

Through such efforts of the government, total yield and yield per hectare have both increased gradually from the Meiji period to the beginning Showa period (1935), and Japan was close to self-sufficiency in rice. However, in some years, rice production was substantially reduced by weather damage or by severe outbreaks of diseases and insect pests, especially blast and planthoppers.

The Post-War Food Crisis and thereafter

Fifty years ago Japan experienced the most severe food crisis in recorded history. That food crisis, which was most acute in the spring and the summer of 1946, was a direct consequence of World War II.

The rice crop harvested in the fall of 1945 was much below normal because of weather (cold summer) and occurrence of blast disease. As of 1946, the government's compulsory food collections from farmers had reached only 60 per cent of the quota for that period. No imported food arrived from September 1945 until March 1946.

Most of the Japanese people suffered from hunger, and food shortages and soaring black market food prices contributed to the hyperinflation that continued until 1948. Therefore, the government at that time focused on a sufficient supply of food as the highest priority amongst its policies.

According to this policy, a huge effort was made in every field of agriculture to meet this goal, as a consequence, self-sufficiency in rice was achieved in 1955. Crop protection, of course, was one of the important contributors to increased rice production, through minimising damage due to diseases, insect pests and weeds.

II. Occurrence of Diseases and Insect Pests in Japan

As Japan belongs to the Asian monsoon area, the summer which is the growing season of rice is characterised by high temperature and humidity. Such climatic characteristics are favourable to the occurrence of diseases and insect pests and consequently to severe damage to rice yield.

In Japan, more than 64 pre-harvest diseases and 140 insect pests of rice have been recorded. The main diseases and insect pests are shown in Tables 2 and 3.

The occurrence of these diseases and insect pests fluctuates from year to year and also from region to region as reported by Yamaguchi (1980) and Iwata (1980), respectively. (Fig. 3 and 4)

Average yield losses of rice due to pests are estimated at about 0.4 to 0.7 million tons annually and account for 3.6 to 5.3 per cent of the average potential production of rice (Table 4). When the pest outbreaks occur, however, the yield losses amount to more than 1 million tons, as shown in Table 5. These yield losses are, of course, in spite of the use of control measures, such as the application of fungicides and insecticides. If the agricultural chemicals were not applied at the time of pest outbreaks, yield losses would be greater.

Kajiwara (1994) summarised yield losses due to outbreaks of rice blast disease without fungicide application based on the experimental results carried out at two prefectural experiment stations over than 10 years. As shown in Tables 6 and 7, the incidence of rice blast (neck blast) fluctuates greatly from year to year and yield losses also range from nearly 0 to 100 per cent. At the Aomori Experiment Station the average yield over a decade in the plot on which no fungicides were used was 62.0 per cent lower than the yield in the plot on which fungicides were used. At the Inahashi Branch Station of the Aichi Experiment Station, average yield was reduced by 71.4 per cent.

These results indicate that the yield losses due to blast disease are very high and at the same time that agricultural chemicals are an indispensable material for stable production of rice.

Recently, studies on the damage caused by diseases and insect pests in crop cultivation without agricultural chemicals were conducted extensively at 69 stations under the auspices of the Japan Plant Protection Association. Twelve crops were tested, including rice, vegetables and fruits. The studies were carried out in 1991 and 1992.

The results of the studies are summarised in Table 8. The results indicate the extent of damage to major crops caused by diseases and insect pests when no fungicides or insecticides are applied. Yield losses in cereals were about 30 to 35 per cent, nearly the same as that estimated by Cramer (1967) and others. On the other hand, yield losses in vegetables and fruits were much higher than those previously recorded. Particularly, the damage rates of apple and peach were 97 to 100 per cent because of the cultivars used to meet consumers needs in terms of taste and quality are highly susceptible. (See Tables 4-8 and Figures 3-4 at the end of the report).

III. Japan's Agricultural Policies and Pesticide Use

Until the mid-1970's

Because self-sufficiency in staple foods, especially rice, was the highest priority of agricultural policies at the time of the post-war food crisis, promotion of plant protection was also a high priority. Since 1950, plant protection has been carried out in conformity with the Plant Protection Law enacted and enforced in that year.

The Plant Protection Law

This Law was originally enacted to cope with the urgent need to increase food production immediately after World War II. The Law seeks to prevent losses caused by pests and to enhance the capability for preventing the accidental introduction of new pests which would be liable to occur in the confused post-war conditions.

Originally this law integrated and strengthened both the Pest Control Law enacted in 1896 and the Import and Export Plant Materials Inspection Law enacted in 1914. Therefore, the law consists of two parts. One concerns plant quarantine, the other covers domestic pest control. All of the government administration concerning plant protection in Japan has been authorised under this law.

The framework of domestic pest control under this law consists of the emergency control of pests, control of designated pests, and plant protection at prefectural level.

Emergency control is carried out: a) against pests introduced incidentally from abroad, b) where there is danger of critical damage due to rapid spread of pests, c) where there is danger of hindering exports by incidence of pests. Regarding control of designated pests, which are indigenous and important, the government has the responsibility for administering pest forecasting programmes, for carrying out control planning at the prefectural level, and for assisting farmers in the purchase of agricultural chemicals and pest control equipment.

Subsidisation of the purchase of pesticides and pest control equipment

Based on the Plant Protection Law, the purchase of pesticides by farmers was subsidised to encourage pest control activities. The amount of the subsidy increased remarkably after 1948 because of the "Campaign to Increase Food Production". In the initial stages of this campaign recommendations were made, such as: control the yellow rice borer with DDT, disinfection of seeds and seed potatoes with organo mercuric fungicide, and control of the lady beetle of potato with arsenate and other insecticides.

Subsidies for these control measures are shown in Table 9. Subsidies were allocated continuously for the purchase of pesticides including copper material and BHC for controlling a large scale outbreak of the rice blast and the leaf- and planthoppers in 1949. Subsidies for pesticides increased tremendously in 1952 and 1953 following the development and introduction of highly effective pesticides for rice diseases and insect pests. Thus, parathion and ceresan slaked lime mixture were put into practical use for the control of the rice stem borers and rice blast, respectively, in 1952.

The policy of subsidies to encourage the use of pesticides was continued until 1954. This policy contributed substantially to increased rice production through minimising yield losses due to the pests. The self-sufficiency in rice, which had been a great wish of the Japanese people for a long time, was achieved in 1955. On the other hand, the policy had led farmers to depend excessively on agricultural chemicals for controlling diseases and insect pests, and consumption of agricultural chemicals in Japan had increased dramatically as a result.

Table 9. **Subsidisation for the purchase of pesticides. (1 000 yen)**

Year	Normal control	Emergency control	Total
1948	46 086	-	46 087
1949	88 420	-	88 420
1950	227 990	-	227 990
1951	268 750	150 000	418 750
1952	594 799	363 553	958 352
1953	923 811	1 652 966	2 576 777
1954	237 453	657 000	894 453
1955	-	10 647	10 647
1956	-	50 304	50 304
1957	-	3 905	3 905
1958	-	64 687	64 689
1959	-	-	-
1960	-	-	-
1961	-	-	-
1962	-	-	-
1963	-	167 518	167 518
1964	-	-	-
1965	-	-	-

Rice price and agricultural chemicals use

Since 1955, pesticide subsidies, except for emergency control, have been abolished. The reasons for this change in policy were: a) the use of pesticides had extended to the whole country and farmers had learned the efficacy of pesticides, b) the cost of the subsidies had caused financial difficulties, c) therefore, pesticides should be used at the farmers own expense, and expenditure for pesticides would be considered as one of the factors for the determination of the price of rice.

The price of rice has been decided upon by the government in consideration of the findings of the Rice Price Council (Beika-Shingikai). The computation of the price of rice was not always by the same method and the method has been modified in accordance with economic and other social conditions. In general, the mean of various production costs incurred by the selected farm households has been incorporated into the official rice price. The authorised cost for agricultural chemicals used is shown in Table 10.

Table 10. **Expenditure on agricultural chemicals in rice production (yen/10a)**

year	Expense (in Yen)	year	Expense (in Yen)
1961	471	1976	4 609
62	480	77	4 846
63	567	78	5 304
64	556	79	5 535
65	653	80	6 109
66	795	81	6 606
67	925	82	6 705
68	1 119	83	7 309
69	1 464	84	7 133
70	1 480	85	7 580
71	1 672	86	7 569
72	1 790	87	7 672
73	2 119	88	7 521
74	3 089	89	7 307
75	4 106	90	7 530
		91	7 579
		92	7 308

From : Agricultural Chemicals Survey 1961-1992,
Japan Plant Protection Association
Expense is authorised price for insurance.

However, we cannot afford to overlook that farmers, even without such measure, would still apply pesticides for the control of rice pests. This is because Japanese farmers have made continuous efforts to maximise their product income from their small paddy fields by minimising yield losses.

The validity of this approach is demonstrated by the data shown in Table 11 and by studies on the damage caused by diseases and insect pests in cultivation without agricultural chemicals. In general, diseases and insect pests cause a reduction in quality, in addition to the yield loss. For example, when the bugs or some pathogenic fungi attack rice panicles after heading, rice grains are stained or spotted with brown to black, and are graded in a lower class. There is a big difference between the purchase price of the highest grade rice and that of the lowest as shown in Table 11, impacting adversely on farm household income.

Table 11. **Rice price–differentials due to the quality (yen/ton)**

year	The Highest grade	The Lowest grade	Differences
1965	106 467	99 133	7 334
1975	262 667	246 333	16 334
1985	315 083	276 417	38 666
1995	277 767	236 600	41 167

* Government purchase price (brown price)
Rice quality was divided into 5 grades until 1978, and into 13 grades after 1979.

According to the results of experiments carried out at several stations, loss of rice without agricultural chemicals crop was 27.5 per cent and the diminution of income was 34 per cent, compared to normal cultivation with agricultural chemicals. In Japan average gross income from rice production was 154 194 yen per 0.1 ha in 1991. Therefore, gross income without pesticides would be decreased by 52 426 yen (54 194 x 0.34). On the other hand, reduced expenditure for rice production where no pesticides were used was 7 579 yen (the cost for agricultural chemicals) plus 1 749 yen (the cost of agricultural chemicals application), or a total of 9 328 yen. Where no pesticides were used, income amounted to 25 577 yen. This was 54 847 yen loss than that of normal cultivation (70 424 yen), a reduction of 63.7 per cent.

Relationship between pests forecasting programme and pesticide use

Forecasting the occurrence of diseases and insect pests in Japan was started under the name of the Programme of Forecasting and Early Detection of the Occurrence of Insect Pest and Disease in 1941.

The programme was motivated directly by an extensive outbreak of planthoppers in Western Japan and of blast in Northern Japan in 1940, causing a loss of some 465 000 tons to rice production. The forecasting programme was initiated with the purpose of securing staple food production and timely distribution of control supplies as well as executing pest control work at the most suitable time.

In 1951, activities of the programme were incorporated into the Plant Protection Law enacted in 1950. Details of the programme organisation and activities are described in Yasuo et al. (1980).

Under this Law important pests have been designated as important for the forecasting programme by the Minister of Agriculture and Forestry. Although the designated pests were initially limited to important pests of cereals, some destructive fruit and vegetable pests were added successively. As of the end of 1995, the designated pests were the following 41 diseases and insect pests in total.

Rice:	blast, sheath blight, bacterial leaf blight, planthoppers, leafhoppers, rice borers, black rice stink bug, rice leaf miner, rice leaf beetle
Wheat and allied:	rusts, powdery mildew, scab
Sugar cane:	oriental chich bug
Citrus:	arrowhead scale, scab, melanose
Apple:	Alternaria leaf spot, blossom blight
Pear:	black spot
Grape:	ripe rot
Japanese persimmon:	persimmon fruit moth
Pineapple:	pineapple mealybug
Fruit in general:	Comstock mealybug, citrus red mite, European red mite, oriental fruit moth, smaller tea tortrix
Tomato:	late blight, grey mould
Cucumber:	bacterial spot, downy mildew, powdery mildew
Watermelon:	gummy stem blight
Chinese cabbage:	bacterial soft rot
Cabbage:	black rot
Lettuce:	Sclerotinia rot
Vegetables in general:	aphis, tobacco cutworm, cabbage armyworm, diamondback moth, common cabbageworm (common white)

Investigations of the designated pests are carried out by the prefectural forecast officer and/or district forecast officer periodically according to the established standard methods. The results of the investigations are delivered to the Plant Protection Division, MAFF.

Information from the pest forecasting programme is released by the national and prefectural governments. The National pest occurrence forecasts are issued by the Plant Protection Division after consideration by experts of plant diseases and insect pests in the national institutes.

Agricultural pest information made available at the prefectural level consists of reports on occurrence forecasting, warning, caution, and situation of specific pests, etc. The report on occurrence forecasting is released once a month. The report for “warning" is released when a widespread outbreak of an important disease and/or insect pest is forecast and urgent control measures are required. The report for “caution" is also released when a widespread outbreak of an important disease and/or insect pest is forecast but not to the extent that immediate control measures are required.

The payments from the national government to the prefectural governments for the forecasting programme are shown in Table 12. The breakdown of the costs of the forecasting programme in 1980 are shown in Table 13.

Table 12. **Trend of budget for forecasting programme, 1971~1980 (1 000 yen)**

Year	Salary	Investigation	Total
1971	213 219	162 608	375 827
1972	237 169	189 685	426 854
1973	264 120	219 486	483 606
1974	301 855	227 848	529 703
1975	481 723	257 045	738 768
1976	622 665	248 356	871 021
1977	683 193	248 407	931 600
1978	729 453	266 536	995 989
1979	734 967	274 145	1 009 112
1980	758 888	278 798	1 037 686

From S. Yasuo et al.: Plant Protection in Japan, 1980

Table 13. **Budget of Forecasting Program 1980 (1 000 yen)**

Item	Amount of Subsidy	Remarks
1. Salary	758 888	
1) Prefectural forecast officer	228 554	Subsidisation rate: 1/2
2) District forecast officer	530 334	S.r.: 1/2
2. Investigation	278 798	
1) Forecasting program for ordinary crops	59 725	S.r. for designated pests: 10/10 S.r. for non-designated: 1/2
2) Forecasting program for fruits & tea	37 399	S.r. for designated: 10/10 S.r. for non-designated: 1/2
3) Forecasting program for vegetables	95 415	S.r.: 2/3
4) Identification of fungal resistance to fungicides	34 737	S.r.: 1/2
5) Plot for judging the most suitable period for control	35 097	S.r.: 1/2
6) Equipment for more efficient investigation & observation	6 555	S.r.: 1/2;
7) Special investigation	9 870	S.r. for designated: 10/10 S.r. for non-designated, interpret. investigation: 2/3 S.r. for pref. investigation: 1/2
Total	1 037 686	

From S. Yasuo et al. : Plant Protection in Japan, 1980

The establishment of the plant pest forecasting programme has contributed to self-sufficiency of rice through minimising yield losses due to pests. Subsidies to the programme may promote pesticide use indirectly, because Japanese farmers (mainly rice cultivation) apply pesticides according to the forecast information. The forecast systems for pests in Japan, however, were not likely to established without subsidy from the government and revenue from the prefectural government because of the small size and low income of Japanese farm households.

Since 1970

Japanese agricultural policies until the late 1960s were focused on achieving self-sufficiency of staple food and maintaining stable production. The use of pesticides was promoted as part of these policies. Self-sufficiency in rice was achieved in the middle 1950s and stable production has been maintained since then.

In the late 1960s, agriculture, particularly plant protection, reached a turning point. Since the release of Silent Spring by Rachel Carson in 1962, concern has been raised about the use of pesticides because of their toxicity and because of residues. At almost the same time, the incidence of "Minamata disease", which is a mercuric toxicosis caused by organomercuric material contained in drainage from a chemical factory, accelerated an Anti-Pesticide Campaign by NGOs -- organomercuric fungicides had been used widely for controlling rice blast and other diseases at that time. Thereafter, the policies in terms of agricultural chemicals have been focused mainly on pollution issues affecting human, animal and environmental health.

Agricultural Chemicals Regulation Law

Originally this law was enacted in 1948 to guarantee the quality of pesticides and plant growth regulators as well as to protect farmers from inferior and illegal agricultural chemicals.

The law was amended in 1971 to reinforce the registration and the control over chemical use. The purpose of the amended Law is to promote stable agricultural production, to protect human health and to contribute to environmental conservation. It does this by helping to standardise the quality of agricultural chemicals and by ensuring their safe use by establishing registration systems and exercising control over the sale and use of agricultural chemicals.

Under the framework of the law, new agricultural chemical products submitted for registration must satisfy criteria concerning quality, efficacy, toxicity, residue on/in the crop and in the soil, damage to aquatic organisms and water pollution. After registration, the agricultural chemicals are monitored and regulated in conformity with the Environmental Quality Standard for Water Pollution (established in 1970 and revised in 1993) under the Basic Environment Law, the Evaluative Guidelines for Water Quality on Agricultural Chemicals in Public Water Areas (established in 1993) and the Standards on Food under the Food Sanitation Law (enacted in 1959 and revised in 1968) by the Ministry of Health and Welfare. As of Dec. 31. 1995, the Standards on Food are established for 108 agrochemicals for 130 crops.

Restricted Use of Agricultural Chemicals

Furthermore, the Agricultural Chemicals Regulation Law regulates the use of agricultural chemicals at several stages after registration. When chemical residues of a product are detected in water or in/on food in excess of the standard, the Ministry of Agriculture, Forestry and Fisheries and the Environment Agency can restrict its use according to the law.

The results of monitoring of agricultural chemical residue in water in the environment carried out for the past 10 years (from 1984 to 1993) have shown that of 5 281 samples analysed for the presence of 26 agricultural chemicals, only 106 had detectable residues, no sample has exceeded the standard level, and one month later the residues were all below ND level (i.e. not detectable).

Recently, the residues of herbicide Simazine (CAT) were detected in water from some points of some rivers at a level slightly in excess of the standard. This may have resulted from the frequent use of Simazine as a herbicide in some golf links.

After consideration by the Deliberative Council for Agricultural Materials (Nogyo Shizai Shingikai), Simazine was designated as one of the agricultural chemicals with possibility of water pollution by the government. As a result, Simazine use was not banned, but its use was restrained by almost all users.

Policies and countermeasures toward risk reduction associated with pesticide use

Establishment and promotion of sustainable agriculture

During the multilateral trade negotiations of the GATT-Uruguay Round, the Ministry of Agriculture, Forestry and Fisheries proclaimed a new policy on food, agriculture and rural development. The establishment and promotion of sustainable agriculture considering conservation of environment are stated as one of the important subjects of the new policy.

The new policy states that it is necessary to promote a) improvement in methods used for controlling diseases and insect pests by mean of synthetic agricultural chemicals because of the risks they may pose to the environment, b) improvement in methods of application of inorganic fertiliser used to maintain soil fertility, and c) recycling of unused organic materials.

In this connection, some groups of farmers are starting to practice natural or organic agriculture (Shizen, Yuki-Nogyo) in which crops are cultivated without synthetic pesticides (or in which use is greatly restricted) and inorganic fertiliser. The products of such farmers groups are sold directly to consumers in response to a strong demand for such products. This movement has expanded gradually and the government is supporting organic agricultural practice indirectly.

Appropriate pest control based on pest occurrence forecast information

The nation-wide pest occurrence forecast information is provided to agricultural instructors through the network of MAFF and prefectural governments. Before the 1970s, the purpose of pest forecasting programme was to promote, rather than reduce, the timely use of pesticides for the prevention of pest occurrence. Recently, the purpose of this programme has been modified towards the avoidance of unnecessary pesticide use under instructors' guidance to farmers.

Occurrence of pests usually differs from region to region. To ensure effective pesticide application based on the forecasts, it is indispensable to know accurately the economic injury level of pests and the control threshold in every region. To support this, studies on the ecology and population dynamics of each pest are being carried out at the national institutes and prefectural experiment stations.

Furthermore, practical forecast methods in each region and district are being improved by farmers themselves or farmer's associations at their own expense.

Promotion of biological pest control

As an alternative to pest control using synthetic pesticides, biological pest control is recommended and its practical use is being promoted.

The control method utilising natural enemies against particular insect pests such as scales of fruit trees was established successfully at the beginning of this century. Based on this knowledge, many efforts to seek and introduce new natural enemies were made after World War II. Several natural enemies have already been used. Biological pest control has been carried out since 1984 and is advanced by the national institutes and prefectural experiment stations under strong leadership of the Plant Protection Division of MAFF.

Some 28 research projects have been undertaken, the results of which will promote biological control technology. Some of the results, for example, on the use of natural enemies and sex pheromones, have already been utilised in practice by farmers.

Development of new, safer agricultural chemicals

Since the middle 1960s, chemical producers have been promoting the development of new agricultural chemicals which are highly effective and environmentally friendly. A number of superior agricultural chemicals has been developed both within the country and introduced from abroad.

These have been registered after passing through various strict tests and inspections. Some are highly effective in extremely small amounts, such as insect growth regulators. Others are effective due to their role in increasing host resistance, rather than to their direct fungicidal action. Yet others are biological materials, such as Bt materials.

Improvement of formulation and application methods of agricultural chemicals have also been promoted to reduce the adverse effects to mammals and the environment. For example, driftless formulations, pack formulations and automatic application machines have been developed and used in practice.

Through the promotion of pesticide risk reduction measures consumption of pesticides in Japan has gradually been reduced since the middle 1970s, as shown in Fig. 5.

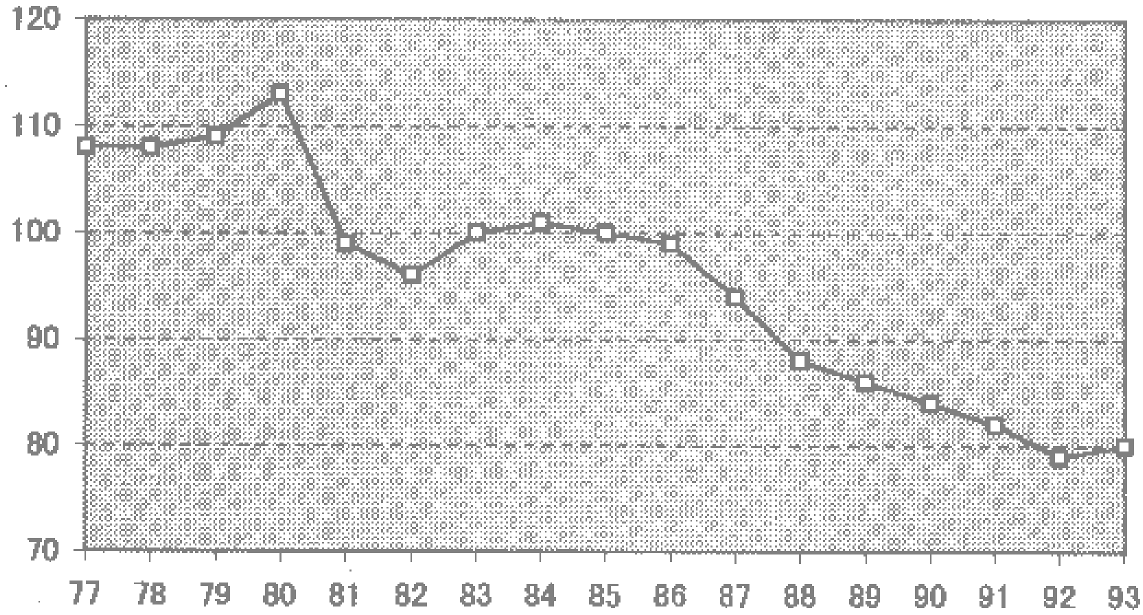


Fig. 5 Index of Yearly Consumption of Agricultural Chemicals (in volume)
1980 = 100, corresponding to 602,000 tons
From Document of Plant Protection Division, MAFF

IV. The New Staple Food Law and its Effects on Pesticide Use

In Japan, supply and demand of rice had for a long time been controlled by the government under the framework of the Food Control Law enacted in 1942. Although the Law has been amended in response to changes in Japan's social and economic situation, the government has retained control over the rice sector from production to distribution and sale.

In recent years, the situation surrounding the production, distribution and consumption of rice has changed significantly as explained by the Food Agency (1995). The government abolished the Food Control Law, and enacted in November 1995, the new Law for Stabilisation of Supply-Demand and Price of Staple Food. The new Law aims to strengthen Japan's rice farming through producer incentives and introduction of market principles and deregulation of rice distribution. A sufficient supply and stable price of rice are also fundamental goals of the law.

In the framework of the law, it is provided that the government will adjust rice production, rice stockpiles and operations concerning imported rice under the minimum access commitment of the agriculture agreement of the Uruguay Round, with the intention of securing the stable shipment and distribution of rice based on the basic plan. While there are therefore some government-imposed restrictions, such as production adjustment to prevent surplus rice, growers are now, in principle, able to produce and sell rice freely under the law. Moreover, there is now no direct subsidy for rice production.

It is still uncertain how the new Staple Food Law will affect plant protection for rice. Rice cultivation without pesticides by growers who have introduced natural or organic agriculture may increase. On the other hand, the Koshi-hikari variety of rice, which is the leading variety with good quality due to its particularly excellent taste, but which is unfortunately susceptible to blast disease, had a 28.7 per cent share of whole acreage of rice cultivation in 1995. It has long been recommended to cultivate blast-resistant varieties or recently to cultivate varieties with isogenic multi-lines with various resistance genes. However, the cultivation of Koshi-hikari may not be decreased quickly because of strong consumer demand. This tends to increase fungicide use when climatic conditions are unfavourable. Therefore, the use of pesticides may in the future remain almost at the current level without the development of innovative new technology.

V. Future Problems

Table 14 shows annual whole cereal production and production per year in various countries in the world. The table illustrates that the amount of cereal production per capita in Japan is very low, compared with that in other developed countries.

Pinstrup-Andersen and CGIAR gave a warning that, since the increasing rate of cereal production in the world has slowed or declined slightly and world population continues to explode, we will, therefore, be in danger of a shortage or crisis of food in the coming 21st Century. Taking these warnings into consideration, I consider that Japan should increase the self-sufficiency rate of food (cereals) up to nearly the same level of EC countries. If so, it will be necessary to increase the production of cereals in the future, although we have a dilemma how to overcome the problem of surplus foods caused by the inflow of foreign products of the moment.

As mentioned often in this report, the use of pesticides and alternatives will play an important role in the increased productivity through minimising crop losses due to pests. Research and development of pesticides and alternatives to make them more effective and more environmentally friendly should therefore be promoted further.

VI. Conclusions

Japan's agricultural policy from the middle 1940s to the middle 1960s was focused on achievement of self-sufficiency in staple foods. The policies resulted in an increase of pesticide consumption.

Crop and income losses due to pests are extremely high in Japan. Therefore, it is difficult to keep stable crop productivity without pesticides. Pesticides are an essential input to production.

Since the early 1970s, pesticide risk reduction policies have been promoted. These policies have been effective, and as a result of these policies, pesticide consumption has reduced steadily (Fig. 5).

The nation-wide pest occurrence forecast information has contributed to damage reduction due to pests with a lesser use of pesticides since the 1970s. These information systems may play a more important role in the future in minimising yield losses due to pests with minimum pesticide use by means of an established control threshold of each disease or insect pest in every region.

Table 14. **Cereals Protection and Self-sufficiency per capita in the World**

Country	Production (1 000t)	Self-sufficiency (kg/per capita)	Country	Production (1 000t)	Self-sufficiency (kg/per capita)
Japan	14 322	116	USA	284 248	1 149
China	365 472	336	Canada	47 955	1 827
Korea, Republic	8 892	210	Argentina	17 274	541
Korea, DPR	12 040	563	Uruguay	1 414	460
Thailand	25 996	469	Paraguay	1 764	424
Indonesia	49 893	279	Brazil	43 701	296
Philippines	13 981	232	Chile	3 148	243
Vietnam	19 059	292	Peru	2 437	112
Malaysia	1 731	100			
Nepal	4 798	260	Egypt	10 287	199
India	192 516	237	Ethiopia	5 925	120
Pakistan	20 908	192	Rwanda	268	38
Bangladesh	27 518	258	Kenya	3 460	140
Turkey	22 966	414	Somalia	608	83
Iran	9 677	179	Ghana	1 247	86
Iraq	1 371	75	Algeria	1 778	73
			Libya	302	69
France	57 140	1 017	Nigeria	11 183	106
Germany	36 980	470	Congo	10	5
UK	22 526	394	South Africa	15 244	440
Italy	16 935	294	Angola	287	29
Denmark	8 808	1 716			
Swiss	1 203	184	Australia	21 743	1 294
Netherlands	1 368	92	New Zealand	671	203
Belgium	2 324	236			
Finland	3 791	764			
Norway	1 252	296			
Poland	26 958	712			
Romania	19 998	864			
Bulgaria	9 661	1 075			
ex-Soviet Union	203 460	707			
Czechoslovakia	12 047	774			

Cereal production: From "Production yearbook FAO" 1989.
Self-sufficiency: Divided production by estimate population in 1989.
Estimate population in 1989: From the statistical state of the world countries. Ed. 1992-93 (Sekai-kokusei-zue. Kokusei-sha Tokyo)

Biological control is recommended and promoted as an alternative to synthetic pesticides. Some biological control techniques are already being practised but most are still in development.

The new Food Law was enacted on 1st November 1995, and the production and sale of rice in the domestic market became open in principle. Production will no longer be directly subsidised. Pesticide use for rice production is likely to remain steady without the development of innovative new technology because of the consumer's demand for high quality rice. Therefore, government leadership will be needed further for minimum pesticide use.

Taking the shortage of world food in the 21st Century into consideration, Japan should increase the self-sufficiency rate of food (cereals) to the same level as that of EC countries. If so, pesticides and alternatives would play a more important role in the stable food production through minimising crop losses due to pests. Research and Development of pesticides and alternatives, to develop more effective and more environmentally friendly techniques, should be promoted (by the government).

BIBLIOGRAPHY

CGIAR (1995), Sustainable Agriculture for Food Security in Developing Countries. Ministerial-Level Meeting, Lucerne, Switzerland, Feb. 9-10, 1995

CRAMER, H. H. (1967), Plant Protection and World Crop Production. Pflanzenschutz-Nachrichten “Bayer" 20/1967, 1524pp.

FAO (1992), Production Year Book

FOOD AGENCY, JAPAN (1993), An Outline of Food Agency Operation. The Japan International Agricultural Council for the Food Agency, March, 1993, 20pp.

FOOD AGENCY, JAPAN (1995), An Outline of the Staple Food Law The Law for Stabilisation of Supply-Demand and Price of Staple Food--, The Japan International Agricultural Council for the Food Agency, January 1995, 24pp.

FURUHATA, T. (1994), Trends of Promotion for Development and Utilisation of Biological Agrochemicals in Japan (in Japanese), Proceedings of Symposium on Development and Utilisation of Biological Agrochemicals, held on Sept. 6-7,1994 in Tokyo, 16-20, Japan Plant Protection Association.

HORI, M. et al. (1980), 30 Year's Development of Plant Protection *in* Plant Protection in Japan, 1980, Agriculture Asia, Special Issue No. 11, 2-29.

IWATA, T. (1980), Major Rice Insects and their Control. *in* Plant Protection in Japan, 1980, Agriculture Asia, Special Issue No. 11, 140-149.

JAPAN PLANT PROTECTION ASSOCIATION (1994), An Investigation Report on Crop Losses due to Pests in the Cultivation without Agrochemicals. (in Japanese), 42pp.

JAPAN PLANT PROTECTION ASSOCIATION (1995), Statistical Survey on Agrochemicals for 1994. (Nohyaku-Yoran) (in Japanese)

JOHNSTON, B. F. and JOSLING, T. E. (1990), Agriculture and Economic Development: Japan's New Challenge. in Agricultural Policies of Japan. SGII No. 9, 73-80.

KAJIWARA, T. (1994), Crop Losses due to Diseases and Insect Pests.(in Japanese), Agriculture and Horticulture 69(1), 84-90

KNUTSON, R. D. et al. (1990), Economic Impact of Reduced Chemical Use. Knutson and Associates, 72pp.

MINISTRY OF AGRICULTURE, FORESTRY AND FISHERIES, Report of the Rice Price Council for 1965, 1975, 1980, 1985 and 1995 (in Japanese).

PINSTRUP-ANDERSEN, Per, (1994), World Food Trends and Future Food Security. IFPRI

STATISTICS AND INFORMATION DEPARTMENT, MAFF (1962), Report of Survey on the Rice Production Cost in 1961. (in Japanese).

STATISTICS AND INFORMATION DEPARTMENT, MAFF (1992), Production Year Book in 1991. (in Japanese).

STATISTICS AND INFORMATION DEPARTMENT, MAFF (1994), Production Cost for Rice, Wheat and Allied in 1993. (in Japanese).

STATISTICS AND INFORMATION DEPARTMENT, MAFF (1994), Abstract of Statistics on Agriculture, forestry and Fisheries for 1994.

YAMAGUCHI, T. (1980), Main Diseases of Rice Plant and their Control. *in* Plant Protection in Japan, 1980, Agriculture Asia, Special Issue No. 11, 126-140.

YASUO, S., TSUDA, Y. and MORITA, T. (1980), Plant Pest Forecasting Programme *in* Plant Protection in Japan, 1980, Agriculture Asia, Special Issue No. 11, 30-41.

Table 4. **Average annual production of rice and the yield losses due to diseases and insect pests. (1 000 ton)**

Year	Av. annual production	Av. potential production	Av. annual yield losses		
			Total pests	Diseases	Insects
1951-1960	10 841.7	11 461.4	619.7	412.3	207.4
		(100)	(5.14)	(3.60)	(1.81)
1961-1970	13 157.2	13 895.7	738.5	534.5	204.0
		(100)	(5.32)	(3.85)	(1.47)
1971-1980	11 954.2	12 511.8	557.6	462.0	95.6
		(100)	(4.46)	(3.69)	(0.77)
1981-1990	10 748.8	11 153.0	404.2	316.0	88.1
			(3.62)	(2.83)	(0.79)

( ): Percentage of yield loss to average potential production of rice.
Source:: Modified from the Statistical Yearbook statistics and Information Department, MMAF. Japan.

Table 5. **Yield losses of rice due to pests in years in which pest outbreaks occur (1 000 ton)**

Year	Production	Potential production	Yield losses			Remarks
			Pests total	Diseases	Insect-pest	
1953	8 239	9 225.4	986.4	751.9	234.5	blast
		(100)	(10.69)	(8.15)	(2.54)	
1963	12 812	13 825.3	1013.3	876.4	136.9	blast
		(100)	(7.33)	(6.34)	(0.99)	
1966	12 745	13 644.5	899.5	470.5	429.0	blast and
		(100)	(6.59)	(3.45)	(3.14)	brown plant hopper
1980	9 751	1 0571.4	820.4	729.5	90.9	blast
		(100)	(7.76)	(6.90)	(0.86)	

( ) : Percentage of yield loss to potential production.
Source : Modified from the Statistical Yearbook, Statistics and Information Department, MAFF. Japan.

Table 6. **Yield loss by occurrence of rice blast at Aomori Agric. Exp. Stat.**

Year	controlled with fungicides		without fungicides	
	% of neck blast	yield	% of neck blast	yield
1971	0.2	551	13.8	508
1972	21.5	365	96.5	50
1974	2.5	627	92.1	198
1975	16.1	309	95.8	27
1976	6.7	577	51.2	267
1977	0	473	0.5	471
1978-(1)	0	512	4.5	515
1978-(2)	0.1	515	1.0	482
1979-(1)	2.2	488	82.8	89
1979-(2)	0.1	579	11.9	423
1980	80.8	98	100.0	2
1992	0.2	563	1.6	488
Average	10.87	471.4 (100)	45.98	293.3 (62.0)

Remarks:

1. Yield: brown rice kg per 10a was calculated from the results per 3.3 sq. m (1 experimental plot).
2. (1) and (2) of the year are showing the data of the different experiment.
3. Fungicides used are not same always, but all of them are registered on for rice blast.

Table 7. **Yield loss by occurrence of rice blast at Inahashi-Branch station of Aichi Agric. Exp. Stat**.

Year	controlled with fungicides		without fungicides	
	% of neck blast	yield	% of neck blast	yield
1968-(1)	9.8	121	35.9	99
1968-(2)	4.8	196	34.0	86
1968-(3)	11.5	108	74.9	37
1969	1.6	400	14.4	328
1970	1.3	531	9.8	347
1971	13.4	251	69.3	71
1972	1.4	421	13.2	375
1973	0.8	440	3.9	417
1974-(1)	22.4	271	84.2	67
1974-(2)	8.7	349	66.7	128
1977	0.9	425	3.7	389
1978	1.0	537	5.2	487
1979-(1)	8.1	421	24.3	342
1979-(2)	1.6	548	18.8	373
1980-(1)	1.0	420	3.4	410
1980-(2)	1.1	481	5.5	435
1982-(1)	24.5	138	69.4	25
1982-(2)	7.2	338	34.7	216
1983	24.0	237	40.0	120
1984	7.0	452	53.7	309
Average	7.58	354.3 (100)	33.25	253.1 (71.4)

Table 8. **Yield losses due to the pests of major crops where no agricultural chemicals are used.**

Crops	Yield losses without agri- chemicals (in percent)		
	maximum	minimum	average
rice (paddy)	100	0	27.5
wheat	56	18	35.7
soybean	4	7	30.4
apple	100	90	97.0
peach*	100	100	100.0
cabbage	100	30	63.4
radish	76	4	23.7
cucumber	88	4	40.7
tomato	93	14	39.1
potato	44	19	31.4
egg plant*	21	21	20.9
corn*	28	28	28.0

* shows the result of only one trial.

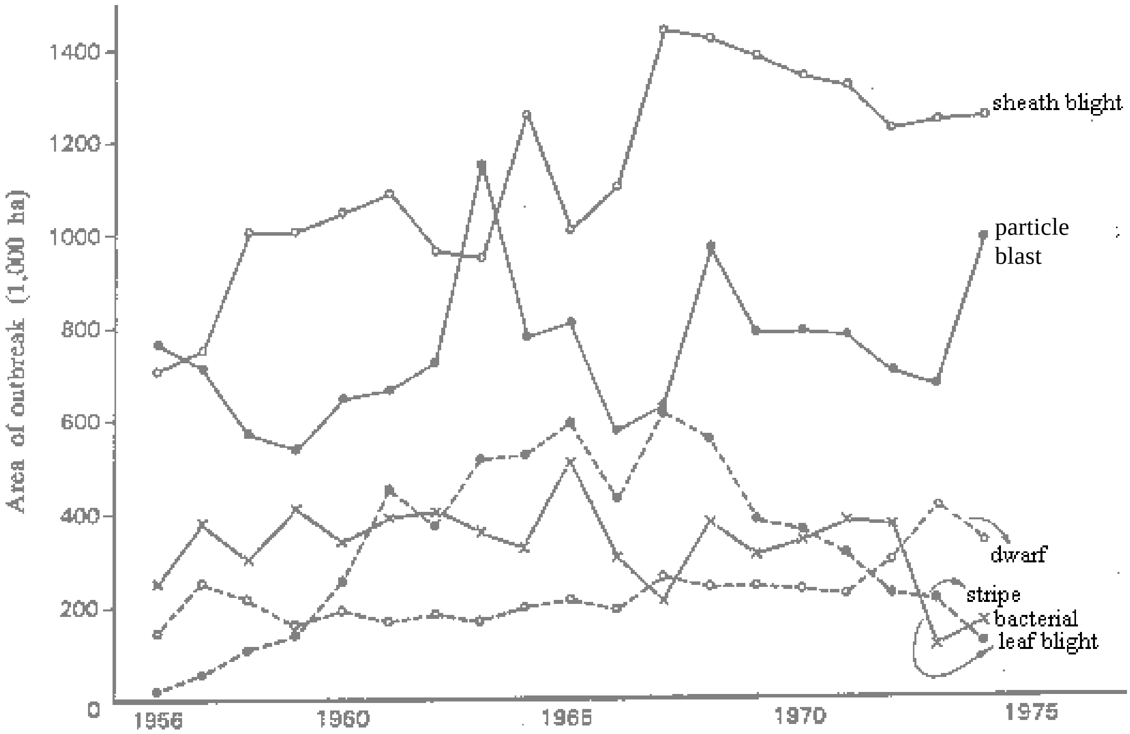
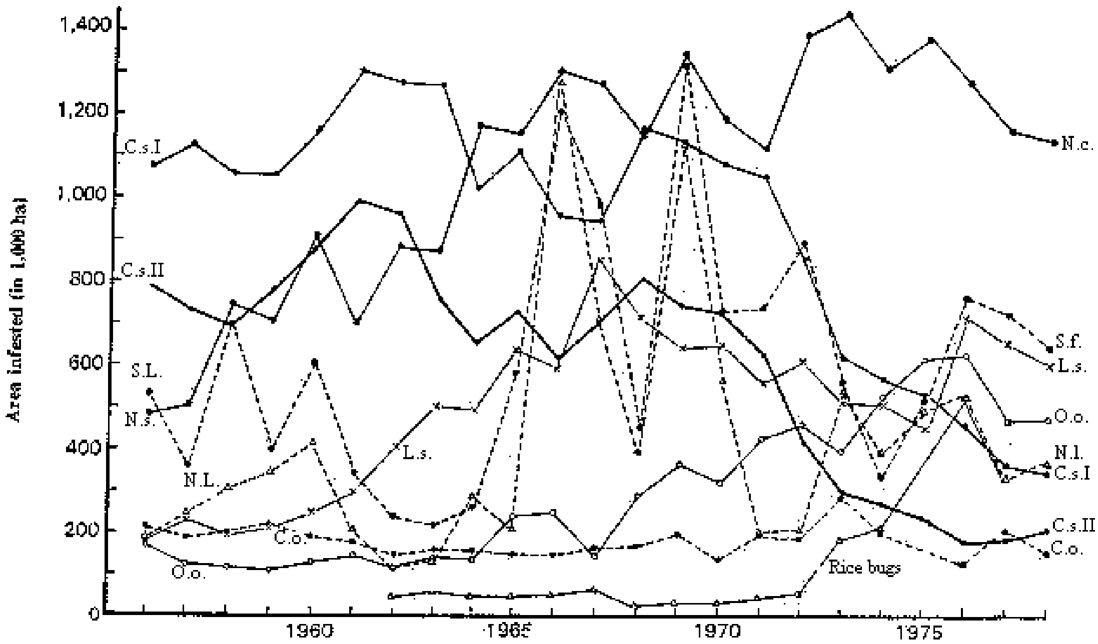


Fig. 3 Changes in the areas affected by main rice diseases in Japan
From: Yamaguchi, T. Plant Protection in Japan, 1980



C.s.I First generation of the rice stem borer
C.s.II Second generation of the rice stem borer
N.c. Green rice leafhopper
S.f. White-backed planthopper
N.l. Brown planthopper
L.s. Smaller brown planthopper
C.o. Rice stem maggot
O.o. Rice leaf beetle

Fig. 4 Variation in the area of rice infested by major insect pests.
From: Iwata, T. Plant Protection in Japan, 1980

ANNEX 6

POLICY CASE STUDY OF SWEDEN

Dr. Olle Pettersson
The Swedish University of Agricultural Sciences
Research Information Centre, Box 7058
75007 Uppsala, Sweden
(This report is based on a original paper
by Mr. Pettersson and on comments
by the Swedish Board of Agriculture)

TABLE OF CONTENTS

I. Background to Swedish Agricultural Policy

As in many other European countries, agricultural policy in Sweden evolved from the 1930s. At that time, measures were introduced to help farmers facing economic problems during the times of depression. Already at the dawn of agricultural policy one important aim was - if not explicitly expressed - to maintain the income for farmers by means of import restriction and price subsidies. Over time, this combination of protectionism and commodity-linked price support led to overproduction, increased state intervention and bureaucracy.

Following World War II, agricultural policy focused on three goals: production (national food supply), distribution (income parity and stability) and efficiency (rationalisation to make farm incomes compatible with reasonable consumer prices and over all economic growth). This policy orientation dominated to the 1980s.

Structural changes in society, including a much smaller share of the population directly involved in agricultural production, decreased the political power of the agricultural sector. Sweden's farm structure has evolved in patterns broadly similar to those in other advanced industrial nations. It is marked by a growing concentration of land and capital, increasing size of farm operations, loss of farm land, increasing specialisation, rising yields and labour-saving technical change. Conflicting goals within the traditional policy agenda surfaced. In particular, new public demands on food safety and environment came into focus and traditional policy became increasingly obsolete.

Agricultural surpluses, the budgetary burden and concern over the environmental effects of a highly subsidised and increasingly intensive agricultural sector led, in 1990, to the introduction of a new agricultural policy. The general direction of the reform was deregulation of domestic markets for the major agricultural commodities.

Transition measures affecting land use were introduced to encourage a quick adjustment to the effects of the reforms, particularly in terms of the significant decrease in the area expected to be sown in grain. For example, farmers entitled to income support could apply for a one-off conversion or adjustment grant to allow them to switch from growing foodstuffs to other cultivation that does not compete with existing crops, or to convert their land to extensively grazed pasture. By 1994, 13 per cent of the country's arable land, or 363 000 hectares, had been converted to such uses.

Already in the 1960s and 1970s there were piecemeal responses to environmental and other "green" demands on agricultural policy in Sweden, resulting in, for example, more strict regulation of pesticides and farmland-preservation measures. During the 1980s and 1990s more and more environmental and health aspects were included in agricultural policy. This was combined with specific environmental programmes to decrease the overall impact of modern agriculture on the environment. The pesticide reduction programmes should be considered within this context. Other non-traditional policy measures with relevance for the environment are targeted supports for preservation of agricultural landscape and biological diversity, food security and regional development.

II. Pesticide Use in Sweden

Pesticide use varies between countries and regions depending on environmental conditions and the structural characteristics of agricultural systems. The dominant trends in Sweden as well as in other industrialised countries have generally been similar -- yields have increased and production efficiency has been enhanced through the utilisation of improved plant and animal varieties, together with technical and chemical means. The area required to meet the country's needs for food has been reduced over the years. Some basic statistics describing Swedish agriculture, including pesticide use, are shown in Table 1.

Table 1. **Facts on Swedish agriculture (1993)**

Per cent agricultural land of total area	8	(including pasture)
Hectares of cultivated land[1], of which	2 872	
Pasture land	576	
Conversion/set aside	368	
Bare fallow, etc.	56	
Wheat	304	(mainly winter wheat)
Rye	46	
Barley	420	(mainly spring barley)
Oats	322	
Rye wheat	35	
Mixed oats/barley	25	
Rape	145	
Leguminous plants	55	
Sugar beets	51	
Potatoes	36	
Cattle[1]	1 807	(of which 525 dairy cows)
Pigs[1]	2 277	
Sheep[1]	470	
Herbicides[2]	1 093	
Fungicides[2]	241	
Insecticides[2]	15	
Seed dressings[2]	76	

1) In thousands
2) Sales of tonnes of active ingredient

Source: Statistics Sweden, 1994

Sweden, like Finland and Norway, is characterised by a relatively moderate degree of agricultural specialisation in comparison with the most intensive agricultural areas in other

OECD countries and areas in developing countries where cash crops are grown. It follows therefore that the environmental impacts and other side-effects of pesticide use will be less severe.

Arable land in Sweden comprises about 2,9 million hectares which is about 8 per cent of the country's area. Most of the agricultural and horticultural activities take place in the Southern part of the country because of climate and soil conditions. In the southernmost part, most European crops except grapes, corn and sunflowers are grown. In the plain districts around the great Swedish lakes, the most frequent crops are winter wheat, oats, barley and oilseed rape. Further north there is a large proportion of forage crops especially grass.

Sweden’s agricultural area is highly diverse. The Southern parts contain fertile plains and resemble the granaries of Central Europe in terms of agricultural structure and yields. The sparsely populated areas in the deep forests of the northern parts of the country represent quite different conditions for agriculture, and also for pesticide use. Soil types vary from heavy clays, with relatively little nutrient leaching and almost negligible soil erosion, to sandy soils exposed to wind erosion.

All of Sweden has a relatively humid climate. In the agricultural areas, the annual rainfall varies from around 600 mm to more than 1000 mm, half of which passes through the soil to the drainage system. The large amounts of precipitation and run-off lead to the diffuse water pollution caused by agriculture. Although nitrates account for most of the pollution, water-soluble pesticides have also shown up in some cases.

Due to the relatively humid and cold weather, weeds tend to be more of a problem than that of insects and fungus diseases. Thus, compared to the rest of the European continent, herbicide use is relatively more intensive compared to that of fungicides and insecticides. The use of pesticides in Sweden expressed as amount of active ingredient, area treated, and doses applied is shown in Tables 2-5.

Table 2. **Sales of pesticides in agriculture and horticulture, tonnes 1981-1994**

Year	Seed dressings	Fungicides	Herbicides	Insecticides	Growth-regulators	Total
1981-85 (av.)	161	599	3536	150	82	4528
1986*	199	869	4207	160	243	5678
1987	119	470	1781	63	84	2519
1988	101	662	2029	112	75	2982
1989	120	445	1871	50	35	2521
1990	97	608	1658	38	49	2450
1991	86	696	1073	27	43	1925
1992	90	479	956	36	32	1593
1993	76	283	1105	26	41	1531
1994*	90	317	1526	46	47	2026

* The sales are bigger than the use. Compare with Table 3.

Source: Swedish Board of Agriculture, 1996

Table 3. **Estimated use of pesticides in agriculture and horticulture according to a farmers' questionnaire, tonnes 1988-1994**

Year	Disinfectants	Fungicides	Herbicides	Insecticides	Growth-regulators	Total
1988	140	660	2200	110	10	3120
1989	120	490	1910	40	40	2600
1990	100	500	1650	40	40	2330
1991	90	530	1140	20	20	1800
1992	90	420	1050	40	10	1610
1994	90	260	1190	30	20	1590

Source: Statistics Sweden, 1995

Table 4. **Crop area treated with pesticides in per cent of crop area**

Crop	Herbicides						Fungicides*						Insecticides					
	88	89	90	91	92	94	88	89	90	91	92	94	88	89	90	91	92	94
Cereals	83	82	77	71	75	83	12	15	13	15	10	14	47	12	12	5	23	19
Potatoes	41	49	44	44	50	47	82	92	87	88	82	69	19	15	19	13	17	15
Sugar beets	97	98	97	97	95	99	9	-	-	-	-	-	51	48	39	25	48	43
Oil-seed	40	46	46	48	42	44	1	-	-	3	-	-	67	54	46	55	63	73
Other crops	6	6	6	4	3	3	-	-	-	0	0	0	1	2	2	1	1	1
All crops	50	50	48	42	42	45	8	9	8	9	6	7	30	12	11	7	16	14

* Seed dressings are not included

Source: Swedish Board of Agriculture, 1996

Table 5. **Number of dosages used in agriculture, based on pesticide sales (1000 dosages)**

Year	Herbi-cides	Fungi-cides	Insecti-sides	Growth-regulators	Total
1981	2043	1703	491	25	4262
1982	2227	1909	596	38	4770
1983	2002	1583	577	96	4258
1984	2016	1899	782	166	4863
1985	1930	1898	1026	151	5005
1986	3509	2549	1299	288	7645
1987	1359*	1365	552	94	3370
1988	1464*	1205	782	83	3534
1989	1582*	1421	504	44	3551
1990	1625*	1248	394	56	3323
1991	1381*	1237	472	49	3139
1992	1299*	1091	549	34	2973
1993	1537*	927	455	46	2965
1994**	2423	1246	803	50	4522

* The number is probably slightly underestimated.

** The number of dosages are calculated from the sold amount of pesticides. In 1994 the sales of pesticides were higher than the use. The true number of dosages used are therefore much less than the number shown that has been calculated from the sold amount.

Source: Swedish Board of Agriculture, 1996

The tables show that the boom in herbicide use in corn and soybean production in the US in the 1970s and 1980s has no analogy in Sweden. The herbicide and seed dressing use in Sweden, measured in area treated, have been relatively stable since the 1960s with a slight decrease during the last few years. By contrast, as a result of a specific combination of agro-ecological (crop rotations), technological and economic changes, the use of fungicides and insecticides increased during the 1970s and 1980s. Recently, however, fungicide and insecticide use has decreased, primarily due to decreased grain crop area.

III. Alternative Pesticide Policy Goals

The demand for reduced pesticide use in Swedish agriculture emanated from public concern about the environment. This concern was generally formulated and did not initially consider the sophisticated distinctions between amounts of active ingredients, risk assessments for specific compounds, or the doses for different kinds of pesticides. Thus, in the initial Swedish discussions on the matter, it was not unequivocally clear which criteria or parameters should be used to evaluate the results and effects of implemented pesticide programmes.

At least three different of reduced pesticide use are relevant. First, we have the traditional goal to reduce the *risks* posed by pesticides to human health and the environment. Second, there is the desire to reduce the *total land area treated* by pesticides. Related to this is the question of how intensively pesticides are used on the treated areas.

Third, a more roughly specified aim could be to decrease the *amount of active ingredient* used. This objective has the advantage of being easily measurable, but is strongly influenced by factors, such as changes in technology, economic conditions, or the substitution of one crop with another. It is thus difficult to distinguish changes in the trend of pesticide use from other, more transitory, influences on pesticide use. A decrease in pesticide use resulting from a decrease in agricultural production, for example would reduce the total amount of active ingredient used. The same applies to changes in the assortment of pesticides from high-dose to low-dose, which may or may not imply a decrease in environmental and health impact.

IV. Overview of the Swedish Pesticide Risk Reduction Programme[47]

In the spring of 1986 the Swedish Board of Agriculture, the National Chemicals Inspectorate and the Swedish Environment Protection Agency were asked by the Swedish Government to develop a programme on how to reduce the risks to health and the environment, resulting from the agricultural use of pesticides.

The aim of the programme was to reduce the risks to human health and the environment. The risk reduction scheme consists of three main groups of action:

- change over to pesticides which are less hazardous to health and the environment.

---

47 The following considerations are primarily based on Swedish Board of Agriculture (1994) and Emmerman and Petersson (1995).

- reduction in the use of pesticides. The Government - and Parliament - decided that the use of agricultural pesticides measured in kilograms of active ingredient should be reduced by 50 per cent in five years from 1986 to 1990 compared to the average use in 1981-85. In 1990 the Parliament adopted a new bill which calls for a further reduction in the use of pesticides in agriculture by another 50 per cent between 1990 and 1996.

- special measures to protect health and the environment.

Different authorities are responsible for different parts of the programme. The Swedish Board of Agriculture is responsible for activities on reducing the use of pesticides and also co-ordinates the programme as a whole.

V. Different Strategies for Different Pesticide Problems

Different strategies are used in the reduction programme for different pesticide problems (weeds, pests and diseases). For weeds, the strategy must be long-term in character. It has been concluded that herbicides should be used every year at a low dose and complemented with other methods (e.g. changed crop rotations, and use of crops which are able to compete with weeds) to keep weed pressure low. Because weed pressure in grain crops in Swedish agriculture has decreased as a long-term effect of herbicide use and other weed control methods, it is possible today to use lower doses of herbicides and still maintain weed populations at acceptable levels without creating any increased problems in the future.

Experience from research on cereal weeds has shown that under Swedish conditions, the best yields are obtained at half the recommended dose which means a 70-75 per cent herbicidal efficiency. Crop stress and thus lower yields can occur if higher doses of herbicides are used.

Problems with pests and diseases vary more significantly between different years depending on a number of factors, including especially weather. Thus, chemical control of pests and diseases has a more short-term outlook than weed control; chemical control during previous years is of less importance. The strategy for chemical pest control is to try to adjust the control measures to what is necessary each separate year. Such considerations are integrated in a long-term perspective in comprehensive strategies such as *integrated crop protection*.

VI. Implementation of the Pesticide Reduction Programme

Training and Certification

Pesticide formulations are registered in three classes: 1, 2 and 3. Class 3 pesticides are available for "amateur use". Since 1990 all farmers and farm workers who carry out the application of pesticides need a certificate for professional use. A three day course is required for those using class 2 pesticides and an additional day for those using class 1 pesticides. The certificate is valid for five years and an additional one day course is required for its renewal.

During the 1988/89 and 1989/90 seasons, roughly 20 000 people participated in this training. About 30 000 certificates have been issued. The County Advisory Boards are responsible for these courses. There are today six types of courses depending on type of production (agriculture, horticulture, green areas, seed dressing, forestry and apiculture). One third of the time is spent on optimising the methods to control weeds and pests and diseases, including non-pesticide based alternative methods.

Extension Efforts

Five regional plant protection centres have been established to promote *integrated crop protection* with chemical control adjusted to farmer needs. The most important target group of the centres include state, private and commercial field crop production extension officers. A total of about 600 people are involved. There is close collaboration with the centres and the staff at the *Swedish University of Agricultural Sciences* and thus links to the basic and applied research within the fields of plant production and pesticide use.

The work at the regional plant protection centres is concentrated on the following activities:

- The centres provide pest forecasting and warning services. In each district during the crop season information is collected at least once a week on 50 pests and diseases of 9 crops from about 800 fields. This information is analysed at the plant protection centres. On the same day the main group of extension officers receive a summary of the situation in the field. This summary serves as a basis for the next morning's telephone conferences, where different problems and solutions are discussed. About 170 persons are connected to these conferences each week. Afterwards at least 4500 farmers are informed directly or indirectly by plant protection letters from the centres or from other extension officers.

- The centres publish information on how to improve strategies to combat pests, diseases and weeds taking into account relevant new policies, changed prices on products, new pesticides and alternative methods, changed registrations of pesticides, etc.

- Together with the Swedish University of Agricultural Sciences, the centres test and further develop different forecasting methods.

- The centres initiate field trials, follow up and collect results, co-ordinate advisory services by making demonstration plans, and participate in field courses.

- The centres support teachers and authors with course materials and communicate results from trials, forecasting and warning activities, and other activities through courses, conferences, radio and television, articles, information letters, other documents, and books.

Special interest has been devoted to information systems. For example it is possible to put together all data collected by the forecast and warning systems very quickly and to sort and compare the information in different ways. Information has been collected since 1988. There is also an on-going IT (information technology) project whose purpose is to make information readily available (in the form of articles, books, pictures, etc.) about pesticides, weeds, pests and diseases.

An important part of the programme is to focus on the possibilities to reduce the use of pesticides, especially on information on reduced herbicide dose rates. The *Swedish Board of Agriculture* has in various ways initiated and granted support to the advisory services at the County Boards. The aim is to communicate knowledge on the risks to the environment and the possibilities to reduce the use of pesticides. Demonstration trials showing for example the effectiveness of herbicide used on the farm at full, half or quarter dosage is important.

During 1993/94 the following activities were carried out in the areas of reduced dosage, application technique, enhancement of knowledge of flora and fauna, and appropriate handling of pesticides (how to store pesticides, fill and clean equipment, etc.):

Demonstration trials:	about 250
Field- or farm courses:	about 300 with about 7 000 participants
Other courses :	about 100 with about 3 500 participants
Individual advisory service:	about 550

Research and Development

In connection with the pesticide reduction programme, there has been special funding of applied research important for the aims of the programme. Publicly funded research on pesticide use and effects is important in the development of pesticide use guidelines tailored to particular crops or types of farms. Such research may reveal situations in which pesticide use is not economically motivated, thereby eliminating certain cases of overuse. Much of the research activities have been carried out at the Swedish University of Agricultural Sciences. Areas of special interest are: 1) reduction of the risks of pesticides, and 2) chemical control adjusted to needs (dosages, forecasting, alternative methods, etc.). Priority is given to applied research and extension activities which can relatively quickly give practical solutions. Until now the resources have been concentrated on projects in the following areas:

- *Weeds*: Work has focused on opportunities to reduce the dose of pesticide applications, and new and alternative methods. One practical task has been to develop d*osage-keys* which can help the farmer adjust the dose.

- *Pests and diseases:* This includes projects on application dose and intensity, and development of forecasting systems. The use of weather data has become more and more important and is incorporated in various information systems. There are also projects on alternative methods including biological control.

- *New techniques:* Work has focused on the economic and environmental advantages of sprayer testing. Methods which can reduce the dosage and the risks of losses to the environment by wind have also been tested and developed.

- *Flora and fauna:* Unsprayed and sprayed edge zones have been compared, for example as regards changes in weed and bird populations.

A special programme for the voluntary testing of sprayers has been in operation since 1988. Between 1988 and 1992 about 7 400 sprayers were tested, which represented about 30 per cent of the total number in agriculture and about 50 per cent of the pesticide treated area. About 170 test examiners have been trained. The test frequency is about 1 400 tests per year and the trend is increasing.

Regulation of Pesticides: Registration Procedures

Another important aspect of the 1986 legislation was that regulations on the use of individual compounds were made stricter, thus reducing associated risks. The new regulations include "cut-off criteria" for determining whether pesticides are acceptable from health and environmental protection standpoints. Today, pesticides can only be approved for a maximum of 5 years at a time.

During 1990, 450 of around 600 pesticide products were due for reconsideration. As a consequence, the manufacturers did not apply for continued registration for 100 products and asked that another 50 should be withdrawn. The Chemicals Inspectorate denied re-registration for another 50 products which did not meet the new criteria.

Altogether, this re-registration procedure has resulted in a reduction in the number of registered pesticide products from 700 to 350. Following this process, the total of active ingredients used in Swedish agriculture was reduced to about 100. *This re-registration procedure is probably more important for risk reduction than the decrease in the amounts of different pesticides used.*

The re-registration procedure for pesticides is consistent with the substitution principle that is expressed in section five of the Swedish Act on Chemical Products (SFS 1985:426) as ‘anyone handling or importing a chemical product must take such steps and otherwise observe such precautions as are needed to prevent or minimise harm to human beings or to the environment. This includes avoiding chemical products for which less hazardous substitutes are available.’ Through application of the substitution principle a pressure to employ new and improved pesticides is maintained.

Improved pesticides are continually developed and marketed. Often, they are efficient in lower doses than the older ones. This is often accompanied with more specific knowledge on the mode of action of the compounds. This may include lower toxicity to non-target organisms and low persistence in the environment and thus decreased health and environmental impact. Sulfonylurea herbicides are good examples of this new generation of pesticides. Thus, technological development itself results in the use of fewer kilograms of pesticides.

Because many of the new compounds pose much lower risks to human health and to the environment, regulation authorities and the pesticide industry could share a common interest in promoting their use. In addition, the newly introduced products are very often more profitable than those that are withdrawn.

VII. Programme Costs and Finance

It is difficult to calculate the costs of the pesticide risk reduction programme precisely because the activities involve a large number of government agencies and universities. However, the Swedish Board of Agriculture spent about SEK 21 million on the programme in 1993/94. The programme was financed by the Government through environmental levies. In addition, from 1986 to 1992, a price regulation levy was also put on the pesticides, probably in itself explaining a small part of the reduction in pesticide use. Currently, a tax of about 7,5 per cent of the price is raised on pesticide sales whose receipts are not directly related to programme financing.

The use of environmental levies means that the agricultural sector is collectively financing the pesticide reduction programmes. In this way the policy is *consistent with the Polluter-Pay Principle (PPP)*. If all pesticides caused the same health and environment hazard wherever they were used, the environmental levies would also be efficient. However, because the doses as well as the environmental impact from individual pesticides vary, the measures can *not be regarded as fully efficient* because the environmental effect of a particular pesticide application is not directly linked to the size of the levy. There have been suggestions of replacing the uniform levies with ones related to dose and to environmental risks of individual pesticides. Because the uncertainties and difficulties with such a system, it has not been implemented.

VIII. Progress So Far

Technological, political/legislative and structural changes in the pesticide and agricultural sector have influenced pesticide use (in number of doses, kg/hectare, and total) in Swedish agriculture. The total amount of active ingredients used in agriculture in Sweden has decreased steadily since around 1980. However, the area treated increased during the early 1980s after which it has been relatively stable and decreased somewhat during the 1990s.

The many factors influencing pesticide use make it *difficult to isolate and evaluate the specific impacts of the specific pesticide use reduction programmes.* For example, during the 1980s and 1990s, agricultural policy which included the set-aside of agricultural land and lower grain crop prices significantly influenced over all pesticide use. Since Sweden is now a member of the European Union and is influenced by its agricultural policy, future trends in pesticide use in Sweden will also be influenced by general agricultural conditions and profitability within the European Union.

Table 6. **Pesticides in Swedish agriculture that have been suspended or restricted, 1986-1990**

Removed from the market mainly because of			Severely *restricted* because of
Health reasons	Environmental reasons	Insufficient documentation	Health or environmental reasons
Aldicarb	Aldicarb	Carbaryl	Benomyl
Bromacil	Atrazine	Chloroxuron	Captan
Carbaryl	Dicofol	Dienoclor	Carbendazim
Chlorothalonil	Lindane	Lenacil	Diquat dibromide
Cyhexatin	2-Methoxyethyl Mercury Acetate	Metoxuron	Endosulfan
		Sodium Chlorate	
Diaminozide	Terbacil	TCA-sodium	Folpet
Dinocap	Thiram	Ziram	Simazine
1,3-Dichloro-propene	Trifluralin		Thiophanate-methyl
2-Methoxyethyl mercury acetate	Ziram		
Metoxuron			

Source: Swedish National Chemicals Inspectorate

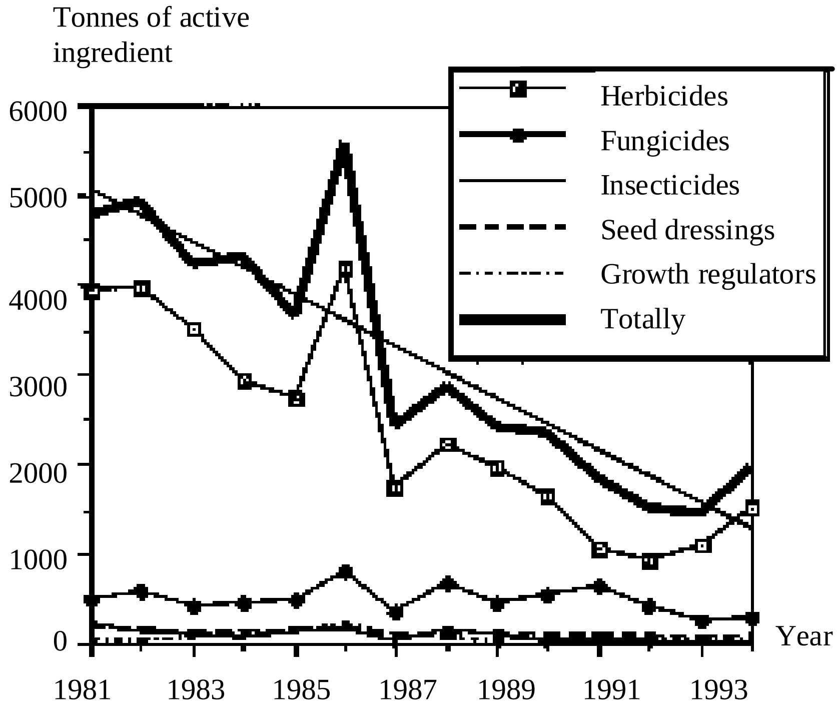
Furthermore, reductions in the amount of pesticides used is not the only policy focus. Many of the old pesticides have been withdrawn in favour of new ones less hazardous to human health and environment. As already suggested, this re-registration procedure is probably more important for risk reduction than the decrease in the amounts of different pesticides used. Changing to new pesticides often has an effect on the risk as well as on the amount of active ingredient used. A list of pesticides in Swedish agriculture that have been suspended or restricted is shown in Table 6.

In addition to the specific pesticide reduction programmes, other policy initiatives worked in the same direction. Take for example the support given to farmers making the transition from conventional to ecological farming thus phasing out the use of all pesticides on their farms. A subsidy of SEK 700-2000/hectare was offered for 3 years. From 1988 to 1993, the acreage under this programme increased from about 12,000 hectares to 46,000. However, because ecological agriculture still represents a small part of the Swedish agricultural land, the importance for the over all reduced use of pesticides is small compared to other measures.

In 1994 the Swedish parliament decided that 10 per cent of arable land, or almost 300 000 hectare, should be farmed ecologically by the year 2000. Compensation is now granted at SEK 900/ha of arable land in zone 1 (Northern Sweden and the forest region of Southern Sweden) and at SEK 1 600/ha of arable land in zone 2 (the rest of Sweden). These measures are contained in the Swedish agri-environmental programme in conformity with the European Council Regulation 2078/92.

Declining Pesticide Use

Both, the sales (Table 2.) and the use (Table 3.) have decreased compared with the average use between 1981-85. In 1993, the total reduction was 65% or about 3 000 tonnes. Usually, sales and use are approximately equal, but there exist exceptions. During 1994, for instance, sales increased by about 500 tonnes, while use remained on similar levels. The discussion about higher levies and the removal of some pesticides from the market caused traders and many farmers to anticipate the buying of supplies for future years. There are, however, no big changes in farmers behaviour observable that would affect the *use* of pesticides (sales during 1995 confirm this). In 1986, a similar instance had occurred, as a planned raise in levies had caused sales figures to increase substantially over previous years.



A large part of the reduction, 2 350 tonnes, consists of herbicides. Approximately 1 800 tonnes of the reduction in herbicide use can be explained by changes in the use of herbicides for cereals. About one third of the reduction for cereals is due to the reduction of dose rates. The increased use of sylfonylureas and the decrease of cultivated area also explain about one third each. The remaining 550 tonnes of herbicides can be explained by the substitution of some herbicides as a result of prohibition and restrictions.

Implementation of the pesticide risk reduction programme has also led to a reduction of the total amount of active ingredients of fungicides and insecticides. In fact, in some areas actual use is probably lower than the economic optimum. Nevertheless, the results have not been as successful and unequivocal as that for herbicides. Two factors are important for the decreased use of fungicides and insecticides in the early 1990s. The prices of grain crops have decreased, and thus the profitability of certain treatments. For the treatment of potatoes with fungicides, there has also been a switch to compounds which are effective in lower doses.

If we evaluate in more detail what has happened with pesticide use in Sweden we find that the use of pesticides measured in kilograms of active ingredient has decreased considerably since 1980. From 1981 to 1990 the reduction is about 50%. Of this, about one fourth is explained by changes in agricultural policy in general, resulting in reduced grain crop area. Roughly one third is explained by technological changes not directly linked to pesticide regulation efforts (primarily the change to pesticides efficient in lower doses). The more direct influence of the specific pesticide reduction programmes account for the remaining one-third to half of the decrease in pesticide use. This includes the outcome of reduced doses and the prohibition and restriction of specific pesticides.

Other Considerations

Thus far, the "new" pesticide policy in Sweden reflected in the reduction programmes, should be considered more as an adaptation to what is technically and economically possible than as a policy completely breaking new ground. The pesticide reduction policy has worked toward adjusting the use of pesticides as closely as possible to needs. Thus, priorities and conditions for commercial agriculture in Sweden have not changed dramatically because of the policy of pesticide use reduction. The costs of the policy at the farm level are small or negligible in most cases.

There are probably opportunities for a further reduction close to the national goal of 75 per cent reduction between the average of use 1981-85 and 1996. There are for example still unnecessary differences in dose rates between different areas in Sweden. There also seem to be further opportunities to reduce the use of fungicides in potatoes and herbicides in sugar beets.

The pesticide risk reduction programme has been supported by the Federation of Swedish Farmers. Their involvement from the beginning has facilitated its realisation.

On the other hand, it has already been seen that in some areas there are more problems with certain weeds, for example thistles in spring cereals. Sometimes there also may be conflicts between different environmental goals, for example requirements on green cover during the autumn and winter in order to reduce nitrogen leakage may result in increased use of herbicides.

There is also some uncertainty about the future effects of agricultural policy on pesticide use. The effect of CAP on Swedish agriculture may challenge the targets of the reduction programme. The acreage of grain crops may increase as a result of increased profitability. In addition, when the set-aside areas of the Conversion Grant scheme are returned to production there will be short-run weed problems in these areas, which will require increased use of herbicides.

IX. Conclusions

- It has been emphasised that there are numerous factors driving the use of pesticides in agriculture. They include agricultural policy, technological change, societal demands for safe food and environmental quality, and government policies (including registration procedures, research and extension, training and certification). The early involvement of and support from the Federation of Swedish Farmers has been crucial for the progress made to date.

- Pesticide reduction policy measures have only marginally changed the conditions for commercial agriculture. The *costs* at the farm as well as the national level are small or negligible.

- The costs of implementing regulation, research and extension activities are financed by *environmental levies* that amounted to SEK 40 million in 1994. In addition, from 1986 to 1992, a price regulation levy was also put on pesticides, probably in itself explaining a few per cent of the reduction in pesticide use in the 1980s.

- The *risks of pesticide use* for human health and the environment *have decreased*. However, it is not possible to quantify the changes given imperfect knowledge and information about risks both before and after the implementation of policies. Nor is it possible to quantify the decrease in actual emissions of pesticides to water and air.

- Market interventions such as import tariffs and *commodity-linked price support* in most countries have had the effect of stimulating the use of pesticides. In the main grain crops, this is primarily true for insecticides and fungicides since application of these pesticides will vary from year to year and from crop to crop due to variation in commodity prices and frequency and severity of pest attacks. Export levies have, of course, a countervailing effect.

- A *decrease in food price subsidies* and de-linking of farm support and production should tend to reduce pesticide use. The 1990 Food Policy Act moved more in the direction of direct payments to farmers and reduced commodity-linked support.

- The measures used in the Swedish pesticide reduction programme include re-registration procedures as well as research and extension efforts and environmental taxes and levies. *The extension activities including farmers training programmes have been particularly important for reduced pesticide (especially herbicide) use.* The use of lower herbicide doses has been important in this context. Also, the phase out and prohibition of specific pesticides have been important for risk reduction and also for reduced over all use.

- Environmental levies have been of minor direct importance for pesticide use and risk reduction. The same is true for specific programmes promoting the transition to ecological/alternative agriculture. From 1988 to 1993, the acreage under these programmes increased considerably but because it still represents a small part of total Swedish agricultural land, the importance for the over all use of pesticides is small compared to other measures.

BIBLIOGRAPHY

BERNSON, V. (1993), The role of science in pesticide management - an international comparison. The Swedish experience *Reg. Toxicol. Pharmacol.,* Vol. 17, pp. 249-261.

BERNSON, V. and EKSTROM, G. (1995), Swedish pesticide policies 1972-93: Risk reduction and environmental charges *Rev. Environ. Cont. Toxicol.,* Vol. 141, pp. 27-70.

CULLINEY, T. W., PIMENTEL, D. and PIMENTEL, M. H. (1993), pesticide use and policy in the US in: *The Pesticide Question: Environment, Economics and Ethics*, Pimentel, D. and Lehman, H. (eds.), Chapman and Hall, New York.

EMMERMAN A. and PETTERSSON, O. (1995), Reduced pesticide use in Swedish Agriculture, *OECD Conference of Directors and Representatives of Agricultural Research, Agricultural Advisory service and Higher Education in Agriculture. Paris 4-8 September 1995. Case Study Number 4.*

OSTEEN, C. (1993), Pesticide use and policy in the US in: *The Pesticide Question: Environment, Economics and Ethics,* Pimentel, D. and Lehman, H. (eds.), Chapman and Hall, New York.

PETTERSSON, O. (1993), Swedish pesticide policy in a changing environment in: *The Pesticide Question: Environment, Economics and Ethics,* Pimentel, D. and Lehman, H. (eds.), Chapman and Hall, New York.

PETTERSSON, O. (1994), Reduced Pesticide Use in Scandinavian Agriculture, *Crit. Rev. Plant Sci.,* Vol. 13, No. 1, pp. 43-55.

PIMENTEL, D. et al. (1993), Environmental and social costs of pesticides in: *The Pesticide Question: Environment, Economics and Ethics,* Pimentel, D. and Lehman, H. (eds.), Chapman and Hall, New York.

SWEDISH BOARD OF AGRICULTURE (1996), *Minskade hälso- och miljörisker vid användning av bekämpningsmedel,* Rapport 1996:1.

SWEDISH NATIONAL CHEMICALS INSPECTORATE (1995), *Försålda kvantiteter av bekämpningsmedel 1994.*

STATISTICS SWEDEN (1995), *Bekämpningsmedeli jordbruket 1993/94,* Na. 31 SM 9502.

VAIL, D. HASUND, K. P. and DRAKE, L. (1994), *The Greening of Agricultural Policy in Industrial Societies,* Cornell University Press, Ithaca and London.

ANNEX 7

POLICY CASE STUDY OF THE UNITED KINGDOM

K. E. Falconer
Department of Land Economy
University of Cambridge
19 Silver Street
Cambridge, CB3 9EP
United Kingdom

TABLE OF CONTENTS

I. Introduction

The primary aim in this paper is to contribute towards the identification of the most appropriate policy responses for dealing with environmental concerns related to the use of agricultural pesticides in the UK. It is necessary, in doing this, to assess the scope of possible policies to reduce environmental risks, the trade-offs that might be involved, and other influences, such as the impacts of agricultural support policies on the effectiveness of potential pesticide risk reduction policies. An important objective is to assess the relative effectiveness of various proposals at meeting environmental risk reduction policy goals, with respect to cost, administrative efficiency and enforceability.

The issue of pesticide contamination of the environment is currently very much on the political agenda, implying that there may now be greater opportunities for reform and progress than before. The *whole* range of economic, regulatory, voluntary and advisory approaches possible to achieve different targets need to be considered, rather than just focusing on tried-and-tested traditional methods of policy intervention. The central issue is about what measures, or mixes of measures, appear to have the potential to achieve environmental objectives at least cost, and under what conditions. Different options are likely to be viewed more favourably in different countries, depending on the scale and nature of the agricultural pesticide 'problem' as well as different traditions of governments and administrations regarding both agricultural and environmental concerns.

The aim here is to assess the development to date of controls on pesticides for environmental and health risk-reduction purposes in the UK, and the possible directions for future policy development. The likely farm-level impact and effectiveness of various policy instruments to reduce the quantity of pesticide applied will be gauged through fieldwork involving a sample of East Anglian cereal farmers, looking at their herbicide use decisions and how they might react to various hypothetical future herbicide use reduction policies. The analysis involves drawing together two main areas of analysis, environmental economics and farm decision-making, to investigate possible ways of encouraging pesticide usage reductions and to enhance understanding of the policy problem.

II. Background to the Pesticide Policy Problem

In the UK over 99 per cent of arable crops receive at least one pesticide application per year (Carter 1993), which suggests that potential environmental contamination from pesticides might be fairly widespread (see Box 1). It has been suggested that complacency followed the phasing out of organo-chlorine pesticides (Otter 1992) and that there has been a relative neglect of pesticide contamination, for example relative to nitrate emissions. However, the pesticide contamination issue in the UK has been gradually moving towards the centre of the political stage, with attention particularly focused on food and water contamination, largely as a consequence of British difficulties in complying with the requirements of the European Drinking Water Directive 80/778 (DWD), the privatisation of the water industry and perhaps a decline in the political influence of agriculture (Hill et al. 1989).

Contamination of water resources is of course not the only form of environmental contamination, but it does appear to be (currently) the most important form. DWD implementation has so far generated a large number of costs, which on the whole have been borne not by agricultural pesticide users, but by the water supply companies and their customers, violating the 'Polluter-Pays Principle'. In 1992 Thames Water anticipated expenditure of over £360m to remove pesticides from drinking water over the following five years (Fawell 1992); by 1995, £400m had been spent, and compliance with the standard is a significant component of the expected increase in annual water and sewerage bills over the next ten years, estimated at up to £77 per household (Rund 1995). Severn Trent Water began capital expenditure of £100 million over four years on technology to remove pesticides from drinking water, with approximately £2 million per annum monitoring costs and £10m per annum operating costs of pesticide removal (Buffin 1994). In 1992 a survey found that the water industry was investing £800 million to comply with the 0.1µg/l pesticide limit set by the DWD, with annual running costs of around £80 million (ENDS 1995).

Box 1. **Pesticide Contamination of Water Resources**

Glasbergen (1992) considers that pesticide contamination of the environment has become much more of an issue since evidence emerged of widespread, if relatively minor, infringements of the Maximum Admissible Concentrations (MAC) laid down in the DWD[48], although this has not been accompanied by increasing evidence regarding the *risks* of pesticide presence. In 1993 roughly three-quarters of the 35 000 violations of DWD standards in England and Wales were due to pesticides (Rund 1995), although there is no evidence that any of these violations were of a dangerous magnitude and duration (DWI 1994). MAFF studies have also shown that concentrations of agricultural pesticides (particularly the herbicides isoproturon, mecoprop, chlortoluron and the insecticide dimethoate) in streams draining arable areas are regularly far above EC limits[49]. Friends of the Earth[50] found that between 1985 and 1987, the MAC for single pesticides was exceeded in Britain in 298 water supplies and for total pesticides in 70 supplies. National Rivers Authority monitoring of samples taken from around 3 500 sites in 1992 and 1993 revealed that 100 of the 120 pesticides monitored for were detected at low concentrations, and just over half were detected above the DWD MAC. However, when results were compared with environmental quality standards set for about 20 pesticides by the EU and DoE, more than 96 per cent of sites were satisfactory.

III. Approaches to Reduce the Environmental Risks and Costs from Pesticides

The number of pesticide violations in water-courses indicate that there are deficiencies in the current system of control at least as far as the DWD is concerned; continued breaches are stimulating increased attention to pesticide usage. As attaining the MACs is currently a legal obligation, the question is how best to meet it. Two options involve either treating water before it enters the drinking water supply, or reducing pesticide usage. It appears that many pesticides, particularly the triazines and urea herbicides, are highly mobile in soil and pose a threat to drinking water under *normal* agricultural conditions, implying that contamination cannot be controlled entirely through improved pesticide design; controls, perhaps quantitative, are needed on pesticide *application* to encourage improved management practices (ENDS 1995). EU-level adoption of a preventive principle and scientific uncertainties may also be considered reasons to opt for a more precautionary approach aiming at prevention of contamination rather than cure.

There are a number of routes taken by pesticides into the environment (e.g. run-off, leaching and volatilisation). Designing separate controls for all of these would be highly complex, so a general solution would be to aim for a reduction in all pesticide usage, although the ultimate aim is to reduce pesticide pollution. The problem is actually measuring and monitoring this, given the characteristics of pesticide contamination, which influence the types of policy appropriate to the problem. Key characteristics of

48 These are set at 0.1mg/l for individual pesticides, and 0.5mg/l for total pesticides, although the latter is currently under review, with proposals to abolish it given its virtual unenforceability.

49 Report 228, p10. "MAFF highlights threats to drinking water", 1994.

50 An Investigation of Pesticide Pollution in England and Wales, London, Friends of Earth.

pesticide contamination include: 1) the diffuse and stochastic nature of emissions makes emissions-based policies infeasible (the Royal Commission on Environmental Pollution concluded in 1992 that the only practical way to control diffuse contamination is to regulate the activities that give rise to it); 2) there are few emissions abatement opportunities once they are released, so more emphasis should be placed in 'prevention' rather than 'cure'; 3) there are large numbers of active pesticide ingredients, with varying environmental risks, so differentiated controls might be appropriate; and 4) usage is very variable, given different crops, pests, weather conditions etc., so there are no standardised solutions to reducing both risks of crop damage and the environmental risks. Hence the problem is a highly complex one, with a number of linked components involved in the overall goal of reducing environmental risk. Understanding these components and their linkages is important, as different policy goals may be best achieved by different policy objectives (Isermeyer 1994).

Pesticide inputs appear appropriate targets as emissions proxies, as (a) they are important in the environmental contamination equation; (b) inputs are relatively easy to measure; and (c) input level is the main variable over which the farmer has control (unlike emissions); thus the importance of understanding the input use decision. Controls on inputs are more origin-orientated than controls on crop type or land use (although treated area may also be closely correlated with non-point contamination) and hence may be more efficient (see figure 1), and consistent with the 'Polluter-Pays Principle'.

Broad-brush policies applying to all pesticides are not necessarily desirable: differential controls may be more appropriate. For example, water contamination by particular herbicides is currently a major concern, suggesting that these should perhaps be targeted according to criteria indicating greatest environmental risk from leaching or run-off. A small number of chemicals account for most detections and DWD breaches in some areas (see DWI 1994): perhaps usage of these should be reduced more than other chemicals. Spatial targeting may be desirable: some areas experience high levels of contamination, others very little. Environmental variables such as soil type, rainfall (intensity, quantity, duration), soil moisture, topology etc.) result in variable environmental risks, as well as cropping patterns, but although modelling is making some progress (e.g. Cooke 1991), targeting vulnerable areas is currently challenging.

Figure 1: **Policy targets and potential policy efficiency**

Environmental damage	HIGHEST EFFICIENCY
↓	|
Pesticide emissions	|
↓	|
Pesticide inputs	|
↓	|
Application/production practice	|
↓	|
Crop output	|
↓	↓
Land use	LOWEST EFFICIENCY

The Agriculture Act (1986) is the starting point in the debate over the need for, and shape of, policy to control environmental risk from pesticide use. This Act requires Agriculture Ministers to seek a reasonable balance between the interests of agriculture, the economic and social needs of rural areas, conservation and recreation. UK government policy aims can be interpreted as improving the compatibility of agricultural activities with the environment, and allowing for the greater market-orientation of production and consumption. Given that agriculture is no longer remote from the debate over applying the 'Polluter-Pays Principle', it is necessary to integrate production with resource conservation requiring the anticipation and prevention as well as remediation of environmental damage, and the consideration of ecological parameters as well as economic ones (Glasbergen 1992).

It may be useful to take an evolutionary perspective to pesticide policy: the premise is that through an improved understanding of 'how we got to where we are' we can better comprehend current influences upon pesticide practices and plan policies for the future (Ward 1995). This suggests examining past pesticide policies, their consequences, the gaps in their coverage, development of concern, shifting emphases and new proposals' appropriateness and feasibility.

IV. The Development of Current Controls Relevant to Pesticides

Traditionally, the UK has used voluntary arrangements where possible in environmental policy (Gilbert and Macrory 1989). Recognition of the need to balance the risks of placing pesticide products on the market against the risks involved in their use led to the establishment in the 1940s, with the co-operation of agro-chemical manufacturers, of the (voluntary) Agricultural Chemicals Approval Scheme (ACAS), to evaluate efficacy, followed in the 1950s by the Pesticides Safety Precautions Scheme (PSPS), to assess safety. These proved to be adaptable and robust in meeting new demands imposed by new perceptions of risks, new technology and developments in agricultural practices, and was flexible in registration requirements, taking a case-by-case approach, avoiding cumbersome legal procedures. A major drawback though was the lack of enforcement powers. Furthermore, following a long period of industry self-regulation, the Royal Commission on Environmental Pollution concluded in 1979 that pesticides were being used excessively, and recommended an explicit policy aim of reducing usage. However, little progress to reduce usage was made; the Food and Environmental Protection Act (FEPA) 1985 merely encoded the existing voluntary schemes, mandating product approval and registration before commercialisation and labelling with statutory conditions of use, covering, for example, maximum dose rates, frequency of applications, crop and targeted pests. The Pesticides Safety Directorate (PSD) administers the approval system, allowing for independent evaluation of products, on the basis of information supplied by manufacturers.

In general, safety arrangements for pesticide use are pesticide-specific, whereas provisions to reduce risks from production, distribution and disposal apply to a wide range of chemicals. Regulation has been by far the most favoured instrument in the implementation of pesticide policy so far, e.g. regulation of pesticide approval procedures, regulation of sales, use and disposal of pesticides. Existing controls focus on controlling the availability and mode of use of potentially harmful ingredients. The proper application of pesticides however is left very much to self-regulation by farmers: responsible usage is assumed. The Health and Safety Executive does make some farm visits, but these are infrequent, focus on the health and safety of employees, and involve negligible inspection of how pesticides are used. FEPA (1985) requires that everyone who uses pesticides on a farm or holding be trained to use them safely and efficiently. Recognised certificates of competence, with regular up-dating, are required for users born after 1963 (although no 'integrated' crop or pest management component is included in this training).

Greater enforcement of existing product conditions of use and Codes of Practice (see Box 2) might help, but it is more likely that the real problem stems from the 'normal' rather than criminal or careless use of agricultural pesticides, and especially the relatively soluble herbicides widely and regularly applied for weed control in cereal production. The belief is that there is little prospect of controlling these losses through improved pesticide design, so the best means of reducing damage to streams will be through controls on applications (ENDS 1995). The current regime however gives virtually no control over usage levels, and includes no incentives to reduce pesticide usage.

The approval and registration system also involves substantial costs, of about £10m per annum, to the pesticide manufacturing industry, and the burden is to increase, with proposals to increase the registration fees by 6 per cent. The PSD is required to recover the full cost of its approval operations, and charges fees on manufacturing companies for product approval or review, rather than on the agricultural users (although it may be possible to pass these costs on through higher product prices), as well as levies to cover monitoring and administrative costs. While the system has doubtless had some beneficial environmental effects, through its screening of compounds prior to commercialisation, there are a number of inadequacies in terms of the costs and delays in processing the information supplied, as well as the fact that some information is simply not available. The product reviewing procedure is similarly handicapped by a lack of resources. The existing system could perhaps be improved, for example by requiring pre-registration testing of products at three different levels, as in Sweden, of which two must be below the lowest rate that gives full control. This would assist dose reductions to the level appropriate for the particular farm/field/crop circumstances if the information was then also disseminated to farmers. A problem currently is that the manufacturer's recommended dose rate includes an 'insurance' component, to ensure that the product works effectively in a wide range of conditions. This is obviously commercially valuable, and hence confidential, information; however, retention of this information hinders farmers attempts to make reductions where possible and apply only the amount of chemical necessary in the conditions.

Box 2: **Codes of Practice of Relevance to Agricultural Pesticide Use**

1. Code of Good Agricultural Practice for the Protection of Water (1991)

This is a practical guide helping farmers and growers to avoid causing water pollution. Failure to adhere to the Code is not an offence but could be taken into account in any legal action. The Code aims to set down good agricultural practice so as to minimise the risks of polluting water while allowing economically viable agriculture to continue. Concern is generally with the risks that can arise from farmers incorrectly storing, preparing, applying or disposing of pesticides; the Code includes for example recommendations with respect to the design and construction of pesticide stores. Farmers are also recommended to minimise the dangers of pesticides drifting into water by using 'the right spraying techniques'. Furthermore, to satisfy health and safety requirements, it is necessary to consider whether or not a pesticide has to be used in the particular circumstances, but this is of course very subjective.

2. Code of Practice for the Safe Use of Pesticides on Farms and Holdings (1990)

This covers different various aspects of pesticide use, e.g. user training and certification, planning and preparation, working with pesticides, disposal of pesticide waste, and keeping records, and gives guidance on meeting responsibilities under the FEPA 1985 (implemented through the Control Of Pesticides Regulations 1986). Again, failure to follow the Code is not an offence. Emphasis is put on the importance of adequate training of those using and disposing of pesticides. In addition, the Code recommends that "pesticides should only be used when necessary, in relation to efficient production , if the consequences of not using them significantly outweigh the risks to human health and the environment of using them" (para. 32). The pesticide that poses the least environmental and health risks yet is still effective in controlling the problem should be selected.

The British Agrochemicals Association (BAA) considers that developments in the UK agrochemical business are being suffocated by excessive regulation of new products [51], and predicts that as a result of 'horrendous and self-defeating' regulation, British farmers could be forced to abandon certain crops as the decline in the availability of crop protection products continues. This is attributed to the high costs of product registration in the UK (relative to most other EU member states, due to the UK's premature adoption of EU registration requirements) placing UK manufacturers at a competitive disadvantage. The BAA suggests that between 1989-1994 the cost of registering a new product rose by 857 per cent and amending an existing product rose by 920 per cent. Delays in approval can also cause costs to agricultural producers, in terms of lost yield and lower crop quality; for example, delays in the approval of the aphicide admire left hop growers with no choice but to use large quantities of ineffective pesticides in 1994, with total extra costs to the industry in excess of £2.5m (House of Commons Agriculture Committee Report 1995).

Differentiation of Policies: Spatial Zoning

Central to the problem is the fact that pesticides are applied heavily in intensive production, and are particularly concentrated in those parts of the country where aquifers are essential water sources. Targeting is very important; the environmental effects of production vary greatly. However, the question of whether positive or negative environmental effects would prevail in any given situation can only be answered empirically. There are a number of provisions in current UK law to apply controls to mitigate the environmental risks of agricultural activities such as pesticide usage, which is important given that there are no provisions in the approval system to spatially differentiate controls over pesticide usage. For example, under the Water Resources Act 1991 the Secretary of State may designate an area as a Water Protection Zone (WPZ) with a view to preventing or controlling the entry of any poisonous or noxious matter into controlled waters, to prohibit or restrict the carrying on in that area of activities which the Secretary considers are likely to result in the pollution of any such waters. However, this is very much 'dormant' legislation, and has not yet been applied to reduce pesticide contamination.

Environmentally Sensitive Areas may also be designated, under the Agriculture Act 1986 . These provide for incentives for certain types of environmental improvements to be made (through the uptake of more environmentally-preferable production practices). Some practices may involve the reduction of pesticide usage, particularly through the switch to lower intensity agriculture. The system allows individual farmers to implement environmentally preferable strategies that best suit their particular environmental characteristics, and is voluntary. Compensation is offered for management in accordance with a 'management agreement', set up on a site-specific basis, which may impose requirements regarding agricultural practices or operations, including restrictions on pesticide use. It is not yet clear though what impact on pesticide usage has occurred due to this provision.

However, there is currently no provision for temporal differentiation of controls, except insofar as specific product approvals place restrictions on product use, such as latest spraying date or cautions against use in certain weather conditions.

---

51 Financial Times, 9 March 1995, "Agrochemical Businesses 'Threatened by Regulation'".

V. Policy Development

Rising public concerns and the requirements of European legislation are now forcing policy re-assessment in the UK. There is a need for new approaches to achieve, and maintain, environmental quality, generally or in particular areas. However, the benefits of pesticide usage need to be balanced with the costs; precaution does not imply total prevention of pesticides usage and minimisation of all risks. Pigovian analysis suggests that it is only 'excessive' levels, giving rise to net social cost, that should be controlled; the problem of course is identifying these levels, particularly given significant uncertainty about the long-run risks.

A policy instrument, to be successful, requires clear definition and indicators to evaluate policy objectives, quantitative targets and outcomes. Different policy options to promote optimal pesticide use may well be applicable to different aspects of control, target groups, and levels of implementation. The EU plays an important role in UK pesticide policy, particularly following the launch in 1992 of the First Environmental Action Plan. This plan includes an objective of reducing the use of chemicals to the point where none of the basic natural processes are affected, and provides general targets of 1) a significant reduction of pesticide use per unit of land under production and, 2) a conversion to methods of integrated pest control, at least in all areas of importance for nature conservation. However, unlike some other EU member states (e.g. Sweden, Netherlands), the UK has no target pesticide usage level; instead, the aim is to minimise pesticide use, rather than arbitrarily reduce it, recognising the manipulation that is possible by substituting other chemicals of lower bulk but higher potency to achieve 'phantom' reductions (i.e. in terms of kilograms of active ingredient but not intensity of use), as in Sweden.

Criteria for Policy Evaluation

There are a number of criteria on which alternative policies can be compared, for example, economic efficiency, minimum interference in private decisions, certainty in reaching objectives, enforcement and monitoring requirements and distributional concerns (see Bohm and Russell 1985). Cost-effectiveness, defined here as the minimum input required to achieve a given level of benefit, is considered the core concept in terms of current political aims.

Policies will be more likely to reach pre-determined environmental goals at least cost if they are perfectly adapted to individual farm situations (for example through targeting, see e.g. Moxey and White 1994), and thus are able to avoid unnecessary restrictions on farmers who contribute nothing or only very little to the environmental problem. However, these can have high administration costs, cancelling out at least part of the potential efficiency gain. Simpler, uniformly-applied policies tend to have lower administrative costs, as well as perhaps greater political acceptance (Hill et al. 1991), although higher economic costs. Only uniformly-implemented policy proposals will be considered in this study, although it is necessary to bear in mind the possibility of targeting instruments by chemical, spatially, or temporally.

VI. Environmental Economics and Policy Options

It has been widely recommended (e.g. by Brouwer et al. 1994) that policies to diminish the use of pesticides should primarily focus on the individual farm-level. The aim here is to identify what policy instruments might be appropriate to meet the goal of reducing pesticide use, and thereby contamination. Voluntary policies are unlikely to be effective if it is felt that the responsibility lies with others, and besides, they have not worked well to date to reduce pesticide contamination in the UK. Other environmental management approaches can be categorised as advisory, regulatory and economic.

Advisory approaches are based on the premise that the provision of better information to farmers will contribute to a reduction in the use of pesticides, and transform practices towards more rational levels of use through raising awareness about farm-level actions to improve responsible pesticide usage. Russell (1995) argues the quantity of pesticide used could be considerably reduced by sensible and efficient management of existing technological options; one question thus is how to create incentives to adopt more environmentally friendly practice. Thus research and advisory services may be able to make an important contribution in assisting farmers to adapt to new conditions. For example, the LINK project aims to develop practical integrated arable systems for the UK (see Ogilvy 1995), and demonstration farms, e.g. under the LEAF (Linking Environment and Farming) scheme, can also play a very important role in encouraging new production techniques involving lower chemical inputs (see Drummond 1995). However, advisory approaches are generally discounted as able to achieve currently demanded environmental quality levels alone, without incentives for change by producers.

Regulation may achieve policy goals with relatively high dependability, given adequate enforcement, or if certain standards must legally be attained. But regulation has been long criticised as too inflexible and bureaucratic, given environmental and producer diversity. Controls may be quantitative e.g. limits on maximum doses (in kilogram/hectare or standard dose/hectare terms); limits on the number or frequency of applications; limits on total farm pesticide inputs (to give an average per hectare pesticide limit); limits on the area or crop treated; or output limits. Alternatively, controls may focus on (qualitative) pesticide application standards, for example sprayer specification; or requirements such as untreated buffer strips alongside water-courses.

Bans on certain chemicals, or other restrictions on input usage generally or in spatial zones may also be implemented. Protecting environmental quality through the careful admission of pesticides onto the market is relatively effective, but it is a rigid system: there is little room for tailor-made measures. Prohibitions or cancellations are administratively relatively easy, but make no effort to tackle to problem at source by changing farming practices. Cancellations are also of great concern to the farming lobby: “UK cereal producers cannot afford to lose the herbicide isoproturon. It would be better to have rate reductions than an outright ban” (Farmers Weekly, 30 June 1995, p5).

Economic Incentives are another policy approach. The UK government currently favours a minimum of compulsion in implementing measures and preserving as much flexibility and freedom as possible for farmers. The Ministry of Agriculture and the farming sector have resisted environmentally-motivated restrictions on their freedom of action, at two levels: 1) the autonomy of the agricultural policy community in administering and implementing policy, and 2) the autonomy of the individual farmer in making decisions on production and land use. Policy theory and UK political rhetoric have recently shifted towards more market-orientated approaches that can, at least in theory, achieve policy goals at least cost by maximising decision-maker flexibility. This is particularly relevant for pesticide policy, given the differing ranges of pest control options available to different producers in different areas. Economic incentive policies such as taxes theoretically allow more cost-effective environmental improvements, given heterogeneous producers, by giving the incentive to abate or reduce activities until the marginal costs of doing this equals the tax rate (Baumol and Oates 1971). Pigovian emissions taxes are of course inappropriate for pesticide contamination, although taxes could be levied directly on inputs.

There are a number of potential pesticide input policy targets. Pesticide heterogeneity has often been cited as a significant challenge to policy design, given the number of variables involved in pesticide usage (e.g. quantity of input, in weight or recommended dose terms; area treated; type of chemical;

chemical cost; output type and levels; land management practices), and the differing magnitudes of these over space, time and chemical involved. Defining pesticide use in terms of quantity by weight risks manipulation of target reductions by substituting lower dosage, but not necessarily lower risk compounds. Defining the target in terms of number of standard doses of all chemicals per hectare, to standardise usage, avoids this. Dubgaard (1991) suggested a flat rate levy per standard pesticide dose, to encourage reductions in *both* quantity of active ingredient and treatment intensity. Alternatively, taxes could perhaps be considered another standardising variable. But taxes are vulnerable to erosion by inflation; are unable to check emission increases if the contaminating activity expands; suffer from *ex ante* uncertain response to any given rate, requiring perhaps costly adjustments; and are difficult to vary spatially, given arbitrage and likely political opposition (Miltz 1987).

Transferable permits allow the advantages of both direct regulations and economic incentives (certainty of goal attainment and compliance flexibility) to be combined. If permits can be enforced, there is little added difficulty in making them transferable. Regionally transferable input quotas, defined in terms of standard doses per hectare for each chemical or chemical categories, if restrictive, provide a strong incentive to farmers to optimise input usage, and may be relatively easy to enforce (e.g. with coupons redeemable on input purchase). They are also insensitive to input price fluctuations, and focus on the total quantity of pesticide used, directly addressing the environmental problem and placing a limit on the quantity entering the environment. Land use permits are another possibility (Pan and Hodge 1994), although land use is less origin-orientated. Still, there do appear to be links between this and the resulting contamination, e.g. isoproturon usage is associated with winter wheat, and detections are higher in areas where this is an important land use

Table 1 below summarises the feasible policy options and Table 2 sets out the different environmental policy mechanisms and evaluates them (according to the author's judgement) on a number of criteria.

Table 1. **Potential Controls for Pesticide Policy**

Control Tool	Performance Indicator	Control Techniques	Compliance Measures
Advice	Farmers taking and acting on advice and information e.g. about thresholds	Improved advice, research and extension services	Voluntary measures by farmers
Design Standards	Pesticide application standards	Sprayer specifications, buffer strips...	Farm inspections /spot checks
Performance standards	Soil loss/pesticide run-off or leaching	Limits on losses	Simulation/field measurements
Input use restrictions	Mode of use/timing/ frequency of application/ maximum dosage/ restrictions on use in certain conditions (frost etc.)	Labelling of formulations; compulsory adherence to these	Spot-checks, farm records
Permits	Inputs, emissions, treated area, crop area	Limits on farm input use/emissions/crop area	Farm records and inspections; input coupons redeem-able on purchase
Compulsory training	More socially desirable levels and types of pesticide usage	Improve knowledge and understanding of farmers; increase decision rationality	Prohibit use or purchase of pesticides without a certificate of competence
Taxes	Input use, emissions, treated area, number of applications	Percentage levy on price, charge per unit (e.g. standard dosage)	Distributor/farmer records
Non-chemical control subsidies	Increased use of reduced/non-chemical pest controls	Compensate farmers for losses resulting from the change	Farm inspections
Transferable permits	As above	Limits on total (catchment) input use, emissions, crop area	As above
Crop insurance	Reduced pesticide usage	Fewer prophylactic sprays	(voluntary)

Table 2. **Policy Tools and Performance According to a Number of Evaluation Criteria:**

Instrument	Efficiency	Effectiveness	Maintainability	PPP	Economic consequences for Farmers	Ability to differentiate policies spatially
Extension, training and education	+/-	+/-	+	+	+/-	+
Pesticide admission regulation	+/-	+	+/-	+/-	+/-	-
Farm pesticide usage limits (e.g. annual quotas)	-	+	-	+	+/-	+
Usage regulations	-	+	-	+	+/-	+
Waste disposal regulation	+/-	+	-	+	+/-	+
Prescriptions e.g. for hazardous substances	+	+	-	+	+/-	+
Pesticide taxes	+	+	+/-	+	+	-
Transferable usage permits	+	+	+/-	+/-	+	+
EFP subsidies	-	+/-	-	-	+	+
Compensation for specified EFPs	-	+/-	-	-	+	+
Compensation for environmental results	+/-	+	-	-	+	+
Yield risk insurance (e.g. for experimenting farmers)	+/-	+/-	-	+	+	+

Key: + : high, positive +/- : moderate, neutral - : low, negative
Efficiency: incentives for optimal marginal usage. Effectiveness: ability to reach and maintain environmental quality objective. Maintainability: low enforcement and monitoring requirements/ feasibility at reasonable economic cost. PPP: 'Polluter-Pays Principle' upheld. Economic consequences: negative if financial outlays required and vice versa.

VII. The Role of Farmer Decision-Making in Policy Design

An understanding of both theoretical and actual decision-maker motivations and influences may contribute towards resolving problems such as socially excessive pesticide use. Before introducing policies that attempt to encourage crop protection decision (CPD) adjustments, it is important to identify principal variables, and understand decision. For example, if prices are considered of minor importance compared to other variables, taxes might not have the input substitution effect expected. Pesticide contamination differs from many other forms of contamination in that the contaminant is purposively introduced into the environment (Fawell 1992); this is unavoidable for its use as a productive input. Contamination thus results directly from the CPD process.

Economic theory suggests that for efficient production pesticides should be used up to the level where the marginal value product equates with marginal cost (see Moffitt 1986). Marginal analysis, balancing costs and benefits of pesticide usage at different levels, gives rise to the concept of a 'threshold' pest density, beyond which it is economically rational to apply pesticides. 'Thresholds' have been interpreted in a number of ways (see Cousens 1987), but the two principal ones are the 'economic' threshold, or the 'optimal' point, for which the pesticide dose is itself a variable, adjusted according to the pest density (so incremental pest damage is balanced by the costs of treatment), and the 'action' threshold, which is the level justifying a pre-determined dosage (ensuring cost-effective, but not necessarily profit-maximising, treatment). Thornton and Fawcett (1990) present an alternative simple balancing model; if the monetary value of spraying exceeds that of not spraying, treatment should be undertaken.

There are a huge number of practical barriers to implementation for either threshold, namely the limited amount of information available regarding pest-response and the yield damage function, and pest densities, given that more than one pest is likely to be present, and in a spatially variable distribution across fields as well as farms. Few quantitative thresholds have been developed so far.

Economic analysis of the pesticide usage decision suggests a number of variables determining privately optimal pesticide usage levels, which might be manipulated to reduce pesticide usage: namely, pesticide price (including application costs), output price, expected yield, pesticide effectiveness and pest density information. But there may be other variables that are important, particularly when the social, organisational and cultural features of the farming world are taken into account.

Economic analysis of the pesticide usage decision usually assumes decision-making under perfect certainty, or risk neutrality if probability distributions are used. But, uncertainty may surround critical variables, such as pest density, and this must be directly considered in CPD analysis. Uncertainty may lead to higher pesticide usage than otherwise as a form of insurance (see Feder 1979) if farmers are risk averse (since pesticides are considered to be risk-reducing inputs). If farmers' risk attitudes differ significantly, this diversity should be assessed and considered in CPD analysis, as different risk attitudes may produce different expected utility maximising choices. Pannell (1990) though found that when a range of sources of uncertainty were considered, income variance was almost unchanged over a wide range of dosages, indicating that optimal dosage would not be greatly affected by risk aversion. However, risk can also affect the CPD outcome regardless of the attitude towards it by altering the expected value of different variables e.g. pest levels, pesticide effectiveness and yield response function (see Auld and Tisdell 1987, Pannell 1990). Pannell (1991) concluded that risk does not necessarily lead to increased pesticide use: uncertainty about different variables affects the way in which pesticide usage will change compared to the perfect certainty scenario, so identifying the dominant effect is important.

Under uncertainty, which may arise from insufficient information diffusion to farmers, perceptions of key variables such as likely crop damage, available controls (and their cost and effectiveness) as well as farmer objectives, are central (Norton and Mumford 1983). Increased information, e.g. through the use of professional agronomists, may increase decision rationality, given CPD complexity, and enable reductions in pesticide usage to be made. A 1990 survey found that over 50 per cent of British farmers regularly turned to outside advisors for guidance on pesticide use, and 22 per cent felt out of touch with agro-chemical technical developments, in terms of product availability, suitability, choice and so on (Agricultural Supply Industry, 5 October, 1990, p3). Ward et al. (1993) found that in the Ouse catchment, all farmers interviewed consulted external sources of advice at some stage, and only 19 per cent of farmers decided which pesticide to use on the basis of their own expertise. The widespread deference of farmers to advisers means that the role of these is crucial to understanding how pesticides are used.

Studies of pesticide use in the EU (e.g. Brouwer et al. 1994) show that the intensity of pesticide use varies widely even within comparable groups of farmers. Russell (1995) interprets this as meaning that the quantity of pesticide used might be reduced considerably by sensible and efficient management of existing technological options without unduly impairing the level of protection against pests afforded to agricultural crops, but this view fails to take into account farm-level variability in need for products: crops and field are by no means homogeneous and it is dangerous to assume that they are. This variability means that responses to different policies may well differ from those expected from a theoretical farm model, depending on the objectives, constraints, motivations and resources of individual decision-makers. Policy instruments would therefore be most effective that take into account regional differences and be designed to stimulate and motivate the individual farmer, as farmers play a crucial role in adopting integrated crop protection and achieving a reduction in the use of pesticides and their emission into the environment.

VIII. Policy Evaluation

It is essential to have some idea of the potential of the instruments selected as 'promising' to deliver in practice what theory suggests in terms of cost-effective environmental risk control. An important methodological issue involves deciding how best to assess policy that is under consideration but that has not yet been introduced. Examination of the experience of other countries where pesticide policies have been introduced is one approach (it is possible to learn important lessons from both successes and failures), although this means that evaluation is limited only to those policies that have been introduced, precluding assessment of novel approaches that may have a significant contribution to make. A further problem is that this limits evaluation to policy operation under particular circumstances which may or may not be similar to those in the country for which policy is being considered. For *ex post* empirical assessment, a baseline is needed against which changes can be assessed; however, it is very hard to gauge 'what would have happened anyway', given shifts in the general economic climate, pattern of activities, technology, environmental awareness and attitudes and so on.

Some evaluations have made use of economic modelling techniques, e.g. a cost-benefit study commissioned by the Department of the Environment from the Water Resources Centre to examine the economic case for restricting pesticide usage as an alternative way of meeting the DWD quality standards. The study concluded that curbs on pesticide usage are a cheaper way of controlling pesticides in water supplies than removing them during water treatment, based on studies of two catchments, the Leam and the Colne (ENDS 1995). No curbs on pesticide usage, a total ban, limitations on usage and water protection zones in which applications of key pesticides would be banned in certain areas, were compared. Costs of various scenarios were calculated talking into account likely changes in yields and cropping together with the policing expenses of limitations on pesticide use, and the costs of pesticide removal from drinking water. In the Leam catchment, the protection zone scenario was found to be the cheapest way of achieving the EC standard, at £0.9m, with almost half of the cost falling on farmers, with the remainder accounted for by policing costs. In the Colne catchment, restrictions on pesticide applications were slightly cheaper than the protection zone approach, but both were less than one-third of the £3.4m water treatment cost. Policing accounted for major costs of both scenarios. In both catchments, the costs of a total ban on pesticides would be prohibitively large. However, the results cannot necessarily be extended directly to the rest of the UK given the high specificity of pesticide usage, hydrology and farming patterns to the areas studied, although the study does suggest that there are substantial savings to be made by restricting pesticide applications rather than cleaning up contaminated water.

IX. Fieldwork: Interviews with Decision-Makers

The main interest here lies in assessing how farmers might react to hypothetical policy changes regarding pesticide input usage. Farmers may be more responsive to some schemes than others, or hypothetically more willing to consider adjustment in production practices under certain policy scenarios, so it is necessary to try and gauge which are likely to stimulate the greatest positive response. Empirical investigation from a decision-making perspective may well reveal important conditions for policy functioning and the workability of selected proposals.

A policy scenario arbitrarily aiming roughly at a reduction in pesticide usage to half current levels was devised (see box 3). The aim was to gauge what type of pesticide reduction policy might be appropriate in practice. These were selected so as to cover a range of policy possibilities, given feasible monitoring, enforcement and administration requirements. Different controls allow different degrees of decision flexibility; the central question was whether and how flexibility would be used, by different decision-makers, or in response to different controls. Current attempts to minimise herbicide usage were also examined.

Box 3. **Proposed Herbicide Controls**

1. Half the current labelled recommended dose to be applied per hectare maximum.
2. Farm input quota of half the current labelled dose per hectare multiplied by number of cropped hectares; herbicide may be applied anywhere on the farm up to the current maximum dosage per hectare within the quota limits.
3. Transferable farm input quotas as above, tradable with other producers within a defined area (e.g. the river catchment/East Anglia..)
4. Farm input quotas as above, with the option to buy extra quota from the administrating authority, at e.g. £10 each.
5. Restriction of herbicide treatment to half the cropped area in any one year.
6. Imposition of a price tax of 25 per cent on all herbicides.
7. Differentiated taxes: imposition of an extra levy on certain herbicides

Given time and resource limitations, the focus was placed on weed management and herbicide usage, as herbicides constitute the largest pesticide category: herbicides are applied to over 90 per cent of all crops and 98 per cent of wheat hectares in the UK. In 1988 herbicides accounted for 61 per cent of all pesticides. East Anglia was chosen as the study area as this has a large arable area (40 per cent of the arable cropping area in England and Wales, and 43 per cent of the wheat area) and high arable herbicide usage (45 per cent of the treated arable area). The region also has significant contamination problems (see Croll 1991; DWI 1994). In 1992, over 90 per cent of DWD violations were due to five herbicides (Carter 1993).

Twenty-one respondents, twelve advisors and nine farmers in East Anglia, were selected, on the basis of prior contacts and some ‘cold-calling’. They were sent a questionnaire regarding current herbicide usage and recommendations and possible responses to a number of hypothetical herbicide controls. Interviews were also carried out with three representatives from the Agricultural Development and Advisory Service (ADAS) and the National Farmers Union.

The sample’s small size meant that although results would preclude statistical analysis, it was manageable for in-depth interviewing in the time available; it was considered more important to get closer to the underlying decision processes, than to conduct a wider, statistically rigorous but more superficial survey. A central aim was to undertake exploratory research, using relatively informal discursive interviewing techniques, to gather information quickly and arrive at tentative descriptions of decision-makers' practices. Understanding why they choose these should aid the further development of pesticide policy.

X. Observations Drawn from the Fieldwork

Interest lay in the extent to which it is possible to model herbicide usage decisions, or whether there are too many intervening factors (e.g. legal constraints, environmental concerns, pride in field cleanliness). If these unmodelled factors are important, it may be hard to predict pesticide usage responses for different controls through economic modelling alone. All respondents appeared very aware of the underlying economics of optimal herbicide use decisions, and the need to balance costs and benefits (trading-off expenditure and weed control efficacy). Weed observation and field history were considered crucial factors in herbicide decisions. Although no quantitative weed density thresholds were used, the threshold concept appeared well-understood and used by advisors. Dose was found to be an important variable, despite limited knowledge of herbicide dose-response curves.

A number of factors emerged though that were not given adequate attention in the CPD modelling literature: the dynamic nature of weed management decisions; the crucial importance of advisors; and the lack of information on alternative weed management techniques. Generally advisors' recommendations were acted upon by farmers, although with occasional adjustment for farm management reasons (such as a field entering set-aside the following year), justifying the focus on advisors. These were considered very important communications channels for new chemicals and weed management techniques; farmers admitted they would be lost without them. Fees were generally considered to be far outweighed by the savings in herbicide costs made possible. Advisors considered though that generally 'farmer pride' was an important motivation still for a high level of weed removal, implying that higher levels of weeds would not be tolerated even if they would not jeopardise long-term control; this could be an important factor hindering herbicide usage reductions.

Respondents were presented with a number of different weed management objectives, and asked to rank the ones they felt to be applicable to them or the farmers they advised (see table 4). Most considered that although eradication *had* previously been an objective, containment was now the goal. One farmer however had returned to an eradication strategy while he considered he could afford it, given current grain prices.

Respondents were asked about the criteria they applied to herbicide usage decisions (table 5) and the information used (table 6). A two-stage decision appeared generally to underlie action. An assessment was made first of what chemical(s), at what doses, were required to control the given weed infestation to the required level for short-term considerations (such as grain yield and harvesting problems), and long-term considerations of the population increase in following years if left untreated or inadequately controlled. The second stage involved considerations of the cost of this level of treatment relative to the perceived benefits in terms of yield or cleaning costs savings. However, this process was not entirely clear-cut given the differences between respondents (farmers were not all sure of how the decision was actually taken by their advisor) and the fact that not all found it easy to articulate the processes involved, decisions being taken as a matter of habit. Different respondents considered different constraints important (see table 7), which is likely to influence the possible options available.

Table 4. **Weed management objectives: number of respondents for each ranking**

	1	2	3	4
Prevent yield loss (weed eradication)	5		3	1
Balance yield loss against costs (weed containment)	6	2		
Avoid harvesting difficulties		5	4	2
Avoid grain contamination		6	5	

[NB: for all tables: 1 = highest ranking; not all respondents mentioned all options, chosen and ranked were applicable from a closed set (pre-tested on trial respondents); some ranked two or more options as of equal importance, so some columns might not sum to 11. Unless otherwise stated, n=11.]

Table 5. **Herbicide usage criterion: number of respondents for each ranking**

	1	2	3	4	5	6	7	8
Price	4	1	3	1		1	1	
Effectiveness in weed removal	8	2	1					
Yield effect	3	3	3					
Advisor's recommendation	3	2						
Season-long effect on weed control		2	2	2	1	1	1	
Availability			1	1	1		2	1
Ease of application		1	3	3		3	1	1
Low environmental toxicity	2	3	2	1	1	1	1	1
Wide application window		3			4			

Table 6. **Variables and information used in the weed management decision: number of respondents for each ranking**

	1	2	3	4	5
Actual/expected infestation level	9	1	1		
Herbicide effectiveness	3	6	1	1	
Estimated crop yield (revenue)	1	3	4		1
Herbicide Price	1	1	2	6	1
Weather conditions/forecast	1	1	1	1	5

Table 7. **Weed management/herbicide usage constraints: number of respondents for each ranking**

	1	2	3	4	5	6	7	8
Weather, soils	8	1						
Weed resistance	5				1	1		
Local institutional factors e.g. protected areas	2	1			1	1	1	1
National institutional factors e.g. health and safety controls	1	2	1	1				
General environmental concerns		1	1	1	1	1	1	
Costs of production, available labour etc.		1	3	1				1
Other crop production requirements		1	3					
Management time available		1	3					
Local standards of good husbandry		1	3	1	1	1		
Insufficient information on herbicide action etc.	1		2	3		1	1	

The relationship between herbicide price and usage is a central research question, as economic incentives work through the price mechanism to encourage substitution away from the contaminating input. If the relationship is loose, incentives might not work to achieve usage reductions adequate for the pre-determined environmental policy goals. Price was considered important by all respondents, although long-term control effectiveness would not be sacrificed for short-term savings: respondents considered that they would pay the costs for 'necessary' weed control until long-term benefits were outweighed by the costs.

Respondents were all very aware of the scope to reduce herbicide applications below recommended doses to increase cost-effectiveness, and exhibited remarkable willingness and ability to dose flexibly for different crop, weed and weather conditions. Interviews revealed a number of factors likely to motivate herbicide use reductions, namely information on alternative non-chemical strategies (especially evidence of economic viability); herbicide resistance forcing farmers down cultural or mechanical routes; declining cereal price; more use of advisors to allow more cost-effective, targeted herbicide use; better product labelling of doses for a variety of crop, weed, and weather conditions; and possibly controls such as dosage limits and taxes. Current high cereal prices were considered to encourage continued high levels of herbicide usage.

All respondents scouted, or had their fields scouted, regularly, between once a week and four times a year and this, combined with field history knowledge (as weeds are relatively endogenous to the cropping system), led respondents to consider that they had a good knowledge of the weed problems of individual fields and areas within them. Thus it appeared that uncertainty regarding weed levels, was not an important factor motivating control. Uncertainty about herbicide effectiveness did not appear important given experience of use (farmers were happy to rely on their advisors' judgements), so this was not considered a factor motivating higher herbicide applications than necessary for (long-term) weed containment as 'insurance'.

However, risk, and perhaps risk attitudes appeared to play an important role in the up-take of new weed management approaches: the general view of farmers was found to be that as commercial producers they preferred not to experiment. A low confidence in alternative techniques to achieve the desired levels of control cost-effectively, and their perceived greater riskiness were considered to encourage continued dependence on herbicidal control. Despite a high level of interest in the alternatives: practical evidence of economic viability was required first.

Tables 8 and 9 show the responses given by respondents for quantitative controls on inputs. Different responses were given by different respondents, reflecting the different constraints and options faced, and different attitudes to alternative techniques, as well as previous efforts to reduce or minimise herbicide usage. This implies that the flexibility permitted under economic incentive policies would be advantageous. A common response was that action would depend on the economics at the time, particularly output prices. The site-and-time specific nature of weed management strategies was also stressed. Several respondents argued strongly that they could not make any herbicide usage adjustments at all, usage already being very finely-tuned to the weed/crop system needs of individual fields, given current prices, so controls would merely bite into profits. However, such responses are to be treated with a degree of caution: in the longer-term adjustments probably could and would be made, particularly as on-going chemical and crop management developments mean that future options are likely to be broader than currently.

Table 8. **Possible responses to a maximum of half the manufacturer's recommended dosage per hectare: number of respondents for each ranking**

	1	**2**	**3**	**4**	**5**
Tolerate more weeds		1	2		1
Change crop variety		2		2	2
Change cropping sequence	2	1			1
Use thresholds as these develop			3		1
Target on weed patches	1	2			1
Use more advice				2	
Use non-chemical weed controls	1	2	2	1	
More careful spray timing			1		
No change in control	4				

[NB: n = 8; some respondents considered it impossible to generalise and cited no response.]

Table 9. **Possible responses to half standard dosage farm input quotas: number of respondents for each ranking**

	1	**2**	**3**	**4**	**5**	**6**
Tolerate more weeds	2	1		1		1
Change crop variety		1		2	2	
Change cropping sequence	3	1	1			
Use thresholds/more information		1	2	1		
Target applications better on fields or patches	6	1	1		1	
Try alternative methods of control		2	4			

Great interest lay in investigating whether or not taxes would actually encourage reduced herbicide usage (see table 10). Long-term control considerations were found to be a great concern; respondents generally considered that herbicide usage would be cut (further) wherever possible, but tax would have to be paid to maintain current use levels in troublesome fields, until profit loss caused a switch from cereals or a cease in production. It appeared from very crude contingent valuation that taxes would be paid up to a fairly high level, around 50 per cent of current herbicide prices. Taxes might currently have little effect given current high grain prices. Differential taxes were widely favoured as being able to encourage the use of environmentally safer alternatives while leaving farmers with the freedom to pursue long-term controls using these, where possible, or paying the (extra) tax where it was still considered necessary to use these herbicides.

Table 10. P**ossible responses to taxes: number of respondents for each ranking**

	1	2	3	4	5	6	7
Reduce herbicide use (e.g. reduce dose)	2	2				1	
Try alternative controls	1	2			1		
Use more information/advice				1			
Target sprays more	1	1					
Carry on as before and pay tax	3						1
Change crop types		2	2	1	3	1	1
Change cropping sequence				1	1		
Fewer prophylactic sprays	1		1	2	1		
Tolerate more weeds							1

[NB: n = 8; some respondents considered it impossible to generalise and cited no responses.]

The treated-area constraint was universally rejected as unworkable; complete herbicide usage flexibility on half the farm would not compensate for a herbicide ban on the other half. Grass weeds were considered likely to become rapidly unmanageable, with severe long-term consequences. Input quotas transferable between farms, although theoretically allowing the most flexibility, were also viewed unfavourably: it was considered that no farmer would be willing to cease herbicide usage on any part of his farm to provide permits for sale (although one farmer managing seven farms as one business considered that transferability would offer him the opportunity to reallocate herbicide usage between these farms and soil types where possible). There *was* a favourable response though to a farm quota (as above) with the option to purchase *extra* permits from the administrating agency at a fixed price. Most respondents considered that they would try to stay within their initial allocation, but favoured the flexibility of allowing herbicide usage at higher levels where this was considered the only control option for their land. Careful quota design is necessary though: farm quotas need to be defined in terms of categories of chemical alternatives (unless the aim is merely to reduce dominance of some contaminants) to avoid the risk of full dosage applications of a larger number of different chemicals on different fields.

XI. Implications of the Fieldwork Findings for Policy Recommendations

The focus here was placed on environmental management approaches that affect farmers' production decisions. It appears that the CPD model presented above is a fair representation of the herbicide decision variables and processes, although the multi-objective nature of weed management also needs to be recognised. Other factors apart from yield protection were important, such as keeping fields clean for aesthetic considerations or control. Price was an important variable, although perhaps secondary in importance to dynamic weed control objectives. Long-term cost-effectiveness appeared to be the paramount consideration. It appeared possible that herbicide price changes through taxes could impact on decisions, although perceptions of a certain minimum level of control necessary for long-term weed control could hinder attempts to reduce herbicide usage. High taxes would probably be necessary to induce significant herbicide usage changes. Differentiated taxes were favoured, particularly if they avoid more general herbicide restrictions, but the 'domino' effect, whereby the next most popular chemicals start to be detected more frequently as contaminants, needs to be avoided by facilitating adjustment to new weed management approaches.

Chambers and Lichtenberg (1994) suggested that whether taxes or direct controls are used should depend on the price responsiveness of pesticide demand; this was hard to gauge in this study, although some price-responsiveness seems likely. Certainly there appears to be a degree of income elasticity, given current attempts at pesticide usage rationalisation.

Risk attitudes, and the insurance use of herbicides, may have been over-emphasised in the theoretical literature; it appeared that respondents generally considered key variables to lie within fairly narrow bands, so different risk attitudes should not alter decisions much. It does appear though that certainly regarding alternative 'integrated' approaches to weed control, there is a great deal of missing knowledge and the resulting uncertainty of consequences leads to reluctance to adopt these approaches, regardless possibly of risk attitude. One critical question for policy implementation to reduce pesticide use is regarding whether or not farmers have sufficient knowledge about possible adjustment options. Dose adjustment for maximum cost-effectiveness, whether stimulated through taxes or other mechanisms, places a large premium on skill and experience, requiring either the use of advisors or increased farmer training. Advisors appear to be of paramount importance in the CPD, influencing the type and amount of treatment, as well as aiding the diffusion of alternative techniques. Use of advisors should perhaps be encouraged, perhaps by subsidising costs.

It is necessary to assess whether and how policy recommendations drawn from the environmental economics review have changed in the light of the CPD modelling and fieldwork. Flexibility in control would seem highly desirable, given heterogeneous producers. As expected, those policies giving more decision flexibility were generally preferred, on the basis that respondents knew how best to tackle their weed problems in their conditions, and controls are highly field-and weed-specific. Targeting of treatments is essential for cost-effective weed control. Fieldwork indicated flexible incentive schemes such as permits with permit purchase options preferable to straight taxes (i.e. compulsory and explicit financial outlays), or input constraints. One of the most flexible policies, transferable input quotas, was firmly rejected though given low confidence in such a market working effectively; the barriers to trading could be further investigated. Hybrid permit/tax schemes encourage cost-effectiveness through allowing decision flexibility, while creating incentives to stay within the allocated quota to avoid tax payments.

However, it is possible to identify a number of possible reasons why input taxes might well *not* work to reduce herbicide usage. For example, the aims of sustaining weed control at acceptable levels into the long-term, with a reluctance to jeopardise this by making short-term usage reductions may well be important. Farmers may prefer to pay taxes up to the level where it is no longer profitable to produce the crop rather than cut back on herbicide applications. Risk aversion in making reductions down to this level may result in a very low price elasticity of demand. Lack of knowledge of alternative strategies may also hinder price-induced reductions; similarly, the costs involved in making decisions on reductions and minimal application levels may outweigh the costs of paying taxes. The multiple objectives of weed control must also be recognised: farmers may derive professional pride in clean fields, and social considerations such as adherence to local standards of 'good husbandry' by local farmers may be important in reducing the willingness of a farmer to reduce applications and weed control levels, even if lower usage rates would *not* have negative profitability impacts.

It is necessary to consider the relationship between quantitative and qualitative policies. There was marked (stated) preference of sample respondents for qualitative regulation over pricing or quantitative control. Reasons for this might include scepticism of respondents regarding the need to reduce chemical usage; the general view of agriculturists that any problems with chemical usage should be solved through the registration process rather than through farm-level control; a strong dislike of more farm-level bureaucracy and an assumption that policies, particularly novel economic approaches, might increase this; fears that quantitative control could severely constrain pest management in bad years; as well as the fact that, unlike taxes, qualitative restrictions involve no explicit financial transfers, and also provide guidelines within which to work, economising on the information needed by the farmer for policy compliance.

It is unlikely that a single instrument will satisfactorily solve the problems of pesticide contamination; combining a range of instruments in tiers of control focusing on different aspects of the problem may be appropriate (e.g. chemical approval and registration, taxes or dosage limits on the quantity used, and zones for vulnerable areas). Recommendations have been made for pesticide policy from a number of relevant bodies in the UK. For example, the National Rivers Authority has recommended more action to curb water pollution from pesticides, e.g. no-spray zones of at least 6 meters adjacent to water-courses; more effective use of set-aside to create buffer zones along water-courses; more research into less intensive farming systems; further improvements in pesticide formulations and handling and a national pesticide pollution prevention strategy to be drawn up by government, regulatory organisations, pesticide manufacturers and distributors and users.

Farmers, recognise that it is in the agricultural sector's own interests to use herbicides responsibly (e.g. reducing usage in conditions of heightened environmental risk), or the pressures for control will increase. Greater knowledge and understanding, at both scientific and farm/advisory levels, of integrated or non-chemical pest management techniques would facilitate their uptake. This implies strengthening research capacity and extension now, *before* the implementation of herbicide controls, to facilitate adjustment away from herbicidal weed management. Research should also be channelled towards advances in weed management techniques that farmers would *actually* implement, rather than focusing on academic issues such as weed density threshold measurement.

Some policies are likely to require supplementary measures or information to relevant agents for successful implementation, for example, if the production and financial risks associated with a switch to alternative farming practices are not clear, farmers might be hesitant to commit to a change, hence greater extension, raising awareness the possibilities and their consequences might be helpful.

XII. Political Issues of Policy Implementation

There may be a number of political hurdles for the development and implementation of pesticide policy. Glasbergen (1992) sets out a three-stage approach to the control of risks from agricultural practices. The first stage involves the development of awareness of the risks; appeals are made to the agricultural sector to take account of environmental risks but reliance on voluntary responses to these pleas is common. The most obvious vulnerable areas might be addressed (e.g. with spatial measures such as zones), to at least reduce the harmful effects of practices, if not questioning the practices themselves. Secondly, if this is considered inadequate, it is followed by re-assessment of the voluntary stance, and strengthening of the existing measures, particularly geared towards changing practices, perhaps with compensatory provisions to cushion farmers against the cost increases. Still though, there is a tendency for regulations to remain within the context of what is considered technically and financially feasible.

However, thirdly, on-going escalation of problems might force a more principled approach to farming itself, with a reformulation of practices along ecological lines. The existing structure of controls may be maintained, but tightened, and new, additional, measures introduced. Glasbergen (1992) considers that the UK is at the transition to the second stage, with the farming sector strongly resisting progress to the third. A deep reluctance to regulate farmers appears to prevail still in the UK, with the government tending towards the view that any controls on pesticides which do not arise from any *proven* public health risks associated with pesticide pollution will only serve to push up the price of food and put European farmers at a competitive disadvantage in global food markets.

A prevailing agriculturist view is that farming practices and agricultural land use patterns are primarily a result of policy decisions which resulted in farmers receiving signals sending agriculture in a direction in conflict with maintenance of an acceptable natural environment (Clark and Lowe 1993). The Department of the Environment (1988) argues that,

"*Agriculturists... whilst accepting the principle that the polluter should pay, consider that they are already complying with it by farming in accordance with the code of good agricultural practice. They also consider that it would be inequitable to be penalised for following government advice consistently given over the last forty years to optimise crop production, or more particularly that one group of farmers of farmers be prevented from following the same good practice as others who are not in sensitive water catchment areas*".

It is important to inform farmers about legislation (and other policy proposals), partly to clarify its meaning, but more important to clarify why it exists. For example, in the UK there is widespread hostility amongst producers to the six-metres unsprayed buffer zone required by PSD for certain chemicals, as they cannot see the need to have a zone this large. Furthermore, enforceability and compliance generally with the provision are doubted. The requirement is widely considered to have been introduced due to the reporting of careless over-spraying of a water-course by one farmer, rather than on the basis of scientific understanding of risks. Co-operation of producers is probably essential for success of controls in meeting their goals. Glasbergen notes that there is a long-established tendency in the UK farming community to co-opt the cause of environmental protection, drawing on a rhetoric and long tradition of 'stewardship' of the countryside by landowners. At the grass roots, farmers resent what they see as interference in the management of their land so controls must be introduced in a way sensitive to these feelings.

XIII. The Implications of Common Agricultural Policy (CAP) Reform

The final section of this paper will look at the linkages between different policy types, particularly the link between policies to reduce environmental risk and policies to guide agricultural production. It is perfectly conceivable that agricultural policy reform could create new environmental pressures that may require adjustment in environmental policies. It is important to know how far the level and form of agricultural assistance and policy affects farm chemical use, given continuing pressure to adjust policies in environmentally positive ways. The structure of agricultural policy may affect the selection and design of pesticide risk reduction policy, or impact upon its effectiveness, for example, if the same environmental risk reduction result be achieved at lower cost by lowering production-linked support. Harmonisation is required; pesticide policy development is not independent of other policy changes, which might help or hinder progress (see Shortle and McLaughlin 1994).

An important area of interest involves exploring to what extent environmental problems in the agricultural sector could be solved (or at least reduced) by reducing the levels of agricultural support (i.e. lowering output prices). Although very indirect, this might have some impact, e.g. through reducing the amount of pesticide applied, both per unit area and in total through reduced production. However, agricultural policy reform might be necessary but by no means sufficient; environmental problems need to be actively addressed, rather than just indirectly. A number of problems might remain: support reductions would affect all producers equally, rather than being targeted on those who cause most environmental problems. A problem is that agricultural policy is applied at the commodity level, whereas environmental problems generally arise at the farm level (they are local, and situation-specific), so agricultural policy is aimed at the wrong level to meet environmental objectives. However, agricultural policy reform may mean that there is more scope to include 'environmental' components, e.g. cross-compliance.

CAP reforms have led to a reduction in the utilised agricultural areas and generally weaker farm economies across the EU, and it is highly probable that farmers have reduced their pesticide inputs in response to economic rather than environmental pressures (Lawson 1994), and set-aside requirements mean that the treated area for most chemicals is now lower.[52] It is important to understand the effects of CAP reform for the use of inputs in assessing the need for other policy innovations to control their use and mitigate their adverse effects.

In the UK, and particularly East Anglia, producers are farming very profitably due to the functioning of the agri-monetary system (with a currently very favourable green exchange rate), which, coupled with the current agricultural support system, means that there is currently a buoyant derived demand for pesticides. This may impact on the effectiveness or otherwise of policy measures such as taxes, dampening their effects on pesticide usage rates, requiring perhaps even higher input tax rates for noticeable input use change. Cereal farm incomes in the UK in 1995/6 were expected to rise by up to 3.5 per cent. High arable product prices are currently encouraging greater production, which is contributing to increasing demand for certain herbicides and other chemicals, which in turn is contributing to rising chemical costs (17 per cent in 1994-5).

Isermeyer (1994) argues that CAP reform has improved the competitiveness of low input systems considerably. Farmers now face a choice between maintaining their existing production systems and crop/resource use patterns, and adapting to change. Ogilvy et al. (1994) show that integrated/low input use systems can be commercially viable and environmentally preferable in terms of reduced use of potentially contaminating inputs compared to conventional systems. Overall, 37 per cent fewer pesticide doses were applied per hectare in the integrated system, with a range of 22-49 per cent reduction over the six sites compared to conventional production methods.

Russell (1995) investigates the effects of changes in output prices and set-aside requirements associated with the reformed CAP on the pesticide usage of a sample of twenty six wheat and barley growers in the North-West of England. The results indicated that reductions in output prices, such as may occur under the on-going system of CAP reforms, can have a significant effect on pesticide use. For example, a 10 per cent change in expected output price could lead to a 30 per cent reduction in use. Russell found the set-aside coefficient to be statistically insignificant, i.e. the results did not support the notion that setting aside land has a measurable effect on average pesticide use for this sample of farmers at least.

---

52 By contrast, some herbicides, e.g. glyphosate for total weed control, are used on set-aside land, and their usage may even have increased. Furthermore, set-aside may indirectly lead to greater grass weed herbicide usage in the following crop.

XIV. Summary and Recommendations for Future Work

This paper has examined the problems of implementing policies to control environmental risk from pesticides, and the potentially most cost-effective ways of achieving satisfactory levels of environmental quality or pesticide usage by investigating the feasibility of various farm-level control mechanisms. Policy design was examined by reviewing the recommendations of environmental economics in parallel with consideration of the characteristics of the pesticide problem. Implementation hurdles were investigated by focusing attention on farmer decision-making, with interviews to gauge how farmers might react to possible alternative regimes. The underlying premise is that it is possible to design potentially cost-effective control mechanisms, possibly including economic incentives, but that there may be farm-level problems of implementation and enforcement to overcome, related to the constraints, motivations and other influences on farm crop protection decision-making. There are a number of farmer-behavioural factors to consider to achieve herbicide reductions, such as pride in weed-free fields, unwillingness to experiment and reluctance to trade-off short-term gain with long-term cost given the endogeneity of weed problems to the production system and the dynamic nature of weed ecology. These all constitute potential barriers to policy operation, particularly for economic approaches to control such as input taxes.

This study has taken a qualitative approach to policy evaluation, as an initial step. Quantitative economic evaluation of various policies, such as input taxes or limits, on different farming types and in different economic circumstances would be useful. A linear, or other mathematical, programming model would be useful for this purpose, using data from regional farms. The focus has been very much on evaluation of the economic consequences of policy possibilities to reduce the environmental risks from pesticides. However, it is essential to appreciate too the environmental consequences of different proposals, as these might vary substantially, depending for example on the resultant effects on pesticide usage. Some form of agri-environmental indicators or a 'yardstick' would be useful in assessing changes in environmental quality, for example that developed by CLM in the Netherlands (see Janssen et al. 1995) or by Kovach et al. (1992) at Cornell, USA. Yardstick development would require data on chemical properties, as well as the effects of environmental characteristics on the environmental burden resulting from pesticide use. The next step in pesticide policy research involves integrated, quantitative, modelling of the farm-level economic consequences and the environmental impacts of the most promising policy proposals discussed here.

BIBLIOGRAPHY

ABRAMS and BARR (1974), "Corrective Taxes for Pollution Control: an Application of the Environmental Pricing and Standards System to Agriculture," *Journal of Economics and Environmental Management*, Vol. 1, pp. 296-318.

AULD and TISDELL (1987), "Economic Thresholds and Response to Uncertainty in Weed Control", *Agricultural Systems*, Vol. 25, pp. 219-227.

BAUMOL and OATES (1971), "The Use of Standards and Prices for Protection of the Environment", *Swedish Journal of Economics*, Vol. 73, pp. 42-54.

BOHM, P. and RUSSELL, C. (1985), "Comparative analysis of Alternative Policy Instruments", pp 395-460 in Kneese, A. and Sweeney, J., *Handbook of Natural Resource and Energy Economics* (North: Amsterdam).

BROUWER, F., TERLIUN, I. and GODESCHALK, F. (1994), "Pesticides in the EC" (LEI-DLO, The Hague).

BUFFIN, D. (1994), *Pesticide News*, 23, pp. 12-13.

CARTER (1993), "Pesticides in Soil and Water", *Pesticide Outlook*, 4, pp. 23-28.

CHAMBERS and LICHTENBERG (1994), "Simple Econometrics of Pesticide Productivity", *American Journal of Agricultural Economics*, Vol. 76, pp. 407-417.

COOKE, H. (1991), "NPZs: Targeting and Land Use over an Aquifer", *Land Use Planning*, Vol. 8, pp. 16 -28.

COUSENS, R. (1987), "Theory and Reality of Weed Control Thresholds", *Plant Protection Quarterly*, Vol. 2, pp. 13-20.

CROLL, B. (1991), "Pesticides in Surface Waters and Ground Waters", *Journal of the Institute of Water and Environmental Management*, Vol. 5, pp. 389-395.

DAVIS, R., GARTHWAITE, D. and THOMAS, M. (1990), Pesticide Usage Survey Report 85 (MAFF: HMSO, London).

DUBGARD, A. (1991), "Pesticide Regulation In Denmark", pp. 48-58 in Hanley, N. *Farming and the Countryside*, (CAB International: Wallingford).

DRUMMOND, C. (1995), Proceedings of a Workshop on Pesticides, Wageningen, The Netherlands.

DWI (1994), Drinking Water 1993: Report by the Chief Inspector of the DWI (DoE/Welsh Office: HMSO).

ENDS (1995), Report 243, “Thames Water Seeks Control on Agricultural Pesticides”, p. 9.

FARMER, D., HUTCHEON, J. and JORDAN, V. (1994), “Socio-Economics of Commercial Implementation of Integrated Arable Systems Under the Reformed CAP”, *Aspects of Applied Biology*, Vol. 40, pp 81-95.

FAWELL, J. (1992), “Pesticides in Water: How Big a Problem?” in National Agricultural Conference Proceedings on Pesticides in Water (RASE: Stoneleigh).

FEDER, G. (1979), “Pesticides, Information and Pest Management Under Uncertainty”, *American Journal of Agricultural Economics*, Vol. 61, pp. 97-103.

GILBERT, D. and MACRORY, R. (1989), Pesticide Related Law (BCPC Publications).

GLASBERGEN, P. (1992), “Agro-Environmental Policy: Trapped in an Iron Law?” *Sociologia Ruralis*, Vol. 32, No. 1, pp. 30-48.

GREEN, E. and MUMFORD, J. (1995), Proceedings, Workshop on Pesticides, Wageningen, The Netherlands.

GUSTAFSON (1993), “Advantages and Potential Pitfalls in the Use of Models for Regulating Control of Pesticide Usage”, Brighton Conference Proceedings: Weeds, pp. 1373-1379, (BCPC).

HILL , AARONOVITCH and BALDOCK (1989), “Non-Decision-Making in Pollution Control in Britain: Nitrate Pollution, the EC Drinking Water Directive and Agriculture”, *Policy and Politics*, Vol. 17, pp. 227-240.

ISERMEYER, F. (1994), in “Workshop on a Framework for the Sustainable Use of Plant Protection Products in the EU”, Proceedings, pp. 160-173 (EC/Dutch Ministry of the Environment/Dutch Ministry of Agriculture).

JANSSEN, H., OSKAM, A. and VIJFTIGSCHILD, R. (1995), Proceedings, Workshop on Pesticides, Wageningen, The Netherlands.

KOVACH, J., PETZOLDT, C., DEGNI, J. and TETTE, J. (1992), “A Method to Measure the Environmental Impact of Pesticides”, *New York’s Food and Life Sciences Bulletin*, 139.

LEATHERS, H. and QUIGGIN, J. (1991), “Risk Attitudes and Policy Interaction”, *American Journal of Agricultural Economics*, Vol. 73, pp. 757-776.

MILTZ, D. (1987), “Economic Aspects of Targetting Environmental Policy,” Unpublished Ph.D. Dissertation, University of Cambridge.

MOFFITT, L. (1986), “Risk Efficient Thresholds for Pest Control Decisions”, *Journal of Agricultural Economics*, Vol. 37, pp. 69-75.

MONTGOMERY, W. (1972), “ Markets in Licences and Efficient Pollution Control Programmes”, *Journal of Economic Theory*, Vol. 5, pp. 395-418.

MOXEY, A., and WHITE (1994), "Efficiency Compliance With Agricultural Nitrate Pollution Standards", *Journal of Agricultural Economics*, Vol. 45, pp. 27-37.

MURPHY, M. (1994), Report on Farming in the Eastern Counties of England, 1992/3 (University of Cambridge).

NORTON, G. and MUMFORD, J. (1983), "Decision-Making in Pest Control", *Advances in Applied Biology*, Vol. 8, pp. 87-116.

OGILVY, S., TURLEY, S., COOK, S., FISHER, N., HOLLAND, J., DREW, R. and SPINK, J. (1994), "Integrated Farming: Putting Together Systems for Farm Use," *Aspects of Applied Biology*, Vol. 40, No. 1, pp. 53-61.

OSKAM, A., VAN ZEIJTS, H., THIJSSEN, G., WOSSINK G., and VIFTIGSCHILD, R. (1992), "Pesticide Use and Pesticide Policy in the Netherlands", WES 26, Wageningen.

OTTER, R. (1992), "Pesticides in Water: the Control of Diffuse Sources" in RASE/ADAS National Agriculture Conference Proceedings (RASE: Stoneleigh).

PAN, J. and HODGE, I. (1994), "Land Use Permits as an Alternative to Fertiliser and Leaching Taxes for the Control of Nitrate Pollution", *Journal of Agricultural Economics*, Vol. 45, pp. 102-112.

PANDEY, S. and MEDD, R. (1991), "A Stochastic Dynamic Programming Framework for Weed Control Decision-Making: an Application to Avena Fatua L", *Agricultural Economics*, Vol. 6, pp. 115-128.

PANNELL, D. (1990), "Responses to Risk in Weed Control Decisions Under Expected Profit Maximisation", *Journal of Agricultural Economics*, Vol. 41, pp. 391-403.

REUS, J., WECKSELER, H., and PAK, G. (1994), "Towards a Future EC Pesticide Policy," (CLM, Utrecht).

PANNELL, D. (1991), "Pests and Pesticides, Risk and Risk Aversion", *Agricultural Economics*, Vol. 5, pp. 361-384.

ROSE, C. (1985), "Pesticides: the First Incidents Report", (London: Friends of the Earth).

RUND, T. (1995), "Pesticides in Water: Meeting the Standards", *Arable Farming*, 25 May 1995, pp. 33-34.

RUSSELL, N. (1995), Proceedings, Workshop on Pesticides, Wageningen, The Netherlands.

SHORTLE, J. and LAUGHLAND, A. (1994), "Impacts of Taxes to Reduce Agrochemical Use When Farm Policy is Endogenous", *Journal of Agricultural Economics*, Vol. 5, pp. 259-270.

THORNTON and FAWCETT (1990), "The Role of Cost-Benefit Analysis in Determining Reduced Input Crop Protection Strategies," (BCPC), Brighton Conference Proceedings Pests and Diseases, pp. 1241-1250.

WARD, N., CLARK, J., LOWE, P. and SEYMOUR, S. (1993), Water Pollution From Agricultural Pesticides, Research Report, Univ. of Newcastle-Upon-Tyne, Dept. of Agric. Econs and Food Marketing (Centre For Rural Economy).

WARD, N. (1995), Proceedings, Workshop on Pesticides, Wageningen, The Netherlands.

WEITZMAN (1974), “Prices Versus Quantities”, *Review of Economic Studies*, Vol. 41, pp. 447-491.

WILLIS and MCDOWELL (1982), “Reviews: Pesticides in Agricultural Run-off and Their Effects on Downstream Water Quality”, *Environmental Toxicology and Chemistry*, Vol. 1, pp. 267-279,

ANNEX 8

POLICY CASE STUDY OF THE UNITED STATES

Leonard P. Gianessi
Senior Research Associate
National Center for Food and Agricultural Policy
1616 P Street, NW, First Floor
Washington, DC 20036

TABLE OF CONTENTS

I. Introduction

Synthetic chemicals are widely used by US farmers to control pests that otherwise would lower crop yields. Pesticides are unique products -- they are the only toxic substances introduced deliberately into the environment for the benefit of society. US pesticide regulatory policy is unique among environmental statutes in that a risk/benefit analysis must be conducted before restrictions can be placed on currently registered compounds. Test requirements to register new compounds are rigorous and expensive. A wide variety of public and private groups affect pesticide policy and the use of pesticides. US policymakers and regulators have struggled with legislative requirements, public concerns, media attention, commercial interests, regional competition, and the vagaries of nature to advance pest control practices and to limit human and environmental exposure. The following report gives an overview of the issues and provides some policy recommendations.

II. Background

Initial use of synthetic chemicals

The introduction of synthetic chemicals to control weeds, insects and plant disease pathogens occurred after World War II. The use of synthetic chemical pesticides became widespread, and their use is generally credited with contributing to dramatic increases in yields for most major US crops [57]. Synthetic chemicals control many pests for which adequate controls had not existed before their introduction:

- Sweet corn production in Florida did not exist before the development of synthetic compounds in the late 1940's, because there had been no effective, economical control of insects [34], [35].

- Strawberry plants in California are plagued with pathogens that colonise and destroy the plant roots. In the 1950's and early 1960's, strawberry yields in California averaged 5 -10 tons per acre annually. In the mid-1960's, California strawberry growers began to use a soil fumigant, methyl bromide, to kill the soil-borne pathogens. Strawberry yields have averaged over 20 tons per acre since fumigation began [4].

- Wild blueberry fields in Maine have been plagued with weeds for centuries. In the mid-1980's, hexazinone (trade name Velpar), a herbicide, was registered and provided outstanding weed control in blueberries [36]. Blueberry production increased from 20 million pounds per year to 50 million pounds per year.

For some crops synthetic chemicals replaced non-chemical practices that were abandoned because of their cost, labour requirements, or because they limited yield potential.

Early in this century, labourers were used to hand-weed and hand-pull weeds out of sugarbeet fields. When labour became increasingly expensive and scarce, sugarbeet growers adopted herbicides for weed control in order to preserve their industry [37].

The primary means of controlling weeds in cotton fields for several hundred years, prior to the development of herbicides in the 1960's, was hand labour. It has been estimated that the use of herbicides replaced the necessity to use about 20 hours of labour per acre on a million acres of cotton in Mississippi annually thus saving cotton growers in Mississippi $10 million a year [38].

Before the introduction of selective herbicides for weed control in California vegetable fields, it was common practice to employ labourers with short-handled hoes to hand-remove weeds. Herbicide use is less costly than hand-weeding, and there is no associated yield loss, that occurs when hand-weeders remove crop plants along with the weeds.

Between 1950 and 1975, corn yields in Midwestern states doubled. During the same period, the use of herbicides to control weeds rose from less than 10 per cent of the acres treated to 98-99 per cent. Corn yields doubled because twice as many plants were planted per acre, increasing from 10 000 per acre in the 1950's to 20 000+ in the 1970's. In the 1940's and early 1950's, corn plants were planted far enough apart so that a tractor could pass on all four sides of each plant to cultivate weeds.

Several US crops had received regular applications of inorganic pesticide compounds during the first 50 years of this century. Synthetic chemicals replaced these inorganic compounds with subsequent benefits of improved crop yields and reduced crop damage.

Successful commercial production of apples in the Northeast has required regular applications of disease and insect control materials since the 1890's. When growers switched to synthetic chemicals in the 1950's, per tree apple production doubled in Pennsylvania, Massachusetts, New York, Delaware, and Maryland. In Maine, per tree apple production tripled. The synthetic chemicals were much less harsh and harmful to the trees [32].

US potato fields had been treated routinely with copper compounds prior to the introduction of synthetic fungicides. Copper produced only partial control of the major potato diseases. The replacement of copper compounds with synthetic fungicides led to a 33 per cent increase in potato yields in eastern states, including Maine and New York.

Current pesticide usage and expenditure patterns

Currently, herbicides for weed control are the most prevalent group of pesticides used in US crop production. Most national crop acreage of field crops, fruit crops and vegetables are treated with an herbicide at least once during the growing year.

The use of insecticides and fungicides varies considerably by crop. For example, while close to 100 per cent of the acreage of crops such as apples and potatoes are treated routinely with insecticides and fungicides, only a small fraction of the nation's soybeans are treated with insecticides, and essentially none of the nation's field corn or soybean acreage are treated with fungicides. Table 1 summarises the national usage of classes of pesticides for selected crops.

Table 1. **Percentage US acreage receiving pesticide application (1994/95)** **% Acres Treated**			
CROP	**HERBICIDES**	**INSECTICIDES**	**FUNGICIDES**
Apples	63	98	93
Grapes	74	67	90
Carrots	72	34	71
Lettuce	60	100	77
Onions	88	76	89
Corn	96	27	0
Cotton	97	75	8
Potatoes	87	88	85
Sorghum	97	2	0
Wheat	56	5	1

Source: [1], [2], [3].

Crops are produced in the US in widely divergent growing regions: under desert conditions in the Southwest, in humid/hot subtropical conditions in the Southeast, and in northern regions with extremely cold winters. Differences in climate conditions have resulted in different pest problems and in differing levels of pesticide use.

Insect pests of soybeans generally do not overwinter in the US but migrate in every year from Central and South America. Usually there are abundant parasites in Southern and Midwestern soybean fields to control these insects [46]. However, in some Southern fields, insect infestations reach such high levels that entire fields can be defoliated without the timely application of insecticides. Thus, in the South approximately 10-30 per cent of the soybean fields are treated with an insecticide. In the Midwest, typically no insecticides are applied to soybeans.

Primary targets of Florida insecticide sprays in sweet corn are numerous insects that overwinter in the state and lay large numbers of eggs that lead to larval and worm damage in the ears of corn. These insects cannot overwinter in sweet corn producing states farther north, such as New York. Thus, while Florida sweet corn acreage is typically treated 7-14 times with commonly used insecticides, New York's sweet corn acreage typically receives two to four insecticide applications [3].

Apples are grown in the eastern US under hot/humid conditions and in the Northwestern U. S. under arid conditions. Diseases of apple orchards found in the East, such as black rot and scab, are not present in the Northwest. Thus, while Pennsylvania apple acreage receives five to seven applications of commonly used fungicides, Washington State's acreage is treated only one to two times [2].

Rice Blast is an important disease of rice in the Southern US where approximately 24 per cent of rice acreage is treated with fungicides [50]. Rice Blast is not a problem in California, and fungicides are not used on rice in the state.

For most crops there is more than one pesticide active ingredient registered to control most individual pest species. The selection of which active ingredient to use in a particular region is based on local conditions and prices of alternatives. It is rarely the case that a single active ingredient is used on a majority of the nation's acreage of a crop for which it is registered. Most pesticide active ingredients are used in the range of 5-35 per cent national acreage treated [20].

Currently approximately 200 active ingredients are used in significant amounts in US agriculture. They are used in varying amounts on the acreage of 90 major crops in many divergent growing regions throughout the country.

Current annual US agricultural pesticide use is estimated at 129 million pounds of fungicides, 454 million pounds of herbicides, 149 million pounds of insecticides and 154 million pounds of other types of pesticides (fumigants, growth regulators, defoliants) [20]. The top ten uses of pesticides in US crop production by state, crop and active ingredient are delineated in Table 2.

Table 2.
Top ten agricultural uses of pesticides in the US

Active Ingredients	millions lbs./yr.	**Crops**	millions lbs./yr.	**States**	millions lbs./yr.
1 Sulphur (F)	83	Field Corn	240	California	152
2 Atrazine (H)	72	Soybeans	74	Florida	55
3 Metolachlor (H)	59	Cotton	72	Illinois	54
4 Alachlor (H)	52	Potatoes	60	Iowa	53
5 Oil (I)	51	Grapes	56	Washington	38
6 Methyl Bromide (O)	44	Citrus	34	Nebraska	33
7 2,4-D (H)	42	Tomatoes	27	N. Carolina	33
8 1,3-D (O)	40	Pasture	25	Minnesota	31
9 Cyanazine (H)	32	Tobacco	24	Georgia	31
10 Metam Sodium (O)	29	Peanuts	24	Indiana	30

F=Fungicide, H=Herbicide, I=Insecticide, O=Other
Source: [20]

US farmers spend approximately $7.2 billion per year for crop protection pesticides [19]. Sixteen active ingredients have annual sales of $100 million or more. These active ingredients are listed in Table 3. Of the top 16 active ingredients, 14 are herbicides and two are insecticides. Most active ingredients (63 per cent) used in US crop protection have sales in the range of only $1 million to $24 million/yr. [19].

Table 3. **US crop pesticide sales: top-selling active ingredients**		
Active Ingredient	**Type**	**US Sales (million/$/yr.)**
Metolachlor	H	451
Glyphosate	H	447
Imazethapyr	H	438
Trifluralin	H	205
Cyanazine	H	184
Atrazine	H	169
Chlorpyrifos	I	169
Dicamba	H	168
Alachlor	H	166
Pendimethalin	H	152
Acetochlor	H	137
2,4-D	H	128
Nicosulphuron	H	123
Terbufos	I	108
Imazaquin	H	105
Bentazon	H	103

H = Herbicide, I = Insecticide
Source: [19]

Some of the active ingredients with the highest volume sales in the US market do not appear in the top-selling list, because of low per-pound selling prices. For example, sulphur ranks highest in volume of use (83 million pounds); however, at an average price of $0.63 per pound, national sales of sulphur total $50 million per year and are ranked 36th. Sixty per cent of the sales of crop protection pesticides in the US are accounted for by three crops: field corn, soybeans, and cotton. Herbicides account for 65 per cent of US national crop protection pesticide sales. Corn and soybean herbicide sales account for 64 per cent of US herbicide sales. Cotton ranks first in terms of insecticide sales for crops in the US, while fungicide sales are highest in fruit and vegetable crops.

Pesticide use trends

Recently, much attention has been focused on trends in the use of pesticides by US farmers. Critics contend that pesticide use data indicate that US farmers have significantly increased their reliance on pesticides [26], [27]. EPA data indicate that from 1964 to 1981 the volume of pesticide active ingredients used by farmers increased from 320 million pounds used per year to over 800 million pounds per year [28]. Since 1981, the overall volume of pesticide use by the agricultural sector has remained relatively constant at 800+ million lbs./yr. EPA data for the time period 1979-1991 indicate that the volume of herbicide use in agriculture has remained fairly constant while a decline occurred for insecticides and an increase occurred in the volume of fungicide use.

Because of the vast diversity of US agriculture, aggregate use trends may obscure many different trends in pesticide use. Examining use trends by crop, state, and class of chemical creates a more accurate and complete picture of pesticide use. For some crops, herbicide use rose significantly in the 1980’s only to be counterbalanced by declines in herbicide use in other crops. For some crops, insecticide use rose in the 1980's while herbicide use declined. Taking a closer look at disaggregated use trends is necessary in order to sort out the real implications of policy decisions and the following influences:

- Development of Integrated Pest Management programmes that rely on economic thresholds and scouting to guide spray decisions

- Registration of new pesticide products that are used at lower per acre rates than older products

- Deregistration of older products, either through voluntary cancellations by registrants or bans by EPA

- Reduced rates of application for currently registered active ingredients

- Development of resistance to pesticides in the pest population that can result in greater applications or applications of different compounds for control.

The following examples illustrate the magnitude of changes in pesticide use that have occurred and the reasons for these changes:

- Annual herbicide use in soybeans declined by approximately 30 million pounds since the late 1980's because of the introduction and widespread use of products that are effective at significantly lower use rates per acre (0.05 lbs./acre) in comparison to older products (0.5 lb./acre).

- Insecticide use in field corn production declined by 50 per cent since 1980 because of a research and education programme showing farmers that certain types of insecticides were not necessary on corn that was grown in an annual rotation with another crop [39] (75 per cent of the nation's corn acres are grown in such rotations) [40].

- The average amount of fungicides for disease control applied in US apple orchards declined by 35 per cent in the past 20 years because of the introduction of new low rate compounds, and research and educational programmes that improved the timing of chemical applications.

- The use of chemicals for killing potato vines in Colorado increased by about 8 million pounds per year after the EPA banned dinoseb, that was used at 2 pounds per acre. Farmers have substituted the use of sulphuric acid at 300 pounds per acre.

- Rice acres in the Delta states were not treated with fungicides for disease control in the early 1980's. Currently, over 800 000 rice acres in the Delta are treated with fungicides for control of the disease "rice blast". Rice cultivars had previously been immune to the disease.

The overall replacement trends in pesticide usage have resulted in significant declines in the usage of certain active ingredients, while other active ingredients have served as replacements:

- Butylate and EPTC were used widely as corn herbicides in the late 1970's and early 1980's (approximately 25 per cent of corn acreage treated combined). Their use declined to approximately 4 per cent acreage treated by 1991. Alachlor and metolachlor largely replaced butylate and EPTC as corn growers reduced their mechanical tillage operations [41].

- Metribuzin had been a major herbicide applied to US soybean acreage, peaking at 33 per cent acreage treated in 1982. The use of metribuzin declined to 10 per cent US soybean acreage treated by 1994 as growers switched to new, low rate, post-emergent soybean herbicides, particularly imazethapyr.

- The aggregate poundage of atrazine used in US corn production declined by about 40 per cent between 1976 and 1994. Available usage surveys show that atrazine was used on the same number of acres as before (70 per cent); however, its usage has declined significantly from 1.4 lb. AI/A to approximately 1.0 lb. AI/A.

- The use of alachlor has declined significantly in the past several years. The decline in alachlor sales 1994-1995 for corn acreage (from 17 per cent acres treated in 1994 to 8 per cent acres treated in 1995) is directly attributable to competition with the newly introduced herbicide, acetochlor.

III. Pesticide regulatory policy

FIFRA background

Congress first attempted to regulate pesticides by enacting the Insecticide Act of 1910 that made it unlawful to manufacture any insecticide or fungicide that was "adulterated or misbranded." Although the Insecticide Act was designed to protect consumers from substandard or fraudulent insecticides and fungicides it was essentially a labelling statute. It did not require that pesticides be registered and that safety standards be specified. In 1947 Congress replaced the Insecticide Act with the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) which required that pesticides be registered by the Secretary of Agriculture before their sale or distribution in interstate or foreign commerce. The Act also required that warning labels be placed on highly toxic pesticides [51]. FIFRA also placed the burden of proving pesticide safety and efficacy on the manufacturer [52]. However the Act had no teeth since the USDA had no power to deny or cancel a registration that failed to comply with provisions of the Act. Congress took corrective action in 1964 when it passed an amendment to FIFRA that authorised the Secretary of the USDA to suspend a registration if necessary to prevent an imminent hazard to the public [51]. However, the cancellation process was very protective of registrants' procedural rights. It allowed registrants to demand both a referral to an advisory committee and a formal hearing. Registration came to be viewed as a property right that could only be taken away by means of a courtroom proceeding [53].

In late 1970, the Environmental Protection Agency was created and assumed the pesticide regulatory functions of the USDA and FDA (Food and Drug Administration). The first pesticide registration guidelines were issued during 1970 for the nearly 600 active ingredients that were registered then with EPA. The guidelines included as a requirement the completion of six studies that form the backbone of present day environmental studies. The included studies were designed to show: (1) rate of dissipation of pesticides in the soil, (2) the mechanism of degradation of pesticide residues (including photodecomposition, the effects of metabolites, impact on micro-organisms, degradation in water), (3) whether residues leach in soils, (4) whether residues move in surface water, (5) whether the pesticide is bound and active, and (6) the levels of pesticides that accumulate in fish, rabbit and bird tissues, and what dose-related symptoms are exhibited by the species. A number of toxicology studies also became a required part of the registration process.

The Federal Environmental Pesticide Control Act of 1972 (FEPCA) completely overhauled FIFRA and increased EPA's pesticide regulatory authority. FEPCA added a new statutory standard for registration by permitting the registration of a pesticide only if it did not cause "unreasonable adverse effects" on human health and the environment. Under the Act EPA was authorised to: (1) classify pesticides into general and/or restricted use categories; (2) regulate pesticide use; (3) require federal registration of pesticides sold intrastate, (4) register establishments that produce pesticides, and (5) require pesticide producers to maintain records for enforcement purposes. Importantly, the FEPCA directed EPA to reregister all currently used pesticides within five years [51]. Several amendments to FIFRA required that old pesticides be reregistered and undergo a much more comprehensive set of tests than were required previously to gauge their efficacy and safety.

In 1978, Congress substantially revised FIFRA by enacting the Federal Pesticide Act of 1978 which granted data submitters ten years of exclusive data rights for new active ingredients and it provided for conditional registration authority, despite the absence of full supporting data to enable EPA to process the backlog of applications for registration.

Congress amended FIFRA in 1980 to provide for a bicameral congressional veto of EPA's prospective rules and regulations under FIFRA and it broadened the powers of the Scientific Advisory Panel [51]. By 1982 EPA had published a set of environmental guidelines entitled "Pesticide Assessment Guidelines, Subdivision N, Chemistry Environmental Fate", which required testing that was far more extensive than had been required previously. An extensive section was also devoted to public comments on proposed regulations [53]. However, since reregistration continued to move very slowly Congress enacted the 1988 FIFRA amendments that established specific timetables for pesticides to be tested and for reregistration to be completed by 1997 [55].

The 1988 amendments established a five-phase reregistration programme for each of the four groups of active ingredients registered prior to November 1, 1984, and a schedule for completing reregistration within three to nine years [51]. As a result of the 1988 amendments registrants voluntarily dropped tens of thousands of registrations--particularly for minor crops, to avoid fees and data development costs [53].

During phase I EPA divided the active ingredients into four groups. Group A lists 194 active ingredients for which EPA already had issued Registration Standards and were exempt from phases II through IV. Groups B and C each list 150 active ingredients for which reregistration standards had not been issued, while list D lists all other active ingredients. In phase II registrants were required to submit to EPA within 90 days responses listing all available studies deemed to be acceptable to EPA, and a commitment to conduct additional tests to fill data gaps that were needed to meet registration requirements.

Although EPA estimated that it would require only 42 hours to complete a phase II response, the actual amount of time required was far greater. In addition the costs to repeat inadequate studies were enormous which forced pesticide manufacturers to form consortiums to share the costs of performing tests on non-proprietary pesticides.

In phase III the registrants were required to submit information and studies on such topics as chronic dosing, oncogenicity, reproductive effects, mutagenicity, neurotoxicity, teratogenicity and residue chemistry. The registrants were also required to reformat every pre-1982 study they wanted EPA to consider in support of a pesticide registration [53]. In mid-1989 EPA listed 134 individual studies that a basic manufacturer would have to submit to support reregistration of an active ingredient used on at least one food crop [53]. In phase IV EPA's task is to quickly review all of the reports submitted during phases II and III to make certain that all of the required studies are accounted for and to identify data gaps.

Phase V requires EPA to determine within one year whether an active ingredient is eligible for reregistration. It also requires the Agency to conduct a thorough and comprehensive evaluation of all the studies submitted within a span of three to nine years to meet the 1997 deadline imposed by Congress. An active ingredient will be cancelled if it fails to be "used in accordance with widespread and commonly recognised practice" and "causes unreasonable adverse effects on the environment" [51]. The objective of completing phase five sets into motion the massive job of sifting through all of the submitted material as part of the reregistration decision making process. The monumental size of the task is made palpable by an estimate given by EPA in mid 1989 that the group B pesticides included at least 8 000 products manufactured by 3 500 companies and would involve the review of between 40 000 to 50 000 new studies [53].

As of March 31, 1994, EPA had reregistered 96 of the 590 active ingredients. There are several reasons that help to explain the slow pace of reregistration. First, EPA staff is not large enough to review and analyse all of the data in a timely fashion. The pesticide programme staff has oscillated between a peak of 829 in 1980 and a low of 555 in 1985. Second, the massive number of tests and data require an enormous amount of time and money to collect, analyse, and interpret.

FFDCA background

The Federal Food, Drug, and Cosmetic Act (FFDCA) was enacted by Congress in 1938 to help protect the public from food contamination caused by chemical residues. If both the United States Department of Agriculture (USDA) and the Food and Drug Administration (FDA) agreed that a pesticide was useful and didn't represent a human hazard a registration was granted for use of the chemical on food crops [53]. In 1954, Congress enacted the Miller Amendment (Pesticide Control Amendment) to FFDCA which required that FDA set a maximum acceptable level (tolerance) for pesticide residues found in and on raw agricultural commodities (RAC) and animal feed for any pesticide registered under FIFRA (section 408) [52].

During the early 1970's the jurisdiction for setting tolerances was transferred to EPA. A tolerance, or an exemption from the requirements for a tolerance, must be established for each of a pesticide's active and inert ingredients before it can be approved for use on food or animal feed. A tolerance is the maximum residue level, usually measured in parts per million (PPM), that can legally be present on or in raw agricultural commodities (RAC).

Section 409 (the Food Additives Amendment) which was added to the FFDCA in 1958 requires that if a pesticide residue in a processed food exceeds the tolerance set under section 408 for the raw version of the commodity, the residue in the processed product will be treated as a food additive [51]. This is significant since section 409 also contained the highly controversial Delaney Clause that states that "no [food] additive shall be deemed safe if it is found to induce cancer when ingested by man or animal [52]."

EPA chose to apply the tolerances established for raw agricultural commodities to processed commodities by applying section 402 of the FFDCA which allows for tolerances to "flow through" between the fresh and processed versions of the same commodity. More than 8 500 food tolerances are listed in the Federal Code of Regulations. Approximately 8 350 of the tolerances are for raw commodities while the remainder were granted for pesticides known to concentrate in processed food [57]. The majority of tolerances are based on average population consumption statistics that were collected during the 1950s and 60s. Unfortunately the consumption statistics potentially underestimate pre-schooler consumption of some or most commodities by a wide margin. To help correct for this deficiency EPA created the Dietary Risk Evaluation System (DRES) which the agency uses to estimate dietary exposures to numerous subgroups, including infants and young children.

Tolerances have been set to reflect the highest residue concentrations likely under normal agricultural practices. Thus, some have argued that tolerances are based on good agricultural practices rather than on health considerations [57]. Others argue that pesticide residues seldom achieve the legal limits since each pesticide is applied to less than 100 per cent of the acreage devoted to a particular crop and the amount of each pesticide applied is frequently below the maximum allowable quantity. As a result residues in most cases are less than half the tolerance levels.

Registrants submit a petition to EPA requesting that a tolerance be established for a particular pesticide and crop. The petition must include: (1) product chemistry data; (2) directions on how to use the pesticide which specifies the amount, frequency and time of application; (3) results of toxicological investigations based on animal and other biological experiments; (4) the amount of the residue remaining, (5) methods to remove the residue, and (6) a statement of the proposed tolerance level for the pesticide and all other components. EPA then performs a risk assessment based on the submitted information.

EPA evaluates the supplied information in several stages to determine whether the tolerance should be granted. First, the no-observable-effect level (NOEL) for the pesticide is determined. This is the maximum dosage at which the pesticide shows no observable effects in animals. The assessment relies on the results of a battery of tests including developmental toxicity studies in two species, a reproduction study, chronic studies in two species, and lifetime exposure studies in two species. Second, the NOEL is divided by a safety factor to determine the Reference Dose (RfD) which is the level of daily exposure which is not expected to create appreciable risks over a human lifetime. Given the uncertainty in extrapolating from animals to humans EPA uses a safety factor which is typically 100 but which can range from 100 to 2000.

The Delaney Clause

The application of the Delaney Clause gave rise to what is referred to as the Delaney Paradox since it results in different residue standards for fresh and processed commodities and can expose individuals to greater health risks. The section 408 standard, which is not subject to the Delaney Clause, permits low levels of carcinogenic pesticides if they pose only minor risk. However, since many of the residues of the known carcinogens concentrate in the processed version of the crop the Delaney Clause becomes operable. As a result the tolerance is revoked on both the fresh and processed commodities as a result of the co-ordination policy. A paradox results since a high risk pesticide that does not concentrate may be granted a tolerance while a low risk cancer causing substitute pesticide that concentrates only slightly will not be granted a tolerance.

To minimise the impact of the Delaney paradox and other aspects of the Delaney Clause EPA established a *de minimis* policy in 1988 for setting section 409 tolerances. The policy enabled the agency to issue a tolerance for a pesticide in those cases "where the human dietary risk from residues of the pesticide is at most negligible," (one in one million) [51]. EPA took the action partly in response to a recommendation made by the National Academy of Science in 1987 that the agency adopt a "negligible risk" rather than a "zero risk" standard in setting tolerances [58]. The report also recommended that all pesticide residues in food, whether marketed in raw or processed form, should be regulated on the basis of consistent standards.

Several environmental and consumer groups asked the courts to review EPA' s negligible risk interpretation since they believed that the provisions of the Delaney Clause had been violated. In 1993, in Les v. Reilly, the Ninth Circuit Court of Appeals ruled that Congress had intended to prohibit EPA from allowing the use of any food additive that is a carcinogen, regardless of the level of risk. Therefore the court held that the *de minimis* policy was unlawful. On February 22, 1993, the US Supreme Court upheld the decision [58], [59]. In response to the court decision EPA announced on July 14, 1993 its intent to revoke the tolerances for the four chemicals named in the Les v. Reilly suit. On March 30, 1994, EPA published a list of 34 active ingredients comprising 100 different chemical and crop combinations that are potentially affected by the Delaney clause [60].

Special review

In 1975, EPA promulgated internal administrative regulations referred to as the Rebuttable Presumption Against Reregistration (RPAR) process (later changed to Special Review). The lengthy hearings concerning the future status of DDT and other pesticides made it clear to EPA that it was impossible for the Agency to simultaneously conduct cancellation proceedings and collect benefit-cost information on forty or fifty potentially problem pesticides. EPA devised RPAR as a way to identify those pesticides that posed a "substantial question of safety" [51]. Under the regulations EPA issued a notice to pesticide registrants if it believed that the continued use of a pesticide posed unreasonable adverse effects to humans or the environment. A Special Review may be conducted if EPA determines that a pesticide may (1) pose a risk of serious acute injury to humans, (2) pose a risk of inducing in humans a toxic effect, (3) result in residues in the environment in non-target organisms at toxic levels. (4) endanger the continued existence of species, (5) result in the destruction of a critical habitat, (6) otherwise pose a risk to humans or to the environment [51].

Between 1975-89 EPA completed Special Reviews of thirty-seven pesticide products [62]. Of the thirty-two pesticides which were reviewed between 1975-85 all uses were cancelled for five active ingredients. For the remaining 26 pesticides some uses were either cancelled or restrictions were imposed [52]. Nineteen of the pesticides that have completed the Special Review process cause cancer in laboratory animals and were used on 245 separate pesticide/crop combinations. As a result of the Special Review process 39 per cent of the 245 uses were cancelled, 4 per cent were suspended for lack of data, 5 per cent were allowed to be used without restrictions, and 52 per cent were allowed to be used with restrictions [62].

The registrant could contest the Special Review by showing either that the benefits of the pesticide outweighed the risks, EPA erred in its risk determination, or that the risk could be reduced or eliminated.

Recent Special Review actions by EPA include:

Inorganic arsenicals. All registered uses (other than as wood preservatives and sealed ant baits) were voluntarily cancelled as a result of the special review.

EBDCs. EPA completed a special review for a group of fungicides known as the EBDCs in 1992 by cancelling a number of uses and placing restrictions on the remaining uses.

Carbofuran. EPA began phasing out most uses of granular carbofuran in 1991 because of risk of bird poisoning. In 1994, EPA granted an extension of uses for two years for rice due to the lack of development of alternatives for rice water weevil control.

Cyanazine. EPA terminated its special review of cyanazine based on voluntary actions of the manufacturers to first reduce cyanazine usage and then cancel all cyanazine registrations after December 31, 1999.

Atrazine/Simazine. EPA initiated special reviews of the herbicides atrazine and simazine in 1994 because of concerns regarding cancer and because of their detection in ground water and surface water drinking water supplies. EPA received 80 000 letters sent during the public comment period and an initial submission of 14 000 pages of research data from the registrant [119]. EPA is expected to make a preliminary decision on the atrazine special review in late 1996.

In recent years, EPA has relied on negotiated settlements with registrants to phase out use of chemicals of concern in lieu of using the formal special review process.

Mevinphos. In response to planned actions by EPA and the State of California to remove mevinphos from the market, the registrant requested that its registrations be cancelled. The registrant also agreed to a voluntary recall of all product still in the channels of trade after sale and distribution of product was no longer allowed. The cancellation was based on EPA's determination that the risks to agricultural workers were unacceptable.

PCNB. Registrants agreed to lower levels of two carcinogenic contaminants, HCB and PCB, in their products, bringing dietary risk down to the negligible level.

Simazine. Twenty-two registrations of simazine used as an algicide in swimming pools were voluntarily cancelled after EPA approached registrants about unacceptable cancer risk to swimmers. EPA subsequently cancelled remaining swimming pool simazine products when their registrants declined to join the voluntary cancellation.

Propargite. The sole registrant of propargite products in the US voluntarily cancelled US registrations for apricots, apples, pears, peas, plums, strawberries, cranberries and figs. Cancellation was based on new cancer studies that detected a potential dietary risk and a cumulative lifetime exposure. Propargite use is being retained for some crops including grapes, nectarines and citrus.

Registration of new products

EPA is responsible under FIFRA for registering new pesticides and ensuring that when used according to label directions they will not cause unreasonable adverse effects to human health or the environment. Depending upon the type of pesticide, EPA can require more than 100 different kinds of specific tests.

Table 4.
1994 Registration activities

Registration Activity	**Description of Activity**	**Number of Decisions**
Registration of new pesticides	First approval for use of pesticides not currently registered in the United States	31
Additional registrations for registered pesticides	Registrations for new products containing pesticide ingredients already approved for proposed uses	782
Amendments to existing registrations	Amendments, for example, to reflect revised labels and changed formulations for products already registered	3233
New uses for previously registered pesticides	Approvals for uses of a pesticide (such as on particular food crops) for which it has never been registered	56
Emergency exemptions (Section 18s)	Decisions on granting emergency exemptions to states or other federal agencies to allow use for a limited period of pesticides not registered for those particular uses.	265
Experimental Use Permits (EUPs)	Decisions on permits that allow pesticide producers to test new pesticide uses outside of the laboratory; generally required if more than 10 acres are to be tested	104
Tolerances	Decisions on approving tolerances, or maximum allowable levels of a pesticide in food or animal feed. Tolerances (or exemptions from tolerances) are required whenever a pesticide is registered for use on a food or feed crop	70
Temporary tolerances	Decisions on approving tolerances for experimental purposes for an unregistered pesticide	26
Special Local Need Registrations (Section 24(c)s)	Registrations of pesticide products by state agencies for specific uses not federally registered. (The pesticides must be federally registered for other uses.)	411

Source: [67]

EPA registered 31 new pesticide active ingredients in fiscal year 1994, more than half of which are considered to be reduced risk pesticides. Reflecting the trend of recent years, a high proportion of new ingredients--15, or nearly half--were biological pesticides. Biological pesticides include "microbial pesticides," which are bacteria, viruses, or other micro-organisms used to control pests, and "biochemical pesticides," which include pheromones (insect sex attractants), insect or plant growth regulators, and hormones used as pesticides. EPA considers that biological pesticides generally pose less risk to health and the environment than chemical pesticides, and imposes fewer requirements on their registration [67].

During fiscal year 1994, EPA implemented its voluntary Reduced-Risk Pesticide Initiative. EPA invites applicants seeking to register new pesticide active ingredients to provide information on how their pesticide presents opportunities for risk reduction. If EPA believes that the pesticide demonstrates such potential, EPA accelerates the registration process for the pesticide [67].

In March 1994, EPA registered the first pesticide under this initiative. Hexaflumuron, has the potential to replace much larger amounts of the termiticide chemicals traditionally used. This product is used with a monitoring system so that the chemical is applied only after a termite problem has been identified [67].

Registering new pesticides for the first time is only one of a large number of pesticide registration actions that EPA carries out each year. The decisions made in 1994 are summarised in Table 4. Both approvals and denials of the requests received by EPA are included in the number of decisions [67].New products are vitally important for the US agrichemical industry since most currently used active ingredients will be going off patent in the next few years. Companies will face increased competition from generic producers, who are likely to sell at a lower price. Thus, there is an expectation of lower overall revenues from currently registered products. New products covered by patent protection become necessary to maintain overall company revenues. In the past several years, chemical registrants have increased significantly their submissions to EPA for the registration of new active ingredients. Recently, EPA has requested that registrants provide a priority list for their new products because of the significant increase in submissions. Part of the reason for the increase is the completion of regulatory studies required for the reregistration of existing products.

The US agrichemical industry is intensely competitive. New products are described in terms of replacing market share for currently-used products. Thus, new products are described typically in terms of improved performance of control of key pests. Additional factors that are important in the acceptance of new products are price, crop safety, soil carryover, and safety to applicators.

EPA has announced a “safer” pesticide policy. If registrants can support their claims that their new products are “safer” than currently-used active ingredients, EPA will accelerate the registration process for the new compound. The safer policy claims of a potential registrant are scrutinised and critiqued by the registrants of currently-used products.

Many of the new products are traditional active ingredients based on chemical synthesis of new molecules. In addition, companies operating in the US pesticide market increasingly are securing rights to chemical active ingredients from Japanese agrichemical companies -- most of which do not have a direct presence in the US market.

Some of the new products are based on fermentation processes. Merck produces the insecticide abamectin through a fermentation process. Abamectin is a naturally-derived insecticide miticide that is a mixture of natural products produced by a soil micro-organism. Abamectin is a relatively expensive product ($5 300./lb.) [88]. At a use rate of .01 lb. AI/A, it has proven to be the active ingredient of choice for pests (such as leafminers and mites) that are extremely hard to control with current alternatives. Abamectin usage is highest in Florida celery (90 per cent of acreage treated), California strawberries (80 per cent of acreage treated), and California cotton (58 per cent of acreage treated) [3], [1].

DowElanco has applied to EPA for registration of a biopesticide, Naturalyte (spinosad), a fermentation product derived from a soil-borne bacteria for insect control in cotton, apples, vegetables, corn, potatoes, and tomatoes. Naturalyte is effective in controlling lepidopteran pests including tobacco budworm, cotton bollworm and Colorado Potato Beetle [89].

1996 Food Safety Legislation

On August 3, 1996, the President signed into law the Food Quality Protection Act which had been unanimously passed in the House of Representatives and US Senate. This reform bill's major points include:

- The Delaney Clause is replaced with a new uniform health standard for both processed and raw foods: "reasonable certainty of no harm from pesticides." This standard would allow the use of pesticides that are calculated to result in no more than one additional cancer per million people if consumed at average levels over the course of a 72-year lifetime.

- EPA is to apply a ten-fold additional margin of safety when assessing risks to children and infants during tolerance evaluations.

- Aggregate exposure from dietary and non-occupational sources have now to be considered by the EPA when assessing the risks of a chemical and setting tolerances.

- Aggregate exposure from dietary and non-occupational sources have now to be considered by the EPA when assessing the risks of a chemical and setting tolerances.

- Incentives are provided for minor use registrations including accelerated registration schedules and time extensions or waivers for data needed for reregistration.

- National uniformity of pesticide tolerances mean states and localities will be limited in setting their own tolerances. However, states will be able to petition the federal government to set a different standard if "a compelling health need exists."

- If a pesticide poses a greater risk than allowed, EPA is allowed to consider benefits of using the pesticide. However, the benefits must outweigh the risks to consumers either in terms of risk-risk trade-offs or in terms of the potential for significant disruption to an adequate wholesome economical domestic food supply.

- EPA is authorised to speed up registrations of new pesticides deemed to be safer and more friendly to the environment, particularly microbial pesticides.

- The EPA will be able to collect $76 million in fees from the chemical industry to pay for re-registering pesticides.

- The law requires EPA to distribute to large retail grocers publications outlining the risks and benefits of pesticides, recommendations on how consumers can reduce pesticide residues and actions taken by EPA to issue tolerances under which benefits have been considered.

Pesticide risk assessments

Multiple risk concerns surround the use of pesticides in US crop production--environmental, food safety, farmworker safety, etc. The concern about risks of pesticides is not new. In 1900, the English government banned imports of apples from the US after an outbreak of poisoning occurred due to arsenic residues. The British government established the first tolerance of 1.4 ppm of arsenic on apples imported from the US, US apple growers devised methods to wash the visible arsenic residues off apples. When synthetic chemicals were first introduced, the FDA did not initially raise concerns regarding the use of DDT on foodstuffs. DDT was considered to be considerably less toxic than arsenic and was used in significantly lower amounts [118].

New concerns regarding risks of pesticides have regularly occurred. Scientists had presumed that the soil would hold and detoxify chemical pesticides travelling through the soil before they reach ground water. However research carried out in the 1980s to fulfil reregistration requirements proved this incorrect [98].

Many of the initial concerns with synthetic chemicals arose after publication of *Silent Spring* in 1962. This book raised concerns regarding threats of pesticide residues to wildlife. At the first “Earth Day” in 1970, one of the concerns was the threat of pesticides to wildlife in the food chain produced by the presence of persistent chemicals in water bodies. These concerns lead to the establishment of the US EPA and the transfer of pesticide registration responsibilities from USDA to EPA. Environmental concerns are still an important component of regulatory activities.

- Granular carbofuron was recently banned from further use in the US due to the possibility of birds ingesting the granules.

- The use of azinphos methyl for control of sugarcane insects in Louisiana is being scrutinised by EPA due to a large number of fish kills linked to run-off of the insecticide.

- EPA has proposed that states be required to develop management plans to protect groundwater from pesticide contamination. The sale and use of pesticides which pose significant groundwater concerns would be allowed only in states with EPA approved plans.

- The USGS has documented pesticide contamination of the nation’s surface waters. Concerns have been raised regarding the safety of water supplies drawn from surface water during periods of high pesticide concentrations and run-off.

There are a multiplicity of other types of risk issues raised by pesticide use and many regulatory programmes have arisen to address them:

- EPA recently promulgated a set of regulation for the protection of workers who apply pesticides.

- EPA is developing rules to protect endangered species from pesticides. This programme is based on the requirement that no federal action can threaten the habitat of an endangered species. If the federally-approved use of a pesticide poses such a threat, the use must be cancelled.

- Recently the EPA announced plans to phase out the soil fumigant, methyl bromide, from use in the US since some of the volatile chemical escapes into the atmosphere and has been linked to ozone damage.

- EPA is examining the presence of pesticides in air and designing programmes to measure and set allowable concentration levels. The state of California suspended the use of the fumigant, 1, 3-D, after unusually high concentrations of the fumigant had been found in fog.

As techniques for measuring chemicals in the environment have advanced, concerns regarding risks have changed. The introduction of new low-rate herbicides (applied at .01 lb/ai/a) have raised new concerns regarding measurements. Initially, registered in the mid 1980s, these new herbicides were not detected in groundwater. However, as measuring techniques were improved, the compounds have been found in groundwater at trace levels. Now, in order to register a new compound, a registrant must provide a proven method to detect the compound in groundwater. Much concern has been raised regarding the potential damage that low-rate herbicides may be causing as airborne drift to susceptible crops. For example, in the Northwest US, cherry growers have claimed that airborne drift of herbicides from wheat fields have damaged their tree crops [64].

Part of the problem with resolving these claims is that the concentrations causing damage may be below the level of detection using current methods [64]. But measuring techniques will continue to be improved. Recently scientists have been able to distinguish pesticide active ingredients at the fentogram level--significantly greater than any other method to date [63].

Some policy makers believe that the methodologies used to estimate risk grossly underestimate the true level of risk posed by pesticides. They believe that there is no defensible basis on which to establish “safe tolerance levels” and that the only unarguably safe level is zero-risk [69]. Others believe that the level of risk is grossly overstated since exposure is generally much lower than allowed by law. The divergence in the two viewpoints is largely due to the shortcomings in the risk assessment process. Current risk assessment techniques are imprecise due to: (1) gaps in the toxicological data, (2) an inability to directly translate the impacts of pesticides on animals to humans, (3) insufficient attention given to special high risk groups such as children, (4) inexact methods to compare risk at high and low levels of exposure, and (5) a lack of hard data on chemical exposure from multiple sources [55].

Policy makers who believe that risk is understated have cited a number of reasons to support their viewpoint. First, they believe that synergism, additivity, potentiation, and other possible joint effects of carcinogens are not given adequate consideration. In a single meal a person easily can consume up to ten pesticide residues [55]. Although synergistic effects of acute toxicants have been documented in animals few if any studies have attempted to determine whether these effects contribute to cancer. In addition animal studies are usually conducted on adults rather than on new-borns which tend to be more sensitive to certain pesticides. EPA sets tolerances by using a chemical by chemical, crop by crop, risk by risk approach and makes no effort to calculate the aggregate human health risks [55]. Second, although risk assessments usually include an uncertainty factor of ten to compensate for data limitations it may be insufficient to protect certain subgroups such as children who are particularly susceptible to certain carcinogens. Third, since children and other cultural and/or religious groups tend to eat large amounts of certain foods they are disproportionately exposed to high risks associated with certain pesticide residues [70].

Fourth, EPA uses a time independent model to estimate the lifetime risk of developing cancer which assumes that the risk from a given exposure is the same at all ages. However, since high levels of exposure may occur during childhood and take decades to manifest itself in the form of cancer, the methodology may substantially underestimate the lifetime cancer risk faced by children [57].

Proponents of the theory that risks are overstated advance a number of reasons to support their position. First, the methods currently used to calculate risks extrapolate from highly uncertain tests on animals, which are exposed to high doses, to humans who are exposed to much lower doses. Second, the tests may be highly inaccurate since the biology or biochemistry of humans can be very different from laboratory animals. Third, with the exception of cancer associated with smoking, overall human cancer rates in the US have not changed significantly over the past 50 years [53]. Rarely, if ever, do scientists have reliable human data with which to evaluate the carcinogenic risk of pesticides. This is because it would be necessary to detect small increases in cancer in a population where one in four people die of cancer from all causes. Thus, if 250 000 people out of a population of one million die from cancer, and the number increased to 250 010 with pesticide exposure, the small increase resulting from pesticides would only be detectable if the pesticides caused an unusual form of cancer [69]. Fourth, since the methods used to determine risk intentionally overstate risk, any subpopulations or highly exposed consumers are already factored into the risk assessment methodology. EPA always uses the worst case scenarios when collecting residue chemistry, toxicology, and consumption data. Tolerances are set to accommodate the maximum amount of pesticide use [71].

Fifth, risk assessment models assume that there is a linear relationship between the level of exposure and the incidence of cancer -- referred to as the “non-threshold” assumption. Proponents of the theory that risk is overstated believe that it is more reasonable to use a “threshold mechanism” which assumes that exposure up to a certain level has no impact [70]. Sixth, EPA measures the risk of a pesticide as the incremental lifetime cancer risk associated with the pesticide as though the alternative to using the pesticide were riskless. In fact, individual risk is correctly computed as the difference between the lifetime cancer risk associated with the pesticide and the alternative [62].

Seventh, Bruce Ames has estimated that the risk of cancer posed by pesticide residues is 10 000 times less than that from natural toxins contained within plants. Natural pesticides are present in all plants and make-up between five and ten per cent of a plant’s dry weight. Although only a small number of the natural toxins have been tested in animal studies some have been shown to be carcinogens. Eighth, food also contains other hazards that are not related to pesticides -- including microbiological hazards which may be the causative agent of diseases, and heavy metals such as lead which is particularly toxic to children [69].

In recent years there has been growing concern that children are at much greater risk from pesticide exposure than adults. The NAS report, *Pesticides in the Diets of Infant and Children,* indicated that children consume some foods in large amounts relative to their body weight, and unlike adults may be at risk of experiencing developmental effects from pesticide residues [57]. Children ages one through five ingest approximately six times more fruit, five times as much milk, three and one-half times as many grain products, and approximately twice as much meat and vegetables per body weight as adult women ages 22-30. EPA estimated in 1989 that the average US daily dietary exposure of infants less than one year of age to unsymmetrical dimethylhydrazine (UDMH) is 17 times greater than average adult exposure [69]. Many bodily functions are at an early stage of development and are particularly sensitive to the impacts of pesticides. Cells that are initiated by a carcinogen during childhood have a much higher probability of being promoted over the 70 or more years of expected life and advance to cancer [69].

Given the greater risk faced by children the NAS report suggested that EPA account for multiple routes of exposure to a pesticide in addition to exposure from food--such as from drinking water. The report also cited the need for better data on infant’s and children’s food consumption patterns, residue concentrations on foods most commonly eaten by infants and children, and the effects of residues on developing central nervous, immune, and reproductive systems [59]. The report also indicated that it is essential to develop toxicity testing procedures that specifically evaluate the vulnerability of infants and children. Of particular importance are tests for neurotoxicity and toxicity to the developing immune and reproductive systems. The NAS study also recommended that an additional 10-fold risk factor be applied by EPA and FDA to the NOEL whenever toxic studies and metabolic/disposition studies show fetal development effects [57].

Much of the debate concerning the health risks posed by pesticides centres on the actual residues that are found in or on both the fresh and processed forms of food crops. The trace quantities of pesticides and their metabolites that are present on or in foodstuffs are termed residues. Oftentimes the actual residue levels found on or in fresh and processed foods are one-tenth, one-one-hundredth, or one-one-thousandth or smaller than the reference dose (residue tolerance permitted at the farmgate) [70]. The results of several studies seem to indicate that food grown in the United States is generally free of significant levels of pesticide residues, although many contain trace levels at the parts per billion and lower [69]. The National Research Council in their report: *Pesticides in the Diets of Infants and Children* also found that residues are skewed toward a relatively small portion of the food supply [57].

Some of the results cited above were obtained from a study conducted several years ago which included the participation of a number of states to determine the presence and level of pesticide residues on food. Residues were found on between 19-25 per cent of the samples submitted. However, only one to two per cent of all the samples were classified as significant by the state food quality assurance agencies. Furthermore the data were derived from analyses of raw, unwashed and unprocessed fruits and vegetables. If the food had undergone normal washing which is routinely done in wholesale fruit and vegetable processing and marketing much of the external residues would have been removed [69].

In contrast some studies have indicated that residue levels are actually much higher. In particular the NRDC cited figures released by FDA which indicate that at least 38 per cent of the food supply contains pesticide residues [72]. However, the results of a study conducted by FDA which used data collected as part of the total dietary study (TDS) found quite different results than were reported by the NRDC. The results of the TDS showed that the dietary intake of pesticides is usually less than 1 per cent of the Acceptable Daily Intakes (ADI) established by the United Nations Food and Agriculture Organisation (FAO) and the World Health Organisation (WHO) [69]. This difference may be due differences in the chosen level of pesticide detection. Whereas the former studies tested for residues at the parts per million level it is possible that FDA study cited by the NRDC tested for residues at the parts billion or even trillion level. This would cause the overall percentage of crops found with residues to increase.

In the case of processed food the National Food Processors Association (NFPA) found that residues are infrequently encountered. When they are found they are present at levels lower than in the raw agricultural product. In 1988 the NFPA assembled data on raw and processed residues as part of an EPA contract. Of the 20 310 samples of processed products 93 per cent had no detectable residues. The NFPA also tested 6 580 samples of baby food during 1987 and found residues in 165 samples (2.5 per cent) distributed among a total of seven foods. The highest concentrations found were considerably lower than EPA tolerances [57].

Residues found on processed foods are lower than ton raw agricultural commodities since the latter are either washed, peeled, shelled, cooked, trimmed or are modified in some other way before they are turned into the final product [69]. A report by the Environmental Working Group, using data obtained from the USDA, concluded that washing, peeling, and coring does not remove or reduce the number of pesticides found on fresh fruits and vegetables. The distribution of residues in a product can also affect the level of pesticide residues. For example, in tomatoes malathion tends to concentrate in the peel or waste, while carbaryl is easily removed by washing and does not tend to concentrate in waste material. There are cases however, when processing can increase the residue levels of some pesticides. For example, the levels of the metabolite ETU were increased by 94.5 per cent in frozen turnip greens due to the degradation of the EBDC fungicide maneb during cooking [57].

Clearly, much uncertainty exists with regard to the multitude of risks associated with pesticides. This uncertainty has led to a variety of predictable outcomes:

- Each toxicity/risk test result is extensively scrutinised and critiqued.

- Regulatory agencies learn as they go along making regulatory decisions. The risk assessment process may be never-ending as the agencies learn about new risk factors and new ways of measuring risks. Reassessments will have to be made regarding products previously studied.

- Regulatory agencies have considerable flexibility in choosing regulatory outcomes. Because numerous assumptions and test interpretations/extrapolations underlie the calculation of aggregate risk, regulatory agencies can select that set of assumptions which produces an agreed upon policy outcome.

- Philosophical differences are an important part of the debate regarding risk. Some question the appropriateness of using a 1 000-fold safety factor. Why not 100? Why not 1 000 000? Why accept any risk?

- There are new tests and risks yet to come. Risks to children were the focus of the new risk debate for the past several years. The most recent set of risk concerns raised by critics involved chemicals that act as hormone disrupters and chemicals that have been linked to breast cancer. Many unassessed issues remain with regard to EPA's assessments of neurotoxicity and mutagenecity risks.

- Risk-Risk trade-offs are involved in all EPA pesticide decisions. EPA usually proceeds one chemical at a time. However, restricting or banning a single chemical will usually result in a replacement chemical being used. Often, the replacement chemical poses some risks of its own. EPA has begun a process of assessing all chemicals registered for the same purpose. For example, EPA is conducting a corn insecticide "cluster" analysis that will allow EPA to assess relative aggregate risks of all corn insecticides as part of its rule-making.

The ongoing risk analysis with regard to pesticides occurs against a backdrop of numerous scientific studies that conclude that the risk of synthetic chemicals in food and water pose an insignificant threat to the population's health [104]. The reason that analysis of pesticide risks continues is due to congressional requirements and due to a very high level of concern in the general population regarding these risks. Numerous public opinion polls indicate that a majority of Americans are concerned about the risk of chemicals in their food [105]. As a result of these conflicting circumstances, regulatory agencies have enunciated policies to "reduce risk" and promote the use of "safer" pesticides.

EPA's policy has been to negotiate settlements in which registrants agree to lower allowable usage rates and agree to drop certain uses from the labels. As a result of such actions, EPA and the industry can claim that the agreement mitigates any unacceptable risk to acceptable levels. Such negotiated settlements are important to the regulatory agencies because they assure the public and Congress that progress is being made. In addition, EPA seeks agreement from registrants in order to avoid lengthy and costly litigation.

Pesticide benefit assessments

EPA is required under FIFRA to weigh the risks and benefits of pesticides use as affected by regulatory actions. This risk-benefit weighing requirement is very different than most other environmental statutes which are entirely risk driven (such as the Clean Air Act). Some critics have argued that FIFRA should be changed to eliminate the benefits calculations [121]. Critics argue that the benefits are to farmers who achieve higher yields and the risks are to consumers who ingest pesticide residues.

Part of problem with pesticide benefits estimation is the lack of models and data bases necessary to rigorously estimate the potential economic effects of regulatory actions. There are only crude models that allow estimation of price effects and industry adjustments that would occur if fruit and vegetable growers were to lose a key pesticide and incur higher costs.

EPA has typically defined a pesticide's benefits in terms of the lost yields and increased costs that would occur if the pesticide were no longer available and growers used likely replacements. The method of identifying replacements and determining the yield effects is straight forward and has not changed for 20 years: an analyst contacts expert extension service specialists (weed scientists, plant pathologists, entomologists) and asks the question: "What would happen to yields and what would the replacements be if pesticide X were to be cancelled?" The expert identifies the likely replacements and provides a numerical estimate of the likely yield effects. These estimates are based on the expert's experience, research studies and farmers experience.

EPA has criticised the benefits methodology as largely a "black box" for which the underlying calculations and assumptions are not made clear and are not replicable or easily changed. In the recent cyanazine Special Review assessment, EPA criticised replacement scenarios that failed to account for the introduction of new products and failed to delineate specifically how non-chemical alternatives were included in the calculations [42].

There has never been a case in which EPA has officially announced that a pesticide posed greater than negligible risks but was not being cancelled because its benefits outweighed those risks. In all regulatory cases, EPA has announced that as a result of the regulatory decision that risks are at acceptable levels -- usually as a result of cancelling certain uses of the compound. Thus, benefit analysis is used by EPA to design cost effective rule making to achieve a risk standard. EPA sets an allowable amount of total ingestion of the residues of the compound. If the registered uses lead to an exceedence of the allowable amount, then EPA looks for uses that can be cancelled with the least economic hardship. EPA will cancel the uses for which there are effective alternatives and maintain registrations on those sites where effective alternatives don't exist. A statistical analysis of EPA decision making showed that the single factor that most clearly explained changes in EPA proposals with regard to cancellation from the initial announcement to the final decision was the estimate of potential economic costs. [62] In those cases for which the economic costs were highest, EPA was more likely to back away from the initial cancellation proposal.

EPA is required, as are all federal agencies, to prepare a cost analysis of its proposed regulatory actions. Thus, even in cases for which EPA does not consider benefits in its rule-making, it is required to estimate the lost benefits that would occur as a result of its regulatory action. For example, in announcing its Delaney implementation policy, (which was a strict technical requirement with no consideration of benefits in the rule-making), EPA estimated the regulatory costs at $500 000 000 a year in lost benefits. EPA has made similar estimates for ground water protection programmes and the potential cancellation of methyl bromide. Very large regulatory cost estimates typically result in questions regarding the magnitude of benefits to society that would result from the regulation. EPA does not quantify the societal benefits of pesticide regulation in terms of dollars.

An important consideration of benefit analysis is the regional impact of EPA decision making. A pesticide may be important to growers of a crop only in certain regions of the country. US growers are very competitive with one another. If production costs go up in any region because of a lost pesticide registration, growers of the same crop in other regions benefit. The question of the regional importance of pesticides was important in the recent congressional debate regarding food safety legislation.

A related benefit issue concerns retrospective analysis of prior EPA bans of chemicals. Critics have claimed that prior bans have not led to economic problems that were forecast at the time [48]. Thus the critics suggest that current lost benefit or regulatory cost estimates should be ignored as overstatements. While it is correct to say, in the aggregate, that US crop production continues unabated, even with prior EPA bans, it is not correct to assume that negative economic effects did not occur as predicted. Growers have paid more for alternatives and have suffered yield loss as predicted:

- Washington potato growers suffered a loss of $36 million due to the suspension of aldicarb, that resulted in diminished control of the green peach aphid [56].

- In Michigan tart cherry orchards, the most effective fungicide for cherry leafspot control was captafol, that was withdrawn from use after 1987. In 1989, severe defoliation occurred because of leafspot. The alternatives to captafol were used. As predicted, cherry production declined in the following year, 1990, albeit by 12 per cent. The reduced supply of tart cherries led to a price increase in 1990 of 20 per cent.

- In 1990, the state of California suspended the use of 1,3-D, a soil fumigant that had been used widely to control nematodes in sugarbeets, carrots, broccoli and other crops. Growers spent $25 million more to purchase more expensive alternatives that did not work as well. In addition, there was a crop loss equal to $75 million because of increased damage from nematodes.

More serious economic effects have been avoided because EPA has acted responsibly in registering new active ingredients to replace the ones it banned. Another type of benefit study has been fuel for much debate in the US Several studies have been conducted that estimate the lost yields if all pesticides were banned for fruits, vegetables and field crops [33] [49]. These studies have been criticised for having no relationship to public policy [54]. However, the studies have indicated the overall value of pesticides to current US farming operations.

EPA has found it necessary to restore certain uses of pesticides because lost benefits were great and alternatives were ineffective. These restorations include aldicarb for potatoes in the Northwest and propazine for sorghum in Texas. The State of California restored the use of 1,3-D in California following large documented crop losses. Of course, these restorations were all based on the acceptance of studies and mitigation measures that indicated that risks were within acceptable limits.

Public involvement

Until recently, negotiations regarding pesticide product label changes -- including the deletion of uses -- were conducted almost exclusively between USEPA and the chemical registrants. Grower organisations were often informed after EPA and the registrant had concluded negotiations to terminate the registration of a key pesticide.

In recent years, EPA has taken the initiative in encouraging commodity and farm groups to be more involved in the regulatory process. This involvement serves to avoid unpleasant surprises after decisions are made and also serves as an additional means for the collection of needed risk-benefit data. For example, EPA has encouraged state farm organisations to survey their members regarding the application of corn herbicides. Several of these surveys have proven very useful to EPA in its atrazine Special Review analyses. EPA has a formalised programme for commodity organisations that want to become "Partners" with the agency in reducing risks of pesticides. A number of commodity organisations have issued joint statements with EPA describing pesticide risk mitigation measures already in place and describing research and education efforts designed to further minimise risk. EPA has used these organisations to help identify research needs in crop pest management and has made grant moneys available for research projects. Commodity organisations have also initiated study tours for EPA regulatory personnel to visit their regions.

Environmental advocacy organisations can play a key role in EPA decision making. Generally, environmental organisations do not make major submissions to the Agency as part of its regulatory process. However, EPA has a set of provisions to keep public advocacy groups informed as decision-making proceeds. Environmental organisations are most likely to get involved as critics of EPA decision-making through the media, meetings with administrators and congressional contacts. If not satisfied with EPA decision making, environmental groups have used the threat of media exposure to compel EPA to change or accelerate decisions. The most famous case of media pressure on EPA was the Natural Resources Defense Council's campaign and CBS's "Sixty Minutes" programme about Alar use in apples which eventually led to the voluntary withdrawal of the product. More recently, the threat of media exposure regarding the presence of propargite residues in foods led the Agency to quickly conclude negotiations with the registrant. Instead of working with the registrant and commodity groups on risk mitigations measures for the product, the Agency simply asked for the registrant to drop the registrations in order to avoid a public relations battle. [65]

IV. Agricultural Policy

Crop subsidy programmes and pesticide use

Traditionally, US commodity programmes provided price and income support for US farmers. For feedgrains, a combination of loan rates and target prices raised the effective market price a participant in the programme expects to receive. To limit the accumulation of surpluses, deficiency payments were made contingent on setting aside a percentage of the programme's base acres. A contentious issue has been how government farm programmes affect pesticide use [97], [45]. Around 1970, several researchers argued that the combination of price supports and acreage diversions encouraged farmers to substitute pesticides and fertilisers for land [117], [43]. In addition, some programme payments were made for high pesticide use crops (such as corn) and not for low pesticide use crops such as alfalfa. In addition, farmers were required to plant a certain percentage of their crop acreage to the same crop, typically corn, year after year. Critics suggested that such monoculture eliminated the possibility of rotational planting with the added benefit of breaking pest cycles and allowing for reduced pesticide use.

Several incremental changes were made to farm programmes. In 1985, base corn yields for subsidy programmes were frozen at 1985 levels, meaning that corn farmers have been responding largely to world-wide price of corn, not USDA's target price. The 1990 Farm Bill eliminated deficiency payments on 15 per cent of participating crop base acres regardless of the crop planted on those acres.

Recent research indicated that corn growers who participated in USDA's feed grain programmes applied about five per cent more herbicides per acre than non-participants [44]. This usage increase may be linked to set aside acreage requirements which have averaged about five to seven per cent. Thus, the total use of chemicals by corn farmers in the feed grain programme may not have been that much different than if they were not in the programme. [44] It has also been noted that a non-programme crop, soybeans, uses just about the same amount of herbicides as does a programme crop, corn.

The 1996 Farm Bill marks a radical departure from the past. Under so-called Freedom to Farm provisions, feed grain growers will receive a payment that is fixed in advance by a contract with the federal government. Farmers can grow anything they want (except fruits and vegetables), graze or hay the land, or do nothing but control the weeds and still receive the payment. Participants must remain in conservation compliance. These provisions are likely to make net income more volatile. Growers are likely to respond by trying to lock in a price for their crop early in a season. The 1996 Farm Bill also makes intermediate reforms in the cotton and rice programmes. They too will get flat Freedom to Farm payments and can switch to growing other crops or grow nothing without penalty. But they also retain a government price guaranty. There is no reason to believe that ending the peanut programme quotas would lead to a shift in production.

Integrated pest management programmes

In the 1960's, entomologists began advocating the use of pest management practices that minimised the repeated use of one chemical for control [98]. The title of "Integrated Pest Management" (IPM) was given to pest control systems that used all suitable tactics (cultural, biological and chemical) to anticipate and prevent pests from reaching damaging levels [98]. The use of two or more IPM Arctics for suppression of pest problems was defined as a pest management system. During the 1970's, IPM programmes were established under a Consortium funded by Congress and operated jointly by the USDA and the EPA, that led to some important changes for alfalfa, apples, cotton and soybean pest management [98]. A 1985 survey of crop protection scientists in 14 states provided estimates of the percentage of crops grown under IPM. These -- subjective -- estimates are shown in Table 5. As can be seen, a high proportion of acres of cotton, soybeans, apples and alfalfa were defined to be grown in IPM systems in the mid-1980's.

The IPM Consortium lost its funding to a reduced programme operated by USDA in 1980. State funding of IPM programmes also decreased. As a result, some of the area-wide techniques on which farmers had relied to time their sprays were disbanded. Michigan's reduced funding for a central computer based IPM system to assist apple growers in timing of sprays led to an increase in insecticide spraying [100].

Table 5.
Estimates of percentage of crops grown in various States under IPM (1985)

State	Crop	Per cent IPM
Arkansas	Cotton	90
	Soybean	100
California	Alfalfa	45
Illinois	Soybean	80
Kentucky	Alfalfa	60
	Soybean	30
Louisiana	Cotton	85
	Soybean	100
Michigan	Apple	42
Mississippi	Cotton	85
	Soybean	30
North Carolina	Apple	25
	Cotton	97
	Soybean	20
Oregon	Apple	59
New York	Alfalfa	75
	Apple	50
Pennsylvania	Apple	90
Texas	Cotton	95
Washington	Apple	70
Wisconsin	Alfalfa	50
	Soybean	67

Recently, the federal government has increased its commitment to IPM funding from $18 million in 1995 to $36 million in 1996. The federal government has an announced goal of having 75 per cent of US cropland under IPM systems by the year 2000. USDA's Economic Research Service is currently collecting data to assess the economics of IPM adoption. Such measurements are based on the mix of pest control methods that are defined to characterise an IPM grower, and the sophistication of the survey. In Texas, a recent survey of 1533 cotton growers determined that 64 per cent of the growers farming 68 per cent of the cotton in the state are IPM producers in that they use 70 per cent of the IPM techniques available [101]. An in-depth survey of pest management practices by New York apple growers revealed some of the nuances that escape simple questions of "yes-no" adoption. For example, although 86 per cent of the survey respondents said they used economic thresholds, only 17 per cent said that the way they use them is to wait for the threshold to spray [102]. Others are more likely to "keep them in mind."

Critics argue that the most widely used IPM strategies stress improved pesticide usage based on monitoring pest populations and setting economic thresholds. [103]. Many scientists have noted that IPM strategies normally depend on pesticides as the primary management tool and have highlighted the need to develop systems that depend primarily on biological control organisms, resistant plants, cultural controls and other ecologically based tactics [103]. IPM programmes also have been criticised for overemphasising insect management with considerably less programme development for disease and weed control.

Increasing support from growers and industry as well as increased Congressional funding has, however, been received in recent years by the biologically-based area-wide programmes of the United States Department of Agriculture

IPM success stories are based often on a quantified reduction in pesticide use. A typical example is to describe how growers used to apply pesticides on a fixed schedule, but as a result of the use of scouting and economic thresholds were able to reduce their sprays without increased pest damage. For the farmers, part of the reason such techniques are worth adopting is that they reduce costs with no increased yield loss or pest damage. Often, pest control and yields improve with IPM techniques because pesticide sprays are timed better. Some typical examples of IPM success stories are:

- After three years of research, an egg sampling method was developed for tomato fruitworm in California. Results showed reduced pesticide applications and net positive benefit of $7 per acre.

- In the Pacific Northwest, beneficial mite species have been relied on to control plant damaging mites. By using pesticides that do not kill the beneficial mites, growers have reduced the use of miticides to about 10 per cent of what it once was.

- In Pennsylvania, it is estimated that relying on beneficial mites for controlling harmful mites resulted in a decline of 1.4 million pounds of miticides being applied to the state's orchards over the past 20 years [106].

But IPM programmes can create drawbacks, too. Since many IPM programmes require a particular type of pesticide, one that kills harmful species without damaging beneficial species, the loss of the selective pesticide often means that the IPM programme is disrupted.

Another reality of IPM techniques is that widespread adoption of pest scouting and use of economic thresholds may increase pesticide use significantly for some crops and in some years. Not all crops are being "oversprayed"; some are being "undersprayed" from the standpoint of economic thresholds and pest damage.

Pest eradication programmes

One pest control strategy recommended by some agricultural scientists is the eradication of troublesome pest species. Eradication of a key species would make it possible to discontinue the use of pesticides for its control. If pest species are eradicated at a very early stage of infestation, the initial need to apply pesticides may be avoided. Generally, pest eradication programmes rely on the use of insecticides. In the case of a well-established pest, insecticide sprays are increased for a number of years to accomplish the eradication. In the case of new or exotic pest, insecticide sprays are targeted to areas where single flies have been found. Eradication programmes rely on continuous widespread pest monitoring to make sure reinfestations haven't occurred. If reinfestations have occurred, insecticide sprays are begun again.

The most prominent recent example of an area-wide eradication programme of a key major well-established pest is USDA's boll weevil eradication programme. The boll weevil has been the major insect pest in US cotton for a century. Growers have tried to control them by almost every means imaginable. Prior to the advent of insecticides, growers burned forests adjacent to cotton fields in an effort to destroy boll weevil winter habitat. Even with the use of insecticides, growers have had to spray 10-12 times per year to control continual infestations. Not only is this costly and time-consuming, but it also seriously damages the populations of beneficial insects that are needed to control other pests. In an effort to break this cycle, growers in several states agreed to a programme to eradicate the boll weevil population. The result, it was hoped, would be a long-term reduction in the number of sprays needed to control the boll weevil. Also, as a result of this reduction in sprays, growers hoped to be able to institute more IPM programmes, by taking advantage of increased predator or beneficial insect populations. Six states have participated in the programme thus far (Arizona, California, Florida, Georgia, North Carolina and South Carolina). The programme is ongoing in two states and is being voted on by growers in five states.

In the states participating in the programme, insecticide sprays were increased for approximately three years. Typically, 10-12 insecticide sprays for boll weevil were made each year before eradication [74]. To eliminate the pest, sprays were increased to 15-20 sprays per year for the duration of the programme. Insecticides were sprayed on winter habitat areas adjacent to cotton fields. Once the programme was completed, sprays were reduced to four to five sprays per year [74]. This reduction not only reflects the result of eliminating the boll weevil, but it also shows the impact of reduced sprays for other pests because of conservation of natural enemies. The federal government has supplied about $10 million annually in funding for the boll weevil eradication programme [75]. Much of the federal spending has gone to purchase insecticides for increased spraying.

Some negative consequences of the ongoing eradication programme in Texas has resulted in a re-examination of the programme. In Texas, increased spraying to eradicate the boll weevil has been linked to outbreaks of the beet armyworm--following the destruction of beneficial insects that usually help keep their populations in check. The beet armyworm outbreaks were sufficient to reduce East Texas cotton yields by $140 million in 1995 [68].

Pesticide usage data indicate that a large share of Texas cotton acreage is not treated with insecticides (40 per cent) in contrast to the use of insecticides on essentially 100 per cent of cotton acreage in most other states [1]. Half of Texas cotton acreage is in the High Plains region. The High Plains have been kept largely free from damaging insects such as the boll weevil for 30 years through a programme that monitors the annual westward movement of insects across the state. When the insects reach the border area of the High Plains, insecticide sprays are used to stop their westward migration [79].

Eradication programmes are usually designed to keep new pests from entering an area. The apple maggot is a serious well-established pest in the Eastern US However, Northwestern apple orchards have been kept free of the maggot even though small populations have been detected in region. A programme has been set up to monitor for the apple maggot and destroy the small populations. If the insect were to become established in Washington State, apple growers would have to apply one to three additional insecticide sprays [76].

One pest that is being monitored closely at the present time is soybean rust which is not present on mainland USA. However, the pathogen that causes soybean rust has been found in Hawaii, Costa Rica and Puerto Rico. US soybean cultivars have little resistance to the pathogen. It has been estimated that if the pathogen establishes itself in the Corn Belt, yield reductions would likely be greater than 10 per cent in nearly all soybean growing regions [77]. Currently very few fungicides are registered for soybeans and usage is low. If soybean rust becomes a problem in mainland USA., it may be necessary to register additional effective fungicides and spray millions of soybean acres to prevent yield loss.

Soil conservation programmes

For the past 60 years, US farmers have been encouraged to reduce their practice of tilling the soil for weed control purposes. The USDA provides funds for adoption of soil conservation practices and Congress has mandated that participation in US farm programmes require the adoption of a soil management plan. Keeping the soil bare of vegetation and crop debris makes the soil susceptible to wind and water erosion. American farmers have reduced significantly their use of tillage and soil erosion rates have declined significantly. Many farmers have switched to no-tillage operations. Many farmers plant cover crops to keep the soil in place during the winter. On average growers have reduced cultivating corn acreage from three to four times a year in the mid 1950's to cultivating only once per year currently [120], [121]. This reduction in tillage was accomplished through the substitution of herbicides for cultivation. Thus, one reason that herbicide use has risen is the interest in reducing cultivation and erosion. In a no-tillage operation herbicides are the sole means for suppressing weeds. When winter cover crops are used, the common practice is to use an herbicide to kill the cover crop before planting the summer's cash crop. In arid wheat growing regions of the US, a significant number of acres are left "fallow" for an entire year in order for the soil to store up water for a subsequent wheat crop. In order to avoid water loss to weeds, an herbicide is used typically to kill weeds on fallow acreage. Thus, one consideration that EPA must make in its regulatory analyses is the impact of its regulatory activities on soil conservation practices. The herbicides that are used typically in reduced tillage and fallow operations are inexpensive, broad spectrum active ingredients, such as 2,4-D, paraquat, atrazine and glyphosate. Recent USDA analysis of the potential impact of a cancellation of triazine herbicides indicated that corn farmers would be likely to cultivate one more time if the triazines were not available [73].

Soil conservation programmes may be leading to the need to use fungicides to control increased disease problems. The microclimate of debris on the soil's surface creates the perfect environment for the development of plant diseases. Increased incidence of diseases in no-till crops, such as corn and wheat have been reported recently.

V. Special Issues

Pest resistance problems

Pest populations usually have a tiny proportion of individuals that are naturally able to withstand a particular chemical that kills the vast majority of the population of that species [112]. These rare individuals naturally possess this resistance as part of their genetic makeup. If a particular pesticide is used on the same site year after year, these naturally resistant individuals, or biotypes, can multiply [112]. Thus, resistance evolves through the selection of the rare resistant individual until it becomes a predominant part of the population.

A large number of insect species, disease pathogens and weed species have developed some level of resistance to more than one class of pesticides. Some level of resistance has been detected for 504 species of insects and mites [103]. The problem of resistant pest populations is regularly cited by critics of pesticide use as a reason to move away from relying on chemicals and as a reason to fund research into non-chemical control methods [103].

Management of pesticide resistance has become an important focus of research programmes and regulatory actions. Research has shown that even pesticides with reported resistance problems can be used effectively under careful usage conditions. For example, resistance conditions often can be overcome by timing applications to the early stages of pest growth, by altering chemicals with different modes of action, by limiting the number of sprays during the certain portions of the growing year, etc. Resistance monitoring has become a very important strategy. Resistant populations have not built up evenly throughout the country. For example, although the Colorado Potato Beetle has shown a high degree of resistance in New York and Pennsylvania, resistant populations do not exist yet in Maine (where the growing season is shorter). Thus, many chemicals can still be used effectively in Maine while their effectiveness is limited in states further south.

Regulatory decisions are increasingly important in the management of resistance. For example, when the potato late blight fungus developed populations resistant to applications of metalaxyl, the USEPA provided growers with the emergency use of three fungicides which were registered in Europe but not in the US EPA has changed its policy regarding granting emergency exemptions. Previously, EPA would provide growers with a single new pesticide in those cases where resistance problems had created an emergency. Growers would then use the new compound exclusively until resistance problems emerged and it was necessary to ask EPA for another registration. In the case of leafminers of celery in Florida, this problem required EPA emergency exemptions every few years. EPA changed its policy and granted the use of two active ingredients to manage the leafminers. The celery growers and registrants have adopted policies of alternating the compounds so that resistance doesn't build up.

One of the concerns in US pest management is that many new chemicals are very specific in their mode of action -- typically disrupting a single enzyme of a weed, pathogen, or insect. This characteristic has allowed the new chemicals to be used at very low rates with few risk concerns for mammals. However, this very specific, highly effective mode of action enables resistant populations to be selected very quickly. In the case of the highly effective insecticide, imidacloprid, resistance management plans were recommended immediately upon its introduction to control whiteflies [114]. It may be the case in the US that the reductions in pesticide use amounts that have occurred recently will not be sustainable. When resistant populations build up, it is often the case that growers will need to increase rates of application or return to chemical products with higher rates of application. For example, in the 1960's, apple growers reduced significantly their use of fungicides for apple disease control when the highly effective benomyl became available. Benomyl was used at 1/16th the dosage needed for older fungicide [115]. However, pathogen resistance built up quickly to benomyl, and growers returned to heavy reliance on the higher rate, older compounds. In EPA's Special Reviews of older products such as the EBDC's, atrazine, and 2,4-D, the importance of the chemicals in resistance management plans is a key issue.

Organic crop production

Sales of organically produced foodstuffs increased 22 per cent to total $2.8 billion in 1995 [5]. A growing demand exists in the US for foodstuffs produced without the use of synthetic chemicals. Organically produced foods tend to cost more at the retail level than conventionally produced foods. A Chicago survey indicated that organic vegetables cost 63 per cent more than their conventionally grown counterparts [6]. The weekly price premium for organic green romaine lettuce averaged over 100 per cent more than conventional price [9]. Recent price premiums for organic vegetables range from 68 per cent for onions to 200 per cent for tomatoes [9]. Organic producers explain that organic production methods generally result in lower yields and higher labour costs, particularly for weed control [6], [7]. Organic vegetable growers in California rely on workers with long-handled hoes to remove weeds. An organic vegetable acre in California can require from 18 to 73 hours of hand-weeding. A recent report on California organic cotton growers indicated that cotton yields are about 20 per cent lower, and because of the higher costs due to hand-weeding, organic cotton costs from two to four times what conventional cotton costs [78]. Organic production methods are not a feasible option for growers of all crops in all parts of the US In Florida's semi-tropical climate, research indicated that yields of organically grown vegetables would be 35 per cent to 80 per cent lower than conventionally produced vegetables. The highly labour-intensive organic production option was determined to be commercially unfeasible in Florida [10].

In response to a request from the organic industry, Congress included a title in the 1990 Farm Bill that established procedures for developing a national programme for organically grown foods. The title requires USDA, through a National Organic Standards Board (NOSB), to set national minimum standards for the marketing and labelling of organic produce [11].

The NOSB has prepared a list of synthetic materials that are allowed for use in organic crop production. These include antibiotics (streptomycin and oxytetracycline), chlorine bleach, hydrogen peroxide, fixed coppers, petroleum distillates (light oils for suffocating insects), elemental sulphur, Bordeaux mixture, lime sulphur, soaps, and plastic mulch. In addition organic growers are allowed the use of microbial insecticides, such as *Bacillus thuringiensis* products. The NOSB rejected including other synthetic materials, such as abamectin, on the approved list for organic growers.

The organically approved pesticides are not without their risks. A US environmental group recently devoted eight pages to describing the human health and ecological impacts of *Bacillus thuringiensis* [15]. They noted that few studies have been conducted on the chronic health effects, carcinogenicity or mutagenicity of BT. Sulphur ranks first in terms of total illnesses reported by California farmworkers 1984-1990 [16]. Copper is widely used in eastern US organic tomato production to control diseases [17].

Conventional apple growers in California generally spray a synthetic insecticide, such as azinphos-methyl, up to twelve times per year to kill codling moth. Organic apple growers in California rely on a natural insecticide, *Bacillus thuringiensis*, to kill codling moth. *Bacillus thuringiensis* is a natural pesticide; it is derived from a soil micro-organism; it does not last as long as the synthetic compound and, as a result, needs to be applied up to 24 times per year to control codling moth adequately [14].

The nation's media have reported on the trend of wine grape growers' converting to organic methods [12]. Organic grape growers in California typically use sulphur to control disease problems, especially powdery mildew. The USDA has shown recently that there are three synthetic fungicides (fenarimol, triadimefon, and myclobutanil) that control powdery mildew in grapes with four applications for a total of one pound of synthetic active ingredient per acre per year [13]. Organic growers cannot use these compounds because they are synthetic. Organic growers must use sulphur, that must be applied 12 times per year for a total of 72 pounds of active ingredient per acre, to achieve equivalent control.

Biotechnology products

Major US crop protection companies have invested hundreds of millions of dollars into developing pest control products based on genetic engineering. The proposed introduction of the genetically engineered substances has led to a host of new issues that regulatory agencies, including EPA, have had to consider. The major products that have been introduced thus far are genetically altered plants. Before genetically altered plants can be introduced into the US, the US Department of Agriculture must make a determination that they would not prove a threat to US crops or natural flora. Thus, USDA has had to assess whether it is likely that the genetically altered plants would exchange genes with wild plant species, and, as a result, create new, hard-to-kill weed species. USDA has approved the introduction of two types of genetically altered plants:

- Genetically altered plants that tolerate the use of herbicides that would damage the unaltered plant

- Genetically altered plants that express pesticides (plant pesticides) that kill insect pests that chew or suck on the plant

Many objections and concerns regarding safety were raised prior to EPA's approval of the first genetically altered plants and their associated chemicals. Introduction of genetically altered herbicide tolerant plants has been debated strenuously since 1990. Critics argued that the use of biotechnology to develop herbicide tolerant plants would merely perpetuate dependence on herbicides, increase herbicide use, and lead, in some cases, to the increased use of high-risk herbicides [80]. These arguments were countered with examples of how herbicide resistant crops could decrease the amounts of herbicides used (in cotton, for example) or lead to increased use of safer herbicides -- such as glyphosate and glufosinate [81]. Critics also raised concern with EPA regarding the food safety risk that might be caused as a result of the herbicide degradation products in edible tissues of the plants [82].

EPA has approved the use of the herbicide glyphosate with genetically altered soybeans and cotton and bromoxynil with genetically altered cotton. Additional registrations are pending for glyphosate on genetically altered corn and glufosinate on genetically altered corn and soybeans. 1996 marks the first year that herbicides could be used with genetically altered crops. The new herbicide products have to compete with other products for market share.

Genetically altered cotton plants that express the BT toxin were planted for the first time in 1996, after approval by USDA and EPA. Approximately two million acres of US cotton were planted to the genetically altered cotton in 1996. Much of the promise of the new plant was based on the decreased need to use insecticides to kill three key pests of cotton: tobacco budworm, cotton bollworm and pink bollworm. These insect species would be killed by the plants themselves when they start to feed on them and ingest the BT toxin. Critics are concerned about the potential for the genetically engineered plants to lead to widespread resistance to BT. Prior to approving the use of the cotton plants with the BT gene, EPA required that a resistance management plan be adopted. The plan relies on "refugia," nearby plants that do not contain the BT toxin to sustain pest populations that can mate with and dominate the genes of any resistant insects [29]. Recently (July 1996), reports of failures of BT cotton to control cotton bollworm on 20 000 acres have come from Texas [29]. The failure to control bollworms may be the result of unusually hot weather and failures of the plant to produce enough BT toxin to kill most of the bollworms [29]. Nevertheless, this failure has led critics to ask EPA to suspend the registration for BT cotton because of the potential of resistance developing to BT [29].

Other products of biotechnology that are potential additions into the US crop protection industry include genetically altered viruses for insect control and genetically altered plants with increased resistance to plant diseases. Controversy has arisen over the possibility of developing genetically altered beneficial insects, that would tolerate insecticide sprays. The tolerance of beneficial mite species to insecticides would make it possible for fruit growers to use insecticides to control insect pests, such as codling moth, without killing off the beneficial mites that would consume populations of harmful mite species. Thus, use of the genetically altered mites would reduce or eliminate the need for miticide sprays.

All products of biotechnology must past the risk tests imposed by EPA, USDA and FDA. In addition, they must pass farmers' tests regarding reliability, cost, and efficacy of control. Genetically altered plants need to yield as well as the best commercial cultivars. Key agronomic traits need to be passed. Recently, a gene was introduced into potato plants granting tolerance to biomoxynil. Although weed control and crop tolerance were excellent, the genetically altered potatoes yield fewer US #1 potatoes than the currently used cultivars [86]. As a result, the project will not be pursued. Genetic engineering of plants, in addition to changing tolerance to herbicides or expressing the BT toxin, may change other traits in the plant that affect yield and agronomic characteristics and, as a result, lead to a lack of commercialisation.

VI. Economic Analyses

Price factors

Pesticide producers and retailers often adjust the price of pesticide products based on changed circumstances, such as the introduction of new competitive products. For example, when newly introduced soybean herbicides from American Cyanamid began to compete effectively with older products in the mid-1980's, the prices of two BASF soybean herbicides (acifluorfen and bentazon) were cut by 40 per cent [90]. While the use of some other soybean herbicides declined precipitously following the introduction of the new products, acifluorfen and bentazon maintained significant market share. Price reductions have been led to expansion of market share.

Reductions in the price of glyphosate also have been a part of Monsanto's strategy to compete with generic products [92]. Glyphosate's patent expired in several European countries in 1991. The US patent expires completely in the year 2000. Monsanto has increased the production capacity of its glyphosate plants in the US and abroad in order to meet world-wide volume sales expectations and in order to compete as a low per unit cost producer. Recently, Monsanto granted a license to Cheminova to engage in US glyphosate sales, for which Monsanto will receive royalties.

Another price factor that affects pesticide usage is the price of the crop. In certain cases growers incur yield losses from diseases and insects in lieu of using pesticides. In these cases, although use of the pesticide would increase yields, the value of the increased yield would not be sufficient to cover the cost of the pesticide. In the Southern US uncontrolled foliar diseases reduce soybean yields. Research has demonstrated that the use of fungicides would control the diseases effectively and increase soybean yields approximately eight bushels/acre [94]. However, with the price of soybeans at $5 per bushel, the cost of the spray is not covered by the value of the increased yield [94]. Thus, fungicide applications are not made typically to US soybeans.

As the price of commodities increase, it often follows that pesticide use increases. For example, yields of US wheat have been lowered typically by 20-30 per cent because of uncontrolled diseases [96]. With the recent price increase for wheat in the US, growers have determined that the cost of a fungicide application is more than paid for by the subsequent increase of three to four bushels of wheat per acre [25]. As a result of the higher price for wheat, fungicide use on wheat is increasing.

Risk-based fees systems

Registration of pesticides constitutes a fined cost. Economists have suggested that one way to reduce the cost of registration is to impose a fee system that is based on the level of toxicity and exposure to particular pesticides. The estimated risks would be measured and translated into monetary terms. According to economic theory the optimal pesticide use fee should equal the total expected damage to human health and the environment from pesticide use at the margin. They claim that the advantages of this system over other approaches is that it (1) provides an incentive to use lower risk pesticides and will lower the overall use of pesticides, (2) gives growers greater flexibility while protecting human health and the environment, (3) the weights will indicate to the pesticide industry which chemical characteristics are deemed desirable, and (4) it is likely to be more effective in shifting growers and the industry toward the use of less risky pesticides [61].

Numerous issues are connected with the use of economic instruments[53]. California currently imposes a sales tax on pesticides and uses the revenue to fund pesticide-related environmental programmes. The state's "mill tax" is applied in addition to the standard sales tax to every substance considered an "economic poison." A uniform rate of $0.022 per dollar of sales (22 mills or 2.2 per cent) is assessed on all agricultural and non-agricultural pesticides (including disinfectants and water treatment chemicals). The tax is collected from pesticide registrants, brokers, and dealers by the DPR. At the current rate of 22 mills, the tax generates approximately $25 million annually. Mill tax revenues currently provide about half of the total amount spent on pesticide-related environmental protection in California (about $50 million annually).

The mill tax is not well suited for creating economic incentives to influence decisions about the use of more- or less-hazardous pesticides. The mill tax is based on a pesticide's sale price and does not discriminate between pesticides with different environmental health impacts. Users of more expensive pesticides will pay more with an increased tax rate, rather than users of more hazardous pesticides. While basing the tax on pesticide sales clearly facilitates its administrative implementation, it makes it more difficult to target the more environmentally damaging pesticides for the highest tax increases. The mill tax's emphasis on pesticide price rather than environmental impact can produce unwanted policy outcomes. In general, newer pesticides coming to market are designed to minimise potential adverse environmental impacts and pose fewer risks than earlier-generation pesticides that remain in widespread use. However, newer pesticides are usually more expensive than older pesticides because they are under patent protection. A pesticide tax based on sales aggravates the price differential confronting users who are choosing between new and old pesticides to control pests, and can contribute to the existing economic incentive to continue using older, more-hazardous products.

A second approach would place a tax on the volume of pesticide used or on the pounds of active ingredient applied. A per-pound tax on pesticides would be similar to the federal tax on CFCs. Taxing pounds applied could directly affect the overall amount of pesticides used in California, with the scale of reduction dependent on the magnitude of the tax increase.

An administratively simple tax would increase the cost of a pound of active ingredient by a uniform amount. Such an approach would be relatively easy to implement through the current mill tax system since pesticide registrants already have to report the pounds of active ingredient they sell. However, a uniform tax per pound would create pricing anomalies that undermine the goal of reducing environmental risks. While such a tax could reduce the volume of pesticides used, it would create an incentive to purchase more-concentrated (and potentially more-hazardous) formulations.

Many relatively safe pesticides have low prices per pound and are used in large quantities. For example, a tax of $1 per pound of active ingredient would raise the price of sodium chlorate by 65 per cent. Sodium chlorate is a relatively low-risk pesticide, and such a substantial price increase would dramatically reduce its use. The same tax would have much less impact on the price of more-expensive and more-hazardous pesticides. Chlorpyrifos, for example, is among the 10 most-hazardous pesticides in terms of farmworker illnesses, non-farm-worker illnesses and hazards to aquatic life. A tax of $1 per

---

[53] The following eight paragraphs are excerpted directly from [18].

pound would raise the price of this pesticide by less than 10 per cent. In the absence of risk-ranking, a pound tax on pesticides could lead to serious market distortions, penalising high-volume but low-risk pesticides and creating incentives to use low-volume but high-risk substitutes.

From the standpoint of reducing environmental impacts, it would be important to incorporate risk-ranking into a per-pound tax to balance out potential pricing anomalies. This approach is more easily modified to incorporate risk than the sales tax approach, because environmental impacts in part depend on the amount and type of active ingredient in a formulation. Products with greater percentages of the more-toxic active ingredient pose greater environmental risks and could face a higher tax per pound of use.

A risk based tax on pesticides has clear conceptual advantages over a uniform sales tax or per-pound tax, but it would be difficult to implement in the absence of a consensus about the relative hazards posed by different pesticides. If a major purpose of taxing pesticides is to reduce their adverse environmental health impacts, then it would be advantageous if the tax system created effective price signals that discourage use of the most dangerous pesticides. However, defining this list of pesticides to be targeted with high taxes presents a challenging implementation problem. There are a variety of types of adverse environmental impacts caused by pesticide use, and no easy way to identify the worst pesticides overall. For example, acute toxicity to farmworkers, chronic toxicity to food consumers, and groundwater contamination are all important types of pesticide impacts. In many cases, pesticides that rank high in one impact area pose little threat in others. A ranking of the ten top pesticides in the areas of farmworker illnesses, non-agricultural illnesses, acute toxicity, frequency of groundwater contamination, and hazards to wildlife indicates that no pesticide ranks in the top ten in every category and only two, parathion and chlorpyrifos, are found in more than two categories.

Pesticides rank very differently depending on the risk attribute chosen, and no single dimension is adequate to serve as the sole basis for a risk-ranking system. A tax system that focuses only on a single impact area could stimulate reductions in the sue of some problem pesticides, but it would create incentives to switch to other pesticides that might present even greater hazards in untaxed impact areas. The most effective approach would establish tax rates based on a multi-attribute ranking that integrates risk evaluations across all dimensions of concern. While several approaches to more-comprehensive risk ranking are currently under development [21], [22], [23], [24], neither the scientific nor pesticide stakeholder communities have reached a consensus on a list that classifies pesticides into hazard categories. Pending the development of such a list, implementation considerations appear to constrain the design options for a pesticide tax to either a uniform tax rate (based on sales or pounds applied), or a variable rate scaled by reference to only a single type of adverse environmental impact.

VII. Conclusions and Policy Recommendations

Pesticide usage patterns in the US are determined by a large set of factors: variations in weather by year and region, EPA and state regulations, commercial interests of manufacturers, and economic factors. Pesticide policymaking is largely uncoordinated in the US There is no overall plan for which chemicals should be used in any cropping system. Pesticide regulatory decisions are complicated and involve numerous trade-offs among policy goals. Restrictions on a particular chemical may lead to use of a chemical with certain other higher risks or with negative implications for integrated pest management programmes. Every regulatory decision needs to be analysed in terms of alternative policy goals, such as, reducing soil erosion and managing resistance. US regulatory agencies lack the financial resources and expertise to co-ordinate effectively the interactions among all these policy goals. However, even in the face of these constraints, the following policy recommendations can be made.

- The Federal government should collect additional pesticide use data and assemble risk/benefit analysis models for pesticide rule making. Explicit goals should be established for US agriculture in terms of amounts of production, location of production and costs of production.

- The Federal government should establish offices of crop protection for major crops. These offices shall be responsible for making recommendations concerning appropriate pest management strategies for each crop.

- The Federal government should re-examine agricultural research policy goals in terms of the need to maintain adequate control methods for important pests. The National Academy of the Sciences should undertake a study that assesses the future role of pesticides in US agriculture.

- The Federal government should initiate a series of educational programmes regarding the role of pesticides and pests in US crop production.

- The Federal government should appropriate $ 100 million per year for the training and employment of pest management specialists throughout the country.

- New pesticides active ingredients should be registered based on used. Evaluations of the acceptance and usage of new products by farmers should be conducted.

BIBLIOGRAPHY

1. USDA (1996), *Agricultural Chemical Usage: 1995 Field Crops Summary,* National Agricultural Statistics Service, March.

2. USDA (1996), Agricultural *Chemical Usage: 1995 Fruits Summary*, National Agricultural Statistics Service, July.

3. USDA (1995), Agricultural *Chemical Usage: 1994 Vegetables Summary*, National Agricultural Statistics Service, July.

4. WILHELM, STEPHEN and ALBERT O. PAULUS (1980), "How Soil Fumigation Benefits the California Strawberry Industry," *Plant Disease*, March.

5. *Natural* Foods *Merchandiser* (1996), June.

6. "Organic Foods Grow in Popularity," *Champaign Urbana News Gazette*, October 22, 1995.

7. OLDHAM, GARY (1996), "Why Organic Should and Does Cost More," *Texas Organic Cotton Growers Association Newsletter*, Winter.

8. KLONSKY, KAREN *et al.* (1992-1993), *Production Practices and Sample Costs for a Diversified Organic Vegetable Operation on the Central Coast*, University of California Cooperative Extension Service.

9. "Organic Produce Costs More," *Food Review*, January - March 1991.

10. COLLETTE, W. ARDEN and ED CANDER (1980), "The Economic Feasibility of Organic Vegetable Production for Small Farms Under Semi-tropical Conditions," *Proceedings Florida State Horticultural Society*.

11. LYNCH, LORI (1991), "Congress Mandates National Organic Food Standards," *Food Review*, January-March.

12. "Organic Wines Enter the Mainstream," *New York Times*, November 19, 1991.

13. GUBLER, W. DOUGLAS (1991), *Fungicide Benefits Assessment Fruit and Nut Crops--West*, USDA, National Agricultural Pesticide Impact Assessment Program, January.

14. BENTLEY, WALTER J. and MARIO VIVERUS (1992), "Brown-bagging Granny Smith Apples on Trees Stops Codling Moth Damage," *California Agriculture*, July-August.

15. SWADENER, CARRIE (1994), "Insecticide Fact Sheets: *Bacillus thuringiensis*," *Journal of Pesticide Reform*, Fall.

16. PEASE, WILLIAM S. (1993), *et al.*, *Preventing Pesticide-Related Illness in California Agriculture: Strategies and Priorities*, California Policy Seminar, University of California.

17. *The Real Dirt: Farmers Tell About Organic and Low Input Practices in the Northeast* (1994), Northeast Organic Farming Association.

18. PEASE, WILLIAM S. *et al.* (1996*)*, *Taxing Pesticides to Fund Environmental Protection and Integrated Pest Management*, California Policy Seminar, University of California.

19. GIANESSI, LEONARD P. (1995), *An Economic Profile of the US Crop Protection Pesticide Industry*, National Center for Food and Agricultural Policy, November.

20. GIANESSI, LEONARD P. and JAMES EARL ANDERSON (1995), *Pesticide Use in US Crop Production: National Summary Report*, National Center for Food and Agricultural Policy, July.

21. HIGLEY, L. and W. WINTERSTEEN (1992), "A Novel Approach To Environmental Risk Assessment Of Pesticides As A Basis For Incorporating Environmental Costs Into Economic Injury Levels." *American Entomologist*, Spring: 34-39.

22. KOVACH, J., C. PETZOLDT, J. DEGNI and J. TETTE (1992), "A Method To Measure The Environmental Impact Of Pesticides," New York's Food and Life Sciences Bulletin, 139:1-8.

23. PEASE, W. S., J. LIEBMAN, D. LANDY and D. ALBRIGHT (1996), Pesticides in California: Use Patterns and Strategies for Reducing Environmental Health Impacts. University of California Policy Seminar.

24. PENROSE, L., W. THWAITE and C. BOWER (1994), "Rating Index as a Basis for Decision Making on Pesticide Use Reduction and for Accreditation of Fruit Produced Under Integrated Pest Management," Crop Protection, 13(2): 146-152.

25. "Bumper Wheat and Barley Crops Enable Growers to Afford Spraying," Capital Press, June 7, 1996.

26. ROSENFELD, ALLEN et al. (1993), Agrichemicals in America, Public Voice for Food and Health Policy, May.

27. CURTIS, JENNIFER et al. (1993), After Silent Spring, Natural Resources Defense Council, June.

28. ASPELIN ARNOLD L. ARTHUR H. GRUBE and ROBERT TORLA (1992), Pesticides Industry Sales and Usage 1990 and 1991 Market Estimates, Office of Pesticide Programs, USEPA, Fall.

29. "Pests Overwhelm BT Cotton Crop," Science, July 26, 1996.

30. MARLATT, C. L., "The Annual Loss Occasioned by Destructive Insects in the United States," 1904 Yearbook of Agriculture, USDA.

31. American Pomological Society, History of Fruit Growing and Handling in United States of America and Canada 1860-1972, 1976.

32. KEARL, C.D. (1972), "Apple Cost Accounting," Proceedings New York State Horticultural Society.

33. KNUTSON, RONALD D. et al. (1993), Economic Impacts of Reduced Pesticide Use on Fruits and Vegetables, American Farm Bureau Research Foundation.

34. WILSON, JOHN W. (1954), "One Hundred Years of Professional Entomology - The Contributions the Professions Has Made to Florida Agriculture," Proceedings Florida State Horticultural Society.

35. KELLY J. F. (1978), "Florida Sweet Corn - Past, Present and Future," Illinois Crop Protection Workshop.

36. HANCHAR, JOHN J. et al. (1985), "An Economic Evaluation of Hexazinone Use for Weed Control in Lowbush Blueberry Production," Hort. Sciences, 20(3), 404-405.

37. Weed Technology in Colorado - And A Program for Research, Colorado State University, Agricultural Experiment Station, General Series 779, July 1962.

38. HEADLEY, J. L. and J. N. LEWIS (1967), The Pesticide Problem: An Economic Approach to Public Policy, Resources for the Future Inc.

39. Illinois Research, Winter 1993/94.

40. DABERKOW, STAN and MOHINDER GILL (1989), "Common Rotations Among Major Field Crops," Agricultural Resources: Inputs Situation Outlook, Economic Research Service, USDA, August.

41. PIKE, DAVID R. et al. (1991), " A Case Study of Herbicide Use," Weed Technology, July-September.

42. USEPA (1996), "Cyanazine: Notice of Preliminary Determination to Terminate Special Review; Notice of Receipt of Request for Voluntary Cancellation," Federal Register, March 1.

43. FARRIS, D. E. and J. M. SPROTT (1971), "Economic and Policy Implications of Pollution from Agricultural Chemicals," American Journal of Agricultural Economics, Vol. 53, No. 4 (Nov.), pp. 661-62.

44. RIBAUDO, MARC O. and ROBIN A. SHOEMAKER (1995), "The Effect of Feedgrain Program Participation on Chemical Use," Economic Research Service, USDA.

45. OSTEEN, CRAIG D. and PHILLIP I. SZMEDRA (1989), Agricultural Pesticide Use, Trends and Policy Issues, USDA, Economic Research Service, Report No. 622.

46. NEWSOM, C. D. et al. (1975), "A Pest Management System for Soybeans," Louisiana Agriculture, Summer.

47. ROSTOV, WILL (1994), Prospering Without Methyl Bromide, Pesticide Action Network, January.

48. EWG (1995), Pesticide Industry Propaganda: The Real Story, April.

49. KNUTSON, RONALD D. et al. (1990), Economic Impacts of Reduced Chemical Use, Knutson & Associates, College Station, Texas.

50. USDA (1992), Agricultural Chemical Usage: 1991 Field Crops Summary, National Agricultural Statistics Service, March.

51. MCKENNA & CUNEO, AND TECHNOLOGY SERVICES GROUP, INC. (1991), Pesticide Regulation Handbook: Third Edition, Washington, D.C.

52. REICHELDERFER, KATHERINE, MAUREEN KUWANO HINKLE (1989), "The Evolution of Pesticide Policy: Environmental Interests and Agriculture," in Carol S. Kramer, ed., The Political Economy of US Agriculture: Challenges for 1990s, National Center for Food and Agricultural Policy.

53. MARCO, GINO J. et al. eds. (1991), Regulation of Agrochemicals: A Driving Force in Their Evolution, American Chemical Society.

54. AYER, HARRY and NEILSON CONKLIN (1990), "Economics of Ag Chemicals: Flawed Methodology and a Conflict of Interest Quagmire," Choices, Fourth Quarter.

55. MEYERHOFF, ALBERT H. and JENNIFER CURTIS (1994), Testimony on Legislation to Amend the Federal Food, Drug and Cosmetic Act and the Federal Insecticide, Fungicide and Rodenticide Act, House Agriculture Committee, Subcommittee on Department Operations and Nutrition, June 10.

56. SCHREIBER, ALAN (1995), "The Value of Aldicarb (Temik) Use on Potatoes," Agrichemical and Environmental News, Washington State University, April.

57. NRC (1993), Pesticides in the Diets of Infants and Children, National Academy Press.

58. GAO (1994), Pesticides: Options to Achieve a Single Regulatory Standard, May.

59. VOGT, DONNA U. (1994), Food Safety: Congressional Options For Revising the Pesticide Residue System, Congressional Research Service, September.

60. NACA, Legislative Update: Crop Protection Chemicals.

61. CEA (1993), Memorandum: Risk Based User Fees for Pesticides, Executive Office of the President, October 19.

62. CROPPER, MAUREEN L. et al. (1992), "The Determinants of Pesticide Regulation: A Statistical Analysis of EPA Decision Making," Journal of Political Economy, Vol. 100 (11), p. 175-197.

63. "Mass Spectral Method Distinguishes Pesticides," Chemical and Engineering News, November 13, 1995.

64. PFLEEGER, THOMAS et al. (1992), Effects of Glean, A Sulfonylurea Herbicide, on the Reproductive Biology and Fruit Set in Cherry Trees, USEPA, Corvallis Environmental Research Laboratory, PB 92-142652, February.

65. "The Politics of Propargite," Agrichemical and Environmental News, Washington State University, April 1996.

66. "Oat Problems Still Trouble General Mills," New York Times. July 11, 1994.

67. USEPA (1995), Office of Pesticide of Programs Annual Report for 1994, Office of Pesticide Programs, EPA 735-R-95-001, January.

68. "Farmers Sue, Saying Weevil Sprays Killed Profits, Too," New York Times, August 4, 1996.

69. TWEEDY, B. G. (1991), et al., eds., Pesticide Residues and Food Safety: A Harvest of Viewpoints, ACS Symposium Series 446.

70. The Keystone National Policy Dialogue on Food Safety and Pesticides, Keystone Center, September 1993.

71. VOGT, DONNA U. (1994), The Delaney Clause: The Dilemma of Regulating Health Risks from Pesticide Residues, Congressional Research Service, September 30.

72. BROWNER, CAROL M. (1993), Testimony Before Subcommittee on Departmental Operations and Nutrition, Committee on Agriculture, U. S. House of Representatives, September 22.

73. USDA (1992), The Effects of Restricting or Banning Atrazine Use to Reduce Surface Water Contamination in the Upper Mississippi River Basin: A Summary, The National Agricultural Pesticide Impact Assessment Program, June 26.

74. BACHELOR, J.S., Impact of Boll Weevil Eradication on Cotton Production and Insect Management in Virginia and North Carolina, Department of Entomology, North Carolina State University.

75. Boll Weevil Eradication: A National Strategy for Success, National Cotton Council, 1994.

76. DOWELL, ROBERT V. (1990), "History of Apple Maggot in the Western United States," Apple Maggot in the West, University of California, Division of Agriculture and Natural Resources, Publication 3341.

77. YANG, Y. B. et al. (1991), "Assessing the Risk and Potential Implication of an Exotic Plant Disease," Plant Disease, October.

78. "The Cotton Brief," New York Times, June 20, 1993.

79. HALDENBY, ROGER K. (1992), "Keeping the High Plains Free of Boll Weevil; A Quiet Success Story; 28 Years of Containment," Proceedings Beltwide Cotton Conferences, National Cotton Council.

80. GOLDBURG, REBECCA et al. (1990), Biotechnology's Bitter Harvest, Biotechnology Working Group, March.

81. DUKE, STEPHEN O. et al. (1991), Herbicide Resistant Crops, Council for Agricultural Science and Technology, May.

82. HOPKINS, DOUGLAS (1995), "Regulatory Options to Address Environmental Risks of Herbicide Tolerant Crop Plants," Proceedings Southern Weed Science Society, 48th Annual Meeting.

83. "Roundup Ready Soybeans Set to Go," Successful Farming, October 1995.

84. HAHN, KEVIN L. and MICHAEL R. HUGHES (1993), "Weed Control Options for 'STS' Soybeans," Proceedings North Central Weed Science Society, Volume 48.

85. DOTREY, PETER A. et al. (1990), "Weed Control in Sethoxydim Tolerant Corn," Proceedings North Central Weed Science Society.

86. EBERLEIN, CHARLOTTE V. et al. (1995), "Yield and Quality of Transgenic Potatoes Expressing the BXN Gene," Proceedings Western Society of Weed Science.

87. "Fungicides Attack in Different Ways," Peanut Farmer, May 1995.

88. BEERS, ELIZABETH H. and JAY F. BRUNNER (1991), Washington State Apple and Pear Pesticide Use Survey 1989-90, Washington State University, September.

89. LARSEN, L. (1995), "Laboratory Toxicity of Spinosad to Late Second Instar Tobacco Budworm Compared to Commercial Standards, 1994," Arthropod Management Tests: Volume 20, Entomological Society of America.

90. Chemical Weed Control for Field Crops, Pasture, Rangeland and Noncropland, 1986-1994, Agricultural Experiment Station, Kansas State University.

91. "Monsanto Outlines Downturn Strategy, "Chemical Marketing Report, March 13, 1989.

92. "High Hopes at Monsanto," Chemical Week, October 23, 1991.

93. KNAKE, ELLERY (1995), "New Developments for Weed Control in Soybeans," Pest Management and Crop Development Bulletin, University of Illinois, Co-operative Extension Service Bulletin No. 21, August 18.

94. RUPE, JOHN C. and MARK J. COCHRAN (1990), Comparison of Application Timing of Two Foliar Fungicides for the Control of Soybean Diseases, Arkansas Agricultural Experiment Station, Report Series 315, June.

95. PIKE, DAVID R. et al. (1995), Biologic and Economic Assessment of Pesticide Use on Corn and Soybeans, University of Illinois, National Agricultural Pesticide Impact Assessment Program Report Number 1-CA-95.

96. MILIUS, E. A. (1994), "Effect of Foliar Fungicides on Disease Control, Yield, and Test Weight of Soft Red Winter Wheat," Crop Protection, Volume 13, Number 4.

97. TOLMAN, JONATHAN (1995), Federal Agricultural Policy: A Harvest of Environmental Abuse, Competitive Enterprise Institute, August.

98. LESLIE, ANNE R. and GERRIT W. CUPERUS (1993), Successful Implementation of Integrated Pest Management for Agricultural Crops, Lewis Publishing.

99. ADKISSON, PERRY L. (1985), et al., "Impact of IPM on Several Major Crops of the United States," in Integrated Pest Management on Major Agricultural Systems, Texas A & M University, Agricultural Experiment Station MP-1616.

100. FLORE, JIM et al. (1992), Michigan Fruit Industry Survey, Michigan State University Agricultural Experiment Station, Research Report 524, April.

101. FUCHS, THOMAS W. (1996), "Status of IPM Implementation in Cotton in Texas," in Abstracts Third National IPM Symposium/Workshop, USDA.

102. MCDONALD, DANIEL G. and CARROLL J. GLYNN (1994), "Difficulties in Measuring Adoption of Apple IPM: A Case Study," Agriculture, Ecosystems and Environment, 48:219-230.

103. NRC (1996), Ecologically Based Pest Management: New Solutions for a New Century, National Academy Press.

104. "Chemicals in Food? A Panel of Experts Finds Little Danger," New York Times, February 16, 1996.

105. VAN RAVENSWAAY, EILEEN O. (1995), Public Perceptions of Agrichemicals, Council of Agricultural Science and Technology, January.

106. HULL, LARRY A. and EDWIN G. RAJOTTE, "Integrated Pest Management in Apples," Pennsylvania State University.

107. USDA (1989), The Biologic and Economic Assessment of Carbofuran, Report Submitted to the USEPA, December 22.

108. Pesticide Use Reduction Assessment, Report prepared by the Committee on Agriculture, Nutrition and Forestry, U. S. Senate, June 29, 1994.

109. DEXTER, ALAN G. et al. (1983-1995), "Survey of Fungicide Use in Sugarbeet in Eastern North Dakota and Minnesota," Sugarbeet Research and Extension Reports, North Dakota State University Extension Service.

110. PIKE, DAVID R. et al (1990), Pesticide Use in Illinois: Results of a 1988 Survey of Major Crops, University of Illinois, Co-operative Extension Service, Circular 1301.

111. RINEHOLD, JOHN and JEFFREY J. JENKINS (1994), Oregon Pesticide Use Estimates for Vegetable Crops, 1993, Oregon State University Extension Service, October.

112. HEAP, I. and I. MORRISON (1991), Herbicide-Resistant Weeds, University of Manitoba, March.

113. “Growers May Have to go Back to the Future to Fight Rice Weeds,” Ag Alert, March 15, 1995.

114. WILLIAMS, LIVY, III, et al. (1996), “Development of a Resistance Management Program for Imidacloprid,” Proceedings Beltwide Cotton Conference, National Cotton Council.

115. OTA, Pest Management Strategies in Crop Protection, 1979.

116. PRIMIANI, M. et al. (1990), “Resistance of Kochia to Sulfonylurea and Imidazolinone Herbicides,” Weed Technology, January-March.

117. RICHARDSON, JAMES W. (1973), “Farm Programs, Pesticide Use, and Social Costs,” Southern Journal of Agricultural Economics, Vol. 5, No. 2, pp. 155-63.

118. HARMAN, S. W. (1948), “Controlling Codling Moth With DDT and Other Materials Experimental Results,” Proceedings New York State Horticultural Society.

119. “The Atrazine Review,” Top Producer, January 1996.

120. “Pest Management Practices on 1993 Corn, Fall Potatoes and Soybeans,” RTD Updates: Integrated Pest Management, USDA, ERS, August 1994.

121. KNAKE, ELLERY L. (1990), Weed Control Systems for Lo-Till and No- Till, University of Illinois, Co-operative Extension Service, Circular 1306, October.

ANNEX 9

OVERVIEW OF RELATED WORK IN THE OECD

The synthesis report on *Agricultural policies, pesticide policies and the environment* resulted from a free-standing body of work initiated under the OECD Joint Working Party of the Committee for Agriculture and the Environment Policy Committee. However, there is ongoing work in several other fora that directly or indirectly relates to the issues raised by the environmental impacts of agricultural pesticide use. The possible references to these related activities should, in particular, be taken into account in the discussions of a possible future work programme on the basis of this report. The following projects are currently in preparation or under way:

Environment Directorate

Economics Division

- The *Project on Subsidies and Tax Disincentives to Sound Environmental Practices* will be conducted, in response to the request on the Environment Ministers of the Group of Seven, in several sectors, including the agricultural sector. The study will focus on the costs and benefits of removing subsidies and will be presented to the OECD Council in 1998. It will draw heavily on work ongoing in other areas of the OECD, including the projects that are overseen by the Joint Working party on Agriculture and the Environment, in particular the effect of subsidies reform on pesticide use. The study will include case studies based on the calculation of marginal effective tax rates of alternative products or modes of production. One likely case study is the comparison of the marginal effective tax rate on input-intensive versus input extensive-agriculture.

Environmental Health and Safety Division, Pesticide Programme

- The *Data Requirements Project* works toward harmonisation of data requirements for the registration of chemical and biological pesticides. The project aims to reduce the number of tests industry must do and facilitates inter-governmental sharing of pesticide evaluation.

- The *Test Guidelines* and *Hazard Assessment Programmes* are working to develop, improve and harmonise pesticide testing and assessment methods. This improves the quality of pesticide evaluation, reduces uncertainties, and contributes to inter-governmental sharing of the evaluation workload.

- The *(Re)Registration Project* provides structures within which OECD countries exchange and use each other's pesticide evaluation reports, thereby reducing their workload and streamlining the pesticide evaluation and registration process.

- The *Risk Reduction Project* is helping countries reduce the risks associated with pesticide use through information sharing and co-operative projects. To date, the project has completed a survey of countries' risk reduction activities and held a workshop (Uppsala, Sweden, October 1995). The Project is now considering initiation of projects to develop indicators to measure progress in risk reduction and to develop systems for on-going information exchange.

State of the Environment Division

- The *Programme on Environmental Data* collects the best available data on the environment from OECD Member countries and from various international sources, and promotes the international harmonisation of these data. These data are published every two years in the *OECD Compendium of Environmental Data*, which also includes a table on pesticide use in agriculture. The pesticide data are drawn from existing international (FAO) and national sources (statistical yearbooks) and are broken down into four major categories: insecticides, fungicides, herbicides, and other pesticides.

- The *Programme on Environmental Indicators* aims at developing reliable, readable, measurable and policy-relevant environmental indicators. It includes the development of a core set of environmental indicators to be used in the OECD Environmental Performance Review Programme, sets of indicators for the integration of environmental concerns into sectoral policies and indicators linking the environment to the economy (resource accounting, expenditures). The OECD Core Set of Environmental Indicators covers a broad range of environmental issues and includes one indicator on pesticide use.

Joint Working Party for Agriculture and Environment

- The *Agri-Environmental Indicators Project* has proposed to develop indicators for pesticide use, working in co-operation with the Pesticide Programme Risk Reduction Project. The approach being considered is to classify pesticide use data into different environmental risk integrating parameters such as mobility, persistence and toxicity. While an appropriate risk classification system is being developed, initial work could begin to collect data on the quantity of pesticide active ingredient applied per crop and/or per hectare.

  The Indicators Project is also considering the development of indicators to assess the environmental impacts of farm management practices. These would be analysed, among others, with respect to nutrient management, pest management, soil management, irrigation management, and whole farm management. Most relevant to pesticide use are the pest management and whole farm management indicators.

- A study on *The environmental effects of farmland diversion programmes* has been prepared on the basis of country experiences in Canada, the European Union, Japan and the United States.

- A study on *Co-operative approaches to sustainable agriculture* has been prepared on the basis of experiences in Australia, Canada, the Netherlands and New Zealand.

ANNEX 10

RECOMMENDATIONS OF THE OECD/FAO WORKSHOP ON

PESTICIDE RISK REDUCTION IN UPPSALA

Following are the recommendations as formulated by the different working groups of the OECD/FAO workshop on Pesticide Risk Reduction held in Uppsala Sweden, 16-18 October 1995. Corresponding to the mandate of the OECD Risk Reduction Group, the recommendations of the workshop are of a more technical nature than the broader based policy recommendations arrived at in this report. Nevertheless, they point into the same direction and display a remarkable complementarity to the key points identified above.

The recommendations fall into two general areas: first, *minimising risks associated with pesticide application and handling;* second, *reducing reliance on chemical pesticides by increasing the use of biologically-based farming methods.* With regard to the former, the workshop noted that pesticide registration offers an essential foundation for risk reduction -- by providing for the evaluation and control of risks associated with individual pesticides -- but that a wider approach, which addresses risks more comprehensively and involves the people who use pesticides, is necessary. With regard to the second area, the workshop stressed the need for practical, farmer-driven programmes to facilitate the transition from chemical-intensive agriculture to an agriculture that maximises the use of horticultural and biological tools to grow healthy crops and control pests.

The detailed recommendations made by the four working groups are summarised below under the four categories of pesticide policy, economic instruments, farming methods, and safety. To a large extent, the recommendations in each category were made by the corresponding working group. However, the groups also made recommendations that involved each other's areas, and these have been placed in the most appropriate subject area. The recommendations are further summarised on page 8, according to who should be responsible for further action (i.e. OECD, FAO, countries, industry).

Pesticide Policy

Recommendations for establishing policies and policy frameworks that encourage pesticide risk reduction were made in nine areas:

Implementing pesticide risk reduction programmes
OECD and FAO should urge countries to implement national pesticide risk reduction programmes that use an integrated approach, encouraging participation of all important actors from a local to national level. Such programmes could include instruments and activities in

seven categories: (1) regulations; (2) instruments/activities to promote safe use and improved farm management; (3) advice, education and training; (4) monitoring and evaluation; (5) information exchange; (6) economic instruments; and (7) research and development.

Agricultural policy
The agricultural policy of all OECD and FAO countries should encourage a shift toward biologically-based farming methods. FAO should assist by developing a code of principles for integrated pest management (IPM).

New technologies
Governments and other relevant actors should encourage research, development and commercialisation of new products that are low-risk and farming practices and technologies which support risk reduction.

Information exchange
OECD and FAO should initiate activities to facilitate information exchange among countries.

Measuring progress
OECD should develop protocols to measure progress in pesticide risk reduction. This would include systems for collecting data on pest management and pesticide use (see also recommendation of Farming Methods and Economic Instruments Working Groups).

Workshops and other projects
FAO and OECD should organise regional workshops and projects to address issues related to pesticide risk reduction, including the policy instruments outlined in this report.

Training and education
National governments should support training, education and certification programs and should support agricultural extension services, which have a key role in transmitting information to farmers about new technology (see also recommendation of Safety Working Group).

Registration
OECD and FAO should facilitate a process whereby countries with established registration systems can assist other countries seeking to establish or improve their registration process.

Risk assessment
OECD, in co-operation with other international agencies, should strengthen its efforts to improve and harmonise pesticide risk assessment methodologies.

Economic Instruments

The recommendations for further activities made by the Economic Instruments Working Group are very general in nature. The reason was explained by the group as follows: "... [E]conomic instruments are an important component of pesticide risk reduction policies, and therefore should be taken into account in developing such policies. Economic instruments will probably be more effective when integrated with other kinds of instruments. Analysing and evaluating various economic instruments requires an in-depth study at various economic levels, geographic scales, etc. Also, the interaction with other types of instruments should be taken into account." The recommendations fall into five broad areas:

Consideration by IFCS
Economic instruments should be considered in the national programmes called for by the International Forum on Chemical Safety.

Characteristics of instruments
Economic instruments should be designed to permit and encourage innovation in technology and practice among farmers, industry and consumers.

Context for instruments
Economic instruments should not be considered in isolation but should be integrated with each other and with other risk reduction activities.

Opportunities for risk reduction
When analysing agricultural economic policy and economic development policy, OECD and FAO should consider the effects on pesticide use and opportunities for risk reduction.

Measuring progress
OECD should take the lead in establishing systems to monitor pesticide risk reduction and the effectiveness of economic instruments in achieving this reduction. (See similar recommendation under Farming Methods.)

Farming Methods

Recommendations to increase the use of biologically-based farming methods were made in eight areas:

Support for transition to biologically-based farming methods
Countries should provide technical assistance, economic incentives, and/or other such means of support to encourage farmers to reduce their reliance on chemical pesticides and to adopt biologically-based pest management systems, such as those listed in Annex 5. These pest management systems must be economically viable.

Farmer-driven research
Countries should expand and encourage farmer-driven participatory research and education efforts based on demonstration farms and field-based experiments.

Farmer exchanges
OECD and FAO should encourage countries to initiate farmer exchange programmes, so as to facilitate sharing of information and experience concerning farming methods that reduce reliance on pesticides. Countries should organise such exchanges.

Methods to measure progress
OECD and FAO should develop protocols and/or methodologies to:

- measure pesticide use, pesticide reliance, and pest management systems,
- show the relationship between different pest management systems and pesticide use, reliance and risk,
- measure progress in reducing risks from and reliance on chemical pesticides.

Countries should use these protocols/methodologies to monitor their progress in reducing pesticide risk.

Workshops
OECD and FAO should organise regional workshops and projects to address issues related to pesticide risk reduction. These should include workshops to:

- discuss the policy instruments and approaches outlined in this report,
- evaluate integrated pest management and organic methods, develop an inventory of viable options, and develop strategies for implementing these options.

Expanding biologically-based farming in developing countries
OECD and FAO should help developing countries introduce, expand and promote farming methods that reduce reliance on chemical pesticides.

IPM Code of principles
FAO should develop a "code of principles" for integrated pest management that countries could adopt as national policy. These principles should take into account the need for IPM programmes to be locally based, and the need for worker safety.

Information exchange
OECD and FAO should facilitate information exchange between the developing and the developed countries, particularly at a regional level, on integrated pest management successes and innovative approaches which have advanced risk reduction. The OECD and FAO should discuss appropriate mechanisms and information requirements for this exchange.

Countries should support and use international networks to share information about farming methods that reduce reliance on pesticides.

Safety

Recommendations to improve the safety with which pesticides are used were made in nine areas:

Training and certification
Countries should establish properly targeted, staffed and funded training and certification programmes for regulatory officials, extension and training officers, and farm level workers. Developing countries should be given assistance to establish such programmes.

Labelling
Both international organisations and countries should adopt the principle of simplicity and clarity for pesticide labelling. OECD should transmit this recommendation to the International Labour Organisation Co-ordinating Committee on Chemical Classification Schemes and Hazard Communication.

FAO Code of Conduct
Countries should implement the FAO Code of Conduct for the distribution and use of pesticides, in order to establish good agricultural practices and reduce risks associated with the use of highly hazardous products.

Registration systems
All countries should have a product registration system to control the use of pesticides. National governments should, where appropriate, initiate co-operative regional efforts to implement and improve these systems.

Poor-quality products
OECD and FAO should address the problem that poor-quality products not meeting the specifications of registration are in international trade. OECD countries should improve their certificates of pesticide registration so as to give more complete information on product composition. The purpose would be to discourage distribution of poor-quality products to developing countries.

Post-registration monitoring
OECD countries should develop guidelines on the form and implementation of post-registration monitoring and surveillance. This should cover both human health and environmental monitoring.

Product and container stewardship
Industry should extend its product and container stewardship so that products and containers are designed to facilitate safe handling, ready rinsibility and appropriate disposal.

Personal protective equipment
All parties involved should be made aware that certain types of personal protective clothing and equipment (e.g. that which covers the body and traps heat) is not appropriate for use in tropical conditions. Governments should take this into account in their registration decisions and in pesticide labelling. Pesticide manufacturers should identify products that require such equipment, and should design safer alternatives that would be appropriate for use in hot climates.

Application equipment
OECD countries should implement systems for certification and inspection of spraying equipment to reduce spillage and waste of pesticides and increase efficiency of delivery to crops. Where appropriate, such systems should also be implemented in developing countries.

Measuring progress
Countries should monitor their progress in reducing pesticide risk.

SUMMARY OF RECOMMENDATIONS AND RESPONSIBILITIES

Responsibility	Recommended Activity
OECD/FAO	· urge countries to implement national pesticide risk reduction programmes · initiate activities to facilitate information exchange between countries on: - national risk reduction programmes - IPM and other alternatives - safety implications of various formulation types - measures to facilitate choice of lower risk alternatives · organise regional workshops to: - evaluate new policy instruments - evaluate biologically based farming methods, strategies for implementation · facilitate a process by which countries with established registration programmes can help others to develop and/or improve such programmes · consider effects of pesticide use and opportunity for risk reduction when analysing agricultural economic policy · develop systems to measure progress in risk reduction, e.g. - pesticide use - pesticide reliance - pest management (and effect on use & reliance) - effectiveness of economic instruments · help developing countries introduce, expand and promote farming methods that reduce reliance on chemical pesticides · address problems of poor quality pesticides · improve labelling (advice to International Labour Organisation)
OECD	· improve risk assessment methods · develop guidelines for post registration monitoring and surveillance
FAO	· develop 'Code of Principles' for IPM
Countries	· adopt and implement national pesticide risk reduction programmes · amend agricultural policy to encourage, facilitate use of biologically based farming methods · provide technical assistance, economic incentives and/or other measures to help farmers adopt biologically based pest management systems · expand and encourage farmer-driven research and education, e.g. through demonstration farms, field-based research · encourage research, development, commercialisation of safer technologies (methods, products, product packaging) · support information-transfer systems (e.g. agricultural extension service) · establish training and education programmes for users · initiate farmer exchange programmes · implement the FAO Code of Conduct for pesticide use · monitor progress in reducing pesticide risks · improve certificates of registration
Industry	· develop safer products that can replace highly hazardous pesticides and that do not require personal protective equipment (crop protection industry) · design better personal protective equipment (equipment manufacturers) · extend product/container stewardship programmes (crop protection industry)