The Bichel Committee 1999

Report from the Sub-committee on Production, Economics and Employment

Miljøstyrelsen
Miljø- og Energiministeriet

Preface

The Sub-committee on Production, Economics and Employment, which is part of the Bichel Committee, was appointed in autumn 1997 to assess the economic consequences of phasing out the use of pesticides. This report is a result of those assessments and is one of five technical background reports that form the basis for the Bichel Committee's final report to the Minister of Environment and Energy.

The other four background reports cover: the consequences for agriculture and for the environment and health, the legal possibilities of phasing out the use of pesticides and, lastly, the overall consequences of a total switch to organic farming.

This is the first time in Denmark – and probably also internationally – that such an extensive interdisciplinary analysis has been conducted, of the consequences for agricultural of a total or partial phasing-out of pesticide use and of a total restructuring for organic production.

The sub-committee’s economic analyses were based on agronomic and scientific results arrived at by the Sub-Committee on Agriculture and the Sub-Committee on Environment and Health. The sub-committee used the reductions in yield for different crops mapped by the Sub-Committee on Agriculture to calculate economically rational crop rotations and associated gross margins for different types of farm. On the basis of these operational analyses, the sub-committee then calculated the socioeconomic consequences in a general equilibrium model for the entire Danish economy.

The sub-committee also tried to arrive at a valuation of the environmental and health consequences of phasing out pesticides. However, it is much more difficult to quantify the gains than the costs.

The main analyses concern agriculture, but the sub-committee also looked at market gardening and forestry.

The sub-committee based its report on a number of consultants' reports. The consultants, the members of the sub-committee and the secretariat have all made a major contribution to the creation of the report, and we take this opportunity to thank everyone concerned for their good work.

Niels Kærgård
11. March 1999

1 Introduction

On 15 May 1997, the Folketing (the Danish Parliament) unanimously passed a parliamentary resolution urging the government to appoint a committee with independent expertise to analyse all the consequences of totally or partially phasing out the use of pesticides in agriculture and to examine alternative methods of preventing and controlling plant diseases, pests and weeds.

The committee was to assess the consequences for production, the economy, legislation, health and the environment, and employment.

The results of the committee's work were to be used in the coming work on a new pesticide action plan.

Appointment of main committee and sub-committees

In the mandate of 4 July 1997, the Minister of Environment and Energy stipulated that a main committee be appointed with expert members from research, the agricultural industries, the "green" organisations, consumer organisations, the foodstuffs and agrochemical industries, the trade unions and relevant ministries. Its members were to cover the specialist areas of agriculture, economics, legislation, employment, health, the environment and ecology.

In addition, four sub-committees were appointed. Their task was to facilitate the main committee's final reporting by drafting specialist background reports.

The main committee had the task of coordinating and discussing the sub-committees' work and of preparing the final report for the Minister.

The sub-committees were to cover the following areas:

1. agriculture
2. production, economics and employment
3. environment and health
4. legislation

As points of reference for their work, the sub-committees were to use both the optimum production from the standpoint of operating economy and the production achieved by the agricultural industries to date. They were to assess the consequences for production, the economy, legislation, health, employment and the environment.

In their work, the sub-committees were to evaluate scenarios for total and partial phasing out of pesticides and examine the consequences of restructuring for organic farming, taking into account activities already in progress concerning such restructuring.

An analysis of restructuring for organic farming is given in a separate report in which factors relating to cultivation are discussed, together with economic, employment and environmental factors.

The mandate for the Sub-committee on Production, Economics and Employment

The mandate

On the basis of the above-mentioned cultivation systems and the other existing framework conditions for production, the sub-committee was to evaluate:

1. the consequences of the different cultivation systems for agricultural production and earnings, including the cost to the agricultural sector of restructuring production
2. the economic parameters relating to the environment, such as costs for cleaning up drinking water and soil
3. the economic consequences for derivative industries such as dairies, abattoirs, the chemical industry and producers of alternative agents and methods
4. the economic consequences for the consumers.

The sub-committee was to identify any areas in which a partial or total phase-out would cause particular problems and suggest how these problems could be solved, e.g. through research and development. In its evaluation of the consequences for employment, the sub-committee was to include the impact on employment both in agriculture itself and in the derivative industries.

Composition of the sub-committee

Composition of the sub-committee

Professor Niels Kærgård, The Royal Veterinary and Agricultural College Chairman)
Mikael Skou Andersen, Reader, University of Aarhus
Alex Dubgård, The Royal Veterinary and Agricultural College
Johannes Christensen, Research Director, Danish Institute of Agricultural and Fisheries Economics (SJFI)
Søren E. Frandsen, Research Director, Danish Institute of Agricultural and Fisheries Economics
Els Wynen, Visiting Reseacher, Danish Institute of Agricultural and Fisheries Economics
Jan Holm Ingemann, Reader, University of Aalborg
Forskningsleder Valdemar Smith, Danish Institute for Studies in Research and Research Policy, Århus.
Lars Gårn Hansen, Senior Scientist, Institute of Local Government Studies – Denmark (AKF)
Christian Ege Jørgensen, Head of Secretariat, The Ecological Council
Jørgen Birk Mortensen, Reader, University of Copenhagen
Niels Peter Skrubbeltrang, Chief Consultant, Agricultural Advisory Service.

In addition, Claus Vangsgård, M.Sc., Association of Danish Waterworks, participated in some of the sub-committee's meetings.

The sub-committee held 19 meetings.

The Danish Environmental Protection Agency provided secretariat assistance, drawing on expertise from the Danish Institute of Agricultural Sciences.

The following persons were attached to the secretariat:

Lise Nistrup Jørgensen, Senior Scientist, Danish Institute of Agricultural Sciences
Erik Steen Kristensen, Chief Scientist, Danish Research Centre for Organic Farming
Anne Marie Linderstrøm, Principal, Danish Environmental Protection Agency
Kaj Juhl Madsen, PhD., Agronomist, Environmental Protection Agency.

The sub-committee's report was edited by Aage Walter-Jørgensen, Danish Institute of Agricultural and Fisheries Economics.

2 Description of pesticide consumption in the agricultural sector

2.1 Introduction

The purpose of this chapter

This chapter gives a brief outline of pesticide consumption in the agricultural sector and its composition, and of pesticide usage in different types of production and types of farm. The description forms the basis for the fundamental considerations concerning regulation of pesticide consumption given in chapter 3 and for the analyses in the subsequent chapters of the economic consequences of restrictions on the use of pesticides in agriculture.

Pesticides have increased productivity

... and reduced the need for manual labour

The introduction of pesticides in agriculture has helped to increase productivity and has thus contributed to steadily rising production since the Second World War. The use of fungicides and insecticides has led to increased yields in arable farming, and the use of herbicides has reduced the need for manual labour. In addition, pesticides make it possible to avoid losses during storage of the products. Pesticides thus have many applications that affect the production and consumption of the means of production in a number of ways.

Pesticides cover a multitude of products. They are classified as herbicides, fungicides, insecticides and growth regulators. In addition, there are chemical agents for disinfecting soil in greenhouses and insecticides for controlling flies and pests in stables, cowsheds, etc. and storage facilities. These classes are subdivided into products with specific properties for specific uses. In the present context, the analysis focuses on the main classification of pesticides.

The agricultural sector accounts for 80 per cent of consumption

Agricultural consumption of pesticides is estimated to account for 80 per cent of total consumption in Denmark (Danish Environmental Protection Agency, 1998a). Besides this usage, pesticides are used for vacuum-impregnation of timber, protection of wool against moth and the carpet beetle, combating flies, ants and other vermin in the home, rat control, control of growth of algae, etc., and there are agents for preventing damage by game in forests and orchards. These applications are not dealt with in this analysis.

In this report, the Sub-committee on Production, Economics and Employment describes the development and composition of pesticide consumption in the agricultural sector and examines the use of pesticides at different types of farm with a view to determining the significance of the form of farming for the scope and nature of pesticide consumption. The sub-committee has also analysed the significance of the structure of the agricultural sector for pesticide consumption and, lastly, the expenditure on chemicals in market gardening.

2.2 Pesticide consumption in the agricultural sector

Farmers began using pesticides after the Second World War. They used them initially for prevention and control of pests in the most important crops. However, with the development of new chemical agents and improved spraying equipment, mechanical and manual weed control was increasingly replaced by chemical control, and chemical control of fungal diseases in crops became increasingly common. Later, chemical regulation of plant growth (e.g. shortening the stems of cereals) gained a footing.

Upswing in consumption in the 1950s

The real upswing in the use of pesticides began in the 1950s. From the middle of that decade to the beginning of the 1970s, pesticide consumption rose fivefold, reaching a level corresponding to around 6.7 million kg active ingredient in 1973. Following a fall in the mid-1970s, consumption then rose again to a new high (7.5 mill. kg active ingredient) in 1982/83 and thereafter fell steadily to 3.7 mill. kg in 1997. Altogether, consumption has thus halved since the beginning of the 1980s.

More efficcacious agents

However, account must be taken of the fact that the reduction in the consumption of active ingredient has been accompanied by an increase in the efficacy of the agents, which means that there has actually only been a small reduction in pesticide consumption.

Considerable fall in consumption since the beginning of the 1980s..

From and including 1981, statistics have been kept of the composition of pesticide consumption (Figure 2.1). It will be seen from this figure, that herbicide consumption fell by about 40 per cent from 1983 to 1997, although with considerable fluctuations from year to year. Fungicide consumption peaked in 1984 and then fell continuously, ending in 1997 at 35 per cent of the 1984 level. Insecticide consumption fell by 80 per cent in the period shown, while consumption of growth regulators (not shown in the figure) rose from just under 100 tonnes in 1981 to 400 tonnes in 1984 and then, in the period to 1997, fell to approximately the level at the beginning of the 1980s. The fluctuations in consumption in 1995-96 were due to hoarding in 1995 in connection with the increase in the tax on pesticides in 1996.

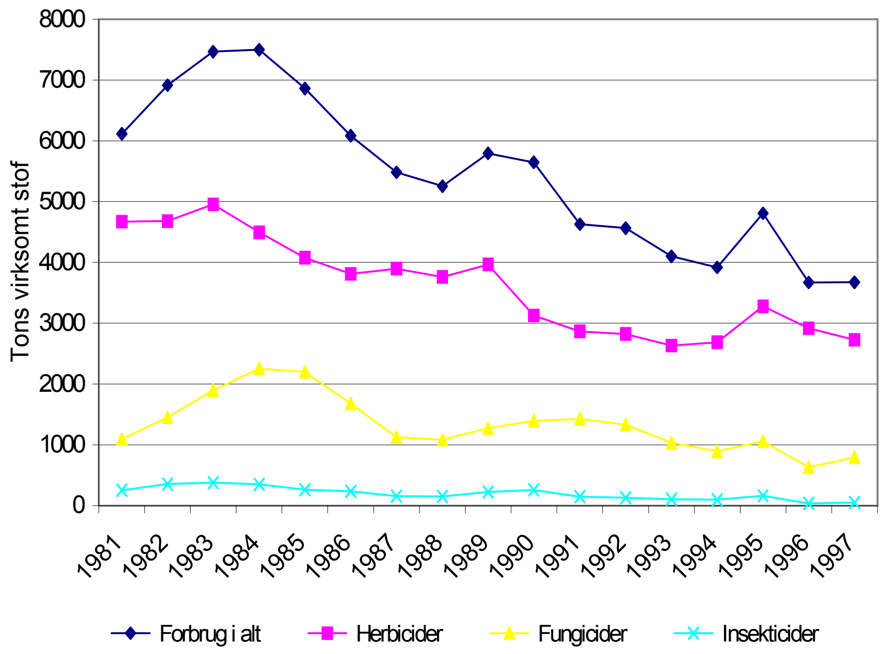


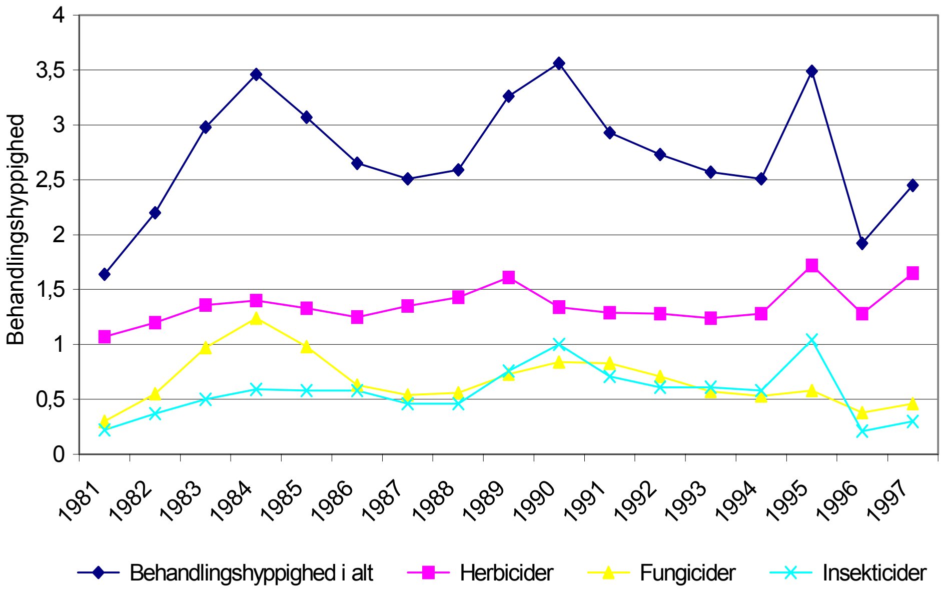
Figure 2.1
Pesticide consumption in the agricultural sector
(Figure texts: Tons virksomt stof = Tonnes active ingredient
Forbrug i alt = Total consumption
Herbicider = Herbicides
Fungicider = Fungicides; Insekticider = Insecticides)

... but only slightly declining treatment frequency index

The corresponding statistics for treatment frequency show that the number of applications per ha has varied between 2.5 and 3.5 per year since the beginning of the 1980s, with a downward trend towards the end of the period. (Figure 2.2). In 1995-1996, the treatment frequency index was affected by the above-mentioned hoarding, see the comment concerning Figure 2.2. Herbicide applications lay in the interval 1-1.7 per year, with a slightly rising trend until 1996, when consumption fell. Treatment with fungicides fluctuated between 1.2 and 0.3 per year, with a declining trend. The treatment frequency index for growth regulators has averaged 0.1, with a downward trend since the mid-1980s.

Goal only partially achieved

It must thus be concluded that the government's pesticide policy goal of a 50 per cent reduction in pesticide consumption from 1983-85 to 1997 has been achieved, but not the goal of the same reduction in the treatment frequency index. As described below, one reason for the latter is a major change in land use from spring cereals to winter cereals, which has resulted in an increase in treatment with pesticides.



Source: Danmarks Statistik, Statistical 10-year Review
(Figure texts:
Behandlingshyppighed = Treatment frequency index
Behandlingshyppighed i alt = Total treatment frequency index
Herbicider = Herbicides
Fungicider = Fungicides
Insekticider = Insecticides)

Figure 2.2
Treatment frequency index for pesticides
Note: The treatment frequency index expresses the number of times it is possible, with the recorded consumption, to treat the entire acreage with pesticides, assuming the normal dosage.
Source: Danmarks Statistik, Statistical 10-year Review and "Environment" 1995:15

Reasons for change in consumption

Reasons for change in consumption

Several factors are implicated in the described development of pesticide consumption. The rising trend up to the beginning of the 1980s must be attributed to more widespread use of chemical prevention and control in practice. The typical course of events when new technology is introduced is that the most enterprising producers use the technology first. Use of the technology then spreads to other producers, first at an increasing rate and then at a decreasing rate as the technology becomes common practice.

Table 2.1 below, showing the expenditure on pesticide treatment measured in DKK per ha, gives a picture of the effect of pesticide usage on production costs in farming. The farm accounts statistics do not offer the possibility of differentiating between different classes of pesticides, i.e. the differences that are observed between crops and types of farm, are due partly to differences in the composition of the consumption and partly to differences in the price of pesticides. However, the figures give a picture of the distribution of the consumption and, at the same time, show the total spending on pesticides in the different forms of production and types of farming.

Big variation in consumption between crops

As shown in Table 2.1, the expenditure on pesticides is far greater in the production of beets and potatoes than in the production of cereals and grass. Almost no pesticides are used for grass. It will also be seen that pesticide consumption is far higher in winter cereals than in spring cereals. Measured in relation to total production costs, pesticide consumption is particularly high in sugar beets for sugar production, which must primarily be attributed to the use of costly herbicides. The differences indicated mean that changes in the crop composition will, over time, affect total pesticide consumption.

Table 2.1
Consumption of pesticides in crops, average 1994/95-1996/97

	DKK per ha	Percentage of costs, total
Wheat	**547**	6.0
Winter barley	**452**	5.3
Spring barley	**323**	4.2
Rape	**495**	6.7
Sugar beets	**1,630**	10.4
Potatoes	**1,142**	6.0
Fodder beet	**1,612**	8.4
Grass and greenfeed	**110**	1.6
Rotation grass	**27**	0.4
Permanent grass	**5**	0.1

Note: The figures concern expenditure on chemicals, most of which are pesticides.
Source: Danish Institute of Agricultural and Fisheries Economics, Economics of Agricultural Enterprises

Change in land use…

As shown in Figure 2.3, there has been a substantial switch from production of barley (mainly spring barley) to wheat since the beginning of the 1970s, accompanied by a fall in the acreage with grass and greenfeed up to the beginning of the 1990s. This has in itself increased the need to use pesticides. Working in the same direction is a growing acreage with seed for sowing and industrial use (rape), while a gradual fall in the acreage with root crops for fodder is working in the opposite direction. The trend in the 1990s has been affected particularly by the introduction of compulsory set-aside and a falling acreage with industrial seed, which has reduced pesticide consumption.[1] It should be noted that set-aside does not affect the treatment frequency figures because they have been calculated without set-aside.

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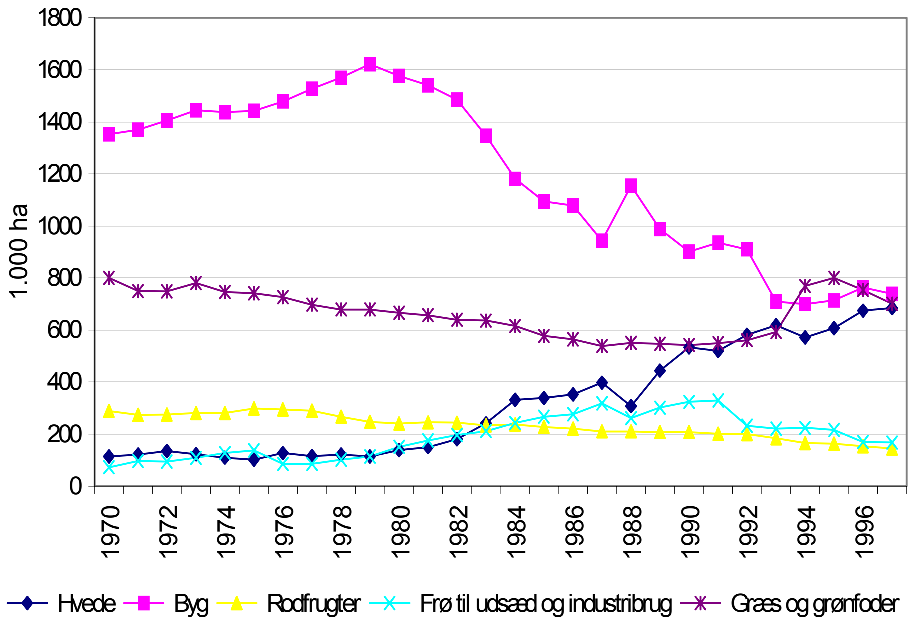
[1] In 1992, the set-aside acreage was 220,000 ha, rising to 250,000 ha in 1994 and then falling to 147,000 in 1997.

… explained in part by the EU's agricultural policy

The changes in land use in recent years must be attributed particularly to the 1992 reform of the EU agricultural policy, which implied a reduction in the price of cereals, oil seed and rape, among other crops, the introduction of compensation payment for the crops in question and a requirement concerning compulsory set-aside. The fall in the acreage with seed for sowing and industrial use is a direct consequence of this change, which means that rape is now produced at world market prices. As will be explained in connection with the analyses, a reduction of farm product prices has a significant effect on the intensity of production and the consumption of pesticides in arable farming.



(Figure texts:
Hvede = Wheat
Byg = Barley
Rodfrugter = Root crops
Frø til udsæd og industribrug = Seed for sowing and industrial use
Græs og grønfoder = Grass and greenfeed)

Figure 2.3
Land use in farming
Source: Danmarks Statistik, Statistical 10-year Review

Acreage with fodder beet is falling

The acreage with grass and greenfeed comprises both set-aside acreage, permanent grass and – after 1992 – also set-aside laid to grass.[2] The reduction in root crops is due mainly to a fall in acreage from more than 200,000 ha in 1970 to 37,000 ha in 1997, corresponding to a 5 per cent fall per year. This big fall must be attributed to production of fodder beet being cost-intensive compared with production of grass and greenfeed. However, the trend has also been affected by the fact that yields have increased over time, which, combined with quota limitation of milk production in the EU, has reduced the need for green-fodder acreage.

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[2] Set-aside acreages have been placed slightly differently in the statistics since 1992, which makes comparison between years difficult.

Switch from spring to winter cereals

One reason for the switch from spring barley to winter wheat is that winter wheat generally produces a higher yield than spring cereals and has therefore been an attractive alternative to spring cereals. In addition, the possibility of controlling couch grass chemically in crops has reduced the need for soil preparation in the autumn. The appearance of more efficacious herbicides, fungicides and insecticides may also have contributed to this development.

Significance of the structure of farming for pesticide consumption

Larger consumption at full-time farms

The above-mentioned differences between crops with respect to pesticide treatment are reflected in the consumption of pesticides in the different types of farming. The general picture is that full-time farms have a higher consumption than part-time farms. As shown in Table 2.2, full-time arable farms have the largest consumption and also the highest treatment frequency index. That is because arable farmers concentrate mainly on production of cash crops (winter cereals, rape and sugar beet), which, as mentioned, have a relatively high consumption of pesticides.

Table 2.2
Pesticide consumption in the main types of farming, 1996/97

	Full-time farms			Part-time farms		
	Arable farms	Dairy farms	Pig farms	Arable farms	Dairy farms	Pig farms
Kg active ingredient per ha	2.2	1.2	1.3	1.2	0.8	0.9
Treatment frequency index[1]	3.6	2.4	2.4	2.4	1.4	1.9

[1] The treatment frequency index is calculated by dividing the consumption of active ingredient by the recommended dose per ha.
Note: The table is based on the Danish Institute of Agricultural and Fishery Economics' accounts statistics for the 1996/97 operating year, supplemented by information on the composition of the pesticide consumption. The material is based on 607 farms selected from around 2,000 farms on which the statistic are based.

Dairy farmers and pig farmers use fewer pesticides than arable farmers

Dairy farms and pig farms have a somewhat lower consumption of pesticides and a lower treatment frequency index. In the case of dairy farms, it is particularly in the production of fodder beet that treatment with pesticides is needed, but with the fodder-beet acreage falling and greater concentration on wholecrop, it is estimated that the use of pesticides is diminishing. The lower pesticide consumption at pig farms is due particularly to a low production of root crops (fodder beet and sugar beet for industrial use) and to the fact that pig farmers grow more spring cereals and rape than arable farmers. The said differences in land use must also be seen in relation to the fact that livestock production is concentrated on lighter soils and that the type of soil in itself affects land use.

The above-mentioned analyses are based on a questionnaire-based survey of a representative selection of farmers. Danmarks Statistik's treatment frequency figures in the different forms of farming show approximately the same picture, in that the treatment frequency at arable farms in 1994 was 2.8 standard doses per ha compared with 2.0 at dairy farms and 2.8 at pig farms (Danmarks Statistik, 1995). The latter figures are the averages for all farms.

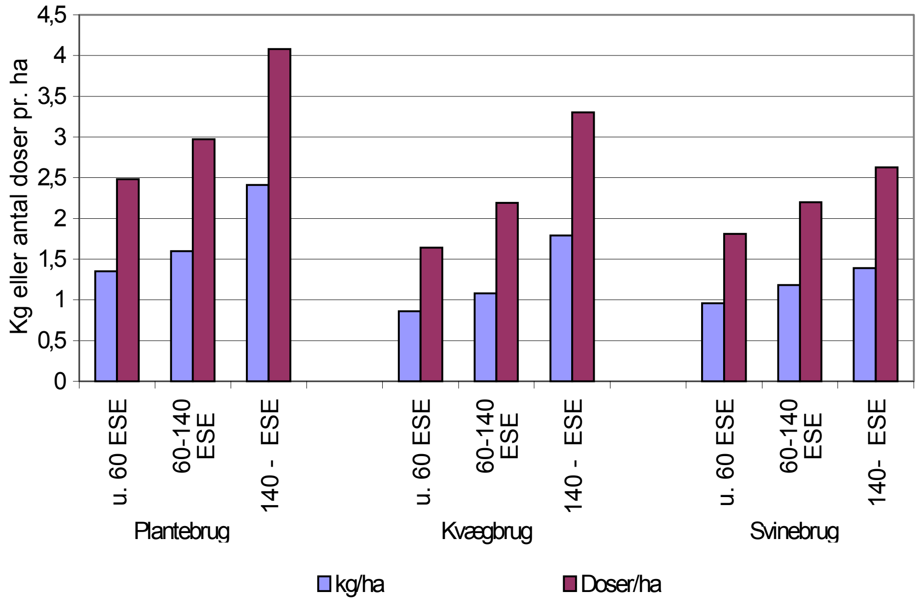
As indicated above, pesticide consumption at part-time farms is considerably lower than at full-time farms. This must be attributed in part to different cultural practices. Full-time farmers are very dependent on their earnings in farming and their production is therefore more efficient than that of part-time farmers, who base their earnings more on work in other occupations. However, it should be noted that the averages shown cover a considerable variation between farms and that there are full-time farms with a low pesticide consumption, just as there are part-time farms with a high consumption. Organic farming has not been included in the analysis.

Difference between size groups ...

When a breakdown of full-time farms by size is carried out, it is found that pesticide consumption per ha increases with the size of the farm (Figure 2.4). Here, farm size is expressed by the European size unit (ESU), which is based on a calculated standard gross margin per farm that takes account of the size of any livestock production. A breakdown of part-time farms by size reveals the same picture.

... is explained by different land use

The reasons for the above-mentioned differences include different land use in the size groups, with the type of soil also playing a role. Large arable farms have a relatively larger acreage with beets and potatoes than small ones (Table 2.3), which means higher pesticide consumption. In the case of dairy farms, the proportion of winter-cereal acreage increases with farm size, while the proportion with spring cereals and grass falls, which also results in higher pesticide consumption. In the case of pig farms, a considerably smaller proportion of the acreage is used for cereals at large farms than at small ones and, at the same time, the proportion used for beets and potatoes increases with the size of the farm, with a consequently higher consumption of pesticides.



(Figure texts:
Kg eller antal doser pr. ha = Kg or number of doses per ha
Plantebrug = Arable farms
Kvægbrug = Dairy farms
Svinebrug = Pig farms
Doser/ha = Doses/ha)

Figure 2.4
Consumption and number of standard doses in size groups, full-time farms 1996/97
See comment and footnote to Table 2.2.
Source: Schou (1998b)

There are thus several factors that influence pesticide consumption, but the principal factor is the land use. In an analysis of the significance of the structure of farming for pesticide consumption, Schou (1998b, p. 30) states that the differences in pesticide consumption between the types of farm and size groups can, in principle, be attributed to two factors: either differences in the individual crops (e.g. that winter wheat is sprayed more intensively at an arable farm than at a dairy farm) or differences in crop composition. Both factors undoubtedly affect pesticide consumption. Schou also states that pesticide consumption seems to show a falling tendency from east to west in Denmark, which must be attributed to the fact that there are more dairy farms and pig farms in the western part of the country than in the eastern part.

Table 2.3

Land use at full-time farms broken down by size, 1996/97

	Arable farms ESU groups			Dairy farms ESU groups			Pig farms ESU groups		
	u. 60	60-140	140-	u. 60	60-140	140-	u. 60	60-140	140-
Spring cereals	23	21	21	28	21	15	24	29	21
Winter cereals	40	44	40	9	13	22	51	46	46
Rape	4	4	3	1	1	2	5	4	8
Pulses and seed	11	9	11	1	1	2	5	6	5
Green fodder	0	0	0	11	17	14	1	0	0
Beets and potatoes	10	11	15	7	7	8	1	3	4
Grass	3	2	2	41	34	29	3	3	3
Set-aside	9	9	8	2	6	8	9	9	10

See note to table 2 and the text. Source: Schou (1998b).

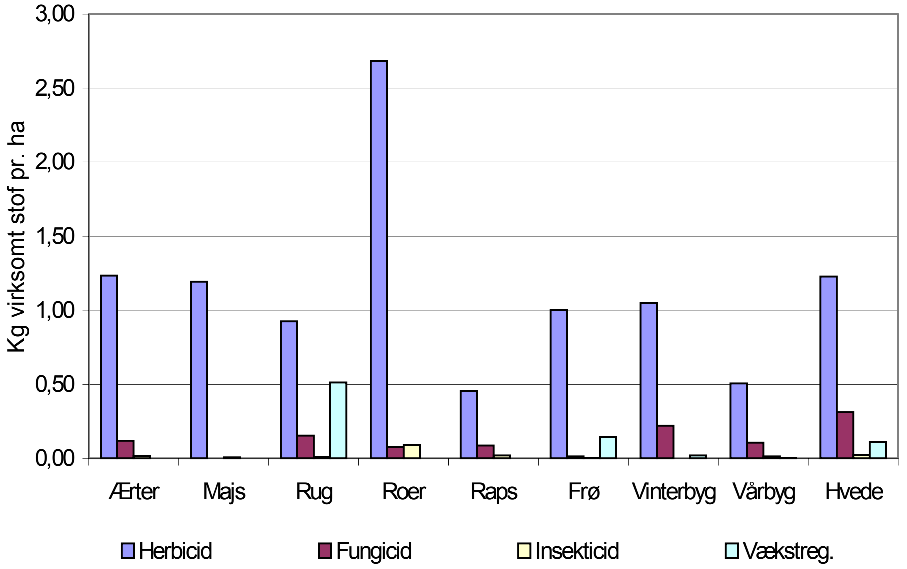
Composition of pesticide consumption

Consumption and ...

The composition of the pesticide consumption varies with the crops. As shown in Figure 2.5, herbicide consumption is highest in beets and lowest in rape and spring barley. In maize, largely only herbicides are used. Fungicides are used particularly in cereals and peas, and insecticides in rape and beets, while growth regulators are used in rye, and winter wheat and in seed production. The analysis concerns the 1997 harvest and thus includes pesticide consumption from autumn 1996 to the 1997 harvest. Potatoes are not included in the figure because consumption in the harvest year in question was affected by a very severe attack of blight, with a consequently abnormally high consumption of fungicides (more than 6 kg per ha).

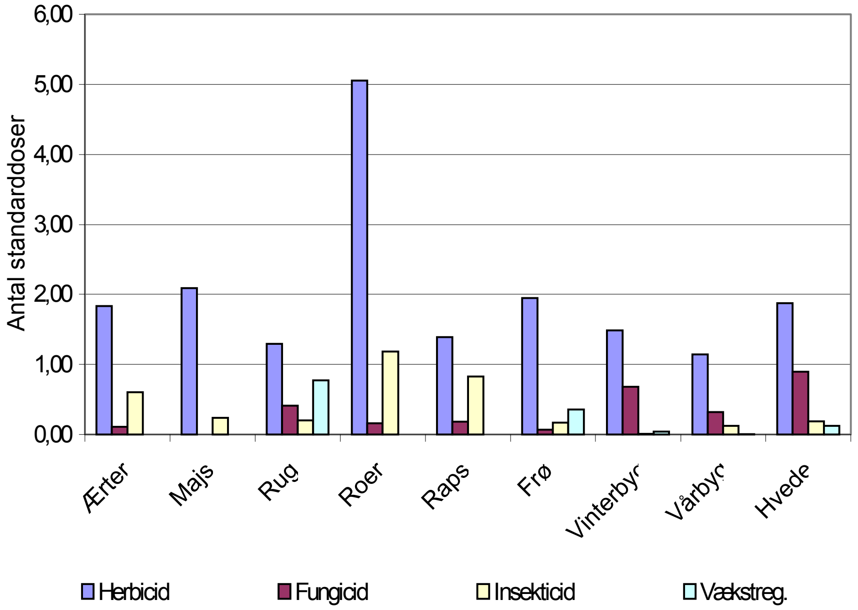
... treatment frequency index varies between crops ...

The treatment frequency shows largely the same picture, with use of 5 standard doses of herbicides in beets and up to 2 standard doses is peas, maize, seed production and winter wheat, just over 1 standard dose in the other crops (Figure 2.6). Treatment with fungicides lay between 0 and 1 standard dose, with the highest treatment frequency index in winter wheat. The treatment frequency index for insecticides was 1.2 and 0.8, respectively, in beets and rape, while, for growth regulators, it was 0.8 in rye and 0.4 in seed production. In total, the treatment frequency index for pesticides was 6.4 in beets (6.6 in potatoes) and 2-3 in the other crops, apart from spring barley, in which it was 1.6.



(Figure texts:
Kg virksomt stof pr. ha = Kg active ingredient per ha
Ærter = Peas   Majs = Maize   Rug = Rye   Roer = Beets   Raps = Rape   Frø = Seed
Vinterbyg = Winter barley   Vårbyg = Spring barley
Hvede = Wheat   Herbicid = Herbicide   Fungicid = Fungicide
Insekticid = Insecticide   Vækstreg. = Growth regulator)

Figure 2.5
Composition of pesticide consumption 1996/97. *See note to Table 2.2.*
Source: Schou (1998b)



(Figure texts:
Antal standard doser = Number of standard doses
Ærter = Peas   Majs = Maize   Rug = Rye   Roer = Beets   Raps = Rape   Frø = Seed
Vinterbyg = Winter barley   Vårbyg = Spring barley
Hvede = Wheat   Herbicid = Herbicide   Fungicid = Fungicide
Insekticid = Insecticide   Vækstreg. = Growth regulator)

Figure 2.6
Number of standard doses 1996/97. *See note and footnote to Table 2.2.*
Source: Schou (1998b)

... and between years, depending on the weather

As stated, the above-mentioned figures are based on a questionnaire-based survey for a single year, with the farmers' actual consumption calculated for the individual crops. Consumption naturally varies from year to year, depending on the weather etc., and the results may therefore deviate from the recommended doses. However, the survey is the first of its kind in which an attempt is made to arrive at a representative measure of pesticide consumption in different forms of farming.

2.3 Pesticide consumption in market gardening and forestry

There are no statistics for pesticide consumption in market gardening and forestry, but the account statistics for market gardening give some indication of the pesticides' share of the costs in this sector. As in the case of farming, chemicals comprise both pesticides and other chemical aids – of which growth regulators (growth retardants) are of particular importance in the production of pot plants. In addition, chemical agents are used for disinfecting soil etc.

Pesticide consumption is highest in fruit and berries

As shown in Table 2.4, chemicals' share of the costs in market gardening varies considerably from production to production. The highest consumption is in fruit and berries, in which chemicals account for over 7 per cent of the total costs.

Biological control in greenhouses

In the production of outdoor vegetables, chemical consumption accounts for 2 per cent of the costs. It will also be seen that biological control plays a rather significant role in greenhouse production. Compared with the consumption of chemicals in farming (Table 2.1), the costs for chemicals constitute a relatively small part of the total costs. It is thus only in fruit and berry production that the consumption is in line with farming.

Table 2.4
Consumption of chemical and biological agents in market gardening, 1997/98

	DKK 1,000 per production unit		Percentage of costs, total	
	Chemicals	Biological control	Chemicals	Biological control
Vegetables under glass	10.4	25.1	0.4	1.0
Pot plants under glass	30.9	13.7	0.8	0.3
Outdoor vegetables	21.6	0.2	2.0	-
Fruit and berries	40.0	0.2	7.2	-
Nurseries	28.4	0.3	1.3	-
All production units	28.5	5.9	1.3	0.3

Source: SJFI (1998c)

2.4 Summary

Summary

The analysis shows that the choice of crop is the main factor determing pesticide consumption in farming. There is widespread use of herbicides for weed control in all crops, with the highest consumption per ha in root crops and the lowest in rape and spring barley. Fungicides are used particularly in potatoes, cereals and peas, while insecticides are mainly used in rape, cereals and beets. Growth regulators are used in rye, winter wheat and seed production.

The above usage is reflected in the pesticide consumption in the different forms of farming. Measured by kg active ingredient per ha, pesticide consumption is highest at full-time farms and somewhat lower at part-time farms, which is in line with the somewhat lower intensity production at the latter. Owing to a large production of cash crops, pesticide consumption at arable farms is generally high, whereas dairy farms, with fewer cash crops and a larger acreage under grass, have a lower consumption. Consumption at pig farms is largely level with that at dairy farms.

The analysis also shows that total pesticide consumption in the agricultural sector, measured in kg active ingredient per ha, fell by half from the mid-1980s to 1997, but was not accompanied by a similar fall in treatment frequency index. One reason for this anomaly is a big reduction in the acreage used for root crops in the period in question, which helped to reduce the need for pesticides, while the change from spring to winter cereals worked in the opposite direction.

Compared with farming, chemicals' share of the costs in market gardening is relatively low. It is thus only in fruit and berry production that the share is approximately the same as in farming. The lower consumption is due in part to increasing use of biological methods of controlling pests in greenhouse production.

3 Fundamental considerations concerning regulation of pesticide consumption in the agricultural sector

3.1 Introduction

Uncertainty concerning the effect on health and the environment

The use of pesticides has created a basis for increased productivity and rising yields in the agricultural sector. Farmers thus have a clear economic interest in exploiting the possibilities offered by pesticides. However, the use of pesticides is giving rise to increasing concern about their effect on the environment. There is concern both about possible harmful effects on health as a consequence of pollution of groundwater and products and about the effect of pesticides on fauna and flora. Advantages and disadvantages of the agricultural sector's use of pesticides must therefore be assessed in a general societal framework, in which the risk of environmental and health effects is weighed against the economic benefits.

Unilateral Danish regulation of access to import conventional products

In an assessment of these issues, it must be decided whether they are transboundary or purely national problems. That applies both in economic analyses, since Denmark, as a member of the EU, is subject to the Common Agricultural Policy, and to the choice of environmental instruments. In the case of cross-border pollution, the problems can usually only be solved effectively if the affected countries coordinate their action. It must also be borne in mind that the possibilities of environmental regulation are subject to international agreements (WTO and EU) that do not permit discrimination against imported products, just as a country may only make requirements concerning production standards (*the way* products are produced) in respect of products produced in that country. The following analyses are based on unilateral Danish regulation of pesticide consumption and an assumption that Danish consumers and producers have access to purchase conventional foreign products and means of production.

In the following, the question of prioritising between economic benefits and environmental considerations is discussed in relation to the setting of political goals for pesticide consumption. Also discussed, in the context of weighing between economic and environmental considerations, are the problems of fixing relevant political goals and valuing environmental goods, together with the questions of risk and uncertainty, the precautionary principle and irreversibility, as elements of policy planning. The chapter ends with a discussion of regulation of pesticide usage and the choice of regulatory instruments.

3.2 Prioritisation and goal

Overall assessment of economic and environmental impacts

Externalities for the farmer…

As mentioned, regulation of the use of pesticides in agriculture should be based on an overall assessment of the economic and environmental impacts from the use of pesticides. The need for regulation arises from the fact that the user cannot be directly expected to consider, in his production planning, the impact of his production on the surrounding environment because the impact is not reflected – or is only reflected to a limited extent – in the user's production costs. In other words, environmental damage is an externality for the producer. There is thus no financial incentive for him to reduce the harmful effect on the environment even though, like other population groups, he may naturally have a personal interest in preserving a clean environment.

...Need to be regulated through political restrictions

A possible solution to the problem is to have the producer share the cost imposed by his production on other population groups in the form of damage to the environment so that he has a financial incentive to plan his production with a view to reducing its environmental impact. Such a solution would require government intervention in the form of restrictions on pollution from this source. The classic example is the use of environmental taxes (or quotas) that ensure that pollution does not exceed a societally acceptable level.

Extreme prioritsations is seldom optimal

The basis for such regulation is that the welfare gain from an improved environment varies with the degree of pollution: the greater the pollution, the higher the value attached to an improved environment. Conversely, it is usually relatively cheap to reduce pollution when this is at a high level, whereas it is disproportionately costly to remove the last unit of pollution. It is seldom optimal to choose an extreme prioritisation, such as prohibiting the pollution altogether or one-sidedly maximising the microeconomic return without considering environmental and health impacts. The societally optimal[3] level of pollution is defined as the level at which the welfare loss for the producer from further reducing the pollution is exactly balanced by the welfare gain for other population groups. This also means that it will normally be reasonable from a societal point of view to permit some pollution.

Consideration of future generations' preferences

The procedure is complicated by the fact that the environmental impacts from pesticides can be irreversible, making it necessary also to consider future generations' preferences when fixing the optimal burden. A lack of exact knowledge concerning the long-term environmental impacts of pesticides (on ecosystems, DNA, allergies, etc.) makes the ideal, environmentally based approach difficult.

This raises a number of questions concerning the formulation of the goal for reduction of the pollution:

- The current political goal is to reduce pesticide consumption, but it is in reality the risk of harmful environmental and health impacts that the government wants to reduce. Is it possible to define a measure for the environmental burden that reflects the expected environmental and health impacts of pesticides, and that at the same time satisfies the requirements concerning effective regulation of the agricultural sector's use of pesticides?

- The environmental impact from the use of pesticides in agriculture varies with the natural circumstances. In environmentally sensitive areas, even a small loss of pesticides to the environment can have serious consequences, while other areas are less sensitive. The same applies to a great extent to the impact on flora and fauna. The extent of the damage also varies with the nature of the agents and the objects of the treatment. How are these factors dealt with in policy planning?

- In order to establish a societally optimal environmental strategy, it must be possible to compare economic and non-economic quantities. The welfare loss

[3] In this context, societal optimality should be understood to mean that the optimisation takes account of both economic factors and environmental values (one could also talk of welfare-based economic optimality), whereas, in socioeconomic optimality, only economic factors are considered.

from reducing production can be approximately expressed as the economic loss to society, while the environmental gain will be expressed as better public health, a better environment or a more attractive countryside - all of which are difficult to value in money terms. Is valuation of environmental goods a viable way of deciding environmental strategies, and how is this handled in practice?

- In many cases, the health consequences of pesticide consumption are not known, and there will often be a considerable time lapse between use of pesticides and harmful environmental and health impacts. How does one handle risk and uncertainty when evaluating environmental damage? Is use of the precautionary principle in policy planning, where the uncertainty benefits the "injured parties", compatible with a societally optimal solution?

In the following, these questions are discussed in relation to the formulation of a societally optimal policy in this area.

3.2.1 The political objective

The political objective includes health and environment

As mentioned, the use of pesticides can have a number of undesirable consequences for human health and the environment. Pesticides can accumulate in soil and water and can harm flora and fauna. The use of pesticides also involves a risk to human health, either in the form of acute poisoning, where a person is, for example, exposed to large doses (while filling a sprayer tank) or in the form of more long-term effects, where persons are exposed to small doses over a long period of time (pesticide residues in food products or drinking water).

Lack of scintific evidence,..

According to the Danish Working Environment Authority (1986), only a few cases of acute pesticide poisoning have been reported, and Christensen & Schou (1998), in a review of the literature, have not found scientific evidence of a relationship between the general state of health and the occurrence of pesticides in Danish food products or drinking water. There are, on the other hand, examples of an increased risk of cancer in workers in the chemical manufacturing industry, and damage to flora and fauna from pesticides has been observed (Christensen & Schou, op.cit. p. 12). Readers are also referred to the report from the Sub-committee on Environment and Health.

... but concern about harmful effects

Even so, there is growing concern that the harmful effects of use of pesticides in practice will increase. In 1987, this led to the Pesticide Action Plan (Danish Environmental Protection Agency, 1997), the aims of which included reduction of pesticide consumption with a view:

- to protecting people against health risks and harmful effects from the use of pesticides. This applies both to the users of the products and to the general public, who must be protected against ingestion via food products and drinking water,
- to protecting the environment – i.e. both harmless and useful organisms among flora and fauna on and in the soil and in aquatic environments.

It was determined in the action plan that total pesticide consumption was to be halved and that consumption was to be steered towards less harmful agents (box 1).

The reduction was to be achieved partly through advisory activities and partly through intensified research on ways of reducing pesticide consumption. It was also stated that the consumption of agents with particularly undesirable health and environmental properties was to be recorded separately as an element of a system for controlling consumption. In addition, a 3 per cent tax on pesticide consumption was introduced to finance the schemes initiated.

In that very same year, 1987, the rules were changed, bringing an end to approval of products deemed to be particularly dangerous to health and introducing the requirement of a review of agents previously registered and classified by the Toxic Substances Board.

The "Action Plan for Sustainable Farming" from 1991 was followed by a decision to require spraying logs and random inspection of sprayers and to make compulsory the part of the training of farmers etc. that had previously been voluntary. In addition, rules were introduced on the use of pesticides in environmentally sensitive areas.

Box 1
Main content of the Pesticide Action Plan from 1986

Pesticide action plan from 1986

Goals:
1. *Measured in relation to 1981-85, the total consumption of pesticides must be reduced by at least 25 per cent before 1 January 1990 and by a further 25 per cent before 1 January 1997*
2. *Consumption must be changed towards less dangerous agents.*

Instruments:
- *Increased advice and research on the use of pesticides and assessment of the effects of that use*
- *Tightening of the approval scheme for pesticides by requiring assessment of their human toxicity and ecotoxicological effects. The tightening of the scheme was made retroactive (requiring reassessment of already approved pesticides)*
- *A requirement that all farms of 10 ha and over keep a spraying log*
- *A requirement that all persons working professionally with pesticides acquire a spraying certificate*
- *Introduction of technical standards for spraying equipment*
- *A ban on the use of pesticides in environmentally sensitive areas (e.g. wetlands, hedgerows and dykes) and closer than 2 metres of lakes and watercourses*
- *A 3 per cent tax on the wholesale value.*

Tax increased in 1996

In 1996, the tax on pesticides was increased[4] and differentiated between types of pesticide (herbicides, fungicides and insecticides). There was no differentiation between the groups of pesticides with respect to their toxicity. The differentiation is thereby presumed to have resulted primarily in the use of cheaper agents rather than in a reduction in the consumption of dangerous agents.

A proxy is a compromise between the ideal and what can be administered

For practical reasons, a decision has been made to link the goal to pesticide consumption in the agricultural sector and to the treatment frequency index, which can be measured with reasonable certainty in practice. However, focusing on the consumption of pesticides instead of the environmental and health impacts means that the goal is distanced from the primary impacts, making it difficult to control the environmental burden. The ideal would be to be able to set the goal in relation to the damage to health and the environment, but owing to the above-mentioned

[4] In 1996-98, the tax averaged 15 per cent of the wholesale price before the introduction of the tax, but almost doubled from 1 November 1998.

constraints, the choice of proxy will often be a comprise between the ideal and what can be administered in practice.

The problem of measuring the damage sets narrow bounds on the choice of proxy for environment and health. Whereas the impact of pesticides on the natural environment can, for example, be expressed by the frequency of selected flora or fauna in areas adjoining cultivated areas, establishing a measure for the health effect of pesticide usage is a different matter altogether. As mentioned, little is known about the relationship between pesticide usage and human health, and it will often be difficult to quantify the harmful effects of pesticides.

Proxy for harmful effect

Therefore, in practice, the only option is to use approximated measures (proxies) for the harmful effect of pesticides, such as the degree of pollution of the groundwater, the toxicity of the agents, the risk of leaching or – as in the case of the Pesticide Action Plan – the amount of active ingredient. It is obvious that the further the application of the measure is from the real harmful effect, the more difficult it becomes to control that effect. However, as described later, it is also important for the control of pesticide usage to be linked so closely to the production that the farmer/producer can relate to it.

OECD (1997) suggested classifying pesticides environmentally in risk groups based on their mobility in the soil, their biodegradability and their toxicity. When this is combined with information on standard doses per ha, it becomes possible to get an expression of the agents' potentially harmful effect. However, that does not solve the problem of fixing an acceptable level of use of the agents, since to do that, one must know the relationship between the agents' toxicity and the damage to health caused by that.

Threshold value for pollution of the groundwater

The above-mentioned problem led to the establishment of threshold values for permitted concentrations of pesticides in the groundwater, which in practice meant that it was not permissible for measurable quantities to be found in drinking water, using the measuring methods available at that time. Such limits are an example of a prioritisation that does not take account of the toxicological risk of harm and that therefore precludes any economic weighing against other solutions, such as treating the drinking water. This problem is taken up below in connection with the discussion of the precautionary principle.

In the discussion so far, it has been implicitly assumed that there is one goal to be met. In reality, there are a number of partial goals that it is considered desirable to fulfil at the same time: the use of pesticides involves a risk to both the environment and health, and there will often be a complicated interaction between different impacts that must be combined into a common goal. For example, the use of insecticides affects the number of prey in the environment and thus the basis of life of higher animal species. At the same time, pollution of the groundwater with pesticide residues can result in a risk of poisoning of humans and animals. What weight should be assigned to the different harmful impacts? Should damage to human health be given a higher weighting than damage to animals and the environment? These questions are taken up in the following section in connection with valuation of environmental goods.

3.2.2 Valuation of pesticide externalities[5]

Societal analysis requires valuation of health and environmental goods

As described above, regulation of the use of pesticides in the agricultural sector should, in principle, be based on a societal analysis of the economic and environmental effects of the use of pesticides, the aim being to optimise society's welfare. Such an analysis is difficult because economic and environmental considerations are not directly comparable: the consumption of marketed goods can be expressed in kroner and øre, while the environmental impact of pesticides, for example, can be expressed by the number of wild plants in a given area, the non-appearance of a given species of bird or the concentration of pesticide residues in the groundwater. We are thus faced with the problem of weighing different environmental goals against each other and evaluating their importance with respect to welfare in relation to the loss of welfare from limiting the consumption of produced goods. The basis for such weighting will often be valuation of the environmental goods.

Economic valuation must reflect the population's preferences

Economic valuation is based on the fact that policy planners seek to ensure that society's resources are used in accordance with the population's preferences. Valuation of environmental goods is an attempt to profit the political decision-makers with information on the strength of the population's preferences for different environmental goods – expressed by the hypothetical willingness to pay for these goods. In other words, one attempts to measure the market consumption that the population will be willing to forego in return for a specific improvement in the quality of the environment. When the value of an environmental good is thus calculated in monetary units, it becomes possible to compare the gain from producing or preserving the good with the costs involved in that.

The consumer must choose

It is a fundamental economic axiom that scarce goods that have alternative uses cannot be free in the societal sense of the word. That applies both to produced goods and environmental goods and it is based on the fact that, when not all needs or wishes can be satisfied, the consumer has to choose. If more resources (in the form of manpower, capital, etc.) are used for environmental purposes, there will be a societal cost in the form of fewer resources for production of goods and services for consumption. Conversely, it must be reckoned that, all else being equal, increased production of tangible goods will reduce environmental quality.

Cost-benefit analysis

The idea of valuing environmental goods is that, provided prices can be put on such goods, it will be possible to carry out a *cost-benefit* analysis, in which changes in the value of produced goods are compared with changes in the value of environmental goods and, by that means, assess the welfare consequences of regulating agricultural use of pesticides.[6] The difficulties of such an analysis are compounded by the fact that it should, in principle, incorporate future generation's preferences and take account of cross-border pollution.

There are, in principle, two possible approaches to such valuation: the preference-based method, in which one seeks to measure people's willingness to pay for environmental goods, and the non-preference-based method, in which one typically looks at the socioeconomic costs of repairing environmental damage.

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[5] The section is to a large extent based on Dubgaard et al. (1998a), Dubgaard (1999) and Dubgaard & Østergård (1999).

[6] The method corresponds, in principle, to the conventional welfare analysis, in which welfare is measured by value growth in society, but where the income measure here also includes the value of environmental goods.

Preference-based method

Preference-based method

The aim of the preference-based method is to identify people's willingness to pay for non-market goods. The problem is that most environmental goods are in the nature of public goods, for which a market does not exist.[7] In other words, there is no instrument for pricing the good. This situation is often described as a *market failure.* When making a valuation on the basis of the preference-based method, one seeks to solve this problem either by interviewing consumers to identify their willingness to pay for the goods in question (direct method) or by observing consumer demand for market goods associated with the consumption of non-market goods (indirect method).

As an example of *direct valuation,* Dubgaard & Østergaard (1999) mention a Dutch survey carried out to determine consumers' willingness to pay for biodiversity through scheduling of environmentally sensitive land (Brouwer & Slangen, 1998). Here, a conditional valuation was carried out to establish a monetary estimate of the gains achieved by the rest of the population from cultivation agreements. The willingness to pay covered both the utility value and the non-utility value of plants and birds in the areas in question. Examples given include Oskam & Slangen (1997), who focus on the gains from implementation of a protection programme for landscapes in which farming is the primary activity and a study of preservation of pasture-land *(hagmark)* in Sweden at the beginning of the 1990s (Drake 1992).

As an example of *indirect valuation,* Dubgaard et al. (1998a) mention that the value of a recreative area could be fixed on the basis of consumers' statements about what they are willing to pay to visit the area (the travel-cost method). Measuring recreative values on the basis of differences in house prices in different recreative environments is another example of indirect valuation.

Non-preference-based method

Non-preference-based method

The aim of the non-preference-based method is to estimate the societal value of an environmental good on the basis of the cost of repairing environmental damage. The analysis is based on two assumptions: firstly, that specific political limits have been set for the pollution (e.g. the content of chemicals in drinking water) and, secondly, that the socioeconomic cost of achieving the political goals reflects the value that the consumers assign to the environmental goods in question.

An example of such a valuation is a Danish analysis of the technological and economic feasibility of treating drinking water (Chrintz 1997). The result arrived at is that the cost of treating drinking water by means of carbon-filter analysis is DKK $3/m^3$. For pesticides that can only be separated by osmosis, the cost is DKK $6\text{-}7/m^3$. It is stated in the analysis that some types of pesticides and their breakdown products cannot yet be removed from drinking water.

Dubgaard et al. (1999) also report a Danish analysis now in progress, the aim of which is to calculate future savings within the drinking water supply system if pesticides are no longer used in Denmark. In this connection, importance is attached to the fact that *future* losses as a consequence of *earlier* times' use of pesticides cannot be prevented by stopping using pesticides in future, since, seen economically, this is a "sunk cost". The aim is thus to devise an alternative cost analysis that covers only the societal savings that can be expected from non-use of pesticides in the future. Such an analysis requires estimation of the extent to which

[7] For price formation to be able to happen in a market, one consumer's purchase must prevent others from consuming the same good (rivalisation) and access to the market depends on payment of a price for the good (discrimination). Public goods do not fulfil these conditions and therefore cannot be priced in the market.

the pesticides that farmers are permitted to use today will cause pollution of the groundwater, and the time horizons involved.

Summary

Summary

The requirement concerning valuation depends to a great extent on whether economic benefits are to be weighed against environmental values or whether the environment policy goal has been fixed in advance. If the starting point is that pesticide pollution must not exceed certain threshold values (e.g. 0.1 μ/litre groundwater), it is, in principle, of no interest to try to value the environmental gain. In this case, the task is to achieve the agreed goal in the most efficient way, i.e. to find the method that will ensure achievement of the goal at the lowest possible cost. An example of such an analysis is treatment of drinking water versus a ban on the use of pesticides. The method precludes any weighing between economic and environmental considerations.

If, on the other hand, the aim is to weigh economic benefits against environmental values, the environmental gains have to be measured. In this case, the criterion for whether a solution is societally acceptable is that the environmental gains are greater than the economic losses from ensuring them. The above-mentioned analysis of future savings within the drinking water supply system if pesticides are no longer used is an example of a valuation in which the savings are taken as a measure of the value assigned to pesticide-free drinking water by the consumers. By comparing the savings with the costs of stopping using pesticides, an expression is obtained of the *cost-benefit ratio*, which must be smaller than one in order to be societally acceptable. Such an analysis ensures that the *benefits* are greater than the *costs*, but does not guarantee societal optimality.

As mentioned earlier, for societal optimality, the marginal environmental benefits must equal the marginal costs of improving the environment. It is thus necessary to know the value of the environmental gains from changed pollution in order to indicate the optimal solution. This makes special requirements concerning the valuation of environmental goods, and the valuation is made even more difficult by the fact that the analysis must, in principle, cover the impacts on both health and the surrounding environment in order to get a complete picture of the societal benefits from reducing the use of pesticides. It is thus very difficult to indicate the societally optimal solution to the use of pesticides in agriculture.

Lastly, it must be added that the value of environmental goods must be expected to vary with the economic prosperity of the population. High-income population groups generally attach more importance to environmental goods than low-income groups, which underlines the problems of transferring results of valuation studies from one country to another.

3.2.3 The precautionary principle

The precautionary principle is linked to uncertainty concerning:

Measurement of the impact of pesticides on the environment and health is encumbered with considerable uncertainty.

- optimal pesticide usage

Firstly, it is difficult to fix the optimal use of pesticides in agriculture. There are several reasons for this, including the fact that the timing of the treatment is vital. In periods with severe pest attacks, a delay in treating the crop in question can result in a need for extra heavy dosage to achieve the desired effect, while in periods with few pest attacks it can be difficult to dose sufficiently finely (only part of the crop is attacked, but for practical reasons the entire acreage is sprayed). Furthermore, the farmer’s financial result is uncertain owing to fluctuations in the harvest yield. Production planning and treatment monitoring are thus also encumbered with uncertainty, which will also be reflected in the harmful impact.

- extent of pollution

Secondly, there is uncertainty about the extent to which pesticides used in agriculture end up in the groundwater and the food chain and about when this can be expected to occur. The uncertainty concerning the time frame means that the needs of future generations must be taken into account when assessing the extent of the damage.

- impact on health and environment

Thirdly, there is uncertainty concerning the harmful effect of pesticides on human health and the environment because, in many cases, too little is known about this.

In the following, the precautionary principle is discussed in relation to these uncertainties.

Definition of the precautionary principle

The precautionary principle

The potential harmful impact from the use of pesticides is causing widespread concern, both in the general public and in scientific and medical circles. With a view to preventing harm to the environment and health, Denmark and the EU have chosen to set restrictive threshold values for the content of pesticides in drinking water and food products.[8] Owing to the uncertainty concerning the effect of harmful substances in the aquatic environment, agreements that consideration for the environment shall have priority in cases in which there is uncertainty about the outcome – the so-called *precautionary principle* – have been incorporated in a number of international treaties and declarations.

… gives priority to the environment

The precautionary principle was originally developed in German environment law and, partly via the North Sea Convention, found its way from there to the Union Treaty. In German, the word used is “vorsorge”, which actually means prevention, and the principle means orienting the planning of society’s activities (production, energy supply, etc.) towards preventing environmental problems – especially irreversible problems – before they arise. For a detailed description, readers are referred to Boehmer-Christiansen (1994) and Zimmermann (1990).

The precautionary principle is embodied in international agreements …

The principle is mentioned in the conclusions from the first North Sea Conference in Bremen in 1984 and is embodied in the ministerial declarations at the subsequent North Sea Conferences (see the box). It has since been embodied in a number of other international agreements (Danish Environmental Protection Agency).[9]

The precautionary principle

Accepting that, in order to protect the North Sea from possible damaging effects of the most dangerous substances, a precautionary approach is necessary which may require action to control inputs of such substances even before a causal link has been established by absolutely clear scientific evidence.

The Ministerial Declaration at the Second North Sea Conference in 1987
Source: Danish Environmental Protection Agency (1998b)

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[8] The threshold value of 0.1 µ/litre was originally set as the lowest measurable quantity. The low threshold value reflects a political wish for pesticide-free drinking water at any price.

[9] The precautionary principle is, for example, embodied in the Bergen Declaration on Sustainable Development (1990), the Montreal Protocol on Protection of the Ozone layer (1990), the UN’s Framework Convention on Climate Change (1992), the Rio Declaration on Environment and Development (1992) and the UN Convention on Biological Diversity (1992).

… and in EU policy …

A formulation of the precautionary principle is also embodied in the EU Treaty from 1992 (The Maastricht Treaty), which states: “Community policy on the environment shall aim at a high level of protection taking into account the diversity of situations in the various regions of the Community. It shall be based on the precautionary principle and on the principles that preventive action should be taken, that environmental damage should as a priority be rectified at sources, and that the polluter should pay.” It is also stated in article 130 R(3) of the Treaty that in the formulation of Community policy, attention shall be paid to (Danish Environmental Protection Agency, 1998b, p. 6):

- existing scientific and technical data
- the environmental situation in the various regions of the Community
- the advantages and disadvantages of implementing a measure and of not implementing it
- economic and social development in the Community as a whole and balanced development in its regions.

It is thus not stated in the treaties that intervention against damage to the environment must await scientific evidence. However, the precautionary principle has a less far-reaching formulation in the Maastricht Treaty than in the above-mentioned international agreements.

… but only indirectly in Danish legislation

The precautionary principle is not mentioned directly in Danish legislation, but the approach is, for example, embodied in the introductory provisions of Environmental Protection Act: "The purpose of this Act is to contribute to safeguarding nature and environment, thus enabling a sustainable social development in respect of human conditions of life and the conservation of flora and fauna.”(Danish Environmental Protection Agency, 1998b, p. 2). The aim of pesticide-free drinking water is another expression of the fact that the precautionary principle has found its way into Danish legislation.

Well-founded uncertainty concerning harmful effect

The crux of the precautionary principle is that well-founded uncertainty concerning the harmful effect of environmentally foreign substances can in itself occasion intervention, even in the absence of certain scientific evidence. The reason for this is the relatively strict requirements made concerning scientific evidence, compared with the complexity of the interaction between environmentally foreign substances’ interaction with nature and health, where it is often difficult to document the possible multivariate relationships. The time factor also plays a role here, in that the relationships can only be documented ex-post, thereby reducing the possibility of avoiding the environmental impacts.
However, the precautionary principle has a broader meaning that also implies a duty to coordinate research and development of new and less environmentally harmful technologies.

Risk and uncertainty in economic analysis

In economic theory one differentiates between *risk* and *uncertainty*, risk being used about outcomes that can be described by a statistical probability distribution, while uncertainty is used about outcomes where there is no empirical data on which to build or where the range of outcomes cannot be delimited. Dubgaard et al. (1998b), in describing the problem, used the example that animal tests can be used to derive statistical probabilities for a relationship between the use of pesticides and the occurrence of cancer in animals, but that transferring such results to risk analysis for humans rests on assumptions that cannot be thoroughly tested because human experiments are precluded. The effect of similar treatment on humans is therefore uncertain.

Uncertainty

Optimal environment policy under risk

In the basic environment-based economic model, the environment is treated as a consumption good in line with produced goods and services, and the consumption must be combined in a way that ensures maximum societal welfare. Other assumptions for the model are that the marginal utility falls with rising consumption and that there is a negative relationship between the production of produced goods and environmental goods (damage to the environment increases with rising production). The optimal societal solution is therefore ensured when the marginal damage to the environment is equal to the marginal cost of reducing the pollution. It is assumed in the analysis that the environmental damage can be valued so that damage and cost can be compared.

In practice, there will be uncertainty about the environmental impact. If the probability of a given outcome is known, it is possible to calculate the marginal damage under various assumptions concerning the consumers' risk assessment. This is illustrated in Figure 3.1, which shows the optimal environment policy under risk with a known probability distribution. The heavily drawn curves show the marginal damage (MD) and the marginal cost (MC) with increased pollution. Here, the MD curve has a probability distribution attached to it, showing the statistical distribution of a given outcome, and the curve E(MD) is the unbiased estimate of the marginal damage.

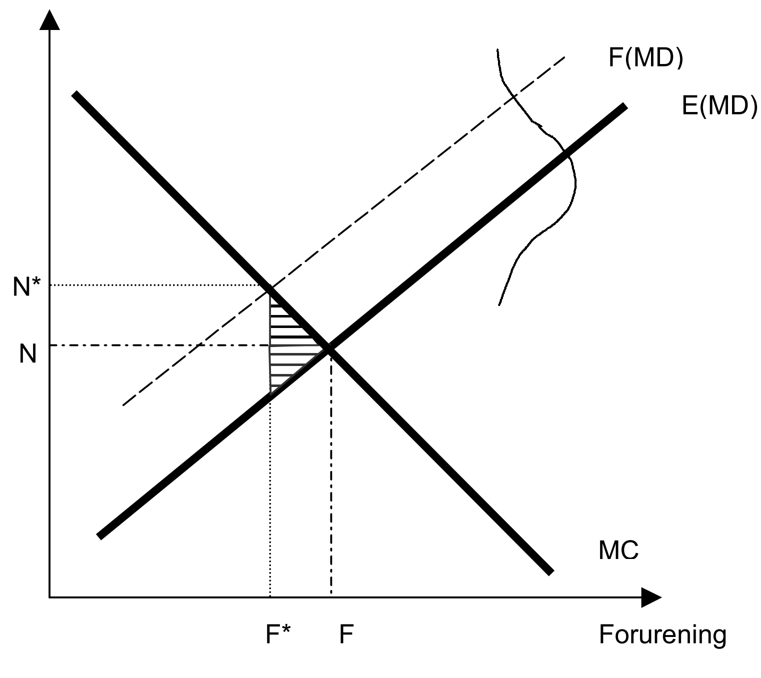

Figure 3.1
Socioeconomically optimal environment policy under risk
(Figure text:
Forurening = Pollution)

However, the decision-maker may be averse to risk and therefore assign greater importance to deviations above the E(MD) curve than to deviations below it. He will therefore not rely on the simple mean value curve, but on the F(MD) curve. In such case, the optimal solution will be not F, but F*. Measured in relation to the risk-neutral consumer, there will therefore be an income loss corresponding to the marked triangle that the risk-averse consumer is willing to pay for greater certainty. This is a risk premium he pays for maintaining the higher level of certainty corresponding to F(MD). There is no question of real uncertainty, but simply of risk aversion.

Optimal environment policy under uncertainty

In many cases, one is faced with making a decision on environment policy without having any real statistics on which to assess the extent of environmental damage. In economic terminology this is called decision-making under *uncertainty,* i.e. there is no statistical probability distribution for the extent of the damage. This is illustrated in Figure 3.2, where the societally marginal damage function is only known in the interval 0 – F. In the case of greater damage, the marginal damage function can be vertical (A) or horizontal (B) or somewhere in between (the probability distribution is not known). One is therefore in a situation in which there is no scientific basis for saying anything about the probability of the extent of the damage (except that it is expected to lie between the vertical and the horizontal curve (A and B)). In such a situation, the risk-averse consumer will most probably choose pollution level F, which is the certain solution, but at high marginal cost (Nc), while the risk-taking consumer will choose solution F'. The triangle C in the figure illustrates the extra cost of choosing the pollution level F instead of F', which must be compared with the environmental benefits gained.

DØR (1998) states, with reference to Arrow & Hurwicz (1972), that, under uncertainty, it is rational to base the decision on extreme outcomes that give the minimum or maximum outcome. As an example of decision criteria, DØR mentions “maximin” and “maximax”, which express the highest

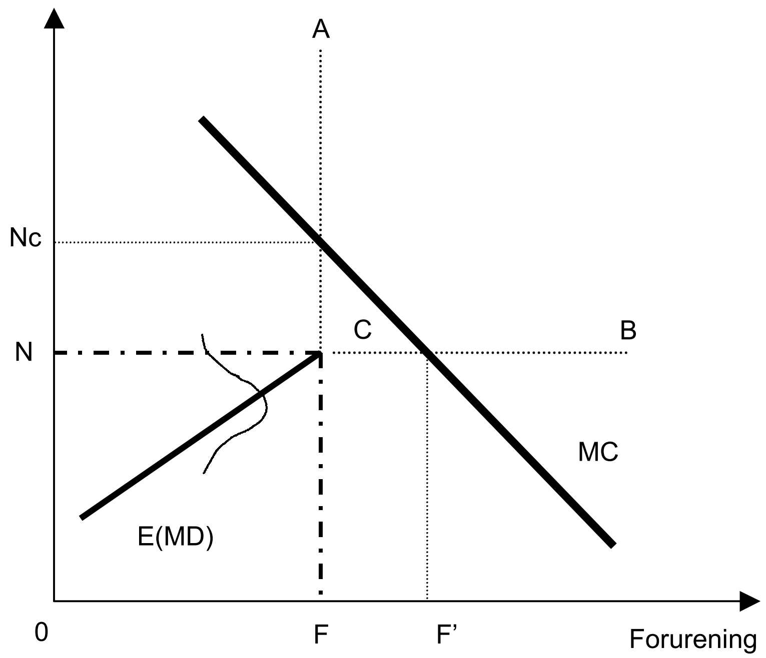

Figure 3.2
Environmental policy under risk and uncertainty'
(Figure text:
Forurening = Pollution)

Choice of criteria for decisions

achievable welfare with major and minor environmental damage, respectively[10], taking into account the cost of alternative intervention against environmental pollution. The method is an alternative way of looking at the precautionary principle, where decision-makers that are averse to uncertainty prefer the maximin

[10] *Maximin*: For each policy, one identifies the maximum possible loss of utility and then chooses the policy in which this loss is smallest. *Maximax*: One chooses the policy that produces the maximum possible welfare.

criterion (pessimistic assessment), while risk-taking decision-makers prefer the maximax criterion (optimistic assessment).

DØR (1998) also points out that the maximin and maximax criteria are suitable instruments for identifying research areas that should be given priority in order to gain new knowledge and thus reduce the uncertainty. The crux of the problem is to narrow down the range of outcomes for events under uncertainty. Therefore, according to the report, it is better to concentrate on improving knowledge about the extreme outcomes than on analysing intermediate scenarios.

Consumer sovereignty

Dubgaard et al. (1998b, p. 3f) have analysed the problems concerning decision-making under uncertainty on the basis of the existing literature. The key words are *consumer sovereignty,* i.e. the right of consumers to remain sceptical about the use of certain substances in food production, even when there is no scientific evidence that the substances in question are dangerous. Buschena & Zilberman (1994) state: "Research in risk perception and risk behaviour shows that it can be difficult to explain people's assessment of different risk factors on the basis of the assumptions concerning rationality and consistency used in economic theory." Pearce (1994) reported a number of experiments that show that people attribute greater probability to events they can envisage than to events they have difficulty in envisaging. Furthermore, there is often a distorted perception of small probabilities, which are either overestimated or underestimated.

Rational updating of subjective assessment

However, Dubgaard et al. (1998b, p. 4) also refer to research aimed at improving decision-making under uncertainty. The conclusion is that individuals carry out rational updating of their subjective assessment on the basis of information concerning the objective probabilities as further information gradually appears concerning the potentially harmful effects of chemical substances and other potential causes of damage to the environment and health.

Irreversibility

Irreversibility comprises:

The above-mentioned discussion focused mainly on decision-making under risk and uncertainty. However, choice of environment policy is also affected by irreversibility in the basis for decisions. This can relate to economic factors, in that decisions to initiate major investments in rectifying environmental damage will be binding on future decision-makers. It can also relate to biological factors since failure to intervene can result in accumulated damage that cannot be rectified at a later date. Lastly, it can relate to the political decision-making process, in that, for reasons of credibility, politicians will have difficulty in changing a policy once this has been decided upon. One can thus speak of economic irreversibility, biological irreversibility and lack of decision-making flexibility, all of which can be translated into economic terms.

- economic irreversibility

Economic irreversibility concerns the situation in which combating pollution implies investment in technical plant that will subsequently be in the nature of a 'sunk cost', i.e. the investment sum cannot be recovered by selling the investment good. An example is investment in water-treatment plant to remove pesticide residue from drinking water. Once the investment has been made, it will – until the plant is technologically obsolete - reduce the possibility of introducing other forms of protection of the groundwater since the costs of the investment must in all events be paid.

- biological irreversibility

Biological irreversibility relates to the situation in which the damage depends on the accumulated pollution, and in which pollution continuously accumulates in nature because nature's capacity for regeneration is exceeded. Complete irreversibility is a situation in which the pollution cannot be removed by nature's own biological processes (e.g. heavy metals), or in which the pollution results in the eradication of species of fauna or flora. In this case, the damage from the accumulated pollution is in the nature of a 'sunk cost' since the damage is not automatically rectified when the pollution ends. Intermediate irreversibility is the term used of a situation in which the pollution exceeds nature's own capacity for regeneration. Pollution of the environment with nitrogen, phosphorus and pesticides is an example of partially reversible pollution in that, here, nature will to a large extent be able to recreate a good environment if the pollution ends.

- lack of decision-making flexibility

Lack of decision-making flexibility relates to the possibility of changing a policy once it has been agreed upon politically. The concept expresses the degree of flexibility in the decision-making process, taking into account both the time factor and the frequency of changes to the policy. One thus speaks of timing inflexibility if a decision must be made *now or never* be made, while the possibility of *postponing* a decision gives timing flexibility. As mentioned, inflexibility can also be due to politicians being bound by earlier decisions (*irreversibility),* while in other cases it will be possible to adjust a policy along the way (*reversibility*).

In some situations, the possibility of waiting with a decision will have an independent value (*option* value), that must form part of the decision-making basis. The option concept has been borrowed from the financial sector, where one can take out an option to buy a product at a pre-agreed time and a pre-agreed price. In other words, one ensures that the product can be acquired at the agreed price, but whether the option is actually used will depend on whether the agreed price is lower than the market price. If this is not the case, the purchaser will choose to buy at the market price. For this security, the purchaser pays a premium (the option value), which is the price for having flexibility in the decision-making process.

Option on future choices

Application of the option concept to the environment problem is based on the fact that irreversibility exists, in the form of either biological or economic inflexibility. The option value relates to the possibility of choosing different policies in the future, i.e. there is flexibility in the decision-making process. In the case of biological irreversibility (the environmental damage cannot be rectified), the option value will relate to the fact that limiting environmental pollution today will give future options. The criterion for choosing the option is that the achieved benefit of having flexibility with respect to solutions must be greater than the associated costs.

Decision now or "wait and see"

Christensen (1999) has analysed the relationships between uncertainty, irreversibility, decision-making flexibility and option value. The analysis is reproduced schematically in Figure 3.3, where uncertainty, irreversibility and flexibility are ordered hierarchically. If there is certainty concerning the outcome[11], the decision-making basis will in all cases be the conventional economic measure NPV(*Net Present Value)*, which expresses the discounted value of future benefits and losses from the policy. If, on the other hand, there is uncertainty about the future outcome, the result will depend on whether there is economic or biological irreversibility and on whether there is flexibility in the decision-making process. The last-mentioned is expressed in the figure by the fact that the decision can be

[11] Here, uncertainty should be understood to mean that the outcome is not known (has not been determined analytically), i.e. the concept differs from the economic interpretation of the concept in that it includes both economic theory's uncertainty and risk.

postponed (wait and see) or must be made here and now (now). If there is uncertainty about the outcome and there is economic and/or biological irreversibility, and there is also a possibility of waiting with the decision, there will be an option value that must be included in the decision-making basis (expressed by NPV+option). In the other cases, the decisions will depend solely on NPV.

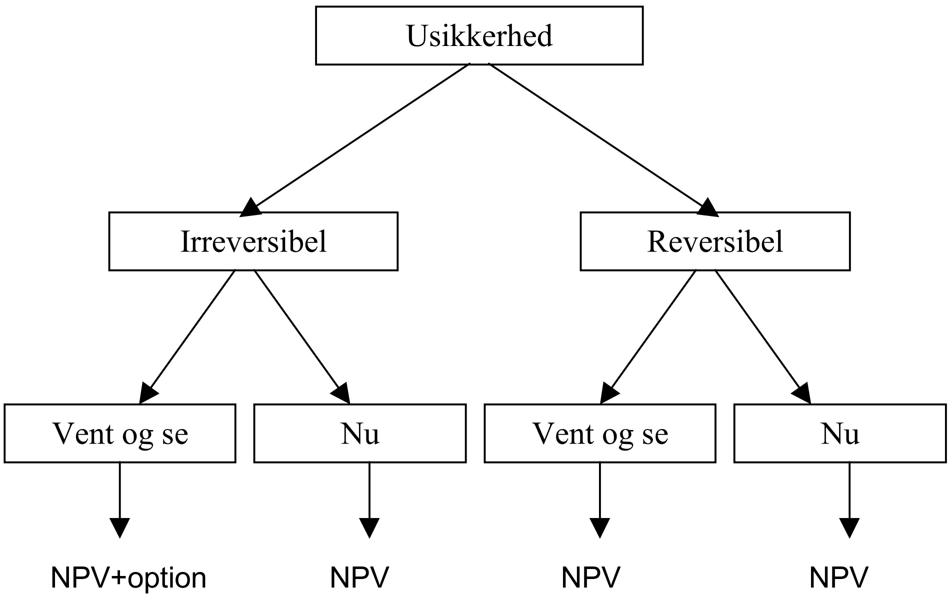

Figure 3.3
Decision-making basis under uncertainty, reversibility and flexibility
Source: Developed on the basis of Christensen (1999 p. 91f)

(Figure text:
Usikkerhed = Uncertainty
Irreversibel = Irreversible
Reversibel = Reversible
Vent og se = Wait and see
Nu = Now

As an example of a situation in which an option value affects the decision-making basis, the Economic Council mentions reduction of CO_2 emission in order to prevent future greenhouse effects (DØR, 1998, p. 241). The problem arises from the fact that the damage from CO_2 is assumed to be irreversible. By reducing the CO_2 emission today, one gains an extra option of using new knowledge concerning the damage caused by greenhouse gases at a later date. If new knowledge shows that the damage is great, one has already introduced new limitations. If, conversely, new knowledge shows that the damage is limited, one will have the possibility of easing the policy. The option value thus relates to the possibility of avoiding damage as a consequence the greenhouse effect that would have been lost if one had not intervened against CO_2 emissions earlier on.

Transferred to the pesticide problem, the option concept can be illustrated by pollution of the groundwater with pesticide residue. Such pollution is - any rate to some extent - irreversible since it will take many years to re-establish clean groundwater once the damage has been done. However, since there is at present considerable uncertainty concerning the damage caused by such pollution, it may be relevant to maintain flexibility with respect to the choice of policy. The option thus consists in choosing between reducing the pollution today (e.g. by restricting farmers' use of pesticides) and postponing intervention, with the consequent risk of dangerous substances accumulating in the groundwater. If one chooses the latter solution, one loses the possibility of an environmental benefit because the pollution is extremely irreversible.

Pollution with pesticides is an irreversible process

The above-mentioned problem is parallel to the precautionary principle, where one chooses to take action against the pollution in order to be "on the safe side". In this connection, it should be noted that option value can exist whether the decision maker is risk-neutral or risk-averse, but that risk aversion will affect the magnitude of the option value. High risk aversion will thus speed up action to limit the pollution if this is irreversible.

Strong, moderate and weak caution

Strong, moderate and weak caution

Pearce (1994) and O'Riordan & Cameron (1994) have attempted to concretise the precautionary principle by breaking it down into weak, moderate and strong caution. With the strong precautionary principle, economic considerations have higher priority than environmental considerations. The view is taken that risky/uncertain technologies should normally be prohibited irrespective of cost. With the moderate precautionary principle, importance is attached to eliminating risks in the choice of technology, but use is made of the proportionality principle that the cost must not be disproportionately high, while the weak precautionary principle approaches traditional cost-benefit thinking that risks must be weighed against costs in connection with risk-reducing environmental initiatives.

Dubgaard (1999) has tried to concretise the three concepts still further:

A. *The strong precautionary principle* covers both risk and uncertainty. The concept prescribes that society shall refrain from activities that involve potential environmental risks – irrespective of the cost, i.e. economic considerations are entirely subordinated to environmental considerations. A total ban on pesticides can be regarded as an expression of a strong precautionary principle.

B. *The moderate precautionary principle* also covers risk and uncertainty. Intervention is initiated on (confirmed) suspicion of harmfulness, but consideration is paid to the cost. Economic considerations enter the equation through use of a *proportionality principle* according to which the costs must not be "disproportionately" high. The 0+scenario discussed later can be regarded as an application of the moderate precautionary principle.

C. *The weak precautionary principle concerns a situation* in which risks must be documented and quantified before a decision is taken on a ban or regulation.

In the American economic literature there is a counterpart to such a precautionary principle in the form of *Safety First Rules* (Buschena & Zilberman, 1994), which can be interpreted as operational criteria for decision-making under risk. Unlike the expected-utility theory, these rules are in the nature of rules of thumb for cautious decision-making behaviour that assumes the existence of quantifiable risks. The rules therefore give no indication of how one should act in the case of decisions associated with uncertainty in the form of non-quantifiable probabilities. One uses economic optimisation principles with the restriction that risks must be kept within prescribed threshold values.

Veterinary standards, sanitary and phytosanitary rules

Lastly, it should be noted that the precautionary principle is used when setting veterinary standards and sanitary and phytosanitary rules. The aim is to protect human, animal and plant life from diseases. Such regulations are monitored internationally to ensure that they are implemented in a way that minimises the negative impacts on international trade. The regulations must also be based on scientific principles, analyses and risk assessments. Labelling with a view to promoting the sale of "particularly environment-friendly products" (eco-labelling) is also an expression of a precautionary principle – in this case with the aim of influencing consumer behaviour to the benefit of environment-friendly products. Such labelling is permitted provided it does not involve discrimination with respect to the origin of the products.

Summary

Summary

The problem of determining a balanced societal solution to regulation of the harmful impacts of pesticides is that there is often a lack of scientific data on the magnitude of the damage and the probability of the damage occurring. In such a situation, *the precautionary principle* means that consideration for the environment should be given priority over economic and other societal considerations, i.e. one chooses the safe solution in order to be on the safe side. However, this choice also has a price, which society has to pay.

It has been shown in the foregoing that identifying a societally balanced environment policy depends on the existence of scientifically based knowledge concerning the magnitude of the damage and the probability of it occurring. The choice of policy will, however, depend on the decision-maker's willingness to take a risk. A risk-averse decision-maker will normally choose a more restrictive environment policy than a less risk-averse decision-maker, even if this implies an economic loss. However, it is important to realise that, in the eye of the decision-makers, the choice will be a balanced one in both situations – environmental considerations are weighed against economic considerations. The difference lies in the fact that the risk-averse decision-maker is more willing to accept an economic loss in order to gain greater certainty concerning protection of the environment.

In many cases, however, well-founded data for pollution and the magnitude of the damage is lacking, and the decision-maker is therefore in an uncertain situation, being without a real basis for a decision. In this situation, the risk-adverse decision-maker will often choose the extreme solution of banning the pollution in order to be "on the safe side", while the more risk-taking decision-maker will perhaps go to the other extreme and ignore the possibility of damage. As stated above, in this situation, the most rational solution would be to base the decision on extreme outcomes that produce minimal or maximum outcomes. However, it is pointed out that research is needed to create more knowledge about the extreme outcomes in order to reduce the uncertainty concerning the outcomes.

Even so, the choice of policy is also influenced by the reversibility in the system. This is because once an investment has been made in an installation to protect the environment or the producers have adjusted to environmental restrictions, it costs to change the policy (economic irreversibility) or because the environmental damage accumulates as a consequence of the pollution exceeding nature's capacity for regeneration (biological irreversibility). In such situations, the time factor gains particular importance because the possibility of postponing the decision can have an independent value that must be included in the basis for decisions. In this case, too, the decision-maker's risk aversion will influence the result because high risk aversion will generally make him tend to postpone relaxing restrictions on the pollution.

The precautionary principle must thus be seen in a broader perspective, where both uncertainty and reversibility are included in the basis for decisions and economic and environmental considerations are weighed against each other.

3.3 Regulation of pesticide consumption

Aim: for the farmer to include consideration for the environment in his planning

As mentioned, in the planning of environment policy measures, societal gains and losses from the use of pesticides must be weighed up. In this connection, it is important that the decision concerning the use of pesticides lies with the farmer, whose aim is to optimise the profitability of his farm. The task is thus to formulate a political framework for the farmer's activities that will encourage him to include consideration for the environment in his planning and thus ensure a *societally* acceptable solution.

A brief outline is given below of the principles underpinning environment policy measures, including establishment of the regulatory framework and choice of proxies for use in evaluating the effect of the policy. A picture is also given of different regulatory instruments and their suitability for regulating pesticide consumption.

3.3.1 Regulatory basis

The regulation must be targeted on the environmental problem

Regulation must generally be based on the environmental problem that is to be solved. If the problem concerns harmful effects on the population's health, the regulation must in principle focus on reducing those effects. If, on the other hand, the problem concerns damage to nature, the relevant proxies will be the wild flora and fauna. Since such damage can occur far from the source of the pollution (farmers' use of pesticides) and the relationships between pesticide usage and harmful impact are often diffuse, one is in practice forced to use proxies for the harmful effect of the pesticides.

Difficult to formulate proxies

Here, one faces the problem that uncertainty concerning the harmful effect of pesticides makes it difficult to define a relevant proxy. If one chooses a proxy close to the 'injured party', it will perhaps express the magnitude of the damage reasonably precisely, but the relationship between the source of the damage and the proxy will be diffuse. If, on the other hand, one chooses a proxy close to the source of the damage, the relationships between the proxy and the magnitude of the damage will be uncertain. Since the user must be able to relate to the chosen proxy in the planning of his production, one often, in practice, chooses a proxy close to the source of the pollution, knowing full well that there will be uncertainty concerning the relationships between the proxy and the damage. The goal of a 50 per cent reduction in pesticide consumption in the agricultural sector is an example of such a compromise. The goal is directly related to the production and can be monitored. The problem is that it is difficult to prove the relationship between consumption and damage scientifically, so the goal tends to be perceived as a political choice.

However, there are a number of ways of improving the regulatory basis. In an analysis of pesticide regulation in the agricultural sector, the Danish Institute of Agricultural and Fisheries Economics (SJFI) (1998b) points out that regulation can be made more targeted by including in the regulatory basis the properties of the pesticides (toxicity and risk of leaching) and the geographical distribution of pesticide usage. The reason for the latter suggestion is that the risk of pollution of the groundwater and damage to nature varies greatly with the natural conditions.

3.3.2 Regulatory instruments

Quantitative or tax-based regulation

When choosing regulatory instruments, one differentiates between rules and taxes. The aim of rules is to limit what the user may do, whereas taxes act economically by favouring (or de-favouring) a given behaviour. Another form of regulation is quotas, which are quantitative restrictions on the user's pollution or production activity. If a fixed quota is imposed on a single user, the regulation is quantitative, but if the quota is made transferable, it can be likened to a tax.

In the choice, account must be taken of both environmental and economic factors (efficiency)

The criterion for the choice of instruments is that the regulation must be *efficient*. In other words, the environmental goal must be achieved at lowest possible cost. When making the choice it is thus necessary to take account of both the impact on the environment and the economic consequences of the regulation.

When taxes are chosen, the problem is to fix the right level of taxation – the level that will ensure achievement of the environmental goal. Since the user must be expected to optimise microeconomically, taking account of the tax, a tax is an economically efficient regulatory instrument that will ensure socioeconomically optimal use of the resources.[12]

If, instead, one imposes quantitative restrictions on the environmental impact, one will achieve the environmental goal, but the economic result will be uncertain. To be economically efficient, the quantitative restrictions must be adjusted to the individual farm's or production unit's economic return.[13]

In the case of environmental regulation, quotas correspond to quantitative control. If the quotas are made transferable, trade in them between efficient and less efficient producers will ensure an economically optimal distribution of the quota restrictions. Quotas are difficult to use when the pressure of damage is differentiated, and to be effective, they must be continuously adjusted to the development of productivity in the sector.

However, in the choice of instrument, attention must also be paid to the administrative costs connected with use of the instruments. A general tax on pesticides is normally easy to administer, it can be imposed at the sales level, and it does not require monitoring of the producers' behaviour – unlike a quota, for instance, which requires monitoring of the producers' consumption. The same applies to restrictions on the treated acreage, observance of buffer zones and other quantitative restrictions on the use of pesticides. Experience from the EU's milk quota also shows that a substantial administrative apparatus is required for a market for transferable quotas to work in practice.

Tax-based regulation is thus administratively less demanding than quantitative regulation and implies revenue for the state. The problem is illustrated in Figure 3.4, in which the MPV curve indicates the producer's demand for pesticides at

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[12]This only applies, however, with the use of general taxes, where the same tax is imposed on all producers and where the damage is all of a kind. With differentiated taxes, the result must be judged in relation to the environmental gains achieved by the differentiation.

[13]The criterion for economic efficiency is that the marginal product value of the pesticide usage is identical for all producers after introduction of the regulation. For a homogenous tax to be optimal, the damage must also be homogenous.

different price levels. The optimal consumption before tax (Q) is determined by the price P. If a tax is imposed, the price increases to T and consumption falls to Q'. The tax revenue thus corresponds to the diagonally hatched area, while the producer's loss corresponds to the entire hatched area. The marked triangle expresses the producer's loss with full reimbursement of the revenue.

The polluter pays principle

The use of taxes raises the question of reimbursement of the tax revenue to the industry. From an economic point of view, the revenue should be used in a way that achieves the greatest possible welfare for society. There is no direct argument for reimbursement - in other words, the regulation is in accordance with the *polluter pays* principle. If it is decided that the revenue shall be reimbursed to the producers, it is important for this to take place independently of the production in order not to reduce the efficiency of the regulation. However, it will obviously not be possible to give full compensation through such reimbursement for the simple reason that the total loss for the producers will be greater than the revenue (illustrated by the marked triangle in Figure 3.4.

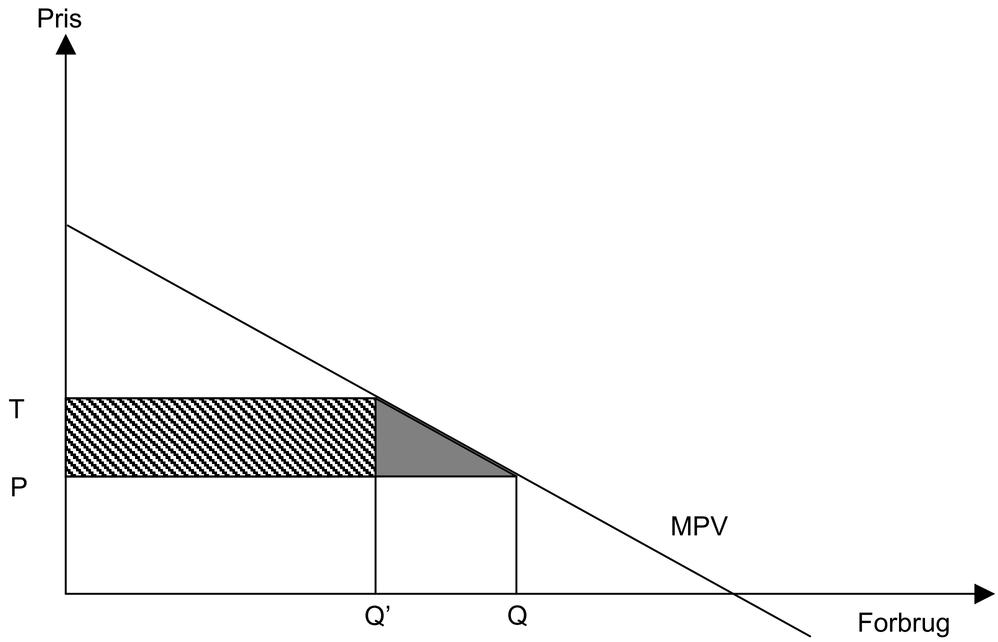

Figure 3.4
Effect of tax on pesticide consumption

(Figure text:
Pris = Price
Forbrug = Consumption

Figure 3.4 can also be used to illustrate the effect of a quota. If the quota is put equal to Q', T will give the shadow price of the product, i.e. the diagonally hatched area indicates the amount the producer is willing to pay for the quota Q' when the price is P. If the buying rights are initially allocated through a sale of quotas (transferable quotas), the state will receive the proceeds of the sale. If, on the other hand, the quotas are distributed free (for example, on the basis of previous consumption), the revenue will be reimbursed to the producer in relation to the size of the individual quota. In this case, the value of the quota remains in the industry. The full-drawn triangle in the figure expresses the amount the producer is willing to pay to increase his quota from Q' to Q.

Tax-based regulation

Tax-based regulation

One of the problems of using taxes is that they will normally be linked to the price of the products and that there is no direct relationship between the price of a product and its environmental impact. All else being equal, old agents whose development costs etc. have been fully depreciated can be marketed more cheaply than later agents. It should also be noted that the use of taxes and quotas may be difficult to administer within an open market like the EU if the restrictions on consumption are significant.

Choice of basis for tax

It has been discussed whether it would be better to base the tax on something other than the price of the agents. The following alternatives have been discussed:

1) Burden index. The ideal basis would be to calculate the environmental burden of the individual agents with average use in Denmark. However, use of a burden index leads to the question: Burden on what? In the formulation of a total burden index, one has to prioritise between different environmental impacts – for example, health, groundwater and biodiversity. These impacts have not been fully clarified, and how they should be weighted in relation to each other would to some extent be a political question. If one gives very high priority to one problem, e.g. groundwater, it may push the user towards agents with impacts in other areas.

2) Amount of active ingredient. A tax per kg active ingredient would favour mini-agents over older agents, but here, one has the same problem as in the case of value taxes that there is no direct relationship between weight and toxicity.

3) Standard dosage (treatment frequency index). The standard dosage is fixed by the producer of the agents but is controlled by the Danish Institute of Agricultural Sciences in Flakkebjerg. In some cases, the standard dosage differs between crops. With good plant protection practice, it is possible to use less than the standard dose. As pointed by Rude (1992), a tax on the standard dose might help reduce the intensity of treatment.

Of the above-mentioned bases for taxation, the standard dose seems, on the face of it, to provide a suitable basis for regulation. The system could be handled at the sales level, possibly combined with differentiation of the tax according to the potential damage. A weighted toxicity index could be designed for aggregation of different factors, including the amount of active ingredient. However, if the standard dosage were used as the basis for regulation, the legislative basis would have to be clarified because it is stated in the legislation that an objective and unambiguous tax basis must be established.

The Parliamentary Fiscal Affairs Committee (1998) has pointed out that standard dosage is not a clearly defined concept since it would, for example, vary with the crop. Therefore, for each of the more than 800 approved pesticides, a decision would have to be made concerning the tax basis. In addition, the tax rates have to be approved by law, which would mean considerable administrative work in connection with the appearance of new agents. The Parliamentary Committee states: "It thus seems doubtful whether the treatment frequency index (standard dosage) is preferable to the present value tax as the basis for taxation." However, it should be noted that Norway, for example, bases regulation on standard dosage.

Differentiated tax basis

From the point of view of administration, taxes are easy to handle because they can be imposed at the sales level. Present tax policy has already gone some of the way by differentiating between fungicides, herbicides and pesticides. If pesticides were divided into hazard classes, further differentiation of the tax basis would hardly be likely to cause any great problems. However, tax-based regulation would be less effective with geographically or regionally differentiated regulation of consumption because the possibility of buying pesticides at lower taxes in other parts of the country would make administration and control impossible. Where there is a need, for example, to protect particularly environmentally sensitive areas, differentiated regulation would be better ensured through quantitative regulation, with restrictions on the consumption of pesticides in the threatened areas.

It has been mentioned that instead of regulating pesticide consumption, one could impose a tax on conventional production. Such a measure would require certification of pesticide-free products along the lines of the eco-labelling scheme. However, for international acceptance, the tax would have to be non-discriminatory and taxes on *uncertified* products would have to be based on objective environmental and health standards (product standards). It is not certain that restrictions based on the way the products are produced (production standards) would be compatible with EU and WTO rules.

Quantitative regulation

Quantitative regulation advantageous with geographically differentiated regulation

The advantage of quantitative regulation is that one can regulate pesticide consumption directly. Quantitative regulation is therefore well suited to situations in which there is a need to differentiate the requirements in accordance with the natural conditions. The threat to the groundwater depends, for example, on the geological conditions. With uniform soil conditions, it can be the total burden in a given area that determines the pollution, but with differing soil conditions, there may be a greater risk of local pollution of groundwater deposits. A ban on the use of pesticides in environmentally sensitive areas is the solution here, but the question is, whether an either/or solution is optimal, seen in relation to the varying conditions that prevail in practice. An alternative solution might be to prohibit the production of crops that require treatment in the most environmentally sensitive locations.

Difficult to ensure economic optimality

The problem with quantitative regulation is that it is difficult to ensure an economically optimal solution. For quantitative restrictions to be economically effective, they must, as mentioned, be adjusted to the individual's farm's economic return, which is extremely difficult, if not impossible, in practice. Furthermore, it requires a substantial administrative apparatus to monitor the pesticide consumption at the individual farms. Quantitative regulation is therefore in general mainly suitable as a supplement to economic regulatory instruments in cases in which differentiated intervention is needed against the use of pesticides in agriculture.

Quota-based regulation

Transferable quotas are an efficient regulatory instrument…

Regulation on the basis of quotas is a form or quantitative regulation that will also ensure an economic distribution of pesticide consumption provided the quotas are made transferable. A national quota can be based on limiting the amount of active ingredient, the number of standard doses, the number of ecotoxicological doses, etc. Another possibility is a quota scheme in which one allots spraying quotas corresponding to a specific acreage fixed at national level. A system of acreage-spraying quotas would make it possible to keep pesticides away from areas designated by county and local authorities as environmentally sensitive areas and drinking-water areas of particular interest. The spraying quotas on the rest of the agricultural acreage could be made transferable in the same way as the set-aside obligations under the EU's common agricultural policy.

SJFI (1998b) mentions the possibility of issuing spraying permits on the basis of the crop composition (corresponding to the codes of practice used to regulate use of nitrogen) or introducing a prescription system for pesticides under which farmers are only allowed to purchase pesticides for problem crops or in the case of a documented risk of fungal or insect attack. The advantage of this type of regulation is that it can be based to some extent on the existing early-warning system (PC-Plant protection). However, a prescription system makes great demands with respect to administration if minimisation of pesticide consumption based on timely intervention is to be achieved. Another fundamental problem with a prescription system may be achievement of the desired environmental effects unless it is actually designed as a quota for a number of standard doses or similar. SJFI (1998b) mentions, as a possible supplementary measure, prohibiting the use of pesticides in the autumn, when the risk of leaching is greater than in the growing period.

... but difficult to adapt to differentiated regulation

Just as with other forms of quantitative regulation, the use of quota schemes for differentiated regulation of pesticide consumption requires an administrative system that can identify the use of pesticides at a detailed level.

Subsidy-based regulation

Subsidy-based regulation

Instead of regulating the environmental impact through tax-based or quantitative regulation, it would be possible to influence producer behaviour by subsidy-based regulation – for example, one could compensate farmers financially for not growing crops or for reducing their use of pollutants in environmentally sensitive areas. In order to fix the compensation, it would be necessary to know the loss to the farmer from reducing his production. However, the loss would naturally vary from farm to farm, so it might be difficult to ensure an economically optimal solution in which the cost to the public purse is minimised. Another possibility would be to invite tenders for quotas for production or use of pesticides in environmentally sensitive areas since this would ensure that it was the producers with the smallest losses that would participate in the scheme. The problem with such a tender system is that it might be difficult to fix exactly the level of compensation that would produce the desired reduction in the level of pollution (see the above discussion concerning quotas).

Fixing compensation

Subsidy-based regulation is not a relevant alternative as an instrument for general regulation of pesticide consumption. First, regulating pesticide consumption through subsidies[14] would be a costly solution for society and, secondly, subsidy-based regulation is fundamentally at variance with the *polluter pays* principle, since the cost of the scheme would fall on the consumer and not the polluter.

Liability

Liability ...

Legislation that opens the way for farmers, importers and/or producers to be made financially liable for any damage caused by pesticides can be regarded as a regulatory instrument, in line with quotas, taxes, etc. The purpose of liability rules is to ensure that the polluters pay the costs of any damage. However, the fact that the polluters have to pay compensation would also (as in the case of tax-based regulation) provide them with an incentive to reduce their use of dangerous pesticides.

The advantage of liability rules (compared with other forms of regulation, including taxes) is that they also provide producers and users with an incentive to find out about the environmental and health impacts of the pesticides used. Since it is the polluters that will pay the cost if they misjudge the damage that can be caused by a pesticide, they will have a clear interest in finding out more about that

[14] With reference to Figure 3.3, it will be seen directly that to get the farmer to reduce his pesticide consumption from Q to Q', he would at least have to be compensated for a loss corresponding to the entire hatched area, including the fully drawn triangle.

before they use the pesticide. With traditional regulation, the polluters simply react to adopted rules and taxes. If these prove to be based on too low an estimate of the dangerousness of a pesticide, it is society – and not the polluter – that pays the bill.

However, liability-based regulation has a number of drawbacks compared with traditional regulation. Firstly, it has to be possible to prove a clear correlation between use of the agent and the damage. This can imply substantial administrative costs in connection with bringing a case against the farmer and, at the same time, the strength of the incentive is reduced if there is a considerable probability of the polluter not being found guilty. Furthermore, the fact that it normally takes a long time to get from the act of pollution to the imposition of a compensation order in itself weakens the behaviour incentives.

… a possible supplement to other regulation

This could speak in favour of regarding rules concerning liability for damage caused by pesticides as a possible supplement to traditional regulation and not as an alternative. The instrument is particularly suitable for situations in which pesticides have been used unlawfully or not as prescribed.

3.3.3 Assessment

Assessment

Regulation of pesticide consumption in the agricultural sector must as far as possible target the problems that are in focus. If the environmental problems concern the location of the production activities, this should be reflected in the choice of regulatory basis. For example, a general reduction of the use of pesticides on an unchanged treated acreage would presumably have a much less positive effect on flora and fauna than if the same reduction in consumption occurred through the establishment of buffer zones and a ban on spraying in environmentally sensitive areas. Similarly, the regulatory basis must take account of the fact that the risk of leaching to the groundwater differs from one agent to another and from one place to another.

Differentiated or general regulation

The choice of regulation (and the aim) must thus be sufficiently detailed to reflect the variation in the environmental impact of the pesticide consumption, both geographically and with respect to the individual agent's impact. An opposing consideration here is the cost of administering the policy. The more detailed the formulation of a policy, the more it will normally cost to control and administer the policy. The choice of regulatory instrument must thus be based on an assessment of the efficiency of the schemes, taking into account the administrative costs.

The regulatory basis must reflect the variation in the environmental impact of the pesticide consumption

Taxes are normally easy to administer, and if the aim is a general reduction of pesticide consumption, a tax is also an efficient instrument, since it ensures that the reduction takes place in the economically most rational way. The same applies to the use of quotas provided these are made transferable. In this connection, the possibility has been pointed out of differentiating the tax according to the harmfulness of the agents and the risk of leaching – and of possibly graduating the tax in relation to the recommended treatment frequency. Another alternative mentioned is the use of liability as a possible supplement to traditional regulation.

Taxes (and transferable quotas) are efficient instruments for reducing pesticide consumption

Quantitative regulation preferable for differentiated regulation

A general tax on pesticide consumption would not fulfil the requirement concerning differentiated action against pollution in geographically delimited areas. For this it would be necessary to use quantitative regulation, with, for example, a ban on the use of pesticides in environmentally sensitive areas or restrictions on the cultivation of particularly burdensome crops. The problem with such a policy is that it would be difficult to ensure an economically optimal solution and that quantitative regulation is generally very demanding with respect to administration. The choice of political regulatory instruments therefore needs closer consideration, including consideration of the possibility of combining quantitative regulation with economic instruments.

4 The problem and the choice of method of analysis

4.1 Introduction

The sub-committee's mandate

According to its mandate, the sub-committee was to assess the consequences for production, economics and employment of phasing out the use of pesticides, taking into account the work on alternative methods of preventing and controlling fungal diseases, pests and weeds. Accordingly, it was to examine:

1. the consequences of the different cultivation systems for agricultural production and earnings, including the cost to the agricultural sector of restructuring production
2. the economic parameters relating to the environment, such as costs for cleaning up drinking water and soil
3. the economic consequences for upstream and downstream industries, such as dairies, abattoirs, the chemical industry and producers of alternative agents and methods
4. the economic consequences for the consumers.

In this connection, the sub-committee was to identify any areas in which a partial or total phase-out would cause particular problems and suggest how these problems could be solved, e.g. through research and development. In its assessment of the consequences for employment, the sub-committee was to include the impact on employment both in agriculture itself and in the upstream and downstream industries.

The task is centred on phasing out the use of pesticides

It is important to note that it was stated in the mandate that the analysis was to centre on phasing out the use of pesticides in agriculture. In other words, the task did not include making proposals for a societally *optimal* solution, which, as described in chapter 3, would require weighing environmental considerations against economic considerations.

Cleaning-up drinking water and soil

It was also stated that the costs of cleaning up drinking water and soil were to be included in the analysis. To obtain a complete picture, the sub-committee has found it important also to assess the possibilities of casting light on the economic consequences of health risks and societal benefits in the form of greater biodiversity from reduced use of pesticides.

Valuation of environmental goods required for complete analysis

It is a condition for this that losses or benefits from a better environment can be valued. As mentioned in chapter 3, there are, in principle, two approaches to such an analysis: *the preference-based method*, in which the value of better environment is valued directly (e.g. through interviews) or *the non-preference-based* method, in which the costs of repairing environmental damage are taken as a measure of the societal benefits of avoiding damage from pesticides.

Depending on whether one uses one approach or the other, the problem can be analysed on the basis of either a *cost-benefit consideration* (the value of avoiding damage to health and the environment) or a *cost-efficiency consideration* (the cost of repairing damage to health and the environment) is compared with the cost of reducing the use of pesticides in agriculture.

Using the following notation:

$M_{benefit}$ = Environmental and health benefits from reducing the use of pesticides

M_{cost} = Cost of repairing environmental and health damage

P_{cost} = Cost of reducing the use of pesticides in agriculture,

the problem can be described by the following models:

Cost-benefit analysis

Model 1: $M_{benefit} > P_{cost}$ (*cost-benefit* analysis)

where the benefits must be greater than the cost for the chosen reduction in pesticide usage to be socioeconomically justifiable.

Cost-efficiency analysis

Model 2: $Min\{M_{cost}; P_{cost}\}$ (*cost-efficiency* analysis),

which shows a comparison of the cost of repairing environmental damage and the cost of reducing pesticide usage in agriculture with a view to indicating the cheapest solution – for example, treatment of drinking water to remove pesticide residue compared with restrictions on the use of pesticides in agriculture.

Societal optimality lies outside the scope of the analysis

As described below, it is not possible to give a complete picture of the environmental and health benefits of reduced pesticide usage. The analysis is therefore concentrated on identifying the sectoral and societal costs of reducing the use of pesticides in agriculture. These can then be compared with analyses on the environmental side. As mentioned, the analyses must be based on phasing out pesticides. In other words, assessing the societally optimal solution, which corresponds to finding $Max(M_{benefit} – P_{cost})$, lies outside the scope of the analysis.

In the following, we first discuss existing economic analyses in the pesticide area and then, in section 4.3, the choice of methods in analyses of reduction in pesticide consumption in agriculture. This is followed in section 4.4 by an evaluation of the usefulness of the concept of analysis.

4.2 Economic analyses - experience

Research on regulation of pesticide usage – a relatively new discipline

Research on regulation of pesticide usage shows clear signs of being a relatively new discipline that has developed in the wake of the last few decades' discussion concerning the dangers of pesticides. There are very few actual analyses in this field, probably due in part to analytical problems. Pesticides comprise several different categories of agent (herbicides, fungicides, insecticides, etc.), and within these categories there is in turn a wide range of agents, e.g. agents developed for specific crops. Furthermore, the fact that pesticides are not means of production in the normal sense of the word, but are in the nature of treatment, means that it is difficult to determine the effect of graduated treatment, which has to be known in order to determine the economically optimal use.

In a study of the literature on economic analyses of pesticide usage, Christensen & Schou (1998) write that the core of the problem lies in determining the agricultural sector's demand for pesticides under different price assumptions, where precisely the multiplicity of agents is a problem. They also write that the selection and handling of the factors that are important for describing pesticide usage depend on the model approach and the degree of aggregation in the analysis.

In the review, we differentiate between:

a. damage threshold models
b. econometric models
c. general equilibrium models and
d. mathematical programming models

Re a

Damage threshold models

A *damage threshold model* is based on the fact that there is a minimum population of pests that it pays to combat with a predetermined dosing of pesticides. Below this threshold, the rational producer will refrain from taking preventive action, whereas he will take action if the number of pests exceeds the damage threshold. Damage threshold models have primarily been developed for use at field and farm level, where it is possible to define damage thresholds for different pests in different crops at a detailed level. There are, however, examples of damage threshold models being used for analysing the aggregated effects of taxes on pesticide usage.

For example, Dubgaard (1987) analysed the effect of taxes on pesticide usage at DKK 100 and DKK 200 per standard dose. At the time of the analysis, a tax of DKK 100 corresponded to an average price increase of 60 per cent, which resulted in a fall in demand of 20-25 per cent. It was assumed in the analysis that the price would lead to a technologically determined fall in pesticide usage of 15 per cent. Correspondingly, a tax of DKK 200 would result in an average price increase of 120 per cent and a 40-45 per cent fall in total pesticide demand, and it was estimated that the land rent on good land would fall by 15 per cent. The last-mentioned scenario was based on an assumption of a technologically induced fall of 25 per cent in pesticide demand.

Rude (1992) also worked with an aggregated threshold model to determine the optimal need for treatment from a farm economy point of view. With 1990 as the base year, he carried out scenario analyses for the development up to 1995 and 2004 and the use of pesticide taxes of DKK 100 and DKK 200 per standard dose. The projection is based on a linear programming model (Stryg et al., 1991), which implies adjusting the crop composition. It is assumed that technological development will result in an efficiency improvement in the use of pesticides of 1 per cent per year and a tax-induced technological reduction in pesticide consumption of 10 and 25 per cent, respectively, at the two tax levels. Depending on the time horizon, the result is a 13-19 per cent reduction in pesticide usage at a tax rate of DKK 100 and a 20-28 per cent reduction at a tax rate of DKK 200.

There is thus some variation in the results arrived at, depending on the assumptions used in the analyses.

Re b

Econometric models

In *econometric models*, the demand for pesticides is estimated on the basis of historical data for production and factor input. The aim here is particularly to determine the price sensitivity of the pesticide treatment with a view to assessing the effect of taxes. In the early studies, pesticides were treated as factor input in line with other means of production. This resulted in high marginal product values, which could be taken to mean that it was economically advantageous to increase the use of pesticides. However, later analyses have made it clear that pesticides must be treated as pest control that increases the realisable part of the potential production and that there will typically be an either/or situation in the treatment, cf. the above discussion of damage thresholds. Christensen & Schou (1998) describe a number of analyses based on econometric models, some of which will be discussed here.

Using an econometric model estimated on the basis of aggregated Danish data for the period 1971-85, Dubgaard (1987), found that the own price elasticities for herbicides and fungicides/insecticides were –0.8 and –0.69, which are considered high. A similar Swedish analysis based on aggregated data for the period 1948-89 shows own price elasticities of –0.93 for herbicides, -0.39 for fungicides and –0.52 for insecticides, which are also considered high (Gren, 1994).

A Dutch study of the effect of price on pesticide consumption in arable farming showed own price elasticities of –0.5 for potatoes and onions and –0.4 for cereal products (Oskam, 1992), and it is stated (Oskam & Wijftigschild, 1992) that most estimates of pesticide consumption in Dutch arable farming seem to lie in the interval –0.5 to –0.2.

On the basis of data for the years 1979-88, Oude Lansink (1997) arrives at an own price elasticity of –0.12 for pesticides in Dutch arable farming. The analysis also includes the interaction between pesticide consumption and input of land, manpower, capital and nitrogenous fertiliser. The author arrives at an intensity elasticity of 0.78 for land, compared with 0.08 for manpower and 0.14 for capital. The cross price elasticity for nitrogenous fertiliser is estimated to be –0.02, which indicates that nitrogen and pesticides are complementary. In a later analysis based on farm data (Ouda Lansink & Peerlings, 1997) an own price elasticity of -0.48 is found for pesticides and a cross price elasticity of 0.02 for nitrogenous fertiliser, which, contrary to the foregoing analysis, indicates that nitrogen and pesticides are substitutes. The results underline the importance of differentiating between analyses at farm level and analyses at crop level.

Re c

General equilibrium models

Unlike the foregoing models, which are based on partial analyses of the agricultural sector or individual farms, *general equilibrium models* (GE models) cover the whole economy. The basis for the models is an input-output table for the entire economy, in which agriculture can be divided into several production sectors. GE models thus enable analysis of the interaction between agriculture and other sectors in the form of adjustment of prices, while sector models typically take the prices as given. However, there are also intermediate forms in which the market adjustment is incorporated in the sector models.

The simplest models are based on an assumption that all markets are in equilibrium and that adjustments occur under completely flexible wage and price adjustment. In practice, there will often be institutional and other constraints on the adjustment, which means that the results of the models can at best be read as very long-term adjustment (e.g. 30 years). Adjustment costs are thus not in themselves included in the models' results. Even though general equilibrium models enable numerical solutions instead of analytical ones, the results found usually represent consistent calculations and not actual prognoses.

The advantage of general equilibrium models is that the individual sectors can adjust to changes in the framework conditions (for example, in the form of a reduction in pesticide usage), so one can see the derivative effects on the entire economy of intervention in an individual sector. However, it must be regarded as a drawback that the models usually work at an aggregated level and that the results depend on, among other things, the permitted possibilities for substitution and the specific choice of substitution elasticities. In general equilibrium models, the technology is usually assumed to be given, which means that the possibility of new technology being developed is not described within the traditional framework of the models.

Christensen & Schou (1998) report some analyses in which general equilibrium models are used to elucidate the pesticide problem. On the basis of German data from 1987/88, Brockmeier et al. (1993) and Brockmeier et al. (1994) used a GE model to analyse the effect on the economy of a reduction in the consumption of chemical products (including fertiliser, pesticides, livestock medicine and other chemical inputs in the agricultural sector). The analyses show that a 95 per cent reduction in chemical inputs would reduce agricultural production by 35 per cent. The model does not include a separate description of pesticides and is also considered too rough to give a reliable estimate of the effect of the total chemical input.

Komen et al. (1997), using Dutch data for the base year 1990, have developed a GE model with a detailed description of agriculture and the agricultural industry, four sectors of which relate to pesticide usage. The model is used to describe the effect of a 100 per cent tax on pesticides with different factor mobility. With low factor mobility, a 100 per cent tax on pesticides is found to reduce pesticide consumption by 11-14 per cent in arable farming, market gardening and the service sector connected with agriculture. Production in arable farming and the chemical industry falls by just under 4 per cent, while production in market gardening and the agricultural service sector falls by 1-2 per cent. In the scenario with high factor mobility, a 100 per cent tax on pesticides results in a 25 per cent fall in pesticide consumption and a 13 per cent fall in the chemical industry’s production. Christensen & Schou (1998) state that, even if pesticides are included as a separate product category in the analysis, the degree of detailing of the input factors is considered insufficient for an adequate description of the interaction between changes in the pattern of production and pesticide consumption.

Re d

Mathematical programming models

More general *mathematical programming models* can be used to analyse the demand for pesticides. As an example, Sundell (1980) analysed the consequences for agriculture of separately phasing out herbicides, fungicides and insecticides and a complete phase-out of all pesticides. Rude (1992) also used a linear programming model to describe structural changes. However, the method does not seem to be very widely used for describing pesticide demand except in the case of analyses of pesticide usage in different, predetermined crop rotations. Christensen & Schou (1998) report a multicriteria analysis by Lakshminarayan et al. (1995), in which an attempt is made to optimise with respect to both economic and environmental partial goals. It is stated in this connection that there can be conflicts between economic and environmental partial goals and also between different environmental goals.

All in all, it must be concluded that the results arrived at are encumbered with considerable uncertainty and that there are only a few examples of analyses of a total phase-out of pesticides. In most of the analyses, the demand for pesticides has been analysed and used as a basis for estimating the effect of taxes on pesticide usage or the focus has been on the adjustment in agriculture with different assumptions concerning reduction of pesticide consumption. It is difficult to find examples in which the interaction between agriculture and the rest of the economy is analysed in sufficient detail to determine the consequences of phasing out pesticides for agriculture, other sectors and the economy as a whole.

4.3 Method of analysis – regulation of pesticide usage in agriculture

The analyses are based on economic models,…

Solution of the task must be based on economic models that can describe the behaviour of agricultural producers with different assumptions concerning the production resources available to them, applied technology, market conditions, and established political frameworks. In the last mentioned, importance is attached particularly to limiting the sector's use of pesticides. For solution of the task, it is also important to analyse the consequences of phasing out pesticides for both primary agriculture and the upstream and downstream industries, i.e. a solution must be sought in which the economic consequences for both the agricultural sector and society are clarified. This accords with the discussion in the previous chapter, where it was stressed that the assessment of environment policy must be based on a societal assessment of the economic and environmental consequences.

… that throw light on the consequences for both the sector and society

However, the type of analysis used also depends on the regulatory scenarios that are to be analysed. It is not possible to design economic models that can be used for any kind of analysis. The models must be designed for the specific problems and levels that are to be addressed in the analysis.

The following scenarios have been analysed:[15]

Choice of scenarios

The 0-scenario
No use of pesticides.

The 0+scenario
The use of pesticides is permitted for crops that cannot otherwise meet specific purity requirements or described requirements for combating quarantine pests, cf. the Danish Plant Directorate's executive orders.

The +scenario
The use of pesticides is permitted for crops in which there will otherwise be a big yield loss or where it is estimated that viable production cannot be maintained without pesticides. For acceptance, there must be a considerable yield loss (more than 15-20 per cent) or the production must be encumbered with such uncertainty that producers must be expected to discontinue it or be unable to fit it into the crop rotation.

The ++scenario
The basic assumption in this scenario is that producers will not suffer serious financial losses due to pests, compared with present production. It is assumed that all available damage thresholds and harrowing are used where these methods can compete with chemical prevention and control.

Free scenario
Model-calibrated present production in the farm-level analyses. This corresponds to present production but with optimised use of land and pesticides, cf. the analyses in the Farm-level Pesticide Model (FPM). In the farm-level analyses, the effect of the other scenarios is measured in relation to the free scenario.

The basis for the analyses is a set of models that have been combined into a complete concept of analysis. The general structure of the concept is shown in Figure 4.1, from which it will be seen that the analyses have three components:

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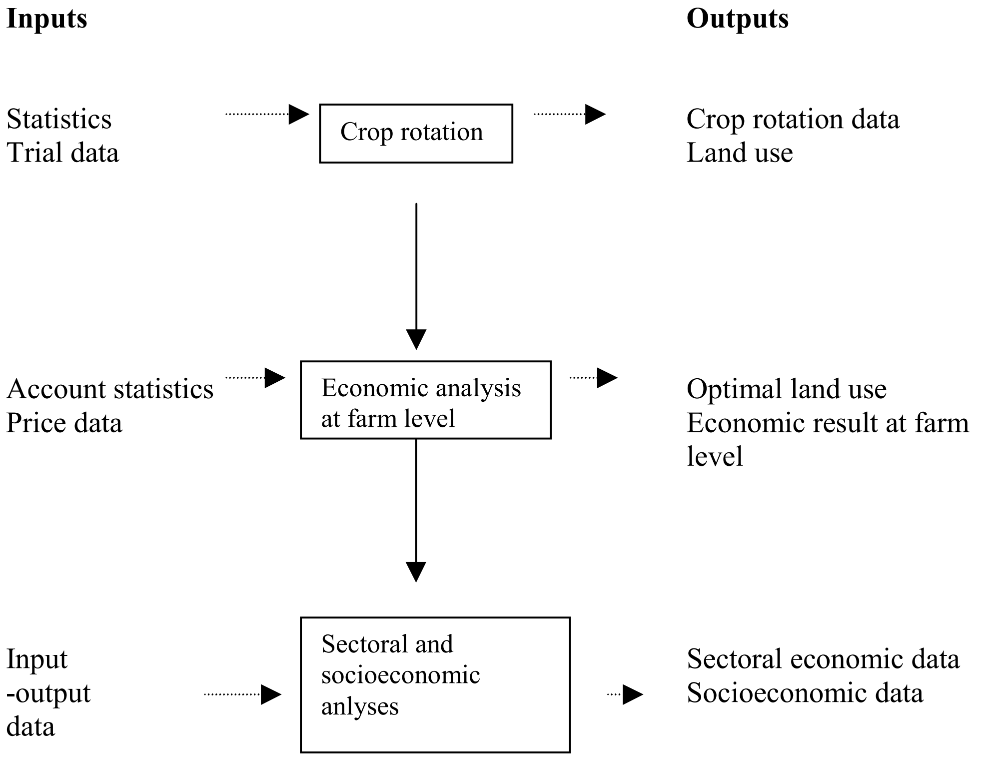
[15] The scenarios are described in detail in connection with the analyses in chapter 5.

Combining analyses at crop-rotation level, farm level and sectoral and socioeconomic level

1. crop rotation analyses to determine the technical and biological relationships in arable farming if pesticides are phased out,
2. farm-level economic analyses, and
3. sectoral and socioeconomic analyses.

Tying the three components together as shown in the figure ensures coherence between the analyses at the different levels, in that the crop rotation models are used as the basis for the analyses at farm level, which then form the basis for the socioeconomic analyses. It is thus possible to provide a consistent description of the consequences of phasing out pesticides at the different levels.

Concept of analysis



Figur 4.1
Outline of concept of analysis

Analyses at different levels have different foci…

As described below, the focus of the analyses at the different levels will differ. The crop rotation analyses include estimates of the *agronomically* feasible crop production with pesticides phased out, while the farm-level analyses focus on land use and the economic effects at farm level of economically optimal crop production with unchanged livestock production and given price conditions. The sectoral and socioeconomic analyses, on the other hand, show the result for the entire sector and for the entire economy with full adjustment of production (including livestock production), taking into account derivative economic effects on other sectors and feedback effects in the form of adjustment of product and factor prices. The different analytical approaches mean that there will be different constraints on the possibilities of adjustment and different time horizons in the analyses.

With the different foci of the analyses, the different models cannot be expected to produce the same result, even in those cases in which the analyses relate to the same level. It must generally be expected that the isolated loss due to regulation will be reduced when account is taken of the possibility of economic adjustment for the individual forms of production and for the sector. On the other hand, it can be difficult to conclude, a priori, whether the individual form of production will be

... but supplement each other in an

hit more or less hard when the interaction with other industries and sales possibilities are taken into account. The value of the analyses thus lies in the fact that the results supplement each other in an integrated description of the problem.

The analyses at crop-rotation and farm level cover all the above-mentioned scenarios, whereas the sectoral and socioeconomic analyses cover only the 0- and +scenarios.

The concept of analysis concerns only farming

It should be noted that the analyses cover only farming because market gardening and forestry have not been included in the concept of analysis developed.

4.3.1 Crop rotation analyses

Crop rotation analyses…

As mentioned, the basis for the analyses is a description of the technologically and biologically feasible production methods and crop-rotation combinations if the use of pesticides is phased out in farming. The problem is that there is insufficient experience of how such phasing out of pesticides affects the structure of production and land use in farming. The existing knowledge concerning conventional farming covers mainly small changes in pesticide usage, which means that it is necessary to "extrapolate" the existing knowledge beyond the intervals for use of pesticides that are covered by the existing research and trial results.

The work was carried out by a working group under the Sub-committee on Agriculture, which had the task of elucidating (Mikkelsen, 1998, p. 5):

… form the agronomic basis for the analyses

- the agronomic aspects of the present crop rotations, related specifically to current pesticide consumption;
- crop rotations in a scenario without pesticides, where livestock production is maintained, together with a crop pattern that includes major specialised productions;
- realistic crop losses in a production without pesticides;
- how stability of cultivation changes; and
- realistic forms of treatment in a 0-pesticide scenario and the
- practicability of the proposed alternatives for substitution of pesticides.

The sub-committee's work also provides the *agronomic* basis for farm-level, sectoral and socioeconomic analyses with a phase-out of pesticides. The analyses are based on assumptions concerning production practice in the present situation and with a total phase-out of pesticides for crops on clayey and sandy soil.

12 types of farm

On the basis of farm accounts data from the National Department of Farm Accounts and Management in 1995 and 1996, which cover around 13,000 farms, the working group set up 12 types of farm and, for each of these, a crop rotation corresponding to existing production practice. The crop loss in the individual crops without use of pesticides was then assessed. For example, for cultivation of winter wheat on clayey soil without use of herbicides, the working group set the yield and agronomic assumptions concerning variety, sowing time, mechanical weed control, etc. Guidelines for production practice were similarly determined for the other scenarios, and yield levels were estimated for all crops. For a detailed description of the crop rotation analyses, readers are referred to the report from the Sub-committee on Agriculture (1999).

Data transferred to the farm model

The calculated yield losses and need for mechanical weed control were then sent to SJFI for use in the farm-level economic analyses of different scenarios. This work is outlined by the double arrow in Figure 4.1, which indicates an exchange of information, where experience from the farm-level economic analyses is confronted with the crop rotation analyses. The calculated results are thus an expression of an agronomically and partially economically optimised situation.

4.3.2 Economic analyses at farm level

Economic analyses at farm level…

The aim of the economic analyses at farm level is primarily to calculate the economically optimal use of land with pesticides phased out. The work is based on SJFI's farm accounts statistics, Series B, for 1995/96, broken down into farm types as shown in Table 4.1. These largely correspond to the forms of operation in the crop rotation analyses. The statistics comprise detailed data for production values and costs in the cultivation of different crops, average land use, yields, etc. When these statistics are supplemented by the above-mentioned information on crop losses, mechanical weed control, etc., it becomes possible to estimate the production economy in the different scenarios for phasing out pesticides.

… cover groups of farms

Table 4.1
Farm types used in the crop rotation models, 1995/96 data

Clayey soil	Sandy soil
Arable farming without livestock	Arable farming without livestock
Arable and pig farming	Arable and pig farming
Specialised arable farming with sugar beet	Arable farming with potatoes
Specialised arable farming with seed growing	Dairy farms with low capacity utilisation
Dairy farms	Dairy farms with high capacity utilisation

Note: The data are based on SJFI's accounts statistics for Danish agriculture. Dairy farms and pig farms follow the definition in the accounts statistics, while sugar-beet growing, seed growing and potato growing are defined as farms where at least 10 per cent of the land is used for the respective crops. Arable farms are a residual group. The breakdown between clayey and sandy soil is based on counties with mainly clayey and sandy soil. The chosen farms represent about half the total agricultural acreage. Source: Mikkelsen et al. (1998)

The FPM model – optimisation of the gross margin in arable farming

The economically optimal use of land and pesticides has been calculated by means of a linear programming model (the Farm-level Pesticide Model (FPM)), which has been developed for the purpose. The criterion for optimality is highest possible gross margin II.[16] For each scenario and each type of farm, the model calculates the land use that gives the biggest possible land and building rent, observing limits on the use of pesticides and various crop rotation restrictions, flexibility constraints, previous-crop effects, feed balances, labour capacity, etc. The level of livestock production is assumed to be unchanged. Livestock itself is not included in the model, but the crop rotation is composed to ensure that supplies of fodder can be maintained during the phasing-out of pesticides. Only the crops grown in present production are included in the analysis. For a more detailed description, readers are referred to Ørum (1999).

[16] Gross margin II is the amount remaining to cover costs in connection with buildings and land etc., when all other costs (including manpower) have been paid. In the present analyses, which focus only on arable farming, gross margin II can mainly be taken as a measure of land rent.

Alternatives to present production

The alternatives to present production are calculated by adjusting the gross margin for yield losses and marginal yields, changed costs for purchasing and placing pesticides, and changes in the cost of mechanical weed control. As the basis for this, use is made of machine station rates for spraying and mechanical soil treatment, together with a fixed hourly rate for manual weed control, cf. Table 4.2. As mentioned, the technical assumptions for the analyses were fixed in cooperation with the Sub-committee on Agriculture.

Table 4.2
Machine station rates and rates of pay

	Price		
Crop spraying (with 15 ha)	DKK	140	per ha
Harrowing (with 10-25 ha)	DKK	143	per ha
Row cultivator (25 ha with 12-row) machine			
Gas-burning of weed (with gas DKK 150/ha)	DKK	260	per ha
Crushing of potato tops			
Hoeing in beets	DKK	400	per ha
	DKK	1,500	per ha
	DKK	103	per hr

Source: Ørum (1999, p. 22)

Assumptions concerning set-aside

Set-aside acreage is included in the analysis in line with cultivated acreage, i.e. set-aside competes with the crops for land. It is assumed in the analyses that set-aside at farm level amounts to minimum 10 per cent and maximum 33 per cent of the acreage with reform crops including set-aside. An area at least corresponding to the set-aside acreage in 1995/96 is taken out of production as 5-year set-aside. In the analyses, this can only be reduced for farm types with cattle. It should be noted that the EU has set an upper limit of 50 per cent set-aside at farm level. In Denmark, the limit is 21.6 per cent (but can be higher in environmentally sensitive areas). The above-mentioned limit of 33 per cent has been chosen in order to allow room for a substantial increase in the set-aside acreage without going right up to the EU's maximum. Since an increase in the set-aside acreage can make it impossible for livestock producers to get rid of the manure, it is assumed in the analyses that the set-aside percentage for animal husbandry may not exceed 10 per cent. In present production, set-aside averages 6-8 per cent of the acreage at dairy farms, compared with 8-10 per cent in other types of farm (12 per cent for arable farms on sandy soil).

Results transferred to macroeconomic model

The economic analyses at farm level provide information on the economic return and optimum land use within the different types of farm with partial optimisation of the economic return in arable farming. The analyses are also used as the basis for establishing the technological and biological assumptions in the analyses of the sectoral and socioeconomic results if pesticides are phased out. The basis for these analyses is the weighed average factor use for all farming, calculated by means of the FPM model.

4.3.3 Sectoral and socioeconomic analyses

The AAGE model – long-term economic equilibrium in society

The basis for the sectoral and socioeconomic analyses is SJFI's AAGE model (Agricultural Applied General Equilibrium model). In principle, the model covers all Danish businesses, which are assumed to minimise production costs, and all Danish households, which are assumed to maximise utility. The model describes both the demand by businesses for semi-manufactures and primary production factors (manpower, capital and land) and the supply of goods and services, and includes a rudimentary description of the public sector. The model also treats businesses' supply of goods for export and importation of goods and services for consumption and production. The model is characterised by all the markets being in equilibrium due to an assumption of completely flexible adjustment of prices and pay.

Model assumptions

The model is based on constant return to scale in production, i.e. the costs per produced unit are independent of the size of the production. Combined with an assumption of full competition in the markets and market-based product and factor prices, this means that there is no profit in the businesses. The database for the model is Danmarks Statistik's input-output table for 1992, where the agricultural industry is divided into eight primary production sectors and five processing sectors.[17] Primary agriculture is thus treated as an average farm with eight production sectors. In other words, the model does not offer the possibility of identifying barriers to adjustment in the industry, such as structural constraints and regional barriers to adjustment of production. The model's output must be interpreted as the result in the long term, where such barriers are negligible.

The whole of the economy is covered

The model enables systematic description of the whole of the economy, since it captures the main interactions and feedback effects in the economic system. The model shows the adjustment of the economy in the long term, i.e. importance is attached to structural relationships in the economy. At the same time, the model makes it possible to throw light on the effect of changes in the price conditions on production and factor consumption and the derivative macroeconomic effects on consumption, employment, foreign trade, etc. This means that the model is suitable for quantifying the effects of changes in structural policy measures.

Technology and changes in consumer preferences are treated exogenously

It should be noted that the model cannot handle disequilibrium aspects and the forming of expectations in the economy. It therefore tells nothing about the scope and duration of adjustments from one equilibrium to another. In relation to the present analysis, this means that the model does not say anything about the possible adjustment costs that the industry will face in the short term if pesticides are banned. It should also be noted that, like most other economic models, the model does not incorporate future technological gains and that changes in consumer preferences must basically be determined outside the model.

As described above, in the farm-level economic analyses on which the sectoral and socioeconomic analyses are based, the farms are classified according to whether they are on sandy or clayey soil. In the sectoral and socioeconomic analyses, the effect of this classification is ensured by weighing sandy-soil and clayey-soil farms together to obtain an average site land quality, which is transferred to the equilibrium model.

Set-aside expressed in extensified farming

The model does not describe set-aside separately, but the set-aside acreage is included in the analyses together with the cultivated acreage, and the set-aside payment is taken into account in the calculation of the economic return. The hectare payments do not affect the intensity of the production but are included in the land rent and thus affect land use. In the sectoral and socioeconomic analyses, set-aside will thus be expressed in extensive production on largely the same acreage.

[17] Agriculture is represented by eight primary sectors (wheat, rape, potatoes, sugar beet, greenfeed, cattle, pigs and poultry), together with five processing sectors (sugar mills, dairies, and cattle, pig and poulty abattoirs).

In order to be able to use the model for analyses of the sectoral and socioeconomic consequences of phasing out pesticides, it has been necessary to adjust the model on some points (Jacobsen & Frandsen, 1999).

Adjustment of the model

Firstly, in its standard form, the model describes the consumption of pesticides as a single item. The model specification has therefore been adjusted on a number of points, such that the consumption of different types of pesticides is specified for different crops. In addition, possibilities of substituting pesticides with other forms of input factors have been incorporated, which is necessary in order to model adjustment of pesticide consumption. The latter takes place in practice by inserting in the model elasticities that determine the degree of substitution in factor use. These changes have been made in consultation with the Sub-committee on Agriculture.

Secondly, it has been necessary to expand the model with a description of 0-pesticide production. This is in reality a new technology that the model's database does not provide a basis for describing. As an innovation within general equilibrium analyses, the model has therefore been expanded by formulating for each cropping sector corresponding sectors with the same production but with a technology/factor composition that does not include pesticides (the 0-scenario) or that includes only limited use of pesticides (the +scenario).

The factor composition in the alternative sectors is determined on the basis of calculation with the Farm-level Pesticide Model (FPM), cf. Ørum (1999).

Transfer of data

The transfer of data has been effected by calculating for each cropping sector in the FPM model the percentage change in factor use when restructuring for 0-pesticide production (the calculation has been made for each of the above-mentioned farm types and weighed together to an average for all farming). The percentages thus calculated have been used as the basis for adjusting the factor input in the AAGE model. For example, Table 4.3 shows the adjustment of factor input in cereal production in the 0-scenario and the +scenario.

Table 4.3
Change in factor consumption per produced unit in relation to present technology, cereals

Percentage change	0-scenario	+scenario
Land	28.4	16.1
Machine station and energy	18.2	11.2
Manpower	18.2	11.2
Semimanufactures	30.9	17.4
Fertiliser	18.1	9.1
Herbicides	-100.0	-88.5
Fungicides	-100.0	-88.1
Insecticides	-100.0	-85.2
Unit costs, total	15.5	7.6

Source: Jacobsen & Frandsen (1999, Tables 3.4 and 3.5)

As will be seen from the table, about 28 per cent more land is needed to produce the same quantity of cereal in the 0-scenario than in present production, which corresponds to a fall of 22 per cent in the ha-yield. For the +scenario, 16 per cent more land is required, corresponding to a fall in ha-yield of 14 per cent. It will also be seen that the input of, for example, machine station, manpower and fertiliser in the production of cereals is around 18 per cent higher per produced unit in the 0-scenario than in present production, compared with 9-11 per cent in the +scenario.

In both scenarios, production of crops with the present production technology is prohibited. Technically, the scenarios are implemented by eliminating production in the traditional sectors, thereby releasing land, capital and manpower – resulting in falling land rent. In such a situation, the land is reallocated to the described alternative crops (i.e. to the types of production that do not use pesticides or that make only limited use of them). In the new equilibrium, the land is reallocated between the existing crops, so that the agricultural land rent is the same in the various types of production. Capital and manpower are reallocated to the alternative crops and to the other sectors of the Danish economy.

Phasing out of pesticides set exogenously

It is stated by Jacobsen & Frandsen (1999) that the theoretical possibilities of substitution described above are not used in the 0-scenario and the +scenario because pesticides are only used within a given, exogenous framework (quantitative regulation). The limited use of pesticides is given as a permitted quantity, depending on the crop and, for example, in a fixed ratio to the input of land (a fixed quantity per ha). This ensures that the input of pesticides in the +scenario does not exceed the limit set in the scenario.

4.4 Evaluation of the concept of analysis

Evaluation

The analyses are based on an economically and agronomically well founded concept of analysis

The present analyses are based on a set of models that have been adapted to the needs of the analyses and that show the economic consequences of phasing out pesticides at farm level, sector level and societal level. The concept of analysis is firmly founded in economic theory, and parts of the model concept have been used for consequence analyses in connection with assessment of other political measures. A strong point is that the economic analyses are based on an agronomically well-founded concept of analysis and that the models have been adapted for the specific problem. This is an advanced analytical technique, which, together with high-quality data, provides a basis for a complete description of the problem.

The models' assumptions affect the result

With the analyses based on model calculations, the results naturally reflect the assumptions used in the models. For example, the analyses at farm level assume full knowledge and transparency in the decision-making process, which are presumably things that only the most skilled production managers can achieve. The analyses at farm level are also focused on adjustment in the relatively short term, whereas, in the sectoral and socioeconomic analyses, the emphasis is on the long-term consequences for agriculture and the Danish economy. Caution must thus be exercised in using the results for medium-term policy planning, where there are barriers to adjustment of production. The results of the equilibrium model will underestimate the cost of adjustment in the short term. Conversely, the results of the farm-level model must be expected to overestimate the cost of adjustment in the slightly longer term, where there are greater possibilities for adjustment.

Set-aside is treated differently

Set-aside is treated differently in the two concepts of analysis. At farm level, limits are inserted for the extent of set-aside at the individual farm, but not in the sectoral and socioeconomic analyses, where the set-aside acreage is included together with the cultivated acreage in the calculations. In both cases, account is taken of the set-aside payment, which is included in the return on the land and thus affects land use. Whereas, in the farm-level analyses, an indication is thus given of the extent of set-aside in the individual farm categories, in the sectoral and socioeconomic analyses, increased set-aside will be reflected in extensified production on a largely unchanged acreage.

Lastly, it should be noted that the models do not provide the possibility of describing technological changes. Therefore, account is not taken in the analyses of the fact that research and development will make it possible to develop crops and production methods that are better able to compete in pesticide-free farming. On the other hand, the chemical industry is constantly developing more environment-friendly products. There are thus contrary movements in the technological development that are difficult to incorporate in such a concept of analysis.

Idealised description gives direction and orders of magnitude

These factors must naturally be included in the evaluation of the results. Even though this is an idealised description of the situation with different time horizons, it is thought that the analyses, despite their limitations, give a relatively reliable indication of the direction of the changes and of the effects of the analysed scenarios.

5. Results

5.1 Introduction

Consequences of phasing out pesticides analysed

The main aim of the analyses has been to determine the consequences for production, economy and employment of phasing out pesticides in agriculture. In this connection, it has been found important to clarify the effects at farm, sectoral and societal level, taken together, with a view to determining the consequences for employment and earnings in different sectors and for the possibilities of consumption in society. We have also tried to clarify environment-related economic parameters, such as the costs involved in treating drinking water.

The analyses are divided into two parts: the economics of regulating the use of pesticides in agriculture and the value of the environmental improvements.

5.2 The economics of regulating the use of pesticides in agriculture[18]

The analyses are based on an integrated concept of analysis

As explained in chapter 4, the analyses are based on an integrated concept of analysis comprising analyses at crop-rotation level, farm level and sectoral and societal level. The economic analyses at farm level are based on a farm model developed at SJFI, while those at sectoral and societal level are based on an adapted version of SJFI's general equilibrium model. The three components have been linked to ensure consistency between the analyses at the different levels, in that the crop-rotation models are used as the basis for the farm-level analyses, and the farm-level analyses are then used as the basis for the analyses at sectoral and societal level. It is thus possible to give a consistent description of the consequences at different levels of reduction of the use of pesticides.

Unilateral Danish regulation

The analyses are based on unilateral Danish regulation of pesticide consumption; it is assumed that Danish consumers can buy foreign products and that there is free access to import competing farm products, e.g. grain, when economically attractive. As described in chapter 4, the prices of agricultural products produced in Denmark are determined endogenously in the sectoral and socioeconomic analyses, where account is taken of sales in the export markets. The resulting prices are thus determined by supply and demand.

Present hectare payment included

It should also be noted that the EU's present hectare payment is included in the analyses. The payment is not assumed to affect the intensity of the production (the yield per ha), but helps keep the land in production and is taken into account in the calculation of the economic return. The same applies to the set-aside payment, which increases the incentive to set land aside. Without this payment, Danish crop production would be bigger. With a ban on pesticides, the payment would limit the economic loss because the producers would at any rate be ensured the hectare and set-aside payment.

[18] The concept of analysis developed is focused on *the agricultural sector* and the derivative effects on the rest of the economy. The economic effects of reduced pesticide consumption in *market gardening and forestry* have been analysed separately, and the results of those analyses are included in the overall assessment of the problem.

Different results at different levels

As described in chapter 4, the foci of the analyses at the different levels differ. This means that, even in cases in which the analyses refer to the same level, the different models must be expected to produce different indications for a phase-out. The reasons for these differences lie mainly in the assumptions for the analyses, which will be described in detail in connection with the presentation of the results.

In the following, we will first discuss the chosen scenarios for regulation of pesticide consumption and will then present the main results of the analyses, with the emphasis on providing an overall picture of the relationships analysed. Readers interested in a more detailed discussion of the analyses are referred to the underlying reports by consultants, on which this chapter is based. Lastly, the results of the analyses are summed up and assessed.

5.2.1 Choice of scenarios

Different degrees of phasing out are analysed

The analyses have been built up around a set of scenarios that are intended to show the consequences of different degrees of reduction of pesticide consumption in agriculture. Initially, the purpose was to determine the effects of a total phase-out of pesticides, but a decision was then made also to analyse the effects of less restrictive policies. Guidelines were therefore established for a number of scenarios describing agricultural production with different forms of phase-out (see the box overleaf). With respect to treatment frequency index, the ++scenario corresponds in all essentials to the Pesticide Action Plan from 1986. For a detailed description of the scenarios, readers are referred to the report from the Sub-committee on Agriculture (1999).

The baseline is present production

Present production, which describes present production and present crop rotation at conventional farms, where pesticides are available, has been used as baseline.

The sectoral and socioeconomic analyses cover only the *0-scenario and the +scenario*, while the economic analyses at farm level cover all scenarios. The *0+scenario* is not included in the analyses because it lies close to the 0-scenario.

Variation in need for treatment

The reason for setting up intermediate scenarios is to examine different degrees of restriction on the use of pesticides. Such an analysis is complicated by the fact that the nature of the treatment and the treatment frequency index vary from crop to crop and by the fact that the type of soil plays a role in the treatment. For example, in winter cereal, it is sometimes necessary to control both monocotyledonous and dicotyledonous weeds with herbicides, while in rape, there is a trend towards using less pesticide by sowing the crop in widely spaced rows and using inter-row cultivation to remove weeds. The biggest use of herbicides is in sugar beet and fodder beet, which are usually sprayed several times a year, while couch grass in the crop rotation is typically treated at intervals of years. The use of insecticides and fungicides similarly varies from crop to crop, with, for example, very frequent spraying against potato blight.

... is reflected by the treatment frequency index

The Sub-committee on Agriculture, with support from farm-level economic research, has calculated the treatment frequency index, expressed as the number of standard doses in different forms of production in the above scenarios. The result can be seen in Table 5.1, which shows the sum of normal doses of herbicides, fungicides and insecticides used. It will be seen that the chosen scenarios describe a gradual reduction in treatment frequency index from present production through the different intermediate scenarios to the 0-scenario. The figures are used in the following as the baseline for comparison of the different scenarios.

Scenarios

0-scenario (analysed at farm level, sectoral level and societal level)
No use of pesticides.

0+scenario (not analysed, see text)
The use of pesticides is permitted for crops that would not otherwise be able to meet specific purity requirements or prescribed requirements for combating quarantine pests, cf. the Danish Plant Directorate's executive orders.

+scenario (analysed at farm level, sectoral level and societal level)
The use of pesticides is permitted for crops that would otherwise produce a big yield loss or where it is deemed impossible to maintain profitable production without the use of pesticides. For use of pesticides to be permitted, there must be a considerable yield loss (>15-20 per cent) or the production must be encumbered with such uncertainty that it must be expected to be discontinued or impossible to fit into the crop rotation.

++scenario (analysed at farm level)
Basically, serious economic losses from pests compared with present production are not expected in this scenario. The scenario assumes the use of all the present damage thresholds and mechanical weed control, where these methods can compete with the chemical methods. Basically, the same crop rotation is assumed as in economically optimised present production, but with lowest possible use of pesticides. A larger number of man-hours for monitoring are assumed than in present production.

Free scenario (analysed at farm level)
Model-calibrated present production in the farm-level analyses. Corresponds to present production, but with land use and pesticide use optimised, cf. the analyses in the Farm-level Pesticide Model (FPM). The effect of the other scenarios is measured at farm level in relation to the free scenario.

Scenarios may be difficult to translate into practical policy

It should be noted that it may be difficult to translate the assumptions for use of pesticides in the different scenarios into regulatory instruments in practice. That applies particularly to the +scenario, which is product-oriented and in which it may be difficult to arrive at the actual treatment frequencies that will ensure against yield losses of more than 15 per cent. However, this is not of any great importance in the present context, where it is not the intention to make concrete policy proposals.

The results of the zero and plus scenarios are given in the following, on the basis of the analyses' technological and biological assumptions. The economic effects of phasing out pesticides, as they appear from the analyses at farm level and sectoral and societal level, are then described. On the basis of the figures in Table 5.1, the results of the analyses are then summarised in an assessment of the economic costs of different levels of reduction of the use of pesticides.

Table 5.1
Treatment with pesticides, number of standard doses

	Present production	Free[1]	++	+	Zero
Clayey soil					
Arable farming	2.4	2.3	1.5	0.4	0.0
Dairy farms	1.9	1.6	0.9	0.3	0.0
Pig farms	2.5	2.1	1.3	0.4	0.0
Arable farms with beets	2.8	2.8	1.8	0.7	0.0
Arable farms with seeds	2.4	2.3	1.5	0.7	0.0
Sandy soil					
Arable farming	1.8	1.1	1.0	0.3	0.0
Dairy farms[2]	1.4	1.0	0.6	0.2	0.0
Pig farms	1.9	1.7	1.3	0.3	0.0
Arable farms with potatoes	3.9	1.6	2.6	0.5	0.0

Note: Except for present production, the figures include set-aide.
[1] Model-calibrated Present Production. Corresponds to present production but with optimised use of land and pesticides as calculated in the Farm-level Pesticide Model.
[2] Extensive operation
Source: Ørum (1999)

5.2.2 Zero and plus scenarios

Zero and plus scenarios

Analyses carried out by the Sub-committee on Agriculture (1999) show that, from an agronomic point of view, it is possible to design crop rotations that can be practised without use of pesticides on most types of soil. In practice, there would be considerable barriers to using such crop rotations and farms would have to be radically restructured in relation to present production. For example, the amount of winter cereal grown would have to be significantly reduced (to max. 40 per cent of the crop rotation) in order to reduce grass weed problems and second crops would have to be inserted when growing spring cereal in order to fulfil the requirement of winter-green fields. In addition, a wide range of cultural measures would be needed in order to minimise pest problems.

Phasing out of pesticides would require considerable restructuring of production

One of the main questions in connection with reducing the use of pesticides is the effect this would have on yield levels and consumption of means of production in farming and thus on the economy of the sector. It is also important to know the effect on employment in farming and upstream and downstream industries and the derivative economic effects on the rest of the economy in order to assess the total cost to society. These questions are discussed in the following.

Yield

Yield losses in all crops …

Yield losses must be expected in all crops if they are to be grown without the use of pesticides. The Sub-committee on Agriculture has found that a 27-29 per cent lower yield must be expected in wheat in the 0-scenario (Table 5.2) as a consequence of leaf diseases, increased pressure of weeds, damage to crops in connection with harrowing, insect attack, changed sowing time and the use of more resistant varieties with lower yields. Considerably lower losses are expected in winter rape, while the yield in seed grass is expected to be halved owing to weed problems and difficulties in removing weed seed without the use of pesticides. The yield in sugar beet is expected to fall by around 14 per cent, while in potatoes, a loss of 40-45 per cent must be expected, mainly due to potato blight. The yield in peas must be expected to fall by about one fifth.

Table 5.2
Yield losses with different phasing-out of pesticides, per cent

	--------- 0-scenario -------		-------- +scenario -------	
	Clayey soil	Sandy soil	Clayey soil	Sandy soil
Winter wheat	29	27	17	15
Spring barley	19	17	14	12
Winter rape	7	7	6	6
Grass seed	50	50	2	2
Sugar beet	14	-	-	-
Ware potatoes	-	43	-	11
Starch potatoes	-	42	-	13
Seed potatoes	-	43	-	8
Peas	21	21	12	12

Source: The Sub-committee on Agriculture (1999)

Somewhat smaller losses are assumed in the +scenario – 15-17 per cent in winter wheat and 12-14 per cent in barley. The fall in the yield in rape is slightly smaller than in the 0-scenario, while in potatoes, it is between 8 and 13 per cent. The yield in peas is estimated to fall by 12 per cent.

... but considerable variation from crop to crop

In practice, there would be considerable variations in the yield losses, and this would be exacerbated by the fact that weeds can propagate in years with low yields. The figures given in Table 5.2 have also been used as the basis for the sectoral and socioeconomic analyses of the consequences of phasing out pesticides.

Land use

Agronomic criteria ...

On the basis of agronomic criteria, the Sub-committee on Agriculture has assessed land use in the case of a complete phase-out of pesticides. In its analyses, crop rotations without use of pesticides are set up for selected types of farm in present production. The results are then scaled up to a total for the whole country.[19] The result is shown in Figure 5.1, from which it will be seen that, for technological and biological reasons, one must expect farmers to switch from winter cereal to spring cereal and rape and to phase out fodder beet, replacing them with peas, wholecrop and grass in rotation. In the analyses, the acreage with potatoes, seed grass and sugar beet is retained in order to show the consequences of a phase-out for these pesticide-intensive crops.[20] The set-aside acreage is assumed to be unchanged.

... set the framework for changes in land use

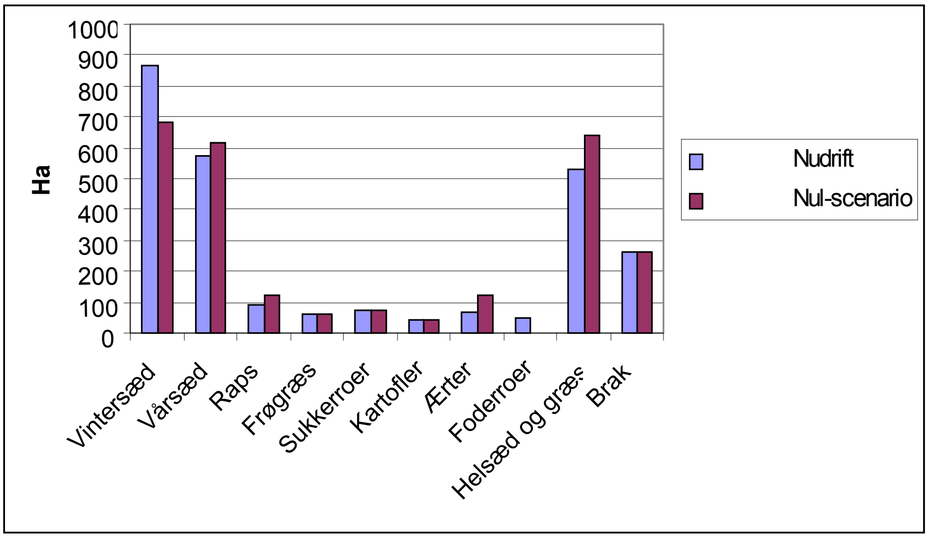
It is important to note that the above-mentioned figures are not an estimate of how land use can be expected to develop if pesticides are phased out, but simply an example of the scope for changes within the agronomic framework. The actual change in land use would depend on how farmers reacted to a ban on pesticides. The agronomic assumptions naturally limit the possibilities of restructuring, but the result would depend on what was economically viable.

[19]The calculation is based on Danmarks Statistik's figures for the number of farms in different farm categories.

[20] Maintenance of sugar beet production is based on an assumption that the Danish quota must be met. It is also assumed that the present acreage with potatoes and seed grass would be maintained.

Switch from winter to spring cereal; reduction of acreage with special crops; increase in acreage with greenfeed

The analyses based on the Farm-Level Pesticide Model (FPM), which is based on optimisation of the gross margin in crop production[21], show that considerable changes must be expected in land use on both clayey and sandy soil in both scenarios (Table 5.3). It will also be seen that the acreage with winter cereal is expected to fall, while the acreage with spring cereal is expected to rise, which harmonises well with the agronomic assumptions in Figure 5.1. Rape and peas would be unable to compete economically at arable farms, while the acreage with peas, in particular, would increase at dairy farms. The acreage with special crops (sugar beet, potatoes and seed) is expected to fall on clayey soil, while the acreage with feed crops rises. It will also be seen that a considerable increase in voluntary set-aside must be expected at arable farms on clayey soil.



(figure texts)
Winter cereal
Spring cereal
Rape
Sugar beet
Potatoes
Peas
Fodder beet
Wholecrop and grass
Set-aside

Present production
0-scenario

Figure 5.1
Land use based on agronomic assumptions
Source: Sub-committee on Agriculture (1999, p. 105)

Support for set-aside increases the set-aside acreage

The picture is much the same for farms specialising in sugar beet, seed and potatoes. Farmers would switch from winter cereal to spring cereal and reduce the acreage with special crops. At the same time, the set-aside acreage would increase considerably, reflecting the fact that it is difficult for crop production to compete when farmers are paid to take land out of production.

[21] As described in chapter 4, the farm model is a partial optimisation model for crop production in agriculture, i.e. the model does not take account of changes in livestock production or the interaction with other sectors of society. On the other hand, crop production is described in far greater detail than in the socioeconomic model.

As described in chapter 4, the farm-level analyses include assumptions concerning upper and lower limits for set-aside. It is thus assumed that set-aside at farm level must be at least 10 per cent and maximum 33 per cent of the acreage with reform crops, including set-aside. However, since dairy farmers and pig farmers must be able to get rid of their manure, it is assumed that set-aside must not exceed 10 per cent at such farms. Consequently, the set-aside acreage rises only slightly there.

Partial versus total optimisation

As mentioned, the farm-level analyses are based on maximisation of the gross margin in arable farming, which includes hectare payments. The analyses are partial analyses in the sense that account is not taken of possible changes in livestock production (the herd size is kept constant in the model) and that changes in price relations in agriculture would have to be expected if such drastic action as banning the use of pesticides were taken. Such changes are not included in the analyses. These factors are captured in the sectoral and socioeconomic analyses, where the interaction between agriculture and other sectors is built into the general equilibrium model (AAGE), and where account is also taken of changes in foreign trade (cf. chapter 4). The model makes it possible to describe the restructuring in agriculture, although at a somewhat more aggregated level than in the farm-level model.

Table 5.3
Land use, farm-level analyses, per cent

	Present production[1)]			0-scenario			+scenario		
	Arable farming	Dairy farming	Pig farming	Arable farming	Dairy farming	Pig farming	Arable farming	Dairy farming	Pig farming
Clayey soil									
Spring cereal	19	3	28	41	19	34	26	15	39
Winter cereal	51	25	48	29	10	39	44	12	39
Rape and peas	14	12	13	2	10	16	-	11	10
Field beet, maize, potatoes and seed	5	5	-	-	1	-	2	-	-
Grass and wholecrop	2	48	1	2	51	2	2	51	2
Set-aside	10	7	10	28	9	10	27	9	10
Sandy soil									
Spring cereal	26	38	44	39	32	45	26	32	50
Winter cereal	40	3	22	20	-	22	40	3	22
Rape and peas	18	5	15	-	8	11	-	8	8
Field beet, maize, potatoes and seed	4	1	2	9	1	5	4	1	2
Grass and wholecrop	3	48	6	3	51	6	3	50	6
Set-aside	27	8	10	29	8	11	27	7	11

[1] Model-calibrated present production.
Note: The calculations show selected types of farms. Cattle farming on sandy soil includes extensive operation.
Source: Ørum (1999)

When account is taken in the sectoral and socioeconomic analyses of the interaction with other sectors and feedback effects in the form of changes in the price relations in agriculture, we get a reduction of 62,000 ha (4 per cent) in the total cereal acreage, while the rape acreage increases by 20,000 ha (11 per cent) in the 0-scenario (Table 5.4). Here, the hectare payments affect the result because they limit the fall in the price of land and help to keep a large part of the acreage in production of cereal and rape. However, as a consequence of lower yield levels, production intensity would fall when pesticide consumption was reduced, i.e. on some of the land, production of cereal and rape would be extensified. As explained in chapter 4, it is not possible in the macroeconomic model to separate set-aside from extensive production. The small fall in cereal acreage would thus presumably mean that, in practice, farmland would be set aside when pesticides could no longer be used. This accords well with the farm-level analyses, which, as mentioned, show that set-aside must be expected to increase at arable farms on clayey soil (Table 5.3).

Fall in production intensity ...

... is an expression of potential set-aside

Table 5.4
Change in land use, socioeconomic analysis, 1,000 ha

	1992 level	0-scenario	+scenario
Cereals	1612	-62	-71
Rape	181	20	7
Potatoes	54	-29	-27
Sugar beet	65	-34	6
Greenfeed	693	105	85
Total	2605	0	0

Source: Jacobsen & Frandsen (1999, Table 5.3)

It will also be seen from the table that the acreage with potatoes and sugar beet is expected to halve in the 0-scenario, while in the +scenario, the acreage with sugar beet increases. The fall in the 0-scenario must be seen in the light of the lower yield and of the fact that no hectare payment is made for potatoes and sugar beet, making it difficult for these crops to compete with cereal and rape for acreage. The increase in sugar-beet acreage in the +scenario mainly reflects the fact that some use of pesticides is permitted. The acreage with greenfeed, which here covers fodder beet, wholecrop and grass in and outside the crop rotation, is expected to increase considerably. This covers a fall in the acreage with fodder beet and an increase in the acreage with wholecrop and grass, which have only a limited need for pesticides.

Different development in zero- and +scenarios

Consumption of fertiliser and supply of nitrogen

The models used have not been specifically developed to describe the fertiliser balance in agriculture. However, the macroeconomic model takes explicit account of the agronomic relationship between change in production and use of fertiliser, in that the use of fertiliser is closely related to the size of the production, as described in section 4.3. As mentioned, the analyses are based on long-term restructuring, in which the requirement of harmony between number of livestock and acreage is assumed to be met through regional reallocation of the production. It is assumed that, in the long term, such restructuring would be without cost. In the short to medium term, there may be regional constraints on the relationship between production and acreage that will affect the costs in livestock production. Such constraints may affect the restructuring of production and limit the fall in crop production.

Considerable reduction in the consumption of bought-in fertiliser ….

As will be seen from Table 5.5, the demand for nitrogen in artificial fertilisers falls in all crops in the 0-scenario, while the supply of nitrogen in manure rises slightly (mainly because of a bigger pig production). In all, the use of artificial fertilisers is expected to fall by 63 per cent in the 0-scenario, while the total use of nitrogen falls by 41 per cent, primarily due to lower production. It will be seen from the table that the fall in total demand would be accompanied by extensive substitution of manure for artificial fertilisers.

The corresponding analyses for the *+scenario* show a somewhat smaller fall in the consumption of artificial fertilisers, especially in cereals, sugar beet and greenfeed (Table 5.6). Consumption of artificial fertilisers is expected to fall by 29 per cent, while total fertiliser consumption falls by 19 per cent.

In this case, too, there would be substitution of manure for artificial fertilisers.

Table 5.5
Change in consumption of fertiliser and supply of nitrogen (0-scenario), per cent

	Artificial fertilisers	Manure	Nitrogen, total
Cereals	-72	-41	-64
Rape	-97	-95	-97
Potatoes	-63	-23	-57
Sugar beet	-64	-26	-55
Greenfeed	-29	48	12
Total	-63	1	-41

Source: Jacobsen & Frandsen (1999, Table 5.4)

Table 5.6
Change in consumption of fertiliser and supply of nitrogen (+scenario), per cent

	Artificial fertilisers	Manure	Nitrogen, total
Cereals	-30	-13	-25
Rape	-95	-94	-95
Potatoes	-53	-41	-51
Sugar beet	-4	20	1
Greenfeed	-4	20	9
Total	-29	1	-19

Source: Jacobsen & Frandsen (1999, Table 5.5)

… but rising intensity of fertilisation

A comparison of the above-mentioned changes in fertiliser consumption and the changes in production mentioned later (Table 5.9) shows a generally smaller fall in fertiliser consumption than in crop production. For example, in the 0-scenario, cereal production falls by 70 per cent, while consumption of nitrogenous fertiliser falls by 64 per cent (Table 5.5) and consumption of nitrogenous fertiliser for greenfeed rises by 12 per cent even though production falls by 1 per cent (Table 5.9). The same picture appears in the +scenario, although the changes are smaller here. The rising intensity of fertilisation is a consequence of the agronomic assumptions on which the analyses are based, as indicated in Table 4.3.[22]

Need to move manure could increase the costs

The above factors naturally raise the question of whether manure could be sold locally or would have to be moved over long distances. In this connection, it must be borne in mind that the macroeconomic model is based on long-term restructuring, with the possibility of moving production if there is a need for that. However, that does not mean that difficulties would not arise in the shorter term in fulfilling the Aquatic Environment Plan's harmony requirements in localities with a high livestock density, with consequent costs in connection with the transportation of manure over long distances. Such costs would affect the economic yield in livestock production and increase the competitiveness of, say, cereal production.

Employment in primary agriculture and processing

Employment falls in primary agriculture …

Phasing out pesticides in farming would generally affect employment in primary agriculture and the associated industries. The effect would be felt mainly in primary arable farming, where employment would fall by more than 55 per cent in the 0-scenario and by almost 30 per cent in the +scenario (Table 5.7). The fall is primarily a result of lower production, even when allowance has been made for the need for extra manpower for manual weeding of the crops, which means, for example, that manpower consumption in the production of sugar beet would rise despite falling acreage and production.

Table 5.7
Employment effect, farming and processing, 1992-level

	Change, %	
	0-scenario	+scenario
Primary agriculture	**-18**	**-10**
Cash crops	-57	-29
Cattle and greenfeed	4	1
Pigs and poultry	6	3
Processing	**-1**	**1**
Abattoirs	3	1
Dairies	1	0
Sugar mills	-71	-7
Total	**-14**	**-7**
Change in number of full-time employees, total	-16.238	-8.058

Note: The calculations are based on unchanged total employment, i.e. the manpower released in the agricultural sector would find employment in other sectors.
Source: Jacobsen & Frandsen (1999, Table 5.6)

…and in the sugar mills …

The fall in sugar beet production is reflected in the sugar mills' employment, which can be expected to fall by around 70 per cent in the 0-scenario compared with 7 per cent in the +scenario. In the livestock sector, on the other hand, production would rise, with a knock-on effect on employment in abattoirs and dairies. In all, it is estimated that employment in agriculture etc. would fall by over 16,000 full-time

[22] With present production put at 100, cereal production in the 0-scenario falls to 30 (70 per cent, cf. Table 5.9). According to Table 4.3, the agronomically fixed additional input of nitrogenous fertiliser in the 0-scenario is 18.1 per cent, which corresponds to a nitrogen consumption of 30 x 1.181 = 35.4. Apart from rounding off, the fall in consumption of nitrogenous fertiliser (100 – 35.4 = 64.6 pct.), is equal to the observed fall in the use of nitrogen according to Table 5.5.

employees (1992-level) in the 0-scenario (14 per cent) and by over 8,000 full-time employees in the +scenario (7 per cent). Most of the reduction would be in primary agriculture.

... and in related industries

Besides the above-mentioned job losses, employment would fall in other industries, including those directly associated with agriculture.

Economic result at farm level

Farm-level economic analyses

One of the main questions relating to reducing the use of pesticides in farming is the extent to which that would affect earnings and production in the sector. As stated above, a considerable fall in the level of yield would have to be expected in arable farming, and even if the optimum use of fertilisers were reduced, a lower land rent would have to be expected – a situation that would be aggravated by the fact that more labour is required for farming without pesticides.

Considerable fall in the gross margin in the 0-scenario ...

...reflected in a lower land rent

Analyses based on the Farm-level Pesticide Model (FPM) shows that a ban on the use of pesticides (*0-scenario*) would reduce the gross margin by 34 per cent on clayey soil and by 24-28 per cent on sandy soil for general forms of production – arable farming, dairy farming and pig farming – but with a somewhat bigger reduction in specialised crop production (Table 5.8). The reduction would generally be biggest at farms producing sugar beet and potatoes, where the return is estimated to fall by 39 per cent and 51 per cent, respectively. The fall in gross margin would largely be reflected in a lower land rent (cf. the footnote to the table). The calculation is based on all other input factors (including manpower) being remunerated at unchanged prices and on agricultural product prices not being affected by the intervention. Nominally, the economic return at dairy farms would be less affected by a ban on the use of pesticides than at other forms of production, but in percentage terms, the fall largely corresponds to arable farms and pig farms.

Significantly smaller losses in the +scenario

In the +scenario, the reduction in the gross margin would be considerably smaller. On clayey soil, the return at arable farms would be reduced by 15-23 per cent compared with present production, while the fall on sandy soil would vary between 8 and 16 per cent, depending on the form of production. For farms specialising in potato growing, the fall would be reduced from 51 per cent in the 0-scenario to 15 per cent in the +scenario. The loss in dairy farming would be 26 per cent on clayey soil and 15 per cent on sandy soil.

In connection with the economic analyses at farm level, the results have been scaled up to sectoral level by weighing the change in gross margin in the different farm categories with the number of farms in the categories. Since, as stated earlier, the analyses are focused on clayey and sandy soil, there is a residual group (representing about half the total agricultural acreage) on mixed soil that is not directly included in the analyses. Of this group, 30 per cent are assumed to be full-time farms in counties with mixed soil and 20 per cent part-time farms spread over the whole of the country.

The analyses show that a fall in gross margin of DKK 2.5 billion (33 per cent) must be expected in the 0-scenario, compared with DKK 1.3 billion (17 per cent) in the +scenario, with most of the losses in cereal production.

Table 5.8
Economic result at farm level, change in gross margin[1]

	0-scenario		+scenario	
	DKK per ha	%	DKK per ha	%
Clayey soil				
Arable farms	-1,130	-34	-640	-19
Dairy farms	- 890	-34	-660	-26
Pig farms	-1,030	-34	-540	-18
Beet production	-1,700	-39	-1,000	-23
Seed production	-1,420	-35	-610	-15
Sandy soil				
Arable farms	- 600	-26	-180	-8
Dairy farms[2]	- 540	-24	-340	-15
Pig farms	- 660	-28	-370	-16
Potato production	-1,980	-51	-560	-15

[1] The analysis concerns gross margin II, which covers building and land rent. Since building stock is not included in the analysis, the figure can be taken as the land rent. The change is measured in relation to the free scenario (model-calibrated present production).
[2] Extensive dairy farming
Source: Ørum (1998)

Sectoral economic analyses

Sectoral economic analyses …

The analyses of the economy of the agricultural sector are based on the general equilibrium model (AAGE), which can be used to illuminate the economic consequences for the sector as a whole and for different production sectors. Unlike the analyses at farm level, which, as mentioned, are based on fixed product and factor prices, the AAGE model includes the interaction with other sectors in the economy and foreign trade, which means that account is taken of changes in supply and demand in the product and factor markets and the consequent changes in prices.

… takes interaction with other sectors into account

0-scenario

0-scenario

A ban on the use of pesticides in farming would have a marked effect on production costs and thus on the Danish agricultural sector's ability to compete internationally. As shown in Table 5.9, *cereal production* would fall by 70 per cent. The reason for this is considerable yield losses combined with poorer profitability in cereal production[23] because assumed intense international competition would not allow price rises without significant, negative consequences for export and import of cereals. Cereal exports would thus fall by almost 90 per cent, while cereal imports would rise by 275 per cent.

Big fall in cereal production …

… and in rape production

In the case of *rape*, exports and production would fall by 100 per cent and 98 per cent, respectively, while the price ex farm would rise by 4 per cent. Rape production would thus largely disappear, and the industry would replace rape produced in Denmark with imported rape, which would rise by more than 500 per cent.

Production of *potatoes* would fall by 69 per cent, exports would disappear, and the price to the farmer would increase by 22 per cent. These effects cover complete discontinuation of production of industrial potatoes because of the assumed intense international competition for these varieties and a moderate reduction in supplies of ware potatoes for private consumption. The reason for the moderate reduction in

Small fall for potatoes …

[23] According to the analyses, the input of means of production per produced unit would rise from 18 to 30 per cent in cereal production without the use of pesticides.

private consumption of Danish potatoes is an assumption of less intense international competition (the consumers prefer Danish potatoes).

Table 5.9
Change in agricultural prices and production, in per cent

	0-scenario		+scenario	
	Prices	Production	Prices	Production
Cereals	2	-70	1	-32
Rape	4	-97	4	-95
Potatoes	22	-69	2	-54
Sugar beet	30	-63	3	-6
Greenfeed	-8	-1	-4	-0
Milk	0	0	0	0
Beef	0	0	0	0
Pork	-1	3	-1	2
Poultry	-1	1	-0	1

Note: The changes are measured in relation to present production.
Source: Jacobsen & Frandsen (1999, Tables 5.1 and 5.2)

... and sugar beet

Although *sugar beet* is the production that would suffer the biggest additional costs per produced unit in the event of a total ban on the use of pesticides, the fall in production would be smaller than in the case of cereals and rape. There are several reasons for this. Firstly, there is almost no import of sugar beet, i.e. the production of sugar beet is not affected by the international competition (prohibitive transport costs). Secondly, sugar beet accounts for a relatively small proportion of the sugar mills' costs, which means that a rise in the price of the primary product would have only a limited effect on their unit costs.

Slight rise in livestock production

A pesticide ban would have relatively limited effects in the livestock sectors. The costs in the greenfeed sector would fall as a result of lower land prices, which it is estimated would reduce the price of greenfeed by around 8 per cent. The consequently lower costs in dairy farming would increase the competitiveness of milk production, but milk production (and beef production) would not change owing to the milk quota.

For both pork and poultry production, falling input prices would lead to lower unit costs, causing production to rise.

As mentioned earlier, the big fall in crop production must be seen in the light of the fact that this is a long-term restructuring, with an assumption of no barriers to restructuring of production, either at the individual farm or regionally. In the shorter term, requirements concerning harmony between number of animals and acreage could increase the cost of restructuring livestock production, which would impair greenfeed's ability to compete for acreage. Such restrictions might therefore help to reduce the pressure of supply in the livestock sector while limiting the fall in the production of, for example, cereals and rape.

Higher milk-quota value

For the industries processing livestock products, there would be generally beneficial effects on production and foreign trade. The biggest effect would be found in the pork and poultry sectors, where production could be increased, while the better economy in milk production would mainly be reflected in a higher value of the milk quota.

+scenario

+scenario

In the +scenario, the possibility of limited use of pesticides means that the crop sectors' costs would increase less, with a consequently smaller fall in production than in the case of a complete phase-out of pesticides. In this case, *cereal production* would be reduced by just over 30 per cent, which would mean a 50 per cent reduction in cereal exports compared with present production and a considerable rise in cereal imports. In this case, too, *rape production* would largely disappear.

Considerable fall in production of cereals, rape ...

Potato production would fall by 54 per cent, while the price would rise by 2 per cent, compared with 22 per cent in the 0-scenario. The more limited effect on the price is due to a lower input, combined with falling factor prices, which would together lead to a limited increase in unit costs. In this scenario, too, production of industrial potatoes would be discontinued.

... and potatoes ...

Sugar beet is the production that would be least affected in the +scenario, falling by only 6 per cent. The explanation for this is that, as mentioned, sugar beet accounts for only a small part of the sugar mills' costs, making it possible for the mills largely to maintain their international competitiveness despite paying slightly higher prices to the producers.

... but only small fall in production of sugar beet

For the livestock sectors, the +scenario would have only a limited effect on prices and production, and for largely all processing sectors, exports would rise slightly and imports fall slightly.

Livestock production unaffected

The result of the above-mentioned changes would be a real fall in gross factor income in primary agriculture of DKK 3.4 billion in the *0-scenario*, corresponding to a 15 per cent fall (Table 5.10). Most of the fall would occur in crop production, with cereals alone accounting for a fall of DKK 3.0 billion. Apart from the sugar mills, the processing sectors would be relatively little affected by a pesticide ban. It is estimated that gross factor income at the sugar mills would fall by DKK 1.4 billion, mainly as a result of falling production of sugar beet in Denmark. In all, it is estimated that gross factor income in primary agriculture and the processing industry would fall by DKK 4.5 billion.

0-scenario: big fall in gross factor income in farming

Table 5.10
Change in gross factor income in farming and processing, fixed GNP prices

	0-scenario		+scenario	
	DKKm	%	DKKm	%
Primary agriculture				
Crop production	-3,950	-41	-2,064	-21
Livestock production	503	4	259	2
Total	**-3,447**	**-15**	**-1,805**	**-8**
Processing				
Dairies	29	1	12	0
Abattoirs	304	3	137	1
Sugar mills	-1,424	- 70	-140	-7
Total	**-1,091**	**- 6**	**9**	**0**
Total	**-4.538**	**- 11**	**-1.796**	**-4**

Note: All amounts are given in 1992-prices. A model-calculated fall in the GNP deflator of 1.63 per cent is used in the 0-scenario and 0.64 per cent in the +scenario as the basis for the conversion into fixed GNP-prices.
Source: Jacobsen & Frandsen (1999, Table 5.7)

+scenario: fall in gross factor income in agriculture halved

The corresponding analyses for the *+scenario* show a fall in gross factor income of DKK 1.8 billion (8 per cent), of which cereals alone account for DKK 1.5 billion. Gross factor income in the livestock sectors would rise and there would also be a small rise in the processing sectors because a fall in the sugar mills would be more than balanced by a rise in the processing of livestock products.

The above-mentioned changes in gross factor income reflect a reduction in the agricultural sector's contribution to income formation in society (return on labour, capital and land). The fall is a result of the phasing-out of pesticides reducing productivity in the sector and thus impairing the sector's possibility of competing for capital and manpower. Capital and manpower would migrate from agriculture and are assumed in the analyses to be employed in other sectors, although at lower real wages. For farming, that means that wages would fall in line with other sectors. In other words, the remaining manpower would suffer a loss of income. In addition, established farmers would suffer a capital loss in the form of falling land rent, and there could also be changes in the value of, for example, the milk quota.

Land rent falls while value of milk quota rises

In Table 5.11, the fall in gross factor income in agriculture is broken down between land, capital, manpower and milk quota. As a consequence of lower production costs in the dairy sector, the milk quota would rise by DKK 702 million in the 0-scenario and by DKK 380 million in the +scenario, while land rent would fall by DKK 470 million (13 per cent) and just under DKK 295 million (8 per cent), respectively. These figures must be compared with the loss of income in agriculture as a consequence of the fall in real wages.

Table 5.11
Breakdown of change in gross factor income in agriculture, DKK mill. in fixed GNP-prices

	Land	Capital	Manpower	Quota	Total
0-scenario	-470	-2,003	-1,675	702	-3,447
+scenario	-295	-1,020	-871	380	-1,805

Note: All amounts are given in 1992-prices. A model-calculated fall in the GNP deflator of 1.63 per cent is used in the 0-scenario and 0.64 per cent in the +scenario as the basis for the conversion into fixed GNP-prices.
Source: Jacobsen & Frandsen (1999, Tables 5.8 and 5.9)

It will be seen directly from this that action against pesticide consumption would result in a redistribution of capital between arable farmers and dairy farmers.

Fixed factors increase the loss

As stated earlier, scaling up the changes in gross margin at farm level results in a loss for the sector, measured in 1992 kroner, of just under DKK 2.5 billion in the 0-scenario (33 per cent loss) and DKK 1.3 billion (17 per cent) in the +scenario, which can be taken as an expression of a fall in land rent. The economic loss at farm level would thus be five time the above-mentioned falls in land rent of DKK 480 million and DKK 295 million. Such a difference is only to be expected because the farm-level analyses are based on fixed product and factor prices and on unchanged livestock production, while the socioeconomic analyses take into account the possibility of savings in agriculture through restructuring of production and the industry's price relations. The analyses thus underline the fact that agriculture's loss would depend greatly on the assumptions used with respect to the mobility of the means of production and the length of the restructuring period.

The above-mentioned changes in agriculture would affect other sectors through a release of resources and a fall in the demand for capital goods. This would be felt most in the sectors associated with agriculture, such as agricultural service and production of commercial fertilisers, in which there would be a marked fall in home market production. Of greater importance, however, would be the indirect effects through the release of manpower, which, as mentioned, would directly reduce the general level of pay. With the above-mentioned conditions, it has been found that wages would have to fall by about 1 per cent in the 0-scenario and by 0.4 per cent in the +scenario for the released manpower to find employment in other sectors.

Released manpower results in fall in real wages

A fall in real wages would, *on the one hand*, improve competitiveness in sectors exposed to competition, resulting in increased net exports of goods and services. *On the other hand*, falling real wages would reduce domestic demand. That would hit particularly the home-market industries, which do not have the same possibility of selling for export. The interaction between the change in supply and demand would be reflected in falling product prices for most industries of the order of magnitude of 1-2 per cent in the 0-scenario and around 0.5 per cent in the +scenario. However, while the export-oriented industries would generally be able to increase production, production would fall in a number of home-market industries.

Increased production in export industries ...

... but a fall in home-market industries

Table 5.12
Change in gross factor income, fixed GNP prices

0-scenario and +scenario	GFI 1992 level DKKm	DKKm	%	DKKm	%
Primary agriculture and processing	41,001	-4,538	-11	-1,796	-4
Building and construction, commerce, services and housing	332,401	-3,739	-1	-1,495	-0
Other sectors	390,140	2,829	1	880	0-{}-
Total	763,542	-5,448	-1	-2,410	-0
Product taxes and subsidies	124,326	-1,549	-1	-649	-1
Gross national product	887,868	-6,998	-1	-3,059	-0

Note: All amounts are given in 1992-prices. A model-calculated fall in the GNP deflator of 1.63 per cent is used in the 0-scenario and 0.64 per cent in the +scenario as the basis for the conversion into fixed GNP-prices.
Source: Jacobsen & Frandsen (1999, Table 5.12)

For example, it has been found that gross factor income in the sectors building and construction, commerce, services and housing, taken together, would be reduced by DKK 3.7 billion in the 0-scenario and by DKK 1.5 billion in the +scenario (Table 5.12), while the total fall in gross factor income would amount to DKK 5.4 billion and DKK 2.4 billion, respectively.

Adjusted for charges and duties, this corresponds to a reduction in gross national product, measured in fixed GNP prices, of DKK 7.0 billion in the 0-scenario and DKK 3.1 billion in the +scenario.

Socioeconomic consequences

Socioeconomic consequences

From a socioeconomic angle, it is the consequences for GNP, real consumption, capital and investments, and exports and imports, that are of interest. As stated earlier, it is assumed in the analyses that total employment would remain unchanged because of flexible pay formation. With the requirement of equilibrium in the balance of payments, this means that the consequences of phasing out pesticides would be changes in the above-mentioned variables. It is also assumed in the analyses that savings in society develop in line with total investments.

Considerable fall in consumption and investment

The main measure of the welfare-related economic consequences is changes in private consumption. As a consequence of lower real wages, disposable income would be reduced, with negative consequences for consumption. Assuming that public consumption was unaffected, real private consumption would fall by DKK 7.6 billion (1.7 per cent) in the 0-scenario compared with DKK 3 billion (0.7 per cent) in the +scenario (Table 5.13). This corresponds to DKK 1,500 and DKK 600 per capita, respectively, measured in 1992 prices[24]. Investments would go down by just under DKK 2 billion in the 0-scenario and by DKK 950 million in the +scenario.

Measured in fixed prices, GNP would fall by DKK 7.3 billion (0.8 per cent) in the 0-scenario, compared with DKK 3.1 billion in the +scenario (0.4 per cent). When this is compared with the aforementioned changes in pesticide usage (Table 5.1), it will be seen that DKK 4.2 billion could be saved by going from a total phase-out to limited use of pesticides corresponding to an increased treatment frequency of 0.2-0.7 standard doses per ha.

Improved balance of trade …

As far as the consequences for foreign trade are concerned, total Danish real exports in the *0-scenario* would increase by slightly less than DKK 6.4 billion, while real imports would increase by DKK 3.8 billion. The growth in exports of other goods and services as a consequence of improved competitiveness in other sectors than agriculture would thus fully make up for the smaller Danish agricultural exports. On the import side, rising agricultural imports would make up for lower imports of other products.

Table 5.13 Change in gross national product, quantities

	Zero and + scenarios			
	DKKm	%	DKKm	%
Private consumption	-7,600	-1,7	-3,301	-0,7
Public consumption	0	0.0	0	0.0
Investments	-1,980	-1.2	-950	-0.6
Stock changes	0	0.0	0	0.0
Export	6,354	2.0	1,589	0.5
Imports	3,825	1.4	531	0.2
Total	-7,281	-0.8	-3,108	-0.4

Note: Gross national product is equal to the sum of private and public consumption plus investments, stock changes and exports less imports. Gross national product is expressed in quantities, which means that the figures do not sum to the total and that the total figures differ from the gross national product in fixed gross national prices in Table 5.12. All amounts are given in 1992 prices.
Source: Jacobsen & Frandsen (1999, Table 5.13).

… despite impaired terms of trade

The terms of trade (calculated as the ratio between the development of export and import prices) would fall by 1 per cent due to falling export prices, in that it is assumed that import prices would remain unchanged. The picture in the *+scenario* is the same except for a far smaller increase in the volume of exports and imports.

[24] Measured in 1999-kroner, DKK 1,700 and just under DKK 700, respectively, per capita.

Global phase-out of pesticides

Global phase-out of pesticides

As mentioned, the analyses here are based on unilateral Danish regulation of pesticide usage, with the assumption that Danish consumers and manufacturers have free access to purchase conventional foreign products and capital goods at internationally determined market prices, and that consumers do not prefer pesticide-free products. As shown above, this means that cereals produced in Denmark would be replaced by imported, conventional, foreign cereals, which would make it possible to maintain Danish livestock production at a largely unchanged level.

... would reduce the supply of agricultural products ...

... resulting in further losses

If similar regulation of pesticide usage were implemented in and outside the EU, the same trend could be expected in other countries, i.e. the supply of cereals would be reduced globally. Such a development would result in an increase in the price of cereals and thus improve the competitiveness of non-pesticide cereals produced in Denmark. However, it would also increase production costs in livestock production – especially pork and poultry production – which would thus be less able to compete. In a global context, such a development would increase food prices with consequent financial loss for the consumers and restructuring of production within and outside agriculture, as described above.

It is not possible to estimate the economic consequences of a global restriction of pesticide usage with the present analytical tools. One could – as has been done in the organic scenarios – analyse a situation in which a ban is imposed on increased importation of traditionally produced cereals (the calculations in question indicate which results one would get). However, that is a very unsatisfactory way of modelling a global reduction of pesticide usage. A satisfactory model would require expansion of, for example, SJFI's global trade model[25] in a number of areas, which is outside the scope of this study. However, a global ban on the use of pesticides in agriculture must be expected to result in substantial socioeconomic losses, while a partial phase-out could probably be absorbed more easily within the framework of a continuous economic adjustment of the structure of industry, where the development of new technology could help to facilitate the restructuring process.

Summary

Summary

The purpose of the analyses carried out is to determine the economic consequences and employment consequences of a total or partial phase-out of the use of pesticides. In this connection, importance has been attached to determining the consequences for both primary agriculture and for the agricultural sector and the national economy, taken together, with a view to clarifying the consequences for employment and earnings in different sectors and for consumption in society.

The analyses cover a total phase-out (0-scenario) and a partial phase-out (+scenario) of pesticides. The latter analyses are intended to show the situation in which limited use of pesticides is allowed for the production of crops that would otherwise result in big yield losses or be discontinued.

The analyses are based on assumptions concerning yield losses and cultivation practice in present production and in the event of a phase-out of pesticides. The yield losses thereby calculated are used as the basis for analysing land use and pesticide usage and the economic return at farm level, assuming partial optimisation of the return in crop production. The analyses have also been used as the basis for fixing the technological and biological assumptions for the analyses at

[25] Global trade model that enables elucidation of the economic and trade consequences of changes in the economic framework for, for example, agriculture.

sectoral and societal level. This linkage of the concept of analysis ensures a consistent description of the consequences at different levels of phasing out pesticides.

The assumptions for the socioeconomic analyses are: equilibrium in the national economy; development of savings in line with total investments; and unchanged total employment due to flexible pay formation. Together with the requirement of equilibrium on the balance of payments, this means that phasing out pesticides would lead to changes in total consumption, investments and foreign trade. Since the analyses are based on long-term restructuring, they do not say anything about the effects that could occur in the short or medium term, where there would be restructuring costs.

The analyses show that a total phase-out of pesticides would result in major costs to society and that, even in the case in which use of pesticides, would be permitted for crops that were heavily dependent on chemical control, limiting the use of pesticides would result in considerable losses. All in all, a total phase-out of pesticides (*0-scenario*), would result in a fall in gross national product of DKK 7.3 billion (0.8 per cent) in real terms, while limited use of pesticides (*+scenario*) would result in a real loss of DKK 3.1 billion (0.4 per cent) in relation to present production.

According to the analyses, the treatment frequency index in present production is 1.4-3.9 standard doses per hectare, depending on the main type of production and the type of soil. If limited use of pesticides were permitted, corresponding to the +scenario, the treatment frequency index would be reduced to 0.2-0.7 standard doses, compared with present production. By going from the 0-scenario to the +scenario, the costs would be more than halved even with a more than 80 per cent reduction of the treatment frequency index. The figures thus underline the fact that a limited reduction of pesticide usage would be relatively cheap, whereas a total phase-out would be very costly.

The aforementioned losses result from a real fall of DKK 3.4 billion in gross factor income in primary agriculture in the *0-scenario*, to which must be added a fall of DKK 1.1 billion in the processing industries and of DKK 910 million in other manufacturing industries. The latter covers a real fall of DKK 3.7 billion in gross factor income in building and construction, commerce, services and housing, while gross factor income in other sectors would rise by DKK 2.8 billion. In all, there would be a real fall in gross factor income of DKK 5.4 billion, 63 per cent of which would be in primary agriculture. The fall must be seen in relation to a loss of more than 16,000 jobs in primary agriculture and to a release of manpower from a number of home-market industries. To maintain employment, real wages would have to fall by about 1 per cent in the 0-scenario.

A fall in real wages would, on the one hand, improve competitiveness in sectors exposed to competition, resulting in increased production and net exports of goods and services. On the other hand, falling real wages would reduce domestic demand, which would hit particularly the home-market industries. The results would be a (real) fall of DKK 7.6 billion in private consumption (1.7 per cent), a fall of DKK 2.0 billion in investments and rising net exports, since falling agricultural exports would be fully made up for by rising net exports in other industries.

In the *+scenario*, gross factor income in agriculture and associated processing industries would fall by DKK 1.8 billion. About 8,000 jobs would be lost in primary agriculture and the processing industry (i.e. about half the figure in the 0-scenario), fewer employees would be released from the home-market industries, and there would be a considerably smaller fall in real wages (0.4 per cent). The fall in private consumption would consequently be smaller (DKK 3.0 billion), and the fall in investments would also be smaller. Despite the reduction in agricultural exports, net exports, taken overall, would also rise in this case.

The fall in gross factor income in agriculture reflects a fall in the agricultural sector's contribution to income formation in society (return on labour, capital and land). The real loss in agriculture comprises a fall in wages for the remaining manpower, falling land rent and changes in the value of production rights (the milk quota). Farm-level analyses, which are based on partial or short-term restructuring of crop production, indicate substantial losses in agriculture. The analyses underline the fact that the losses in agriculture depend on the assumptions used with respect to the mobility of the means of production and the length of the restructuring period. There would also be an effect in the form of a redistribution between arable farmers and dairy farmers as a consequence of a different effect on the return on land and production rights.

The above-mentioned changes are a result of a heavy fall in crop production in agriculture and derivative effects on the rest of the economy. In the *0-scenario*, cereal production would fall by 70 per cent and rape production be largely discontinued. In addition, production of special crops (sugar beet and potatoes) would go down by 60-70 per cent. The big fall in production is due to the fact that Danish agriculture is exposed to outside competition, which means that prices can only rise slightly when production falls. Livestock production would be only slightly affected by the limitation of pesticide usage. There would, however, be a slight increase in the production of pigs and poultry, due in part to low wage costs. Milk production would remain unchanged because it is controlled by the EU's milk quota, but the value of the quota would rise.

The picture is largely the same in the *+scenario*, but cereal production would fall considerably less (by just over 30 per cent) and the fall in production of sugar beet would be negligible (6 per cent). On the other hand, with the assumptions used in the analyses, rape production would be largely phased out, while production of potatoes would be halved. In this case, livestock production would be only slightly affected by the reduction in pesticide usage.

The model concept used has not been developed to describe the effect on the fertiliser balance in the industry, but the economic analyses at sectoral level take explicit account of the relationship between change in production and use of fertiliser as established in the agronomic assumptions used in the analyses. It is assumed here that the intensity of fertilisation would increase if pesticides were phased out. In the *0-scenario*, consumption of nitrogenous artificial fertiliser would fall by 63 per cent, while the nitrogen supply with manure would remain largely constant. In all, the supply of nitrogen would fall by just over 40 per cent. In the *+scenario*, the changes would be about half those figures.

The effect on land use in agriculture has been thoroughly analysed at agronomic level and in the farm-level and sectoral economic analyses. The general picture is a switch from winter cereal to spring cereal and production of fodder beet replaced by a larger acreage with peas, wholecrop and grass in rotation. Agronomically, there should be a basis for increasing the acreage with rape, while it should be possible to maintain the acreage with sugar beet, seed and potatoes.

However, the economic analyses show that, owing to international competition, the acreage with potatoes would fall, while the acreage with sugar beet would fall in the *0-scenario* but increase in the *+scenario*. The acreage with greenfeed would increase, and increased set-aside must be expected at arable farms.

The hectare payments for commercial crops have a marked effect on farmers' land use. Despite a very big fall in cereal production, a corresponding reduction in cereal acreage is not expected, and – as mentioned – it is expected that some rape would still be grown. The explanation lies in the fact that the hectare payments to farmers would keep the acreage in question in production at a very low level of yield. In reality, this means that there would be a basis for a considerable increase in voluntary set-aside, especially at arable farms.

It should be noted that set-aside is treated differently at farm and sectoral level. In the farm-level economic analyses, optimum set-aside is calculated, taking account of restrictions on the extent of set-aside at the individual farm, while in the sectoral economic analyses, set-aside is included with the cultivated acreage. Therefore in the latter case, increased set-aside would result in less intensive cultivation on a largely unchanged acreage.

The analyses are based on an assumption that pesticide-free products compete on an equal footing with conventional products in the marketplace. If, through labelling schemes, for example, the consumers were willing to cover the producers for the loss of gross margin, some of the negative effects for producers could naturally be averted. However, too little is known about the demand for food products produced without pesticides or with only limited use of pesticides to be able to say anything certain about this. It is difficult to see the possibilities for a new labelling scheme parallel with the Ø-label, besides which, a considerable proportion of Danish agricultural production is sold on the export markets, where limited, although growing, attention is paid to the environmental aspects of food quality.

In the present analyses, unilateral Danish regulation of pesticide usage is assumed, although with freedom to import conventional products and means of production. This means, for instance, that Danish cereals would largely be replaced by imported cereals, which would help sustain Danish livestock production. If we assume the implementation of a corresponding regulation of pesticide usage in other countries, we could expect a drop in the global supply of cereals, with consequently increasing prices. Such a development would strengthen the competitiveness of Danish cereals, but at the cost of generally rising prices for food products and global economic loss for consumers.

5.2.3 Effect of different treatment frequency indices

Farm-level economic analyses of different treatment frequency indices

The purpose of bringing intermediate scenarios into the analyses is to determine the relationships between pesticide usage, production and economy with different treatment frequency indices in order to gain a clearer picture of the consequences of different levels of pesticide phase-out in agriculture. The analyses have been carried out only at farm level. The agronomic assumptions for the analyses are based on the technological and biological research and the farm-level economic research. As in the case of the main scenarios, the analyses are based on the Farm-level Pesticide Model (FPM).

The analyses are based on fixed assumptions concerning treatment frequency, and the resulting gross margin is shown in Table 5.14. The table includes present production, which is used as the basis for the analyses, while the Free scenario is the model-calibrated present production, with the use of pesticides and land optimised according to the FPM model. To obtain a uniform basis for comparison,

the Free scenario has been used as the basis for the analyses. Basically, present production corresponds to the pesticide usage in 1994 and to the land use in 1995/96, while the ++scenario largely corresponds to the goal in the Pesticide Action Plan from 1986.
Model-calibrated present production

Model –calibrated present production

The difference between present production and model-calibrated present production (Free) could indicate that farmers' present use of land and pesticides is not optimal from the point of view of production economy. However, it should rather be attributed to the fact that the FPM model is a normative model, in which full knowledge of prices and yields is assumed. In addition, optimisation based on gross margin II is assumed in crop production, whereas, in practice, farmers must be expected to take a more integrated approach in their planning. The important thing is for the comparison between present production and the other scenarios to be consistent, and that is best assured by basing the analyses on the model-calibrated present production.

Small fall in income …

… with limited reduction of pesticide usage …

It will be seen from the figures that with the use of best known technology and with optimum warning conditions (++scenario), it would be possible to maintain the gross margin, even if pesticide consumption were reduced, whereas the gross margin would fall with any further reduction of the treatment frequency index. In the design of the scenarios, efforts have been made to present *optimal* solutions in the sense that the production methods are adapted to the lower pesticide usage with a view to achieving the biggest possible yield, i.e. the different scenarios represent different technologies. The relationships thus calculated between pesticide usage and yield levels have been used as the basis for calculating the optimal land use in the FPM model.

… when "best known technology" is used

The results of the analyses are summarised in Figures 5.2 and 5.3, which show gross margin II in different types of farm and with different treatment frequency indices for clayey and sandy soil. It will be seen clearly from these figures that there is a considerable difference in the average treatment frequency index in the different types of farm. The general picture is that, with optimum use of damage thresholds and warning systems, it would be possible to reduce pesticide usage to some extent without seriously reducing the economic return, but that earnings would soon fall if the treatment frequency index were reduced still further. Farms growing special crops (sugar beet, seed and potatoes) would be most exposed to loss, and farms on clayey soil would generally be worse affected than farms on sandy soil.

Considerable uncertainty concerning "best known technology"

The Sub-committee on Agriculture (1999) states in its report that it may be difficult in practice to meet the conditions for maintaining the economic return with reduced use of pesticides. For example, the necessary damage thresholds have not been developed in all cases and the weather systems require long-term weather forecasts, which are not available today. It is thus difficult to indicate with any certainty the treatment frequencies that would significantly reduce the losses. Besides that, a considerable additional cost must be expected for monitoring the crops. In the analyses, this additional cost has been put at DKK 150/ha. It is also stated that considerable breeding work would be needed to ensure varieties with good disease-resistance on the market.

Table 5.14
Pesticide usage and gross margin in the different types of farm

	Present production	Free[1]	++	+	Zero
A. Treatment frequency index					
Clayey soil					
Arable farms	2.4	2.3	1.5	0.4	0.0
Dairy farms	1.9	1.6	0.9	0.3	0.0
Pig farms	2.5	2.1	1.3	0.4	0.0
Arable farms with beets	2.8	2.8	1.8	0.7	0.0
Arable farms with seeds	2.4	2.3	1.5	0.7	0.0
Sandy soil					
Arable farms	1.8	1.1	1.0	0.3	0.0
Dairy farms[2]	1.4	1.0	0.6	0.2	0.0
Pig farms	1.9	1.7	1.3	0.3	0.0
Arable farms with potatoes	3.9	1.6	[3] 2.6	0.5	0.0
Average, all types	2.1	1.7	1.2	0.4	0.0
B. Gross margin					
Clayey soil					
Arable farms	3,310	3,420	3,430	2,780	2,290
Dairy farms	2,170	2,580	2,290	1,920	1,690
Pig farms	2,900	3,070	3,070	2,530	2,040
Arable farms with beets	4,150	4,310	4,270	3,310	2,610
Arable farms with seeds	3,840	4,080	4,140	3,470	2,660
Sandy soil					
Arable farms	2,220	2,290	2,270	2,110	1,690
Dairy farms[2]	1,880	2,240	2,070	1,900	1,700
Pig farms	2,200	2,320	2,310	1,950	1,660
Arable farms with potatoes	3,720	3,860	3,970	3,300	1,880
Average, all types	2,730	2,953	2,881	2,448	1,986

Note: Set-aside is included in treated acreage
[1] Model-calibrated present production
[2] Extensive production
[3] The low treatment frequency index is an expression of the fact that small changes in the composition of the production can have a considerable effect on the pesticide treatment.
Source: Ørum (1999)

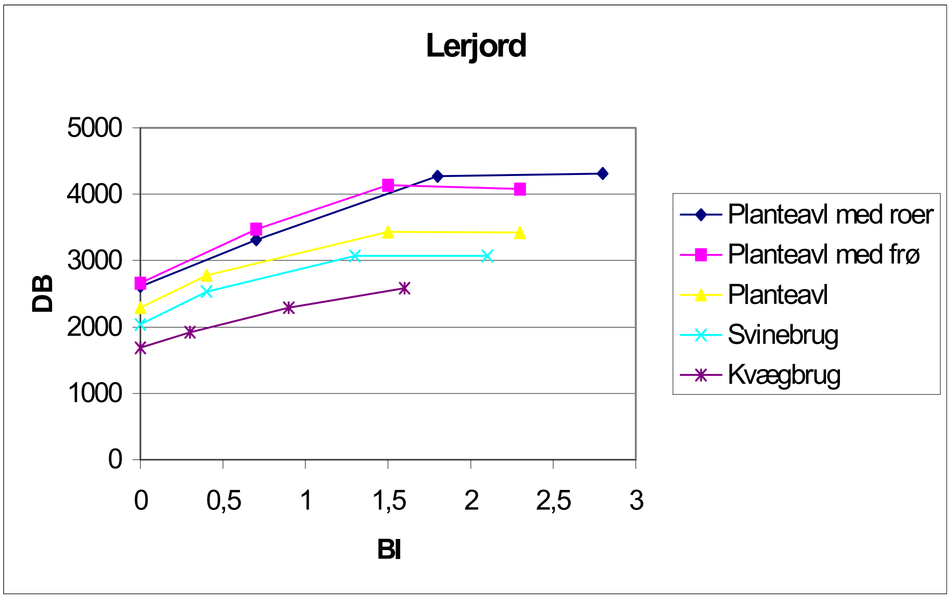


Figure 5.2 Gross margin with different levels of pesticide usage, clayey soil
Source: Ørum (1999)
(Figure text)
Lerjord = Clayey soil
DB = Gross margin
Planteavl med roer = Arable farms with beets
Planteavl med frø = Arable farms with seed
Planteavl = Arable farms
Svinebrug = Pig farms
Kvægbrug = Dairy farms

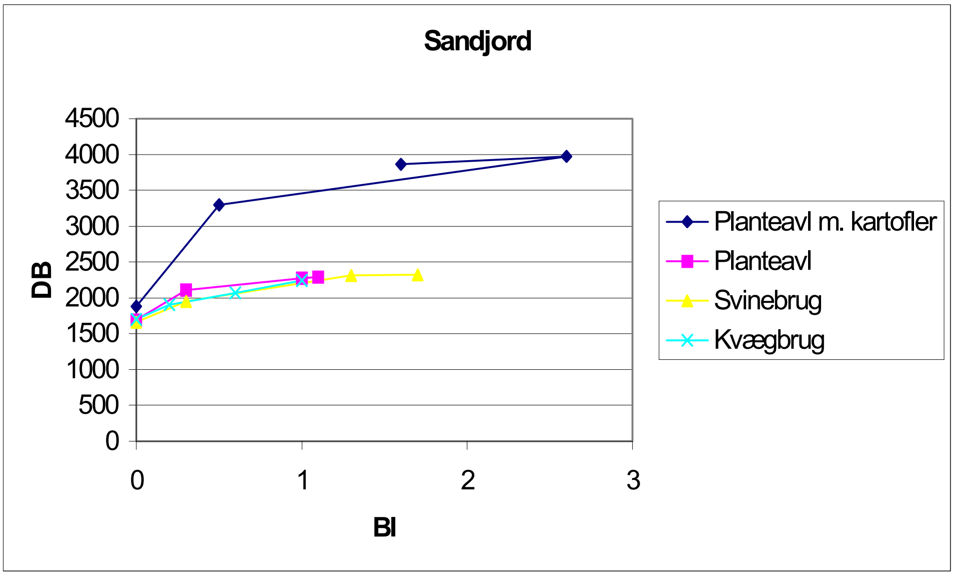


Figure 5.3 Gross margin with different levels of pesticide usage, sandy soil[26]
Source: Ørum (1999)
(Figure text)
Sandjord = Sandy soil
Planteavl med kartofler = Arable farms with potatoes
Planteavl = Arable farms
Svinebrug = Pig farms
Kvægbrug = Dairy farms

[26] The unusual course of the curve for arable farms with potatoes expresses the fact that small changes in the composition of the production can have a considerable effect on the treatment with pesticides.

Examples from practice of reduced pesticide usage

However, this does not mean that it would not be possible, with further research, the development of better monitoring systems and improved advice concerning their use, to get pesticide usage some way below the level for integrated production without impairing production economy. The Sub-committee on Agriculture (1999) thus states that there are examples of intensive advisory activities having led to a reduction of treatment frequency to around 1.3 standard doses per ha at ordinary arable farms without any reduction in the economic result.

5.2.4 Price sensitivity of the analyses

Analyses of price sensitivity

Product and factor prices from the 1995/96 accounting year have been used in the analyses of the economic consequences at farm level. The price of cereals, in particular, has fallen since then and taxes on pesticides have increased. In addition, in connection with the negotiations on enlargement of the EU, a further reduction of the level of subsidies in the EU's agricultural policy is proposed.

Falling product prices result in …

To illustrate the effect of changes in agricultural prices, analyses have been carried out of arable farming on clayey soil. The basis for these analyses is the so-called Santer package's proposal to reduce the price of feed grain by 20 per cent. However, in the analyses, a reduction of 30 per cent in the price of wheat is assumed because the price has already fallen by 10 per cent since 1995/96. A hectare payment of DKK 2,601 for all reform crops except peas is also assumed (the hectare payment for peas has been put at DKK 2,857 per ha), in line with the assumptions in the "Santer package". It is also assumed that set-aside must be at least 10 per cent, that total set-aside must not exceed 33 per cent, and that the price of herbicides increases by 25 per cent and the price of insecticides by 50 per cent as a consequence of increased taxes.

It should be noted that the hectare payments are assumed to be paid as a non-production-related subsidy to farmers, i.e. the hectare payment is not affected by the farmer's decisions with respect to production intensity.
However, the hectare payment is included in the gross margin and therefore affects land rent.

The results of the analyses are given in Table 5.15.

... considerable fall in treatment frequency index ...

Owing to the big fall in the price of cereals, the gross margin – and thus the land rent in model-calibrated present production – falls from DKK 3,418 to DKK 1,967 per ha. At the same time, the intensity, measured by the treatment frequency index, falls from 2.32 to 1.39. In other words, the lower cereal price contributes to a considerable reduction in the use of pesticides.

... and reduced losses from phasing out pesticides

The table also shows that the losses from phasing out pesticides are halved when the analysis is based on the lower product prices. Or, conversely, it does not cost as much to phase out pesticides when the product price level is reduced.

The above analyses apply to clayey soil. For sandy soil, the phasing-out costs after a price fall would be even smaller.

Small costs …

According to Table 5.15, the intensity of pesticide usage would be reduced with the assumption of optimised production. However, the analyses show that the cost of maintaining a higher pesticide usage (than the calculated optimum) would be modest. This indicates that even with lower cereal prices and the current pesticide taxes, there would probably be a need for further intervention in order to ensure a reduction of pesticide usage.

... with precautionary spraying

It must be stressed that the analyses are encumbered with uncertainty, particularly with respect to the assumptions concerning the relationship between price fall and hectare payment. That said, the analyses show that the intensity of production must be expected to fall with lower product prices and that, through that, it would be possible to ensure a reduction of pesticide usage in farming. However, the total effect would depend on how farmers assessed the risk of reducing their use of pesticides. Here, the fact that precautionary spraying does not cost very much would play a role.

Table 5.15
The effect of changed price and subsidy assumptions for arable farming on clayey soil

	1995/96 prices			Changed price assumptions		
	Free	+	Zero	Free	+	Zero
Treatment frequency index	2.32	0.43	0.0	1.39	0.38	0.0
Gross margin DKK per. ha.	3,418	2,776	2,288	1,967	1,666	1,397

Note: The analyses are based on a 30 per cent reduction in the price of cereals compared with 1995/96 and an assumption that the hectare payments for cereals and silage corn are increased by 18 per cent, that the hectare payments for rape, peas, flax grown as oil-seed crop, and set-aside, are reduced by 32, 10, 39 and 6 per cent, respectively, and that the acreage with reform crops must include between 10 and 30 per cent set-aside. It is also assumed that the price of herbicides and fungicides rises by 25 per cent, and the price of insecticides by 50 per cent, as a result of taxes introduced.
Source: Ørum (1999)

5.2.5 Pesticide usage and cultivation risk

Cultivation risk ...

The yields from crop production fluctuate from year to year, depending on the weather. Since a number of diseases and growth of weeds are dependent on the weather, one might expect it to be possible to even out the fluctuations in yields by treating the crops with pesticides. In this connection, it must be remembered that the fluctuations vary from crop to crop, so the farmer can to some extent ensure himself against big fluctuations in earning through his choice of crop rotation. (The farmer has several strings to play on). In addition, the farmer does not necessarily aim for a constant level of yield, but wants to even out the economic yield, in which product prices also play a role. Since fluctuations in the yields for a number of crops often have a negative correlation with the price (e.g. potatoes), adjustment to the market would have an equalising effect that the farmer could include in his planning.

... is linked to economic yield

In order to trace the effect of pesticides on security of cultivation, the Sub-committee on Agriculture assessed the size of the losses without the use of pesticides. The results are shown in Table 5.16, where the crops are ranked in order of average yield in the case of a total phase-out of pesticides, with the yield in present production put at 100. From this it will be seen that the yield from spring cereal would fall less than the yield from winter cereal, that the yield from grass and winter rape would be only slightly affected, and that the yield from such crops as potatoes, seed grass and clover seed would fall sharply.

Pesticides affect the level of yield …

The Sub-committee on Agriculture also set a minimum yield with a phase-out of pesticides. Comparison with the average yield provides information about "how bad things could be" in the individual crops. It will be seen from the table that such crops as wholecrop and maize, fodder beet and peas would provide a high level of yield stability, while for the other crops the difference between average and minimum yield would tend to rise with falling yield level. However, covariation has not been found in years with large yield losses. It would therefore depend greatly on the crop composition whether the yield variation increased or decreased.

... but hardly the yield variation

Analyses based on trials with fungicides do not support the view that pesticides reduce the yield variation. On the contrary, it has been found (Ørum, 1999 p. 61) that the yield variations in winter wheat are slightly smaller in trial plots that are not treated with fungicides than in treated plots. On the other hand, there is a clear additional yield from use of fungicides. The analyses also show close covariation in the yields from year to year in treated and untreated plots. The main effect of the treatment is thus that pesticides offer the possibility of a significant additional yield.

Table 5.16
Yields with a total phase-out of pesticides, present production = 100

	Average yield	Minimum yield	Difference
Clayey soil			
Spring barley	81	70	11
Winter barley	79	72	7
Wheat, 2nd year	73	57	16
Wheat, 1st year	71	50	21
Sandy soil			
Spring barley	83	67	16
Winter barley	78	68	10
Wheat, 1st year	73	55	18
Wheat, 2nd year	70	32	38
Non-soil specific			
Grass	97	96	1
Winter rape	93	74	19
Winter rye	88	72	16
Wholecrop and maize	87	84	3
Sugar beets and fodder beet	86	78	8
Oats	84	75	9
Peas	79	74	5
Spring rape	77	52	25
Potatoes	58	0	58
Seed grass	50	0	50
Clover seed	25	0	25

Source: Calculated on the basis of Ørum (1999, Table 6.5).

Yield variation the same in organic and conventional production

This is also supported by observations from all-year trials with conventional and organic production, in which no difference in yield variation has been found between the two forms of production. The reason why the yields are apparently just as certain in organic production as in conventional production could be that organic farmers use resistant varieties and eliminate the increased cultivation risk in return for lower yields by changing their crop-rotation and cultivation practice. The all-year trials cover mainly dairy farms, where the yield variations for winter cereal, spring cereal, grass and fodder beet have been investigated. The analyses therefore reveal nothing about the pattern of variation at arable farms, including farms with special crops, where, as mentioned above, there can be considerable fluctuations.

Ørum (1999 p. 64) states, for example, that the additional yields from use of fungicides are particularly big in some years but that phasing out pesticides would not necessarily increase the yield variations in the individual crops. The available material does not provide a basis for judging whether the same would be the case for herbicides and insecticides.

Phasing out of pesticides calls for good production management …

It is also stated in the analysis (Ørum, 1999 p. 69) that good production management would be more important if pesticides were phased out and that production would be more climate-dependent.

… to "control" weeds

It would not normally have irremediable consequences if pests or plant diseases were to result in big yield losses in a single year, but the situation with weeds would be entirely different. If weeds were allowed to spread for just a single year, it could have far-reaching consequences for field production. Extra mechanical weed control would be necessary for many years, and in the worst event some of the economically interesting crops, such as seed grass, beets and winter cereal, would have to be left out of the crop rotation. That means that, in the 0-scenario, weed control would have absolutely top priority in the planning of crop rotations.

Partial phasing out causes few problems …

…but would still make big demands on the production manager

The situation would be different in the case of the intermediate scenarios. An unfortunate development with increased weed problems could be remedied by means of herbicides, i.e. mechanical weed control would no longer have top priority in the planning of the crop rotation. On the other hand, effective use of pesticides in the intermediate scenarios would make very great demands on the production manager. He would have to constantly improve his knowledge of new pesticides and their use, and there would also be a need for new warning and monitoring systems etc. These technologies are under continuous development, and very few farmers today have any experience with them. Restructuring for reduced use of pesticides would therefore require technological development and continuous training of advisers and farmers.

5.3 Market gardening and forestry

Market gardening and forestry affected differently

Reducing the use of pesticides would affect production in market gardening and forestry to a varying degree. Compared with farming, these are relatively small industries, but do, however, make a significant contribution to the national economy by supplying the home and export markets. The latter applies particularly to the production of pot plants, most of which is exported. As shown in Table 5.17, market garden production accounts for 8 per cent of gross factor income in agriculture, while forestry accounts for about 4 per cent. Within forestry, a substantial part of the production of ornamental greenery is exported. It is estimated that primary agriculture employs 84,100 full-time workers. Of these, 6,700 are employed in market gardening and 3,000 in forestry.

… depending on products and production methods

Phasing out pesticides in the above-mentioned sectors would affect the production to a varying extent, depending on the products and the production methods. The consequences in market gardening and forestry are described in brief below. For a more detailed description, readers are referred to the consultants' reports on which this analysis is based and to the report from the Sub-committee on Agriculture (1999).

Table 5.17
Gross factor income and employment in primary agriculture, 1997

	Gross factor income		Number of
	DKKm	%	full-time workers
Agriculture, total	30,744	100	84,100
Farming[1]	27,166	88	74,400
Market gardening[2]	2,459	8	6,700[3]
Forestry	1,119	4	3,000[3]

[1] Including fur animals
[2] Including nurseries
[3] Estimate
Source: Danmarks Statistik (1998a) and SJFI (1998a)

5.3.1 Market gardening

When assessing the consequences for market gardening, it is relevant to differentiate between greenhouse production (which comprises greenhouse vegetables and pot plants), fruit and berries, garden seeds and outdoor vegetables, and nursery production.

Greenhouse production

Integrated production in vegetable production

Today, greenhouse vegetables are mainly produced in accordance with the IP (Integrated Production) rules. However, pesticides could not be completely phased out (*0-scenario*) without a substantial reduction in the production of greenhouse vegetables. Losses would differ greatly, both from one market garden to another and from year to year at the same market garden. A loss of up to 50 per cent is not unrealistic, while the average yield is expected to be reduced by 5-15 per cent with a total phase-out of pesticides (DEG, 1998).

Pot plants subject to international rules on pests

The production of pot plants, most of which is exported, is subject to international rules on the maximum number of pests. Ordinary pests can be controlled with useful animals but would be sensitive to changes in the surroundings. 0-tolerance pests cannot be controlled 100 per cent biologically, which means that a ban on the use of pesticides would mean the end of production and exports. There would be some cultures without problems with dangerous pests, but they could not substitute the present export assortment.

Many of the above-mentioned problems would also apply in the case of a partial phase-out of pesticides (the +scenario). If partially phasing out pesticides meant that the requirements concerning 0-pests and quality pests could not be met, most of the production of ornamental plants would be affected and would consequently fall. It must be stressed that the effect would depend greatly on the agents that were permitted.

A total phase-out of pesticides would result in a considerable fall in production

Altogether, restructuring for pesticide-free market-garden/nursery production would mean considerable reductions in the sector as a whole. A partial phase-out could presumably be accommodated in vegetable production, whereas it would be difficult to meet such requirements in the case of pot plants without a considerable fall in production. According to the Sub-committee on Agriculture, the fall in production could be from 0-100 per cent, depending on the culture and the season. Production of vegetables and, particularly, pot plants would face tough competition from conventional production in other countries.

Fruit and berries

Declining production of fruit and berries

Owing to international competition, the production of fruit and berries has shown a downward trend in the last few years and, with the exception of cherries, self-sufficiency is considerably less than 100 per cent and still falling, especially in the case of apples. Today, industrial production of unsprayed products is of negligible size, while there is some production of organic products.

Phase-out would result in big fall in earnings in apples and pears…

On the basis of the earnings in organic production, it is estimated that the gross margin would be reduced considerably for all fruit and berry cultures if pesticides were phased out. The prospects are worst for apples and pears, for which a substantial fall in earnings would have to be expected despite use of the most resistant varieties available, while the loss would be smaller in the production of blackcurrants and strawberries.

… while the loss is smaller in the case of blackcurrants and strawberries

With a total phase-out of pesticides (the 0-scenario), it is regarded as very doubtful whether a commercial production of apples, pears and cooking cherries could be maintained to any significant extent, whereas some production of blackcurrants and strawberries could be expected to be maintained. With a partial phase-out (the +scenario), it is estimated that - assuming that spraying against the main pests could be maintained – the economic consequences could be limited to a 15-30 per cent reduction in earnings (Daugaard et al., 1998).

Garden seed and outdoor vegetables

Production niches without use of pesticides …

Production of garden seed and outdoor vegetables is a relatively small, but highly specialised sector, the main products being onions, cabbage, carrots, peas for freezing spinach for seed. Production niches could be found within the sector where there is little or no use of pesticides in present production, and where a phase-out would not have major consequences for the yield (e.g. squash). For the large productions, however, such restructuring could not be done without serious losses. The sector is characterised by substantial capital investments in mechanisation and handling of the products, which means that restructuring production would be very costly.

... but generally big losses with a total phase-out

It is estimated (Friis, 1998) that restructuring would require prices at the level of present organic products (i.e. premiums of 30-100 per cent) to maintain production if pesticides were phased out.

Nursery production

Nurseries are subject to quality control

Nursery production covers a wide range of products within fruit trees/bushes, ornamental plants and woodland plants. Pesticides are used mainly to combat insects and fungal diseases in young crops, but also to some extent for weed control. One of the problems with limiting pesticide usage is that nurseries are subject to quality control requirements with respect to quarantine and quality pests that would be difficult to meet without the use of pesticides.

Halving of production a possibility

Up to the present time, only a few firms have tried pesticide-free nursery production, and the existing examples have been less than promising (Eskesen et al. (1998). It is estimated that, with a complete phase-out of pesticides (*0-scenario*), the yield from the production would be halved, while the *+scenario* should provide a possibility of maintaining some cultures at a certain level.

5.3.2 Forestry

Little use of pesticides in forestry

Compared with farming, market gardening and fruit growing, very little use has ever been made of pesticides in forestry. Most of the pesticides applied are herbicides, which are used in young stands to combat grass etc. since this can be a threat to survival of the young plants. In addition, pests in the form of mice, deer and weevils cause serious problems. After some years' growth, the culture is able to cope on its own, and pesticides are not used in the following 50-150 years.

Ornamental greenery has to be meet high quality requirements

Ornamental greenery is a highly specialised product that has to satisfy other requirements than timber production. The quality requirements are high and even minor damage can make a product unsaleable. Therefore, more pesticides are used in this production than in other forestry. Owing to the market's high quality requirements, a total ban on pesticides must be expected to undermine the economy of the production of ornamental greenery. Analyses indicate (Østergaard, 1998) that the financial yield from the production could fall by around 80 per cent. The possibility cannot be excluded of new production methods being found that could limit the use of herbicides, but insect attack would remain a serious threat if the use of pesticides were banned.

Considerable fall in income with a phase-out of pesticides

It is estimated that, in *old forest areas*, a pesticide ban would result in a fall of 30-50 per cent in the economic return, and in heath forestry it is doubtful whether it would be possible to achieve a positive return at all. Furthermore, the production would become less valuable with respect to quality.

In the case of *afforestation on arable land*, the conditions for alternative weed control are better than in existing forests. The development of mechanical systems for weed control is moving relatively quickly and, particularly in light soils, there are good possibilities of reducing the use of pesticides. On the other hand, the already slow afforestation on clayey soil would be seriously impeded if herbicides were not allowed.

5.3.3 Assessment

It is difficult, on the basis of the above-mentioned analyses, to calculate the actual loss in market gardening and forestry from phasing out pesticides. Firstly, the sectors cover a broad range of products that would be affected to varying degrees. Secondly, the concepts of analysis discussed in section 5.2 have not been developed to deal with restructuring in market gardening and forestry. In other words, we lack a real analysis of the impact of production and consumption on the means of production in these sectors.

Considerable fall in contribution to society

It is assumed that gross factor income from market gardening and forestry would fall by 20 per cent in the event of a total phase-out of pesticides (0-scenario) and by 10 per cent[27] in the event of a partial phase-out (+scenario). That equates to about DKK 500 million in marketing gardening and DKK 225 million in forestry in the 0-scenario and about half those figures in the +scenario. Compared with the losses in farming, of DKK 3.8 billion and DKK 2.0 billion, respectively, the losses in market gardening and forestry would thus probably increase the total socioeconomic loss by 10-15 per cent in the event of a pesticide phase-out.

[27] The losses are estimated. In farming, the losses are 16 and 18 per cent, respectively.

5.4 Economic valuation of environmental improvements

The purpose of the valuation study has been to establish tentative measures for the socioeconomic value of the health and environmental improvements that a ban on pesticides can be expected to produce.

Socioeconomic value of health and environmental improvements

The improvements include reduced pesticide pollution of groundwater, greater biodiversity and recreational and aesthetic benefits. The alternative cost method has been used to value reduced pesticide pollution of the aquatic environment. Through studies of the international literature, unit values have been found for health effects and saved lives, while valuation of such environmental benefits as greater biodiversity and aesthetic values requires preference-based valuation methods. It has not been possible to carry out empirical investigations within the budget and time schedule for the project. Instead, extensive studies have been carried out of the literature on relevant international and national studies on valuation.

Pesticide pollution of the aquatic environment values …

The valuation studies have not created a basis for a real cost-benefit analysis of a pesticide ban. That is due in part to the fact that the scientific part of the Pesticide Committee's work has not generally led to conclusions on which valuation estimates can be based. That applies, for example, in the health sphere, where it has not been possible to arrive at quantified estimates of the health effects of pesticides. In the case of biodiversity and other "soft" values, it has not been possible to find foreign valuation studies sufficiently similar to the scenarios analysed here for the unit values found to be used. That leaves calculations of benefits based on the alternative cost method, which, in the present context, concerns socioeconomic savings within water supply from a ban on pesticides.

… but the basis for a real cost-benefit analysis is lacking

5.4.1 Savings within drinking water supply

Pesticides are still regarded as a threat to groundwater. In this study, the benefits of phasing out pesticides have been examined on the basis of an *alternative* cost analysis covering the expected socioeconomic savings within the drinking water supply if pesticides are no longer used. It is estimated (Dubgaard, 1999) that, within 30 years, 5 per cent of all ordinary water supply plants with a capacity of more than 1 million m3/year would be able to avoid remedial measures. The same applies to 8 per cent of plants with a capacity of 100,000 – 100,000,000 m3/year, 13 per cent of plants with a capacity of 10,000 – 100.000 m3/year and 20 per cent of ordinary plants with a smaller capacity than 10,000 m3/year. In addition, it is estimated that 25 per cent of all individual extraction units – typically private wells and boreholes – would avoid closure if pesticides were no longer used.

Savings within drinking water supply analysed ...

The saved costs correspond to the construction and operating costs that would otherwise have been incurred for remedial measures. On the basis of the political wish for groundwater of a quality requiring only normal water treatment, we operate with two development scenarios. The first comprises *both* direct remedial measures (moving the well field, amalgamating waterworks, etc.) and expanded treatment. The other comprises *only* direct remedial measures in the form of moving the well field and amalgamating waterworks.

… with and without treatment of drinking water

The size of the saving depends on whether treatment is included as a remedial measure. If treatment were permitted, the countermeasures could be implemented for DKK 96 to 120 million per year, depending on the discounting assumption. If the political objective concerning a decentralised water supply structure in which treatment must only occur as a temporary measure were maintained, the preventive measures would cost from DKK 145 to 183 million per year, depending on the discount rate. For a more detailed discussion of the analyses, readers are referred to Dubgaard (1999). Alternatively, preventive measures could be valued on the basis of cultivation agreements.

Preserving clean groundwater can have a value for society beyond the groundwater resources' utility value in the drinking water supply system. It could be a question of both option value and existence value.

5.4.2 Valuation of health risks

Valuation of health effect of pesticides …

As described earlier, the use of pesticides in agriculture has given rise to increasing concern about the effect of the substances on public health. Therefore, as an element of a socioeconomic assessment of limiting the use of pesticides, it seems obvious to try to assess the value of the health effect. The basis for such a valuation is to try to determine the value of a statistical life and the value of avoiding a statistically serious diseases and certain symptoms of diseases.

… is reflected in the willingness to pay for better health

The traditional way of calculating the value of health risks is to look at the cost of medicine and treatment of diseases and loss of productivity/earnings in connection with the diseases. However, such cost considerations have no foundation in the economics of welfare, which must be based on the public's preferences in order to reflect their willingness to pay for better health. Such an analysis naturally lies outside the scope of this study.

On the basis of studies of the literature, we therefore decided to try to determine unit values for a statistical life and for avoiding diseases and, by combining these with an estimate of the relationship between pesticide usage and disease frequency, to arrive at qualified estimates of the total health value.

Data for valuation lacking

It is concluded (Christensen, 1999) that there is generally great uncertainty concerning the health effects of pesticides and the necessary data for a real valuation do not exist. There is thus no basis for assessing the order of magnitude of these benefits.

5.4.3 Biodiversity

Valuation of biodiversity ...

Biodiversity means the multiplicity of fauna and flora in the natural environment. The concept normally refers to the number of species and individuals in a selected area, but biodiversity can also be used in a wider context as the function and stability of eco-systems. Economically, biodiversity can have both a utility value (outdoor life and genetic resources), option value (possibilities of future use) and existence value (preservation of species etc.). Biodiversity can be regarded as a public good, since there is normally free access to it and one person's use of it does not normally reduce the benefit others derive from it. The market mechanism is therefore only able to a limited extent to register the socioeconomic value of biodiversity.

… difficult without adequate analyses of economic externalities

Foreign studies show (Dubgaard & Østergård, 1999) that there can be substantial values. Therefore, economic valuation can in principle make a significant contribution to the political decision-making process in connection with prioritisation that includes biodiversity. However, it is difficult to handle such a valuation in practice, and there are as yet no complete estimates of the economic externality costs that arise due to pesticides. There are some foreign studies of the economic value of biodiversity, but none of these estimates can be transferred directly to the scenarios here.

5.4.4 Summary

Summary

The purpose of the valuation study has been to establish tentative measures of the socioeconomic value of the environmental improvements that a ban on pesticides can be expected to produce. The alternative cost method has been used to value reduced pesticide pollution of the aquatic environment. The calculated economic orders of magnitude are DKK 100 to 200 million per year with a ban on the use of pesticides, calculated on the basis of the cost of treating drinking water. As mentioned, there are considerable benefit components that it has not been possible to value. This applies primarily to human health effects and biodiversity. Nor would it be sound on the present basis to say anything about the order of magnitude of these benefits seen in relation to the calculated loss figures. A complete cost-benefit analysis of the socioeconomic benefits and disadvantages of ceasing to use pesticides requires extensive empirical analysis of people's willingness to pay for the soft values associated with these scenarios.

6. Summary and conclusions

Background, aims and method

Pesticides have increased productivity …

… but are causing concern about health and environmental damage

The use of pesticides in agriculture has resulted in increased productivity and rising production. However, the use of pesticides is increasingly giving rise to concern about the effect of the agents on the environment, meaning both harmful effects as a consequence of pollution of groundwater and products and the effect of pesticides on fauna and flora. Uncertainty concerning the long-term effects of pesticides has therefore led to demands that use of pesticides be reduced or, possibly, phased out altogether.

The analyses cover:
- *the economic consequences of phasing out pesticides*
- *the cost of treating drinking water*

The purpose of the present analyses is to assess the microeconomic and macroeconomic consequences of phasing out pesticides in agriculture, including the consequences for agricultural production and earnings and the employment consequences. In this connection, importance has been attached to determining the consequences for both primary agriculture and the upstream and downstream industries. The analyses include environment-related economic parameters, such as the cost of treating drinking water.

Unilateral Danish regulation of pesticide usage

This means that attention must be paid to the transboundary nature of the problems. Consideration must therefore be paid to the fact that international trade agreements do not allow special treatment of imported products and that requirements concerning production standards are only allowed in respect of a country's own production. The present analyses are based on unilateral Danish regulation of pesticide use and an assumption that Danish consumers and producers are able to buy competing foreign products and means of production.

The analyses are divided into two sections: economic analyses of reduced pesticide usage in agriculture and economic valuation of environmental benefits. The first section comprises analyses of restructuring at crop-rotation level, farm level and sectoral and societal level, while the analyses of environmental improvements are focused on the cost of treating drinking water, health risks and biodiversity.

Economy of regulating agriculture's use of pesticides

Economy of regulating pesticide usage…

… examined with different levels of phase-out

The above problems have been analysed by means of a number of scenarios designed to describe different *levels* of reduction of the use of pesticides in agriculture. The levels include a total phase-out (*0-scenario)* and partial phase-out *(+scenario)*. The purpose of the latter is to show the situation in which limited use of pesticides is allowed for crops that would otherwise give big yield losses or not be produced at all. The analyses have been supplemented by analyses of the restructuring at farm level with different levels of restriction of the use of pesticides, cf. the discussion of different treatment frequency indices below.

Economic models describe restructuring at farm, sectoral and societal level

The economic aspects of reducing pesticide usage have been examined by means of economic models that have been adapted to the needs of the analysis and that show the economic consequences of phasing out pesticides at farm level and sectoral and societal level. The analyses are based on agronomic assumptions concerning yield losses and cultivation practice in the present situation and with phasing out of pesticides. The yield losses thus calculated have then been used as the basis for analyses of land use and pesticide usage and of the economic return at farm level, which is based on partial optimisation of the return in crop production. The calculations have also been used to establish the technical and biological assumptions for the sectoral and socioeconomic analyses, which are based on a general equilibrium model that includes the interaction with other economic sectors. This linkage of the concept of analysis ensures a coherent description of the consequences of different levels of phase-out of pesticides.

The model assumptions determine the result

Indication of direction and order of magnitude of changes

The analyses are in the nature of consequential analyses, the results of which reflect the model assumptions. For example, in the analyses at farm level, full knowledge and transparency are assumed in the decision-making process, which presumably reflects what the ablest production managers can achieve. The analyses at farm level also focus on relatively short-term restructuring, whereas, in the sectoral and socioeconomic analyses, importance is attached to the long-term consequences for agriculture and the Danish economy. The analyses are thus supplementary analyses that shed light on the consequences at different levels. Although such analyses are naturally encumbered with some uncertainty, it is believed that they give an indication of the direction and order of magnitude of the effects of the scenarios analysed.

Set-aside is treated differently

It should be noted that set-aside is treated differently at farm level and sectoral level. The farm model includes assumptions concerning the level of set-aside at the individual farm – minimum 10 per cent and maximum 33 per cent of the acreage with reform crops (including set-aside) – except in the case of dairy and pig farms, where set-aside must not exceed 10 per cent because of the problem of disposing of manure. The farm-level analyses thus give an idea of the extent of set-aside in selected forms of production. The macroeconomic model does not describe set-aside separately, but the set-aside acreage is included in the calculations together with the cultivated acreage. Therefore, in the sectoral analyses, increased set-aside is reflected in lower average yields per ha (extensified use of land).

0-scenario

Socioeconomic cost of total phase-out DKK 7.3 billion

The analyses show that a total phase-out of pesticides would be very costly for society. In all, a total phase-out would result in a (quantitative) fall in gross national product of DKK 7.3 billion per year (0.8 per cent). Private consumption would fall by DKK 7.6 billion (1.7 per cent), corresponding to around DKK 1,500 per inhabitant. Investments would fall by DKK 2 billion. Exports and imports would increase by DKK 6.4 billion and DKK 3.8 billion, respectively. The main measure of the welfare-related economic effects is changes in private consumption.

At sectoral level, the effect is measured by the change in gross factor income, which expresses the sector's contribution to income formation in society (return on labour, capital and land). Phasing out pesticides would reduce productivity in the sector, thereby impairing the sector's ability to compete for manpower and capital. There would consequently be a "migration" of capital and manpower from agriculture to other sectors, although – in the latter case – at lower real wages. For the agricultural sector, that would mean a fall in the level of wages, i.e. the remaining manpower would suffer a loss of income. In addition, established farmers would suffer a loss of capital in the form of declining land rent and there might also be changes in the value of, for example, the milk quota.

Agriculture's contribution to income formation falls

The analyses at sectoral level show that a total phase-out of pesticides would result in a real fall in gross factor income in primary agriculture of DKK 3.4 billion (15 per cent), of which the cereal sector alone would account for DKK 3 billion. The biggest fall in factor earnings would be on capital and manpower due, as mentioned, to the reduced input of these means of production, while land rent would fall by 13 per cent (DKK 470 million). The fall would be counteracted by a rise of just over DKK 700 million in the value of the milk quota. The farm-level analyses, which are based on partial and short-term restructuring of crop production, show a loss for agriculture of the order of DKK 2.5 billion per year in the event of a total phase-out of pesticides. The calculations thus underline the fact that the loss to agriculture would depend very much on the assumptions adopted concerning the mobility of the means of production and the length of the restructuring period. Besides this, there would be an effect in the form of a redistribution between arable farmers and dairy farmers as a consequence of a different effect on land rent and production rights.

Release of manpower …

… reduces real wages

Besides the above-mentioned changes, gross factor income would fall in agriculture's processing industries and other manufacturing industries by DKK 1.1 billion and DKK 910 million, respectively. The latter covers a fall of DKK 3.7 billion in home-market industries (building and construction, commerce, services and housing) and a rise of DKK 2.8 billion in other industries (including, particularly, export industries). The figures must be seen in the light of the fact that employment in primary agricultural and the processing industries would fall by over 16,000 full-time jobs in the 0-scenario and that capital would be depreciated and manpower released from a number of home-market industries. To maintain employment, real wages would have to fall by 1 per cent. On the one hand, this would improve competitiveness in the industries facing competition, resulting in a reduction in imports and rising production and exports. On the other, falling real wages would reduce domestic demand, and that would affect particularly the home market industries, which do not have the same possibility of selling for export.

Considerable fall in gross margin …

… particularly in the production of sugar beet, potatoes and seed …

The analyses at farm level show that a ban on the use of pesticides would reduce the gross margin by 34 per cent on clayey soil and by 24-28 per cent on sandy soil, depending on the form of production. The fall would generally be bigger at arable farms with special productions, such as sugar beet, seed and potatoes, while the percentage fall in gross margin would be approximately the same at non-specialised arable farms, dairy farms and pig farms. However, in absolute terms, dairy farms would suffer the smallest fall. The analyses are based on all other input factors (including manpower) being paid at unchanged prices and on agriculture's product prices not being affected by the intervention. The fall in gross margin would largely be reflected in a lower land rent.

… but less in dairy farming

The smaller fall in gross margin at dairy farms is due to the fact that, in general, less use is made of pesticides in this type of farming than in both arable farming and pig farming. In the case of dairy farming, the loss would also to some extent be mitigated by the fact that fodder beet could be replaced by wholecrop and grass, which would significantly reduce the need for pesticides.

Big fall in crop production …

The above changes would result from a big fall in crop production. Cereal production would fall by 70 per cent and rape production would largely disappear. In addition, the production of special crops (sugar beet and potatoes) would fall by 63-69 per cent. The reason for these big falls is that Danish agriculture's unit costs would rise, thereby impairing competitiveness. Owing to international competition, the price of cereals and rape would rise only slightly, while the price of potatoes and sugar beet, which are less exposed to international competition, would rise by 22 per cent and 30 per cent, respectively.

… but livestock production only slightly affected

Livestock production would be only slightly affected by the reduction in pesticide usage. There would, however, be a small increase in the production of pigs and poultry, due in part to lower wage costs. Milk production would not change because it is governed by the EU's milk quota, but the value of the quota would rise because of lower production costs.

Increased intensity of fertilisation

The model concept used has not been developed to describe the effect on the fertiliser balance in the sector. The sectoral economic analyses, on the other hand, take explicit account of the relationship between change in production and use of fertilisers, as set out in the agronomic assumptions for the analyses. There, it is assumed that the intensity of fertilisation in crop production increases when pesticides are phased out. In the *0-scenario*, consumption of commercial nitrogenous fertiliser falls by 63 per cent, while the nitrogen supply from manure remains largely constant. In all, nitrogen supply falls by use over 40 per cent. The increasing intensity of fertilisation naturally raises the question of whether the harmony rules could be met. In this connection, it must be remembered that the macroeconomic analyses are based on long-term restructuring, which means that production could, if necessary, be relocated. In the shorter term, the requirement of harmony between number of animals and acreage would imply increased costs for transport of manure, which would affect the yield in livestock production and make commercial crops more competitive.

Switch from winter cereal to spring cereal, larger acreage with greenfeed and increased set-aside

The effect on land use in agriculture has been thoroughly analysed at crop rotation level, farm level and sectoral level. The general picture is that farmers would switch from winter cereal to spring cereal, and would replace fodder beet by increasing the acreage with peas, wholecrop and grass in rotation. Owing to foreign competition, the acreage with potatoes would fall and so would the acreage with sugar beet. The acreage with greenfeed would increase overall and increased set-aside must be expected at arable farms.

Hectare payments affect land use

The hectare payments for commercial crops have a marked influence on the way farmers use their cultivated land. Despite a very sharp fall in cereal production, in the sectoral analyses this is not assumed to result in a corresponding reduction of cereal acreage, and acreage is still expected to be used for rape. The explanation lies in the fact that hectare payments would keep the land in production at a very low yield level, which in reality means that there would be a basis for considerable voluntary set-aside, particularly at arable farms. As described above, set-aside acreage has not been modelled separately in the sectoral analyses, but is included together with cultivated land. Set-aside would thus be reflected in extensified production on largely the same acreage.

Harmony requirements impair competitiveness in livestock production

In view of the calculated big fall in cereal production, it has been discussed whether the concept of analysis used can adequately describe the agronomic constraints between crop production, land use and use of fertiliser. It is believed that harmony requirements and other constraints on production would reduce the yield in livestock production in the short and medium term and thereby, through reduced demand for land for greenfeed, limit the fall in production of, for example, cereals. It is therefore important to bear in mind that the sectoral and socioeconomic analyses indicate a trend towards long-term equilibrium, where such constraints are assumed to be of no importance.

+scenario

Partial phase-out gives somewhat smaller socioeconomic losses

Compared with a total phase-out, the +scenario would result in somewhat smaller losses – a quantitative fall in gross national product of DKK 3.1 billion (0.4 per cent), a fall in private consumption of DKK 3 billion, corresponding to about DKK 600 per inhabitant, and a fall in investments of DKK 950 million, while exports and imports would rise by DKK 1.6 billion and just over DKK 500 million, respectively.

Falling return on land, but rising value of milk quota

At sectoral level, there would be a real fall of DKK 1.8 billion (8 per cent) in gross factor income in agriculture, but a small rise in the processing industries because rising production in the livestock sectors would more than make up for a fall in sugar mill production. As above, the return on capital and manpower would suffer most, while the return on land would fall by 8 per cent (DKK 295 million). Against this, there would be a rise of DKK 380 million in the value of the milk quota. In this case, there would be a real fall of just over DKK 600 million in gross factor income in other sectors, covering falling production in home market industries and rising production in export industries. About 8,000 full-time jobs would be lost in agriculture, mostly in primary agriculture.

Continued considerable fall in gross margin

The analyses at farm level show that the gross margin in the +scenario would be reduced by 18 to 26 per cent on clayey soil and by 8 to 16 per cent on sandy soil. As above, arable farmers with sugar beet and potatoes would suffer the biggest fall. Dairy farms on clayey soil would suffer a relatively big fall in gross margin (26 per cent), while for dairy farms on sandy soil, the fall would be in line with that for pig farms (15-16 per cent).

Fall in crop production …

According to the sectoral analyses, cereal production would fall by 32 per cent, while rape production would be largely discontinued despite a 4 per cent price rise. The price of cereals would rise only slightly (1 per cent), while the prices of potatoes and sugar beet would rise by 2 per cent and 3 per cent, respectively.

… but largely unchanged livestock production

Potato production would be largely halved, while production of sugar beet would fall by 6 per cent. Livestock production would be generally untouched by the reduction in the use of pesticides, but the price of greenfeed would fall, partly as a consequence of a lower land rent.

Increased intensity of fertilisation

It is calculated that consumption of commercial fertiliser would fall by 29 per cent, and total nitrogen supply by 19 per cent. However, as crop production would fall more, the intensity of fertilisation would increase.

Changed land use and increased set-aside

The analyses of land use show that there would also be a switch from winter cereal to spring cereal in the +scenario. It is estimated that the acreage with rape and the acreage with sugar beet would increase slightly, primarily reflecting the fact that some use could be made of pesticides in the production. The acreage with potatoes would fall, while the acreage with greenfeed would increase. As in the 0-scenario, there would be an increase in set-aside at arable farms on clayey soil.

Considerable economic benefit when going from total to partial phase-out

A comparison of the above-mentioned reduction in gross national product with the change in treatment frequency index shows that a considerable economic benefit is gained by moving from the 0-scenario to the +scenario. According to the analyses, the treatment frequency index in present production is 1.4 to 3.9 standard doses per hectare, depending on the main form of production and the type of soil. If limited use of pesticides were permitted, corresponding to the +scenario, the treatment frequency index would fall to 0.2 to 0.7 standard doses per hectare. Moving from the 0-scenario to the +scenario would more than halve the costs, even with a more than 80 per cent reduction in the treatment frequency index from the present level. The problem with the +scenario is that it is difficult to define the treatment that would ensure the expected reduction in treatment frequency index.

Global phase-out of pesticides strengthens production of pesticide-free cereals

The analyses are based on unilateral Danish regulation of pesticide usage, but with free access to import conventional products and means of production. This means that Danish-produced cereals would to a large extent be replaced by imported conventional cereals, which would help to maintain Danish livestock production. In the imaginary event of similar international regulation of pesticide usage, the global supply of cereals would fall and the price of cereals would consequently rise. Such a development would strengthen the competitiveness of pesticide-free Danish cereals, but at the cost of generally rising food prices and global economic losses for the consumers.

Effect of different treatment frequent indices

Different levels of phase-out analysed

With a view to determining the consequences of different levels of phase-out of pesticide usage in agriculture, farm-level analyses have been carried out of the relationship between pesticide usage, production and economy with different treatment frequency indices. The analyses are based on different intermediate scenarios designed to show different treatment frequency indices with optimised production as described in the Farm-level Pesticide Model (FPM). The scenarios in question include the so-called ++scenario, which, with respect to treatment frequency index, largely corresponds to the goal of the Pesticide Plan from 1986.

Yield level can be maintained with limited phase-out of pesticides …

Farm-level analyses with different levels of pesticide usage indicate that, assuming use of best known technology and with optimum warning conditions, it should be possible to reduce pesticide usage to some extent without any reduction in yield level, but that yield levels would fall sharply with any further reduction of the treatment frequency index. In these analyses, efforts have been made to present *optimal* solutions in the sense of aiming to maintain the highest possible yield by adjusting production methods to cope with reduced use of pesticides. The analysed scenarios thus represent different technologies.

… but uncertainty about the necessary technology

In practice, it would be difficult to meet the conditions for reduced pesticide usage without economic losses. The necessary damage thresholds have not been developed in all areas, and the necessary warning systems require long-term weather forecasts that are not available today. It is thus very difficult to indicate the treatment frequency indices that would significantly reduce the losses. In addition, considerable additional costs must be expected for monitoring of the crops. Lastly, action would be needed to ensure access to disease-resistant varieties and the necessary knowledge.

Price-sensitivity of the results

Reduction of price support paid to farmers …

Analyses have also been carried out of the price-sensitivity of pesticide usage at farm level. As illustration, use is made of a 30 per cent fall in the price of cereal, combined with a higher hectare payment, assumed to be paid as a non-production-related subsidy to farmers. However, the hectare payment is included in the gross margin and thus affects the land rent. It is also assumed that the price of herbicides and fungicides is increased by 25 per cent, and the price of insecticides by 50 per cent, corresponding to the latest taxes introduced.

… reduces pesticide consumption …

… and makes phasing out pesticides cheaper

The results of the analyses show that the return on land with optimised production and the given assumptions would fall by 40 per cent, but that the treatment frequency index would fall at the same time from 2.3 to 1.4 standard doses per hectare. The lower cereal prices would thus help to reduce the use of pesticides. However, the analyses also show that the losses from phasing out pesticides are halved when the analysis is based on the lower product prices. The results are for clayey soil. For sandy soil, the phasing-out costs after a price fall would be even smaller.

Pesticide use and cultivation risk

The farmer tries to even out the economic return

The importance of pesticides to the stability of crop production has been analysed at farm level. In this connection, it should be noted that the farmer does not necessarily aim for a constant yield level but tries to even out the economic return, in which product prices also play a role. For some crops (e.g. potatoes), there is often a negative correlation between fluctuations in yields and price, so the market itself has a regulating effect, which the farmer can take into account in his planning.

Uncertainty concerning effect of pesticide usage on yield variation

The problem is that basic data are not available for a sufficiently reliable analysis of whether stability of cultivation would be greater or smaller if pesticides were phased out. Observations from all-year trials within conventional and organic farming have not revealed differences with respect to yield variation. The explanation for this is that organic farmers use resistant varieties and, by changing crop rotation and cultivation practice, have managed to eliminate the increased cultivation risk in return for lower yields. For special crops, where there is a generally greater likelihood of yield losses from pests, there is a lack of data that might throw light on the effect of pesticides on cultivation stability. However, there is generally little doubt that pesticides help to stabilise production by preventing big yield losses from pests.

Weeds a problem

It is stated in the analysis that good production management would become more important if pesticides were phased out and that production would be more climate-dependent. It would not normally have irremediable consequences if pests or plant diseases were to result in big yield losses in a single year, but the situation with weeds would be entirely different. If weeds were allowed to spread for just a single year, extra mechanical weed control might be necessary for many years, and in the worst event, some economically interesting crops, such as seed grass, fodder beet and winter cereal, would have to be left out of the crop rotation.

Need for better production management and warning systems

In the intermediate scenarios the situation would be different. An unfortunate development with increased weed problems could be remedied by means of herbicides, i.e. mechanical weed control would no longer have top priority in the planning of the crop rotation. On the other hand, production managers would need to keep up with new pesticides and their uses, and there would also be a need for new warning and monitoring systems. Advisers and farmers would need regular supplementary training in the use of such technology.

Market gardening and forestry

Market gardening and forestry

Phasing out pesticides would affect production in market gardening and forestry to a varying degree, depending on the products and production methods. Taken together, restructuring for pesticide-free market gardening (0-scenario) would result in considerable reductions in the sector as a whole. A partial phase-out of pesticides (+scenario) could probably in time be accommodated in vegetable production, but in the case of pot plants, producers would have difficulty in meeting the quality requirements and there would undoubtedly be a considerable fall in production. It is also considered very doubtful whether commercial production of apples, pears and cooking cherries could be maintained if pesticides were phased out altogether, whereas some production of blackcurrants and strawberries could probably be maintained.

Phasing out of pesticides would make it difficult to meet quality requirements in market gardening, ...

... nurseries ...

It is estimated that the economic return in nursery production would be halved with a total phase-out of pesticides, whereas, in the +scenario, it should be possible to maintain some cultures. The problem with limiting the use of pesticides in nurseries is that nurseries are subject to quality control with respect to quarantine and quality pests and would have difficulty in meeting the requirements without pesticides.

... and forestry

Compared with farming and market gardening, little use is made of pesticides in forestry. Most of the pesticides used are herbicides, which are used to control grass etc. in young stands. It has been estimated that a ban on the use of pesticides would result in a fall of 30-50 per cent in economic yield in old forest areas and a fall of almost 80 per cent in the production of ornamental greenery. The loss in the case of afforestation on arable land would be smaller. However, the possibility cannot be excluded of new production methods being developed in the longer term that would reduce the need for – particularly – herbicides.

Marked socioeconomic effects

It is assumed that gross factor income from market gardening and forestry would drop by 20 per cent in the event of a total phase-out of pesticides (0-scenario) and by 10 per cent in the event of a partial phase-out (+scenario). That equates to about DKK 500 million in marketing gardening and DKK 225 million in forestry in the 0-scenario and about half those figures in the +scenario. Compared with the losses in agriculture, of DKK 3.8 billion and DKK 2.0 billion, respectively, the losses in market gardening and forestry would thus probably increase the total socioeconomic loss by 10-15 per cent in the event of a pesticide phase-out.

Economic valuation of environmental benefits and health effects

Valuation of environmental benefits and health effects ...

The purpose of the valuation study has been to set up tentative measures for the socioeconomic value of the environmental benefits that a ban on pesticides can be expected to produce. Since it has not been possible to carry out a valuation of environmental benefits within the framework of this study, the analyses are based mainly on studies of the international literature.

... not possible owing to lack of scientific data

The valuation studies have not provided a basis for a real cost-benefit analysis of a pesticide ban because the scientific part of the Pesticide Committee's work has not generally led to conclusions on which valuation estimates can be based. That applies, for example, in the health sphere, where it has not been possible to arrive at quantified estimates of the health effects of pesticides. In the case of biodiversity and other "soft" values, it has not been possible to find foreign valuation studies sufficiently similar to the scenarios used here for the unit values found to be used.

Cost of treating drinking water

Analyses have, on the other hand, been carried out of savings within water supply from a ban on pesticides. Use has been made here of the alternative cost method, in which the expected socioeconomic savings within drinking water supply in the event of a ban on pesticides are used to evaluate the value of clean drinking water. Two development scenarios have been used in the analyses. One comprises direct remedial measures and expanded treatment, while the other comprises only remedial measures in the form of moving well-places and amalgamating waterworks. The analyses show that the economic cost would be in the region of DKK 100-120 million per year if treatment were allowed, compared with DKK 150-180 million if treatment were only allowed as a temporary measure.

Goals include safeguarding the population against contamination of food products with pesticide residue, greater biodiversity and a reduction of CO_2 emission in connection with the production of pesticides. It has not been possible to estimate the socioeconomic value of this group of goals.

Decision requires political weighing of economic and environmental considerations

The analyses thus do not provide a basis for assessing all the *benefits* from phasing out pesticides in agriculture, whereas the socioeconomic *costs* are reasonably well covered. It will therefore depend on a political assessment of whether the achieved value of clean groundwater and other, unquantified, environmental benefits from phasing out pesticides outweigh the socioeconomic costs of doing so and thus warrant such intervention.

Decisions affected by uncertainty and irreversibility

Such an assessment would be encumbered with uncertainty, and the question of the irreversibility of the harmful effects would also have to be considered. Empirical research shows that it is difficult to explain people's assessment of risk on the basis of rational economic criteria. One reason for this may be that people regard scientifically based estimates of the probability of damage as incomplete information, which means that a *safety premium* has to be included in the assessment of the *costs and benefits* of reducing pesticide usage. It has not been possible within the framework of this analysis to estimate the size of such a safety premium. However, economic theory can provide support for policy-makers in situations in which damage to the environment is characterised by uncertainty and irreversibility and can also provide a guide to where input is needed to reduce the uncertainty of the basis for decisions.

Regulation and choice of instruments

Regulation must be targeted

It is pointed out in the report that regulation of pesticide usage in agriculture should as far as possible be targeted on the problems in focus. For example, a general reduction of the use of pesticides on the total acreage would probably have a far less positive effect on flora and fauna than if the reduction were achieved through the establishment of pesticide-free buffer zones and a ban on the use of pesticides in environmentally sensitive areas. Similarly, in the basis for the regulation, account could be taken of the fact that the risk of percolation to the groundwater varies from one pesticide to another and from one place to another.

Detailed control is administratively demanding

The choice of regulatory instruments (and their objectives) must thus be sufficiently detailed to reflect the variation in the environmental impact of pesticide use, both geographically and in relation to the individual product's effect. Against this, there is consideration of the cost of administering the policy. As a general rule, the greater the degree of detail in the formulation of a policy, the greater will be the cost of controlling and administering the policy. The choice of regulatory instruments must therefore depend on an assessment of the efficiency of the schemes that also takes account of the cost of administering them.

Taxes are easy to administer, …

… but requires a high level of taxation

Taxes are generally easy to administer, and if the goal is a general reduction of pesticide usage, a tax would be an effective instrument, since it would ensure reduction in the economically most rational way. However, substantial taxes would be required to ensure a big reduction in pesticide usage. The same applies to the use of quotas, provided these are made negotiable. In this connection, it might be worth looking into the possibility of differentiating the tax on the basis of the harmful effect of the agents and the risk of percolation and perhaps of graduating the tax in relation to recommended treatment frequency. Enforcement of the "polluter pays" principle could possibly be used as a supplement to traditional regulation.

A tax does not meet the requirement of differentiated action

A general tax on pesticide consumption would not meet the requirement of differentiated action against pollution in geographically limited areas. For that, regulatory instruments would be needed – for example, a ban on the use of pesticides in environmentally sensitive areas or restrictions on the cultivation of particularly problematical crops. The problem with such a policy is that it would be difficult to ensure an economically optimal solution and that regulation is generally administratively demanding. The choice of political control instruments therefore requires careful consideration, including consideration of the possibility of combining regulatory and economic instruments.

Taxes on conventional production

It has been mentioned that, instead of regulating the use of pesticides, one could impose taxes on conventional production. Such a measure would require certification of pesticide-free products as with the Ø-label scheme. However, for taxes to be accepted internationally, they would have to be non-discriminatory. In addition, the imposition of taxes on *uncertified* products would have to be based on objective environmental and health factors (product standards). It is not certain that restrictions based on the way products are produced (product standards) would be compatible with EU and WTO rules.

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