UB

Pesticide use and pesticide policy in the Netherlands

An economic analysis of regulatory levies in agriculture

A.J. Oskam, H. van Zeijts,
G.J. Thijssen, G.A.A. Wossink and
R. Vijftigschild

Wageningen Agricultural University 1992

CIP-GEGEVENS KONINKLIJKE BIBLIOTHEEK, DEN HAAG

A.J. Oskam, H. van Zeijts, G.J. Thijssen, G.A.A. Wossink and R. Vijftigschild

Pesticide use and pesticide policy in the Netherlands: an economic analysis of regulatory levies in agriculture / A.J. Oskam, H. van Zeijts, G.J. Thijssen, G.A.A. Wossink, and R. Vijftigschild.
– Wageningen : Agricultural University. – (Wageningen economic studies ; 26)
Lit., index.
ISBN 90-6754-232-6
NUGI 689
Keywords : Pesticides, economic analysis, regulatory levies

Printed in the Netherlands

Preface

This study resulted from a research project financed by the Ministry of Housing, Health and Environment, and the Ministry of Agriculture, Nature Management and Fisheries. The main part of the research was done jointly with DHV-consultants of Amersfoort. After finishing the report "The feasibility of a system of incentive charges on pesticides for the agricultural sector" (in Dutch with a summary in English), we felt that a further study and documentation of pesticide use and pesticide policy in the Netherlands and the principles of a regulatory levy would be interesting, for various reasons. In many countries, increasing attention is being paid to the environmental impacts of pesticide use. This is one of the reasons for examining the policies and research results in other countries. Although the present study concentrates on the economic aspects of regulatory levies it is certainly not limited to that subject. Because of the attention to the 'technical side' of pesticides and agricultural production, it might be considered a multidisciplinary study, with economics as the main discipline. We decided to publish our results in English, to ensure we reach an international audience.

Various people from different backgrounds kindly reviewed drafts of this book or particular chapters. We thank P. van Tilburg, H. Naber, A. Emmerman, A. Dubgaard, S. Rude, A.F. van der Wal, M.A. de Waard and J.C. Zadoks for their comments. Of course, the authors remain responsible for the contents of this book.

The Departments of Agricultural Economics and of Farm Management of Wageningen Agricultural University collaborated in this research project. In addition to the authors, several persons contributed to the final result. A.J. Aaltink, A. de Buck, W. de Jong, J. Rus and L. Verschueren wrote MSc theses on subjects contained in this research project. Chapters 5 and 6 draw on their findings. W. van de Vendel helped make the database used in Chapters 2 and 9. A large part of the text was translated by Mrs. A. Kooijman-Timmers; Mrs. J. Burrough-Boenisch revised the translation and edited the English text. H. Smit assisted in making the computer program for the income calculations in Sections 8.3., 8.4 and 8.5. J. Bijkerk drew the figures. The final typing and layout of the text was done by Mrs. A. de Vries and Mrs. O. Hitters; R. Aalpol of Pudoc advised us on these matters. We thank them all for their important contribution.

Abstract

Oskam, A.J., H. van Zeijts, G.J. Thijssen, G.A.A. Wossink and R. Vijftigschild, 1992. Pesticide use and pesticide policy in the Netherlands: an economic analysis of regulatory levies in agriculture. Wageningen Economic Studies 26, Wageningen Agricultural University, Wageningen, (xi) + 155 pages, 53 tables, 12 figures, 1 scheme, 5 appendices, 127 references, summary.

This study gives a broad overview of the use and application of pesticides in the Dutch agricultural sector. Compared with surrounding countries, pesticide application in Dutch arable farming and horticulture is very high, mostly because the production systems are intensive. The data used in the study are from a database partly compiled from an inventory study related to the Long-term Crop Protection Plan (LCPP) for the Netherlands. The targets of Dutch pesticide policy and the instruments available to implement this policy are explained. Pesticide use and policy in Sweden and Denmark is analysed, and information and research results for some other European countries are also presented.

The main purpose of the study is to derive the level a regulatory levy needs to be to reach the targeted reductions in pesticide use formulated in the LCPP. A chapter on theory, discussing ways of investigating how prices affect pesticide use precedes the chapters devoted to the empirical research. Two different approaches have been used in this study: an econometrically estimated model, based on observed behaviour in the past and representative LP models that enable the effects of new technologies to be studied. These two models led to substantial differences in the levy that will be necessary to reach targeted levels by the year 2000. The range is about 25 to 100 guilders per kg of active ingredient. The income effects for different types of farms and different parts of the agricultural sector are derived. The estimated income effects are smaller than those estimated in the LCPP.

As well as considering a policy based on reducing the volume of pesticide use this study also considers a policy of banning the use of certain compounds. The influence of the latter policy would be substantial, unless substitution of banned pesticides by remaining ones is possible or new pesticides are introduced.

CONTENTS

List of Tables **page**

List of Figures

List of schemes

1. INTRODUCTION

As agriculture has become more technologically sophisticated it has become increasingly dependent on pesticides. Some of these chemicals are emitted into the environment, which may lead to damaging effects. Pesticide residues are increasingly being found in drinking water, soil and surface water (RIVM, 1991). Recurrent reports of such discoveries make "people feel uneasy" (Goewie, 1990). Unless policies are changed, this unease will only increase.

The mere confirmation that pesticides are having an effect on the environment is in itself not sufficient for tackling future environmental problems. A tightening up of crop protection policies is clearly called for. Usually, government policy on chemical pesticides is restricted to permitting the use of certain chemicals, regulating trade in pesticides, and issuing guidelines to users. It is difficult to check if, and to what extent, users abide by the directives. It seems likely, however, that apart from weighing up the economic risk of not using pesticides, producers aim at minimal users costs or maximum profits when applying these chemicals. It is here that the problem lies: unfavourable environmental effects are seldom taken into account by pesticide users. Moreover, in many countries the prices of agricultural products are being kept high artificially (OECD, 1991), whereas prices of pesticides respond directly to the world market. There are therefore no incentives to cut back the use of pesticides, and this influences the techniques that are developed and applied in agriculture.

The book 'Silent Spring' by Rachel Carson made the general public conscious of the important problems of a particular pesticide. Later on the 'green revolution' and the technological developments in crop production throughout the world induced an important increase in pesticide use (Harris, 1990). Although researchers such as Pimental (1980) tackled the problem of calculating the social costs of pesticides, government policies gave little attention to using economic instruments in incorporating external effects of pesticides in production decisions (Just and Bockstael, 1991).

Pesticides give 'non-point pollution'. Sometimes there is a delay between pesticide use and the appearance of pollution (for instance in groundwater). Moreover, little is known about the harmful effects of certain concentrations of chemicals in water, soil and air. Groundwater samples taken in the Netherlands not far under the surface have shown that EC guidelines for drinking water are often exceeded (RIVM, 1991). In our study we did not examine the relationship between the use of pesticides and any eventual emissions.

In the past few years, willingness to reduce the use of pesticides has increased in various countries (Sweden, Denmark, US - California in particular). Concrete measures have either been implemented, or are being considered (Lantbruksstyrelsen, 1989; Dubgaard, 1991; Vulpen, 1991). This is also true for the Netherlands, where owing to intensive farming and the relatively high percentage of arable cropping, pesticide use per hectare has soared (see Chapter 2). Therefore, in the Netherlands, the problem is being tackled along several fronts.

Recently, in the Netherlands the Long-term Crop Protection Plan[1] (MJP-G, 1991), has come into effect. The LCPP's three main aims are: to reduce producers' structural dependence on pesticides; to cut pesticide use; to limit emissions. The LCPP was based on an extensive stock-taking of the problems in which pesticide use in each subsector of agriculture (and per sector for each product) was investigated. A broad and cohesive package of instruments is being deployed to carry out the LCPP. The LCPP strongly advocates the use of favourable and supporting policy instruments such as the stimulation of research, information and publicity, and education.

The Dutch government anticipates that technological development (e.g. integrated crops in arable farming and closed systems in horticulture) will bring results by reducing dependence on pesticides.

In the Netherlands, interest in using economic measures to reduce pesticide use has been growing since the mid-1980s, because of the ever-increasing environmental problems and the widespread belief that the potential of direct regulation is limited. The National Environmental Policy Plan (MVROM, 1989) and its successor, the NMP Plus (MVROM, 1990), illustrate this development. In the NMP Plus (1990) a distinction was made between measures that influence behaviour and those aimed at securing funds for pursuing environmental policy. The first type of policy instrument is called a regulating levy, the second a financial levy. The extent of a regulating levy is linked to environmental targets. In order to provoke as little resistance as possible, the funds obtained are being restituted to the sector: they are not a tax.

Our investigation into the efficacy of economic instruments for regulating pesticide use was largely based on the information available on the use of pesticides combined with detailed economic data from a stratified sample survey of farms, collected and processed by the Landbouw Economisch Instituut (LEI). In all, we had four sources of information to work on:
1) the detailed information about pesticide use;
2) the available information on present agricultural technology and new production techniques;
3) the clear objectives formulated by the government that also consider the use of economic instruments (including a regulatory levy);
4) the data from the stratified sample of the LEI.

This is what makes the study of the pesticide problem so interesting. We have not heard of any comparable study in any other country.

A central issue in this study is the question of the impact of regulating levies on pesticide use. Or, in more general terms: what is the relationship between the price of a pesticide and its use? Several approaches are possible to determine the effect of levies on both the use of pesticides and farmers' incomes. We did economic analyses using econometric

[1] Throughout this report the name Long-term Crop Protection Plan with acronyms LCPP will be used for the Dutch equivalent 'MeerJarenPlan Gewasbescherming' (MJP-G). References, however, are to the MJP-G.

models and linear programming models (called LP models for short).

The econometric models we used are based on historical data on a particular sector and directly link the observed purchased amounts of inputs (pesticides, fertilizers, energy and the like) with the prices of these inputs. So this approach fits in nicely with farmers' actual behaviour in the past. Since pesticide prices have not fluctuated greatly, statements advocating high levies on pesticides must be treated with great care. Technological leaps forward (for instance, a transition to integrated crop production) may also cause problems when using econometric models.

An LP model is based on information about a sector or group of farms in a given year. The difference between gross revenues and variable costs is maximized, given a number of technological restrictions. New techniques can be included in such a model, provided the necessary information is available. This is also true for future regulatory measures. The behaviour assumed in the LP models will often differ from actual behaviour. One of the reasons is that farmers do not employ new techniques as swiftly as is assumed in the LP models (for instance, because of uncertainty and ignorance). Furthermore, it is difficult to include all data (different ways of crop production, restrictions) in the analysis. Therefore simplifications are necessary, which will also create differences between the normative model and reality.

Organization of this report

Chapter 2 gives an analysis of the volume of pesticide use in the Netherlands (in comparison with other countries) and of the problems observed. Furthermore, the policy proposed in the context of the LCPP is discussed. After an overview of the problems of pesticide use and policy proposals to reduce its use, Chapter 3 starts with an economic theory on the use of pesticides. Several approaches or models are discussed on the basis of a production function. Chapter 4 consists of two parts. First, there is a discussion on the experience gained in Sweden with levies on pesticides in recent years. Secondly, an overview is given of existing literature on the results of empirical study or the modelling of the relation between pesticide use and pesticide price or a pesticide levy.

In Chapter 5 the econometric method is described and the results of the study on the sensitivity of pesticide use to the prices of pesticide and agricultural products in Dutch arable farming and horticulture are given. A distinction is made between short-term and long-term effects, and the effects on producers' income are indicated. From this, short-term and long-term price elasticities of the demand for pesticides are derived. In Chapter 6 the consequences of a regulatory levy are analysed, using LP models adapted for this purpose. Ample attention is given to pesticide use, new cultivation methods and crop rotation.

A regulatory levy yields funds. Chapter 7 deals with the principle of such a levy and with the restitution of the money paid (less the administrative costs). Some restitution options are mutually compared. In Chapter 8 the results obtained from the study and the literature are listed, compared and interpreted, leading to conclusions about the possible consequences of a regulatory levy for pesticide use and incomes in arable farming and horticulture. Furthermore, a comparison is made with the economic analysis of the LCPP study, and the usefulness of regulatory levies and the need to have tools to meet the goals formulated for the years 1995 and 2000 are questioned.

Finally, Chapter 9 returns to the information and problems sketched in Chapter 2. First, attention is paid to the policy on compounds: this policy incentive was dealt with briefly in Chapter 2, but its consequences were not considered in the other chapters. The possible effects of the proposed policy on compounds are discussed. In conjunction, we investigated the extent to which optimal cropping plans, as determined in Chapter 6, make use of compounds that will probably be phased out of production between now and the year 2000. The chapter ends with a synthesis of volume policy and the proposed policy on compounds.

The terms of reference of this study

In addition to their economic and technological aspects, regulatory levies also have legal, organizational and financial consequences. The following questions can be asked:
- How can a levy be incorporated in the law, and is it possible to aim for a regulatory levy that is specifically geared to the Netherlands?
- What aspect of pesticide use should be subject to the levy?
- How can restitution of the levy be arranged and could this possibly cause legal problems with the EC?
- Which organization can be put in charge of the levying and restitution? Is adequate control possible and what will be the costs of levying, restitution and control?
- What are the effects of a regulatory levy (including restitution) on the government's share of national income?

These matters are not discussed here, but are dealt with in a report commissioned by the Ministry of Housing, Regional Development and the Environment (MVROM), and the Ministry of Agriculture, Nature Management and Fisheries (MLNV) (DHV and LUW, 1991). In our study the emphasis is on an analysis of the pesticide issue, the effects of a regulatory levy on the use of pesticides and on incomes in agriculture and horticulture, and the consequences of levies and certain other measures designed to combat the problems observed.

Our study is directed at the use of chemical pest control (pesticides) in agriculture and horticulture in the Netherlands. Chemical crop treatments that do not fit into this category are ignored, as is pesticide use in sectors other than arable farming and horticulture. A chemical pesticide is defined as: the active chemical substance intended to prevent or combat diseases and/or infestations. In addition to active components (denoted here as 'active ingredients' or 'a.i.') a pesticide also contains carrier agents, which are considered to be not harmful to the environment.

2. PESTICIDE USE: EXTENT AND PROBLEMS

2.1 Introduction

This chapter examines in detail the composition of the package of pesticides and, in particular, the extent to which they are used in the Netherlands. A comparison with other countries shows the special position of the Netherlands in quantity and composition of pesticide usage. Attention is paid to trends in pesticide use over the past 20 years. Current use in the Netherlands is defined as the average amount used per annum during the years 1984-1988, although more recent data are available. Besides quantities, prices of different categories of pesticides are shown (Section 2.2).

More detailed information about the arable sector is included in Section 2.3. Analysis of prices, quantities and trends at crop level forms a part of this. Various sources indicate different trends in pesticide usage. Section 2.4 describes the problems related to the current use of pesticides. Agricultural and environmental problems have forced the Dutch government to step in to regulate crop protection. Over the years the government has developed several legislative and policy instruments for controlling pesticide use.

Section 2.5 illustrates the government's strategy for the 1990s. The government has set itself and the agricultural sector the task of cutting pesticide use back to an environmentally acceptable level. Existing means of achieving this are being applied in new ways, or are being extended. The government is merely creating the appropriate conditions so that farmers can bring about the reduction (MJP-G, 1991). Therefore, Section 2.6 focuses on the progress the Agricultural Board has made so far. The chapter ends with some conclusions (Section 2.7).

2.2 Volume and structure of the use of pesticides

According to the LCPP (MJP-G, 1991, p. 29), more than 600 crops are grown commercially in the Netherlands and these are threatened by 5000-6000 diseases and pests, comprising viroids, viruses, bacteria, fungi, weeds, nematodes, insects, acari (mites), snails and a number of higher order animals.

The large number of specific crop-disease/pest combinations suggests that an extensive package of pesticides is required. But this is not so because, firstly, only the pests and diseases that cause economic damage have to be controlled and, secondly, broad spectrum pesticides that work on more crops and are effective against many organisms are used.

The Netherlands compared with other countries

As Tables 2.1 and 2.2 show, the Netherlands is a relatively large user of pesticides by comparison with other countries. Table 2.1 gives information on a global scale, if only roughly, because measured in tonnes of pesticides. There were no FAO statistics for the Netherlands; therefore the data used here are from the database (Vijftigschild, 1991; see page 10 and 11 for a short description). Because of the large amounts of nematicides used in the Netherlands, total pesticides is much larger than the sum of the first three columns. Note that Table 2.1 is in total volume of pesticides and not in active ingredients.

Table 2.2 compares the Netherlands with some of its neighbours, and the US and Japan. From this table the special position of the Netherlands with regard to nematicide use, due to soil disinfection particularly in the potato-growing sector, is evident.

Table 2.1 Annual use of three categories (and total use) of pesticide in kg per hectare of arable and horticultural land, in 10 countries

Country	Fungicides	Insecticides	Herbicides	Total pesticides
Brazil	0.2	0.2	0.3	0.7
Denmark	0.2	0.1	1.3	1.5
Ecuador	0.1	0.2	0.7	1.0
Hungary	1.7	0.7	3.8	6.1
India	0.0	0.1	0.0	0.1
Italy[1]	4.9	0.6	2.3	7.8
Netherlands	6.3	1.3	5.6	42.3
Pakistan	0.0	0.1	0.0	0.1
Poland	0.1	0.0	0.6	0.6
Yugoslavia	1.0	1.1	1.6	3.6

Source: FAO (Production Yearbook Vol. 42), 1989; Vijftigschild, 1991
1) CBS (1991) gives much higher figures with a total use of 13.3 kg per hectare in 1986

Table 2.2 Annual use of five categories (and total use) of pesticide in kg active ingredient per hectare of arable and horticultural land, in 10 countries

Country	Nematicides	Herbicides	Insecticides/ Acaricides	Fungicides	Others	Total
Netherlands	9.6	4.5	0.6	4.7	1.4	20.8
Belgium	1.3	6.8	0.6	3.0	0.5	12.2
Germany	<0.1	2.3	0.2	1.2	<0.1	3.8
France	0.2	2.2	0.4	2.9	0.3	6.0
Denmark	-	1.5	0.1	0.7	0.2[1]	2.6
UK[2]	-	4.0	0.2	0.7	0.8[1]	5.8
Ireland[3]	0.4[4]	2.3	0.2	1.1	0.3	4.3
Sweden[5]	0	0.9	0.0	0.3	0.1	1.3
U.S.A.	-	1.2	0.3	0.2	0.5	2.4
Japan	-	4.1	9.5	3.9	-	17.5

Source: MJP-G (1991, p.36); Vulpen, 1991; CBS (1991) Milieufacetten, p. 64
1) Including nematicides
2) Excl. Northern Ireland; data from 1982
3) Data on pesticides for 1990 (Feeley, 1991); see Boer & Van Keulen, 1992
4) Disinfectants
5) See Tables 4.1 and 4.3; period 1988-1990

There are four main reasons for the relatively large-scale use of pesticides in the Netherlands:

1. Dutch arable farming and horticulture concentrates on crops usually grown intensively in narrow rotation. This way of growing is likely to encourage soil-borne diseases, which are suppressed by using appropriate chemicals.
2. Crop yields are relatively high (in kilograms) in the Netherlands. High yields mean that crop damage results in large losses.
3. Both the position of the Netherlands as an exporting country and the international phytosanitary regulations that have to be met contribute to the large-scale use of pesticides, especially in floriculture, seed potatoes and other propagation material.
4. Climate and weather contribute to the extent of pesticide use in total and per category. The maritime climate of the Netherlands generally favours the development and growth of fungi and bacterial diseases and weeds, but is less favourable for insects.

Table 2.3 Annual pesticide use per crop in kg of active ingredient per hectare in 6 countries

Crop	Nether-lands[1]	West Germany[2]	France[2]	Italy[2]	UK[2]	Denmark[3]
Cereals	2.5	-	2.2	0.8	3.4	3.6
Sunflower	-	-	2.7	1.5	-	-
Rapeseed	1.9	-	-	0.4	4.4	2.7
Pulses	5.7	-	-	1.2	2.7	4.8
(Fodder) maize	1.9	1.6	2.8	2.2	-	1.3
Sugarbeet	4.8	4.1	4.8	5.3	3.5	3.7
Potatoes	12.5[4]	6.8	-	5.1	5.8	5.7
Field horticulture	29.1	-	-	12.2	5.7[5]	7.5
Grapes	-	-	54.9	42.2	-	-
Citrus fruit	-	-	-	14.9	-	-
Fruit trees	20.7	-	-	-	-	-
Vegetables under glass	105.0	-	-	-	81.9[6]	-

1) Vijftigschild, 1991 and LEI/CBS, Landbouwcijfers, Table 41a
2) Agrofarma, 1990
3) Dubgaard, 1987, p. 70
4) Excluding nematicides; including nematicides: 72.4
5) England and Wales; MAFF Survey Report 64
6) England and Wales; MAFF Survey Report 62

The importance of the type of farming and the type of product is illustrated clearly by Table 2.3. Differences between types of crops are much larger than between the same crop in different countries. Therefore, the share of a particular type of crop (horticulture, grapes, potatoes, etc.) in the total area influences average use of pesticides considerably. And the greater the share of cereals in the total area, the more the average pesticide use at country level is depressed. The exceptional position of potatoes in the Netherlands is quite clear if all soil disinfectants are imputed to potato farming.

Classification and purpose of pesticides

Many categories of pesticide can be distinguished, depending on the aim of the classification. Below and in the rest of this publication we have used a classification according to the LCPP. Pesticides may also be classified according to active ingredients or intended use: disease and weed control, haulm killing, soil disinfection, control of algae, growth regulation, and application in livestock farming, stock protection, disinfection of seeds, etc. Such classifications are based on agricultural purposes. Another classification is according to agreed use: crop treatment, soil treatment, row treatment, treatment of seed material, aerial spraying, dipping, etc. Moreover, one might use a biological classification: bactericides and fungicides, insecticides and acaricides, and herbicides. Within this classification a further chemical subdivision is possible (dithiocarbamates, dicarboximides, phosphate compounds, triazines, urea compounds, etc.) (CAD-G and PD, 1987; NEFYTO, 1989). The LCPP opts for a mixture of classifications; a distinction is made between soil disinfectants, soil treatments, herbicides, insecticides, fungicides and others.

Soil disinfectants are used to treat the soil in order to kill damaging organisms, or to reduce existing populations considerably, especially nematodes but also weeds. Nematodes are a particular threat to subterranean parts of plants and cause yield losses and degradation of crop quality. The use of soil disinfectants (in kilograms of active ingredient) is especially high in arable farming and bulb growing. Well-known chemicals used in these sectors are: dichloro propene, metham-sodium and ethoprofos. Other sectors where soil disinfectants are commonly used are field vegetable production and nursery stock industry.

The category of soil treatment chemicals is varied and consists of nematicides, soil insecticides and soil fungicides. The latter are more specifically applicable than soil disinfectants. A major user is the flower bulb industry. In arable farming, soil treatment compounds are especially used in seed potato growing; relatively large amounts are used in the nursery stock industry and floriculture.

Herbicides are used to control weeds because weeds depress yields by competing with crops for light, water and nutrients. Furthermore, they can cause problems with harvesting and quality. Herbicides are used especially in grassland management and arable farming. The chemicals mecoprop, MCPA and glyphosphate are used in large quantities in pasture management, whereas compounds containing atrazin are mainly used for weed control in maize. Herbicides are also intensively used in the production of sugarbeets and flower bulbs.

Insects can damage crops directly (biting damage, etc.) and also indirectly, by transmitting viruses. Acarides are mostly included in the category of insecticides; they are used against mites. Mineral oil is an important insecticide in flower bulb growing. (However, mineral oil is also a wetting agent for herbicide applications). Relatively large amounts of insecticide are also used in fruit growing, the nursery stock industry and livestock farming.

Fungicides are used to control fungal diseases which can depress yield and quality. The potato growing sector is a major user of fungicides. The chemicals mostly used here are maneb/fentin-acetate and maneb. The latter is also used in large amounts in onion growing. Other sectors where fungicides are used both absolutely and on a relatively large scale are the fruit growing and floriculture sectors.

Price movements

Many factors influence the use of pesticides (see Chapter 3), the price being one of them. The importance of price varies per subsector of agriculture. We will come back to this later. Figure 2.1 shows a number of price indices that are important in trends of pesticide use. (For details see Appendix I, Table 1).

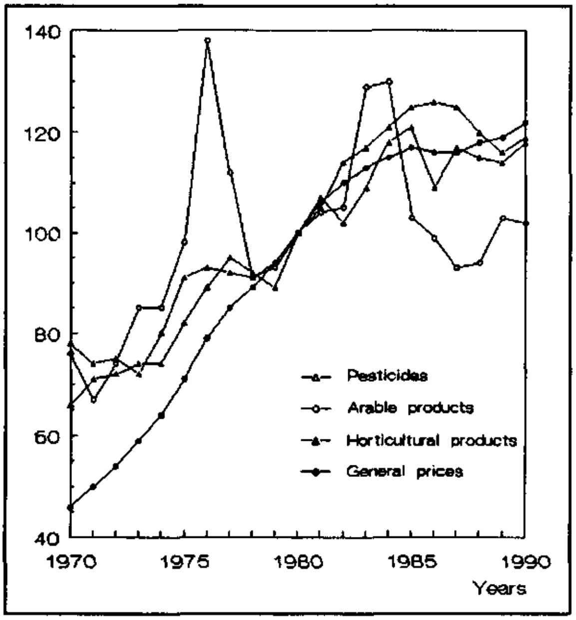

Fig.2.1 Price indices of pesticides, arable products, horticultural products and general prices in the Netherlands

Between 1970 and 1980, the real prices of pesticides (= price of pesticides divided by the general price level) fell, while in the period 1980 - 1990 the prices of pesticides ended up at the same level as general prices. The price relation between pesticides and horticultural products has not changed significantly. The prices of arable products, however, increased less than those of pesticides, especially in the second half of the 1980s.

Use of pesticides on the basis of different data and for different categories of pesticides

We will now describe the extent of pesticide use expressed in kilograms of active ingredient and in guilders. It is generally assumed that pesticide use in the Netherlands has increased over the years, but because of a lack of sales figures the extent of the increase is not known. Pesticide use used to be considered to be a solution rather than a problem. Although in the 1960s the drawbacks of pesticide use became clear this did not lead to registration of amounts sold and/or registration of use. The registration of compounds was considered sufficient. Reus (1990) has summarized the sales statistics that were available over the period 1974-1988. Table 2.4 shows the trends in pesticide sales.

Table 2.4 roughly sketches trends in pesticide use. But it is impossible to say whether pesticide use peaked in the period between 1974/1976 and 1984/1990. What the figures of Table 2.4 do show is that pesticide use remained more or less constant in the periods 1974-1976 and 1984-1986 and has since declined because of decreased soil disinfection.

Table 2.4 Sales of pesticides in Dutch agriculture in 1000 kg of active ingredient; period 1974-1991

Year	Soil dis-infectants	Herbi-cides[1]	Insec-ticides[2]	Fungi-cides	Others	Total sales	Estimated use
1974[3]	8 914	5 208	490	2 936	54	17 600[3]	21 600
1975[3]	9 732	4 804	455	2 235	29	17 400[3]	21 400
1976[3]	11 330	4 509	554	2 235	32	18 700[3]	22 900
1984[4]	10 923	4 075	653	3 958	56	19 700[4]	21 000
1985[4]	10 784	4 090	634	4 363	68	19 900[4]	21 300
1986[4]	12 535	3 894	561	3 575	69	20 600[4]	22 100
1987[4]	8 423	4 026	498	4 070	76	17 100[4]	18 300
1988[4]	8 578	3 760	575	4 147	74	17 100[4]	18 300
1989[5]	9 830	3 330	746	4 052	1 189	19 146	-
1990[5]	8 937	3 468	731	4 140	1 559	18 835	-
1991[5]	7 679	3 312	594	4 281	1 440	17 206	-

1) Including growth regulators (e.g. haulm killers).
2) Including acaricides.
3) Source: Curatorium Landbouwemissie (1980), MVROM (1986); figures relate to part of authorized substances. Actual (real) total use is assumed to be 20 to 25% higher.
4) Source: CBS (1989, 1990), NEFYTO (1989); figures relate to chemicals (compounds) sold by NEFYTO affiliated organizations. Actual total use is assumed to be 7% higher.
5) NEFYTO (1991, 1992); discontinuity for the category 'others' mainly because of including mineral oil.

A database on the use of pesticides in Dutch agriculture and arable farming has been set up (Vijftigschild, 1991) using the data from the LCPP. Data for this database were also obtained from: Crop Protection Guide ('Gewasbeschermingsgids') (CAD-G and PD, 1987), Report 'Pesticides and surface water quality' ('Bestrijdingsmiddelen en oppervlaktewater kwaliteit') (Berends, 1988), Manual 1987 (Handleiding 1987) (CAD-G, 1986) as well as from inside information. Starting points were the list of compounds authorized in January 1987 and the amounts of active ingredient derived from the sources mentioned above. Wholesalers provided data on prices. This database enables the chemical composition of each kilogram of pesticide to be traced (see Appendix II for an explanation of this database). This procedure yields a slightly lower estimate of active ingredient than the figures for pesticides given in the LCPP. The database gives estimated amounts of formulated product, active ingredient and their value in 1987 prices. The 40 324 tons of pesticide formulated cost 634 million guilders. From the database the total amount of active ingredient was calculated to be 20 258 tons (50% of the formulated amount). Table 2.5 reflects how pesticide use (in kilograms and in guilders) is divided over the ten sectors distinguished in the LCPP.

Table 2.5 Amounts of pesticides used in the Netherlands per sector per year 1984-1988 in kg of active ingredient and in 1987 prices (excluding VAT)

Sector	Use		Value		Average price per kg a.i.
	10^3 kg	%	mln gld	%	
Arable farming (incl. fodder maize)	13 979	69.0	358	56.4	25.60
Field vegetables	1 192	5.9	44	6.9	36.90
Flowers from bulbs and bulb growing	2 138	10.6	55	8.7	22.00
Nursery stock industry	510	2.5	19	2.9	37.30
Fruits	466	2.3	21	3.2	45.10
Pasture	721	3.6	62[1)]	9.8	86.00
Public parks and gardens	117	0.6	32	5.0	273.50
Floriculture	557[1)]	2.7	28	4.5	50.30
Vegetables (under glass)	525	2.6	14	2.3	26.70
Mushrooms	53	0.3	2	0.3	37.70
Total	20 256	100	634	100	31.30

Source: Vijftigschild (1991)
1) The data set is incomplete

Arable farming is a front runner in the total use of pesticides, both in kilograms and in guilders. The figures show relatively large differences between sectors in the average price per kilogram of active ingredient. The bulb growing and flowers from bulbs, arable farming and greenhouse vegetable growing sectors stand out for the low average price paid for pesticides. Other sectors such as the floriculture, livestock farming, and especially public parks and gardens show high average prices. The last two sectors are also notable for their small share in active ingredient in the formulated product (35 and 6% respectively while 50% is normal).

Table 2.6 gives estimates per category of pesticide, which show large price differences between different groups of pesticides. Soil disinfectants and (to a lesser extent) fungicides appear to be relatively cheap, whereas weed killers, insecticides and soil treatment chemicals are relatively expensive. Further it can be observed that the category 'other chemicals' is not very homogenous. The price of pesticides excluding soil disinfectants has been worked out as 77 guilders per kg active ingredient.[1]

Table 2.6 Amount of pesticides used annually in the Netherlands, per category; 1984-1988; amounts in kg of active ingredient; in 1987 prices (excluding VAT)

Pesticide	Use		Value		Average price
	10^3 kg	%	mln gld	%	(gld/kg a.i.)
Soil disinfectants	12 866	63.5	65	10.3	5.10
Soil treatment	559	2.8	75	11.9	135.00
Herbicides	2 604	12.9	253	39.8	97.00
Fungicides and bactericides	2 864	14.1	114	18.0	39.70
Insecticides and acaricides	656	3.2	70	11.0	106.80
Other chemicals[1)]	710	3.5	57	9.0	80.60
Total	20 258	100	634	100	31.30
Total (excluding soil disinfectants)	7 392	36.5	569	89.7	77.00

Source: Vijftigschild, 1991
1) Including growth regulators (e.g. haulm killers)

Share of pesticides in total revenue

The costs of pesticides, measured as a share of total revenue, are an indicator of the degree changes in pesticide price influence profits. Table 2.7 shows the relation between the costs of pesticides and total revenue for a number of sectors distinguished by the Landbouw-Economisch Instituut. The larger the percentage, the more an increase in pesticide price will affect use (just like a fall in the price of agricultural products).

From Table 2.7 it follows that arable farming is most sensitive to a change in pesticide price. Comparing the agricultural regions, it can be seen that expenditure on pesticide is highest in the Peat Colonies (a peat soil area in the north-east of the Netherlands; Peat

[1] Here one might observe a difference with the DHV-LUW report (DHV-LUW, 1991, p. 124) and also with the price used by CBS (1989). The correction compared with the DHV-LUW report is due to a more complete set of prices in the database (Vijftigschild, 1991).

Colonies is a literal translation of 'Veenkoloniën'). Obviously the differences are determined more by the region (or rather the type of products grown) than by the size of the farm. As regards the use of pesticides per guilder of crop revenue, the field vegetable sector lies in between arable farming and greenhouse horticulture. In closed cultivations (such as vegetable growing under glass, growing of potplants and floriculture) the costs of pesticides form only a small share of total revenue.

In a similar analysis, Stolwijk (1991), departed from the value added per kg of active ingredient. In his analysis it also appeared that arable farming and, to a lesser extent, flower bulb growing are affected most by changes in the price of pesticides or by restrictions on the use of pesticides.

Table 2.7 Relation of costs of pesticides to total revenue (in guilders); different sectors (for arable farming: subdivided into regions); average 1984-1988

Arable farming		Horticulture	
Farm size and region	Share (%)	Sector	Share (%)
Larger farms (> 158 SFUs)[1]		Fruit	5.8
Northern clay area	8.7	Flower bulbs	3.9
Peat Colonies and northern sand area	11.8	Field vegetables	2.5
Central clay area	8.3	Floriculture	1.6
South-west clay area	9.0	Nursery stock industry	1.5
Smaller farms (> 79 and < 158 SFUs)		Vegetables (under glass)	1.3
Clay area	8.3	Potplants	0.7
Peat Colonies and northern sand area	11.9		

Source: LEI (several years), Bedrijfsuitkomsten in de Landbouw; LEI (several years) Rentabiliteit en Financiering (horticulture).
1) SFU is a measure for standardized net value added of a farm

2.3 Trends in pesticide use in arable farming

Since 70% of the total amount of active ingredient of all the pesticides used in the Netherlands is used in arable farming, it seemed justified to study this sector separately. Recent research by Oskam (1992) gives some insight in pesticide use in Dutch arable farming over the years. That study (covering the period 1970-1987) was done using data acquired from a stratified sample survey. A distinction was made between specialized arable farming, where more than 80% of the area under cultivation is reserved for arable crops (including feed crops), and farms where 50-80% of the land is reserved for crop production. The remaining 20-50% is pasture. Oskam assumed the entire pesticide use was applied to the area of arable farming.

In general, specialized arable farms use more pesticides per hectare. The average use is equivalent to 316 guilders per hectare, the standard deviation being 173 guilders per hectare. For less specialized farms the average use and standard deviation are 216 and 158 guilders per hectare, respectively. This difference partly relates to the cropping plan, because more cereals (excluding wheat), other marketable crops and feed crops, and less potatoes, sugar beets and onions are grown on less specialized farms. In the study all figures mentioned relate to 1980 prices.

Oskam (1992) investigated the upward trend in pesticide use per hectare in two different ways: to what extent the difference in pesticide use can be explained by the farm's cropping plan (detailed analysis); and to what extent pesticides use per farm per hectare can be explained by the annual level of pesticide use and by factors such as cropping plan and location of farm (aggregated analysis).

From the detailed analysis estimates were obtained for the use of pesticides per hectare for two types of farms. Table 2.8 shows the estimated annual increase or decrease in the use of pesticides per hectare for each group of crops. The category 'other crops' was excluded from the analysis. A trend of 11 for wheat means that the annual increase in pesticide use was calculated to be eleven guilders per hectare, based on 1980 price levels. This number reflects the development in pesticide use, in constant prices. The estimated standard deviation of 4 indicates the reliability of the estimated trend.

Table 2.8 Annual increase or decrease in pesticide use in guilders per hectare, measured for two types of arable farms in the Netherlands during 1970-1987; analysis per crop; pesticides at 1980 prices

	Specialized farms (80% area arable)			Mixed farms (50-80% area arable)		
Crop	Trend	Standard deviation	Share area (%)	Trend	Standard deviation	Share area (%)
Wheat	11	4	13.9	5	12	6.9
Other cereals	-2	3	14.7	9	8	18.7
Seed potatoes	34	10	6.4	29	10	3.1
Ware potatoes	19	12	7.0	33	17	3.8
Starch potatoes	21	9	9.5	10	6	4.0
Sugar beet	23	6	16.5	25	8	9.8
Onions	50	22	1.8	-2	28	0.9
Pulse crops	14	8	4.0	21	23	3.2
Trade crops[1)]	14	9	1.8	22	33	1.3
Other marketable crops	3	5	11.9	-8	9	18.2
Average trend	12			9		

Source: Oskam (1992)

1) Rapeseed, linseed, other oil seeds (incl. caraway), flax

It can be noted from Table 2.8 that nearly all crops show an upward trend in pesticide use. Many of these estimated trends (as far as the group of specialized farms is concerned) also differ statistically significantly from zero. According to this approach, based on the assumption that use is crop-related, the average annual increase for both specialized and mixed arable farms is 12 and 9 guilders per hectare, respectively.

The aggregate analysis yielded estimates about the annual increase in total pesticide use. Table 2.9 shows an increase in annual use by 14 guilders per hectare for specialized arable farms (this equals nearly 4% of average use per year for the period 1970-1987). For mixed arable farms pesticide use increases by 10 guilders, which is also nearly 4%.

Table 2.9 Annual increase in pesticide use in arable farming in the Netherlands, in guilders per hectare, derived from the aggregate analysis during 1970-1987; pesticides at 1980 prices

Farms	Trend	Estimated standard deviation
All	13.5	1.1
Specialized (80% area arable)	14.0	1.1
Mixed (50-80% area arable)	9.9	1.0

Source: Oskam (1992)

The data obtained from Table 2.9 support the conclusion drawn from Table 2.8 that for the farms investigated the costs (in constant prices) of pesticides per hectare are increasing considerably each year. A more detailed analysis investigating the upward trend per type of crop found that pesticide use was slightly less than in the aggregated analysis (Table 2.9). This difference might be caused by increased use of crop-independent pesticides, which was disregarded in the detailed analysis. It might also result from leaving out 'other feed crops'.

Note that there is a difference between measuring expenditure on pesticides in constant prices and measuring in kilograms of active ingredient. If farmers are going to use more pesticides containing a restricted quantity of relatively expensive active ingredient, then an increase in the total amount of pesticides used, in constant prices, need not necessarily mean that there is a proportional increase in the use of active ingredient. Given the large increase in pesticide use, an increase in use of active ingredient (in kilograms) is likely. This outcome does not correspond with the findings in Table 2.4.

Poppe (1989) also studied the use of pesticides in arable farming in the Netherlands. Table 2.10 gives an outline of the costs of pesticide use per hectare of arable land for the period 1980/1981-1989/1990.

In Table 2.10 the increase in the volume of pesticides used has been calculated to be 1.7% per year, although it seems to have been somewhat less in recent years. The large fluctuations in pesticide use make it difficult to draw conclusions on the basis of short periods of time.

Table 2.10 Trends in costs of pesticides per hectare of arable land in the Netherlands; 1980/81 - 1989/90

Year	Costs in guilders per hectare			Change in % per year		
	Total	Herbicides	Others	Price	Quantity	Expenditure
1980/81	383	170	213	2.0	6.9	9.0
1981/82	423	193	230	5.0	4.8	10.4
1982/83	441	215	226	5.0	-1.0	4.3
1983/84	509	229	280	7.0	1.9	15.4
1984/85	557	221	336	7.0	1.9	9.4
1985/86	611	226	385	-3.0	13.4	9.7
1986/87	557	212	345	3.0	-11.0	-8.8
1987/88	589	212	377	0.7	5.0	5.7
1988/89	538	188	350	-5.2	-3.7	-8.7
1989/90	541	185	356	-0.5	1.1	0.6

Source: Poppe (1991, p. 28)

Share of pesticides per arable crop

With the help of the Vijftigschild (1991) database a table similar to Table 2.7 was drawn up for the Dutch arable sector. The costs of pesticide use were related to the production value on the basis of the average production value for the period 1985-1989. Since the application of soil disinfectants depends on the whole cropping plan rather than on any individual crop, we left out the costs for soil disinfection (more than 46 million guilders).

Table 2.11 shows the results of the calculations. It appears that a rise in pesticide price (excluding soil disinfection) is felt severely in the production of onions, ware potatoes and sugar beet, and most severely in the production of pulse crops. Analogously it holds that a price reduction of those products will affect pesticide use more than a price reduction of products with a low share of pesticide use.

When soil disinfectants are excluded, the amount of pesticides used for starch and (to a lesser degree) seed potatoes is relatively small. This interpretation of the data follows the LCPP (Vijftigschild, 1991).

Table 2.11 Application of pesticides[1] for different arable crops in the Netherlands and the relation between costs of pesticides and product value

Crops	Pesticides[1]				Product value[2] (mln guilders)	Pesticides in % product value
	Amount		Costs			
	1000 kg a.i.	%	mln guilders	%		
Cereals	463	10.9	38.2	12.3	590	5.4
Ware potatoes[3]	1 279	30.2	75.4	24.2	587	12.8
Seed potatoes	364	8.6	19.2	6.1	332	5.8
Starch potatoes	459	10.9	15.7	5.0	297	5.3
Sugar beet	591	14.0	75.4	24.2	803	9.4
Onions	307	7.2	17.6	5.7	124	14.2
Pulse crops	229	5.4	21.3	6.8	111	19.2
Trade crops[4]	23	0.5	3.9	1.3	44	8.9
Fodder maize	368	8.7	24.9	6.0	687[5]	3.6
Other crops[6]	149	3.5	19.0	6.1	353	5.4
Total	4 232	100	311	100	3 927	7.9

Source: Vijftigschild (1991)
1) Excluding nematicides
2) CBS, Maandstatistiek van de Landbouw, 1989, 1991; average value of total production over the period 1985-1989
3) Including feed potatoes
4) Rapeseed, linseed and other (incl. caraway) oil seeds, flax
5) Quantities from Oskam (1991). An average price of 300 guilders per ton dry matter has been used
6) Grass seed

2.4 Problems with current use

In addition to the aspects mentioned in Section 2.2, there is the fact that pesticide use causes problems. The LCPP distinguishes between agricultural, natural, environmental, and health and labour-related problems (MJP-G, 1991, Ch.3).

The most important agricultural problems concern phytotoxicity, resistance, adaptation, the development of secondary pests and changes in quality.

- Phytotoxicity is manifested as damaged crops. Damage may remain limited to a reduction in yield or quality, but can be more serious, for instance when mistakes are made in the application of pesticides. Damage to crop plants is especially likely to occur when using herbicides to control weeds.
- Resistance occurs when a particular pesticide is used repeatedly. A pathogene or weed population's less sensitive individuals become competitively more advantageous. Continuous selective breeding may lead to sensitive populations being replaced by

insensitive (resistant) ones. Often such populations have become resistant to other pesticides as well.
- Adaptation may occur when using soil disinfectants and soil treatments. Certain micro-organisms live on substances from these compounds and quickly multiply when these chemicals are applied. After some years of soil disinfection and other soil treatment the chemicals used are decomposed before they can become active.
- Using broad spectrum pesticides can allow other, previously harmless organisms to develop into secondary diseases or pests, because their natural enemies have been destroyed.
- The presence of residues on products is in itself an undesirable quality aspect. Moreover, the desirability of production processes relying heavily on pesticide use is being called into question. The amount of residue present and the way of producing will therefore become important issues in the future.

Before dealing with the effects of pesticides on nature and environment we shall first consider how pesticides can end up outside field boundaries (MJP-G, 1991, Appendix 5). Here, we assume that the water table forms the lower boundary of the field. Pesticide emission can be subdivided into emission into groundwater, surface water, air and adjacent soil. The order of volume of emission routes for outdoor farming is very similar to that for cultivation under glass. The most important routes are evaporation (vaporization in greenhouses) and leaching. Emission into the air by evaporation strongly depends on the formulation (i.e. composition) of the pesticide. As well as active ingredient, pesticides contain carriers and additives. Emission via evaporation is particularly likely if the active substance is or becomes gaseous and proper precautions are not taken.

Leaching of pesticides may cause pollution of ground and surface water. The extent of leaching largely depends on the adsorption of a pesticide to soil compounds and on the rate of decomposition. Important factors in this process are the characteristics of the pesticide and of the soil and the way the pesticide is applied.

There is insufficient knowledge about the damaging effects of pesticides on flora and fauna in the Netherlands. It is difficult to interpret the available knowledge because there are many other agents affecting flora and fauna (Hekstra and Van Linden, 1991). However, the LCPP does give some indications about effects on the basis of field and laboratory research done both in the Netherlands and elsewhere (MJP-G, 1991, Appendix 6). The reported effects of pesticides are summarized below.

- Insect life on or near plots where pesticides are used is strongly affected.
- Diminishing butterfly and partridge populations can, in part, be directly attributed to the use of pesticides.
- Occasionally, pesticide use causes the death of fish, bees and birds by poisoning.
- Surface water in areas of greenhouse cultivation often contains such high concentrations of pesticides that aquatic communities are seriously threatened.
- Locally polluted surface water in farming areas occasionally damages aquatic organisms.

Public health can be affected by pesticides in:
- food
- drinking water
- air.

It is the toxic substances in pesticides that are the hazard here. An important parameter for toxicity is the so-called acceptable daily intake (ADI). This ADI is the maximum acceptable amount of pesticide that a human being can ingest per kilogram of body weight during their lifetime without damaging their health. This norm is based on toxicological tests. As yet, the ADI norm has been set for food only and has not yet been established for all pesticides (see e.g. Hegeman and Vos, 1989). There have been no reports of the ADI norm being exceeded in the Netherlands yet. Residue tolerances are fixed on the basis of maximum residues from authorized pesticide use in agriculture.

A recent overview of the maximum concentrations of pesticides in shallow and deep *groundwater* show that the European Guidelines for *drinking* water are exceeded (RIVM, 1991, pp. 319, 320). On several occasions in recent years it has become clear that the drinking water supply in the Netherlands is threatened by different types of pesticides (Van der Vaart, 1987, pp. 106, 107; RIVM, 1991, pp. 325-328).

There are virtually no data available about possible effects of pesticides in the air (MJP-G, 1991; RIVM, 1991).

Relative overrepresentation of toxicosis from pesticides in people working in the agricultural sector indicates that these people run greater risks of damaging their health by pesticide use than consumers and people living near areas where pesticides are used (MJP-G, 1991, p. 59).

2.5 Government policy

In this section we deal with the increasing involvement of the Dutch government in crop protection, excluding activities at local and provincial level. International aspects of crop protection, though important, are only briefly discussed. The government has regulating, financial and stimulating instruments at its disposal to implement crop protection policies.

Instruments

Regulating instruments are enforced by laws. They particularly concern phytosanitary measures and measures to do with registration of pesticides and prescribing their use. Phytosanitary measures serve to avoid the outbreak (and spread) of diseases and infestations. In this respect the following Acts are relevant: Plant Disease Act ('Plantenziektenwet'), Seed and Planting Stock Act ('Zaaizaad- en Plantgoedwet') and the Agricultural Quality Act ('Landbouwkwaliteitswet') (MLV, 1983). The 1962 Pesticides Act ('Bestrijdingsmiddelenwet') is important for the second group of measures. We shall return to this later.

Other relevant acts are: Pollution of Surface Waters Act ('Wet Verontreiniging Oppervlaktewateren'), Provincial Groundwater Protection Regulation ('Provinciale verordeningen grondwaterbescherming'), Nuisance Act ('Hinderwet') Chemical Waste Act ('Wet chemische afvalstoffen'), Environment-threatening Substances Act ('Wet milieugevaarlijke stoffen') and the Soil Protection Act ('Wet bodembescherming').

The Pesticides Act of 1962 (revised in 1975) remains central in Dutch crop protection policy. This Act regulates the approval of pesticides, their use and their sale. The sale, transport, storage and use of a pesticide are prohibited unless explicitly admitted. The most important criteria for a pesticide being authorized are:
- it must be suitable for the purpose;
- it must not have unacceptable damaging side-effects on the environment, public health, etc.

Since all pesticides have side-effects of some sort, beneficial and damaging side-effects will have to be assessed. This is done by the Commission for the Authorization of Pesticides (Commissie Toelating Bestrijdingsmiddelen CTB). Authorization of a pesticide will be granted for a maximum of ten years (often less) and is subject to regulations about the area of application, time of application, dosage, application methods and equipment (MLV, 1983). The CTB consists of representatives from the Ministry of Agriculture, Nature Conservation and Fisheries, the Ministry of Housing, Regional Development and the Environment, the Ministry of Welfare, Health and Cultural Affairs, and the Ministry of Social Affairs and Employment. Recently, the CTB has been reorganized, in response to criticism from the environmental movement and from industry. A major point of criticism, according to Hoeksema (1987), is the impossibility for environmental and consumer organizations to lodge an appeal against the authorization (or renewed authorization) of a pesticide. In "De toelating van bestrijdingsmiddelen" (Authorization of pesticides), Vogelezang-Stoute and Matser (1990) make a number of recommendations. Among others, they question the lack of openness in decision-making and the inaccessibility to records on authorized pesticides. Another point of criticism was that in the past, the CTB had ignored certain procedures. In addition, no data were available on the damaging side-effects of some pesticides. Industry's major complaint is the long time taken for new types of pesticide to be admitted to the market. Moreover, uncertainty about extending the authorization of old types of pesticides was said to be resulting in these chemicals being hoarded (Hoppenbrouwer, 1991).

The financial instruments for controlling pesticide use include financial levies, regulatory levies, financial support, deposit money, creation of markets and preservation incentives (Hegeman and Vos, 1989). So far these instruments have played a minor role in Dutch crop protection policy. However, a financial levy for pesticides is currently being prepared. A regulatory levy, which has been mentioned in the LCPP (MJP-G, 1991, p. 109, 130) forms the central part of our analysis. Pesticide use can be stimulated by research, extension and education. These and other measures, such as covenants (e.g. an agreement between the government and the Agricultural Board), jointly make up crop protection policy (MLV, 1983).

The crop protection policy

Recent Dutch crop protection policy is largely the product of September 1983 Policy Document "Crop Protection in the Netherlands" (MLV, 1983), which takes stock of bottlenecks and possibilities, and proposes some policy incentives. The starting point was that only effective chemicals and methods that do not endanger man and nature would be authorized. Another constraint was that although pesticides use must be minimized, this must not be to the detriment of the international competitiveness of the Dutch agricultural sector.

Unfortunately, this Policy Document did not lead to reductions in pesticide use (see Sections 2.2 and 2.3). This is probably because it lacked clear, quantified objectives. Therefore, in 1987, the Policy Document "Towards a goal-oriented long-term plan for crop protection" was issued. By presenting objectives, methods, starting points and preconditions as well as conditions for phasing in certain tasks, this Policy Document provided the instruments for a goal-oriented policy. In 1990, this led to the issuing of the "Long-term plan for crop protection - policy incentive" (MJP-G, 1990). This policy incentive is related to the Plan on the Structure of Agriculture (MLNV, 1990) which stresses the need for structural changes in agriculture as well as the importance of formulating intended policies.

In brief, the strategy of the LCPP is:
- reduced dependence on chemical crop protection;
- reduction of the volume of pesticide use;
- reduction of emission of chemicals into the environment.

In addition, and as a result of the memorandum on environmental criteria (MVROM, 1989), it was proposed to ban many compounds. The principles underlying this ban were:
- groundwater intended for drinking water must meet EC norms before it has been purified;
- surface water (including ditches separating fields must comply with generally accepted environmental quality;
- compounds must not accumulate in the soil.

This so-called compound-oriented approach is only indirectly considered in this discussion of the LCPP because the harmonization of authorization policies in the European Community after 1992 is creating uncertainties in current policymaking in the Netherlands (MJP-G, 1991, p. 123).

Future targets

In the LCPP, the main issues mentioned above were translated into tasks and measures for achieving the goals set. (For example, measures to bring about reduction of pesticide use, and measures to reduce emissions). For technical background information see the LCPP Background Documents. Ten sectors were distinguished in the LCPP. These are listed in Table 2.12, which also gives an overview of the statistics on pesticide use. Table 2.13 gives information on targeted percentages of pesticide for the different sectors, whereas Table 2.14 sketches the pesticide use (in guilders and in kilograms) for 1995 and 2000 respectively, as targeted in the LCPP, expressed in 1987 prices.

Table 2.12 Statistics on pesticide use (in kg a.i.) for the different sectors in Dutch agriculture, as estimated in the LCPP

Sector	Area (ha)	Use of pesticides 10^3 kg/year	Annual use of pesticides kg/ha
Arable farming (incl. fodder maize)	751 000	14 200	19
Field vegetables	45 200	1 300	28
Flower bulbs	17 900	2 100	120
Nursery stock industry	6 600	500	76
Fruits	23 400	470	20
Pasture	1 150 000	720[1]	<1
Public parks and gardens	700 000	120	<1
Floriculture	6 500	630	96[1]
Vegetables (under glass)	400	470	106[1]
Mushrooms	90	10	112[1]
Total (excl. public parks and gardens)	2 005 000	20 400	10
Total (excl. public parks and gardens and pasture)	855 000	19 700	23

Source: MJP-G (1991)
1) Excluding disinfectants and cleaning material

As the LCPP puts it "a broad and cohesive package of instruments will be applied" to achieve a reduction in pesticide use. The need to apply stimulating policies and supporting measures which complement existing instruments is stressed.

The LCPP identifies the following important changes to be brought about. First, a change in the 1962 Pesticides Policy Document, to provide a legal basis for tightening authorization requirements, targeted use, levies, tariffs and registration of purchases and sales. Fundamental research and research for integrated farming systems have been stimulated by additional funds (8 million guilders per year). To bring about a mental and behavioral change, the extension work done by the National Reference Centre which acts as an intermediary between the government and farmers and growers will be extended. Its counselling, services and training and educational programmes will be expanded. Additional funds and manpower will be provided for this. Furthermore, investment directed towards reducing pesticide use will be stimulated by contributions from the O&S fund (a fund for restructuring and developing agriculture). Finally, a change from conventional to biological and ecological farming will be encouraged by way of experimental farms, education, enforcement of market structures, subsidizing of the extension service and the imposition of a quality mark as well as the introduction of the EC extensification regulation.

Table 2.13 Targeted percentages of pesticide reduction per group of pesticides per sector for 1995 and 2000 in the Netherlands; percentages relative to current use (1984-1988) in each sector

Sector	Soil disinfection		Soil treatment		Herbicides		Insecticides		Others		Total[1]		Total	
	1995	2000	1995	2000	1995	2000	1995	2000	1995	2000	1995	2000	1995	2000
Arable farming (incl. fodder maize)	46	70	40	50	30	45	15	25	42	68	25	39	39	60
Field vegetables	48	66	15	33	20	31	12	22	-	-	15	26	40	56
Flower bulbs	50	72	19	40	3	7	46	62	46	62	37	46	42	61
Flowers from bulbs	75	75	71	79	-	-	30	30	30	30	37	46	65	68
Nursery stock	30	37	30	49	15	33	10	30	-	-	15	34	29	42
Fruits	27	57	-	-	30	55	22	41	19	33	23	43	23	44
Pasture	-	-	-	-	23	25	10	10	-	-	-	-	23	25
Public parks and gardens	-	-	-	-	29	43	-	-	0	0	29	43	29	43
Vegetables (under glass)	62	76	10	10	20	50	20	45	35	50	26	45	50	65
Floriculture	60	75	33	48	20	30	48	67	30	40	44	62	47	64
Mushrooms	-	-	-	-	-	-	40	52	-	-	40	52	40	52
All sectors	45	68	28	42	28	40	25	39	25	39	26	40	37	56

Source: MJP-G (1991, p. 101) and own calculations

1) Excluding soil disinfection

Table 2.14 Projected trends in pesticide use in the Netherlands as targeted in the LCPP, expressed in 10^3 kg of active ingredient and in million guilders, per sector, in 1987 prices[1)]

Sector	Use (kg a.i.)			Value (mln guilders)		
	1984-1988	1995	2000	1984-1988	1995	2000
Arable farming (incl. silage maize)	13 979	8 750	5 671	358	286	215
Field vegetables	1 192	736	545	44	24	20
Flower bulbs	2 138	1 195	797	55	32	24
Nursery stock industry	510	377	323	19	11	8
Fruits	466	340	261	21	19	14
Pasture	721	574	562	62	50	49
Public parks and gardens	117	83	67	32	23	18
Floriculture	557	262	178	28	12	9
Vegetables (under glass)	525	245	170	14	8	6
Mushrooms	53	27	21	2	1	1
Total	20 260	12 590	8 600	634	466	364

Source: adaptation of LCPP and Vijftigschild (1991)

1) The figures given for 1995 and 2000 are merely indicative, because per category of pesticide an average price was set for all sectors combined and this was then used to obtain the figures for 1995 and 2000. For the sectors public parks and gardens and flowerbulb farming, separate prices were set because of the different average price of pesticides used here.

On 13 June 1991 an environmental criteria memorandum, based on the LCPP Governmental Directive, was sent to the Dutch Lower House (MVROM, 1991[a]). The phasing out of the present list of authorized pesticides will be carried through in two stages. One hundred of the 250 authorized active substances are to be banned in principle before 1995 (MJP-G, 1991, p.90). On the basis of the current environmental criteria it has been estimated that ultimately 65% of the list of authorized pesticides will have to be banned principally. In other words: about 100 compounds meet today's environmental criteria.

On 17 June 1991 the final version of the Government Decision on the Long- term Crop Protection Plan (LCPP) was launched (MJP-G, 1991). In essence, this plan corresponds with the 1990 policy plan. Therefore, when in this publication we refer to the LCPP, we refer to both the Policy Incentive and the Government Decision. The minor changes in the final version included:

- A declaration that integrated agriculture is the most desirable solution, with "biological" agriculture playing an important role.
- Areas specially targeted as requiring extra strong measures to bring them up to average environmental quality, and other problem agricultural areas will be tackled by a more comprehensive approach.

- A ban (in principle) of compounds in two stages: before 1995 and before 2000.
- Before 17 September 1991 a list was to be drawn up comprising compounds that will be exempt from banning (in practice: 6 April 1992). This list is to be evaluated in alternate years from 1994 onwards.
- From January 1992, progress in pesticide reduction in the various sectors of agriculture will be assessed on the basis of compulsory sales administration.
- The imposition of compulsory registration of pesticide use has been rejected.

The instruments provided for in the plan are to be changed in accordance with the above.

In the LCPP, the government worked out how a 56% reduction of pesticide use can be achieved in agriculture. In real terms this means that reducing pesticide use in agriculture to 8600 tonnes per annum should suffice for environmental quality to become acceptable. Whether this preventive policy will lead to acceptable, or even negligible risks to ecosystems (targeted standards) remains to be seen (MVROM, 1991[b]).

2.6 Position of the agricultural sector and initiatives it has taken

As already stated, the government has merely created the conditions necessary to bring about a reduction of pesticide use; the real effort will have to be made by the agricultural industry itself. An overview of that industry's progress to date follows. It is restricted to those activities that fall within the remit of the Agricultural Board.

In May 1989 the Environmental Plan for Agriculture was published by the Agricultural Board. The industry came up with a sectoral action plan, of which the Integral Environmental Action Plan is a summary. That plan goes into topics of environmental policymaking in more detail. The emphasis is on developing and stimulating environmentally benign production methods (Agricultural Board, 1989). Pesticide use is discussed under the heading 'dispersion of environment-threatening compounds'. The Agricultural Board aims at eliminating undesirable environmental effects of pesticide use in the 1990s. In greenhouses the emphasis is on closed farming systems (using an artificial growing medium such as rockwool), whereas the development of integrated farming systems and emission reduction are central issues in soil-dependent agriculture. The plan distinguishes between short-term measures (five years) and long-term measures (Agricultural Board, 1989).

A 1990 progress report calls for a consistent government approach. In that report, the Agricultural Board questions the instruments that are to bring about environmentally-benign agriculture; these are policymaking, financial measures, covenants, research, information, education and coordination. It argues in favour of a more balanced and consistent crop protection policy that justifies long-term crop protection. For levies there the conditions in the plan by the Agricultural Board (1989) are referred to. According to the progress report, policy plans tend to favour financial instruments (subsidies and levies) over covenants (i.e. binding agreements). The Agricultural Board, however, prefers a more offensive approach and supports the use of agreements between the government and the Agricultural Board (Agricultural Board, 1990).

The 1991 progress report dwells on sectoral environmental action plans as well as environmental activities on a regional (provincial) scale. The general part contains an assessment of what has been achieved per environmental topic. Research on integrated farming systems has started for the field vegetable, flowers from bulbs, nursery stock industry and fruit farming sectors. The introduction of integrated arable farming has been a success. In the greenhouse and fruit farming sectors good results have been achieved in purifying process water (carbo-flo). In the Peat Colonies, a plan is being implemented to reduce the use of soil disinfectants by about 46%. Another ongoing project aims at promoting integrated pesticide use in apple and pear growing. Another point worth noting in the general section is the use of environmentally accountable systems of arable farming and horticulture. It appears that the flower bulb and mushroom sectors have made headway in this. Attention has also been paid to covenants (Agricultural Board, 1991).

Concluding, it can be said that the agricultural sector seems prepared to take various measures against the undesirable environmental effects of pesticides. So far, the most important instruments used to do this have been: investigating and promoting integrated farming systems, covenants and environmentally accountable systems. All these instruments are still being perfected.

2.7 Conclusions

Pesticide use, measured in kg of active ingredient per hectare, is very large in the Netherlands. This is mainly, because of soil disinfection, the extensive use of fungicides and the relatively large proportion of horticulture. Although information about trends in pesticide use over the past two decades yields rather ambiguous results, it is clear that pesticide use has increased substantially, especially in the first part of the period 1970-1988. The use of soil disinfectants both in terms of volume and in price per kg of active ingredient, is particularly striking. It might be necessary to distinguish between soil disinfectants and other pesticides, because of the large difference in price between them.

Statistics on the amounts, costs and prices of pesticides show large differences between different sectors of Dutch agriculture. This illustrates the need for an analysis distinguishing between arable farming and horticulture. The arable sector needs to be subdivided into regions and products. Differences between products are more important than regional differences.

Because of the damaging effects of pesticide use, this use must be cut back substantially in various sectors of Dutch agriculture (including public parks and gardens). To achieve this the government designed the Long-term Crop Protection Plan, which consists of measures to tackle the volume of pesticide use and related problems. The agricultural sector endorses this volume-related approach.

Information on the trend in pesticide use is patchy. But it is clear that the upward trend in pesticide use that continued throughout the 1980s must be pushed back. However, ever-increasing horticultural production and the increasing area of arable farmland relative to pastures are among the developments that foster pesticide use (see Table 2.12). The government has agreed to assess progress every two years. Before 1995 it will be investigated if progress is according to schedule.

The instruments of environmental policy can be: regulating, financial and stimulating, and communicative. However, it seems that the possibilities offered by financial instruments in cutting back pesticide use are not taken advantage of fully in the Long-term Crop Protection Plan.

Later chapters (4-8) will examine the feasibility of reducing pesticide use and of deliberately ignoring an approach focusing on individual compounds. The research will centre on whether a regulatory levy can achieve the desired reduction in pesticide use (and whether or not such a levy is required). The arguments will be supported by references to the literature and the use of different models. Special attention will be given to the research method chosen. Chapter 3, therefore, begins by placing the theory on the influence of pesticide prices on pesticide use within a general theoretical framework. Finally, in Chapter 9, we will come full circle and return to the effects of policy instruments on pesticide use.

3. THEORETICAL APPROACHES TO EXPLAIN THE USE OF PESTICIDES

3.1 Introduction

Similar to other inputs in agriculture, pesticides are used to increase the quantity and/or quality of production. Theoretical and empirical information on the relation between pesticides and crop output, however, is limited compared with the information available about the effect other inputs, such as fertilizer, have on output (Dillon and Anderson, 1990). This rather uncertain relation between input and output is reflected in the literature by the different methods used to analyse the question central to this research project: what factors determine the use of pesticides? More specifically: what effect does a levy on pesticides have on pesticide use in agriculture? Because a levy is assumed to be equivalent to a price change, this chapter concentrates on the relation between the price and the use of pesticides.

Often, researchers have concentrated on one or more aspects of this relation (Feder, 1979; Moffitt, 1986; Schulte, 1983). The relationship between the price and the use of pesticide can be studied in terms of the level at which it is decided to use the pesticide. There are at least three such levels:

- The crop. Here one can try to explain what factors determine the use of pesticides for a particular crop;
- The farm. The choice of an optimal cropping plan and the use of other inputs can be considered in relation to the price of pesticides;
- An average farm or a sub-sector of agricultural production. Here one concentrates on the functional relation between the price of pesticides and the amount used by the average farm or a group of farms. Such an approach is often less detailed on the effects of pesticide prices on the composition of outputs, sudden changes in production technologies and the use of other inputs.

Although each of the above three levels defines a different decision situation, there are many similarities too, all starting from a concept of optimization and a production function (or a set of production functions). Whether a particular approach is relevant and applicable also depends on the available information.

Pesticide use depends on various factors. The organization of the agricultural sector, the supplying industry and also research, development, extension and education provide the context for the use of agricultural inputs. Economic conditions, technical possibilities and government regulations, however, determine optimal input levels.

The availability of pesticides is of prime importance: the types available, and the frequency and intensity of their use together with the expected results on quantity and quality of output. The second point is the interaction between the availability and the use of pesticides and the relevant technologies in agriculture. If particular types of pesticides are available, technologies which make use of these pesticides become interesting alternatives (for the decision maker (i.e. the farmer) and therefore the industries providing the farmers with their equipment). How interesting they are depends on the prices of other inputs, outputs, available labour and knowledge, capital equipment, etc. Here not only the combination of inputs and outputs that promises the greatest results to the decision maker might be the prime motive. A decision maker might settle for less ambitious results that vary less over time. In other words: there might be a trade-off between expected results and the variability of those results.

The yield of a particular crop or crops in a rotation could depend heavily on damage caused by insects, fungi, nematodes, weeds, etc. and on the application of pesticides. Indications about possible damage could be specific (such as the number of nematodes in a field) or more general (such as the weather that favours the development of particular diseases and infestations). Damage threshold models can be used to explain optimal behaviour under different conditions. Such models indicate the profitability of applying a dose of a pesticide. Focusing on the link between prices of pesticides and the optimal behaviour of decision makers within these types of models is one way of determining the relation between the prices of pesticides and their application. Section 3.3 focuses on this approach.

Another approach is to concentrate on the different technologies that play an important role in influencing farmers to use pesticides, and to define several input/output relations that concentrate on alternative ways of applying pesticides and related issues. Here the search is for alternative and viable combinations of crops. Changing the prices of pesticides might give different optimal combinations of crops and/or different ways to grow and handle particular crops. Here one can use mathematical optimization techniques to derive the relation between pesticide prices and the use of pesticides under the assumption that producers try to maximize their expected results. See Section 3.4.

Considering pesticides as a 'normal input' leads to an approach that explains the use of pesticides by output prices, input prices, level of technology and available quasi-fixed production factors in the production process (Chambers, 1988). This is the normal neo-classical economic approach, which is developed further in Section 3.5.

Section 3.6 deals explicitly with risk elements. Numerous types of risk elements can be therefore determined, that section discusses only the most important ones and their implications for the demand for pesticides, as derived from each of the approaches mentioned above.

Because this chapter concentrates on theory, simplifications are often used. Except for Section 3.4, we consider only one output and one variable input besides pesticides. Moreover, pesticides are considered to be a homogeneous input. Decision makers try to maximize their profits under a number of conditions, such as the availability of a number of quasi-fixed inputs (labour, capital goods, technical know-how), the availability of technologies and the government regulations. Of course, in a particular setting some of these assumptions could be changed.

3.2 General theoretical approach

The use of an input, whether it is at crop, farm or sector level, may be analysed within the framework of a production function. Such a production function gives the level of output related to each level of inputs. Figure 3.1 depicts a possible production function. The horizontal axis is the input (pesticide); the output (crop or product) is along the vertical axis. Input and output are given per hectare, but the per hectare basis could easily be extended to a number of fixed inputs. Depending on the type of disease, insect or weed, etc. the pesticide is intended to combat, very different relations might be relevant: two quite different relations have been presented.

a. Two-level output functions b. Concave production functions

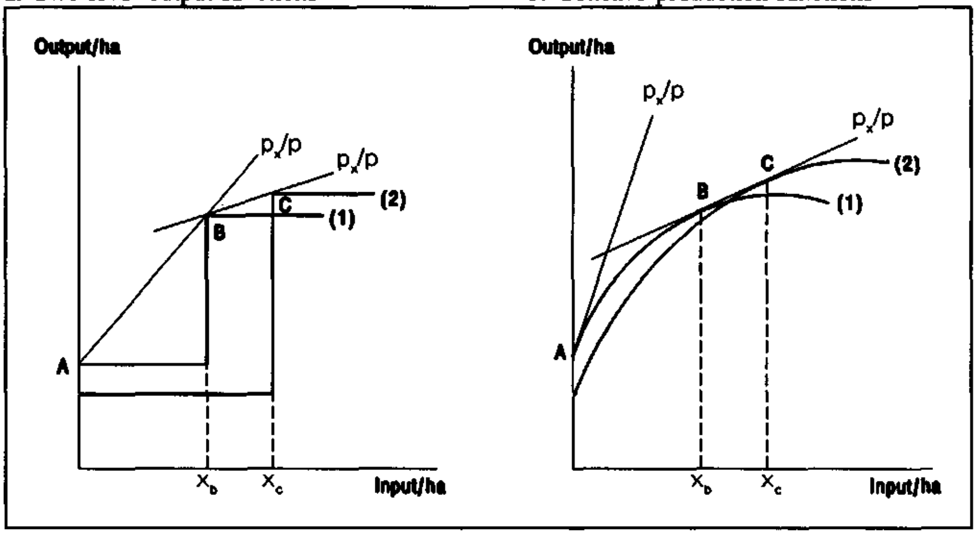

Fig. 3.1 Production functions for pesticides (i.e. input) and optimal input levels under different price relations

a. Two-level output functions b. Concave production functions

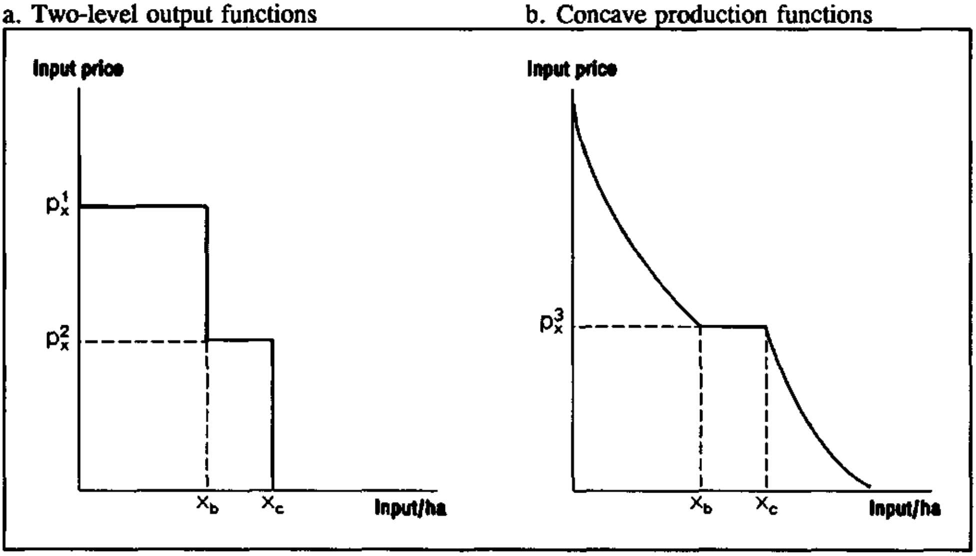

Fig. 3.2 Demand functions for pesticides (input), related to the production functions of Figure 3.1

Figure 3.1a gives a two-level production function, where the higher level can be reached with a sufficient amount of pesticides. Figure 3.1b illustrates a continuous, although decreasing, output effect of pesticides. Both figures incorporate two different technologies.

The optimal application of pesticides can be derived from:

$$\frac{dq}{dx} = \frac{p_x}{p} \tag{3.1}$$

with $q = f(x,t)$

where: q = output
x = input of pesticides
p = output price
p_x = price of pesticides
t = technology

Equation (3.1) states that in the optimum marginal revenue, (p.dq) should equal marginal costs (p_x.dx).

For a given output price (p) it depends on the price of pesticide (p_x) which level of application is optimal. In Figure 3.1a point B is optimal over a broad range of prices p_x. But if p_x increases substantially, point A would be optimal and no pesticides need to be used. All other points on this production function are suboptimal. If p_x is rather low compared with p, another technology might become interesting and C will be the optimal point. Here we assume that there are no differences in other inputs between the different technologies, but this is only a simplifying assumption, which will be dropped in Section 3.4. If present production is in C and prices of pesticides are increasing, then B is optimal at first, and later A is optimal. This illustrates a stepwise reduction in the use of pesticides, either because of the adoption of a new technology, or because input is reduced in line with a different optimum on the production function.

The related demand function for pesticides is given in Figure 3.2a. It is a stepwise declining demand function with optimal input level x_b when the price is between p_x^1 and p_x^2. For a price lower than p_x^2, x_c is the optimal input level. No pesticides are used if the price is above p_x^1. The discontinuities of the production functions translate into the demand function.

Figure 3.1b gives a very different production function for a large part of the price range between input and output. The production function is continuous. Discontinuities arise if pesticide prices are very high or when a shift to another type of technology is optimal. The related demand function for pesticides is shown in Figure 3.2b. Around price level p_x^3 this set of two production functions gives a discontinuous reaction in the amount of inputs.

These two sets of production functions and their related demand functions for pesticides are illustrative of the models used in the sections below.

3.3 Threshold models

The action threshold model and the economic threshold model have been applied in pest control management (Moffitt, 1986; Pannell, 1991). In these models pesticides will be used when the additional costs of using pesticides are outweighed by the damage prevented (i.e. the potential loss). The difference between these two models is that whereas in the economic threshold model both the application and the amount of pesticide applied are decision variables, in the action threshold model the amount applied is a fixed dose (Moffitt, 1986). In both models the damage prevented can be considered to be the revenue obtained from applying pesticides.

The action threshold model is related to the production function of Figure 3.1a, with (say) a choice between two optima: A and B. The vertical distance between A and B times the product price is the potential loss of not applying pesticides. This potential loss is not fixed but depends on a variable D, which is related to the initial stage of a crop and two possible options for the use of pesticides: either no pesticides or a fixed dose. The economic threshold model is more general because the amount of pesticides used is a choice variable. This model reflects the decision making more closely when Figure 3.1b is relevant. We will demonstrate that the action threshold model is a special case of the economic threshold model.

Figure 3.3 illustrates the relation between the number or size of an insect, fungi or weed population, etc. and the revenue from a crop. To simplify matters, these situations are summarized as 'initial level of infestation' ($=D_0$). Consider first the functional relation (1). With a low level of infestation the damage is small and the crop revenue is large. The loss resulting from increasing infestation is reflected by the change in revenue (note that the revenue can increase slightly at a very low level of infestation). If pesticide application reduces infestation to the zero level, it will be profitable when R_0-R_1 exceeds the application costs: say at level T. This level of infestation is the *damage* threshold. For a crop infestation to the left of T, the application of pesticides is not justified economically. For functional relation (2) it will never pay to apply pesticides when application costs are R_0-R_1. In the discussion we refer to function (1).

The time factor in pest control management is a crucial element. It is too late to apply pesticides at the moment that the level of infestation equals T; damage has already occurred. Moreover, a pesticide can take some time to act. The best moment for application depends on the type of crop and the type of damage. This moment, represented by the level of infestation, is called the *action* threshold. The action threshold is a time-related concept: it takes into account the level of infestation, the development stage of the crop and the expected net revenue with and without applying pesticides. The action threshold merely interprets Figure 3.3 differently. It gives the functional relation between the final revenue from a crop in relation to the initial level of infestation at a particular moment. As a time-related concept the action threshold can be used in both the economic threshold model and the action threshold model.

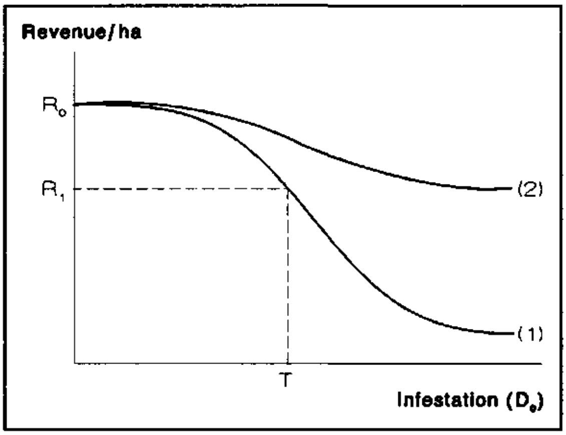

Fig. 3.3 Relation between revenue from a crop and the initial level of infestation

Both models are based on the following simple economic model (Moffitt, 1986; Lichtenberg and Zilberman, 1986):

$$\pi = p.q - (p_x.x + C_a) \tag{3.2}$$

$$q = q(D) \tag{3.3}$$

$$D = D(x,D_0) \tag{3.4}$$

where: π = profit or gross margin
p = price
q = quantity
p_x = price of pesticide
x = amount of pesticide
C_a = pesticide application costs
D = level of infestation
D_0 = initial level of infestation
(all quantity variables are on a per hectare basis)

Equation (3.2) gives the net revenue (or gross margin). The quantity of product in Equation (3.3) is related to the level of infestation which, according to Equation (3.4), is related to the initial level of infestation and the application of pesticides.

If D_0 is the present or observed level of infestation, which is related to future net revenue, a D_0 larger than T implies that the application of pesticides is profitable. Now within the *economic threshold model* the following condition can be formulated.

Calculate the maximum level of:

$$\pi = p.q(D(x,D_0)) - (p_x.x + C_a) \tag{3.5}$$

Here, x is the variable for finding an optimal level of π. With an internal solution ($x > 0$), the optimal level of π can be derived from:

$$\frac{\partial \pi}{\partial x} = 0 \quad \text{with} \quad \frac{\partial^2 \pi}{\partial x^2} < 0 \tag{3.6}$$

This gives the demand function for pesticides:

$$x = x(p_x,p,C_a,D_0) \tag{3.7}$$

and for given values of p, C_a and D_0:

$$x = x(p_x) \tag{3.8}$$

If no internal maximum can be derived, then $x = 0$ and $C_a = 0$. This value always has to be checked against the internal solution, because positive application costs (C_a) might imply that a zero level of pesticide application is optimal.

In practice, growers often apply standard amounts of pesticide. That enables a simplification called the *action threshold model* to be used:

$$\underset{x}{\text{Max}}\ \pi = \underset{x}{\max}\ \{p.q(D(x,D_0)) - (p_x.x + C_a)\} \tag{3.9}$$

in which $x = x^f$ or $x = 0$

where: x^f = standard dose of pesticide (per hectare)

The action threshold T is the minimum infestation level for which the inequality (3.10) just holds:

$$p.q(D(x^f,D_0)) - (x^f.p_x + C_a) > p.q(D(0,D_0)) \tag{3.10}$$

If $D_0 > T$, then the application of the amount x^f is justified economically. Observe that $p.q(D(x^f,D_0)) = R_1$ and $p.q(D(0,T)) = R_0$ in Figure 3.3.

Threshold models can be used to simulate farmers' optimal pest management control. An example for the Netherlands is EPIPRE (see Drenth and Stol, 1990). Although it is unknown to what extent farmers use such models in practice, they can be considered to be a basic framework for helping farmers to make decisions and for use by the extension services. Because of their usefulness in research and extension, these models might be used to derive the repercussions of changes in the price of pesticides on the amount of pesticide applied. To be able to do this, good data must be available on the present level of infestation and the distribution of these levels among the different crops and areas. In Section 4.4 we discuss research in Denmark using damage threshold models. If sufficient information is available this is one of the ways a demand function can be derived for pesticides. Moreover, rather detailed results can be derived on the effects of technical developments on pesticide use.

3.4 Input-output relations at crop level and choices at farm level

Section 3.3 discussed the need of using pesticides for one particular crop. But farmers have to deal with more than one crop. Moreover, crops can be grown in different ways, and the rotation of crops influences the optimal use of pesticides at different price levels. At farm level, therefore, the relation between the price of pesticides and the amounts used depends on many factors.

The leading principle in our analysis is the maximization of the expected gross margin between revenues and the variable costs of crops. Since the problem is not restricted to the choice of growing one (or more) crops and how to grow it (or them), we opted for a method in which an input-output relation is used for each crop or cropping variant. These are the 'activities' whose input-output relations are known (although the size of these relations has not yet been determined). Furthermore, certain rotations - and their corresponding inputs and outputs - can be linked. In relation to Figure 3.1 the input-output relations used are given as points (e.g. A, B, C) along the production function. Points that have been chosen represent 'interesting' input levels. Obviously, the corresponding gross margin depends on product prices and input prices. Hence, maximization of the gross margin runs as follows:

$$\underset{z}{\text{Maximize}} \quad \pi = c'z \tag{3.11}$$

$$\text{Subject to} \quad Az \leq b$$
$$\text{and} \quad z \geq 0$$

where: z = vector of activities
c = vector with gross margins per unit of an activity
A = matrix of input-output coefficients (= technology set)
b = vector of constraints

This is a standard linear programming problem (LP problem), where the relation between the price of pesticides and its application follows from (3.11) by using different price levels (and therefore different c-vectors). Here the following relation holds:

$$x = x(p_x, p_v, p, A, b) \tag{3.12}$$

where: x = demand for pesticides
p_x = price of pesticides
p_v = prices of other variable inputs
p = product prices
A = technology set
b = constraints

Equations (3.7) and (3.12) are clearly similar, except for some right-hand side variables. If p_v,p, A and b are fixed at a particular level a simplified functional relation can be derived:

$$x = x(p_x) \tag{3.13}$$

This is the demand function for pesticides under specified conditions, which is equal to (3.8).

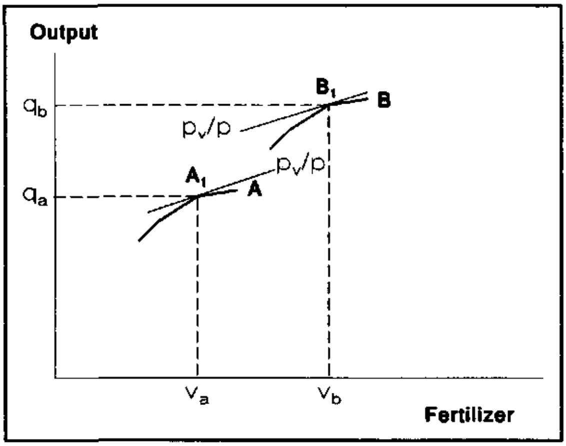

Fig. 3.4 Approximated production function for fertilizer and two different levels of pesticides, representing two different technologies

Two examples will illustrate how activities are defined under different conditions. If there is an interaction between two different inputs, say pesticides and fertilizer, this relation might be incorporated in composing the activities. In this example we assume two different technologies for the use of pesticides, and smooth production functions for fertilizer. In linear programming, smooth production functions are approximated by linear production functions over limited quantities of fertilizer (see Figure 3.4).

For given prices of fertilizer and the product, only one point in the piecewise linear production function is optimal (say A_1 and B_1). The choice between the two technologies depends on:

$$c_a = p.q_a - (p_x.x_a + p_v.v_a) \leq \text{ or } \geq c_b = p.q_b - (p_x.x_b + p_v.v_b) \tag{3.14}$$

where: v = application of fertilizer
p_v = price of fertilizer

For c, p, q, p_x and x see (3.11) and (3.12);
a refers to pesticide level A (= x_a); b to pesticide level B (= x_b)

Because $x_b > x_a$, it depends on p_x which of the two activities gives the highest gross margin, for given prices p and p_v.

Another example is related to two different sets of outputs. The use of pesticide can be influenced substantially by the rotation scheme, e.g. potatoes at a frequency of three or six years. Growing potatoes more frequently might result in a lower yield of potatoes and greater use of pesticides. This does not mean, however, that the activity with the highest gross margin (e.g. potatoes once per six years) will be included in the optimal solution of the LP model for a particular farm. Because of the rotation scheme, the activity with the highest gross margin is strictly related to the other crops. Therefore, the average gross margin per rotation scheme is the relevant indicator.

Clearly, an LP model is suitable for deriving a demand function for pesticides, either by generating solutions for different price levels or by parametric programming (see Gal, 1979). Moreover, additional restrictions on the production process can easily be included, e.g. by means of additional constraints in the vector b. Moreover, new technologies might be added to the technology set (the matrix A). This allows us to analyse the effect of new technologies on the use of pesticides.

3.5 Neoclassical production theory

In Sections 3.3 and 3.4 we tried to explain the use of pesticides by investigating the underlying technical relations. However, pesticide use can also be explained by historical developments. Farmers' use of pesticides can be analysed in the same way as, for instance, their use of fertilizers, energy, seed or labour. The behaviour of agricultural producers can be analysed using neo-classical production theory. Key elements in this theory are the production function and the producer's aim to maximize income (see Section 3.2).

Technology is crucial in neo-classical production theory. The production technology sets the technical limits to a farm's production process. Production technology consists of a number of alternative methods for transforming services and materials (inputs) into goods and services (outputs). According to neo-classical theory this set of production possibilities complies with a number of regularity conditions (Nadiri, 1982). The technology set is often represented by a production function which depicts technically efficient transformations between inputs and outputs, is abstract in nature and does not immediately fit in with existing knowledge of technology because the arguments underlying it do not sufficiently fit in with the technical relations.

The inputs in the production function can be divided into variable inputs and quasi-fixed inputs. Variable inputs are those inputs that can vary in the short term and can be deployed to make the marginal costs of the input equal the marginal profits. Examples of variable inputs for agriculture include pesticides, fertilizers and energy. Quasi-fixed inputs can less easily be varied in the short term because of the organizational form of the agricultural sector. Most farms are family farms where the quantity of labour, land, and capital goods cannot easily be changed in the short term. These inputs are considered to develop gradually towards an optimal level.

The algebraic form of an production function with one output is:

$$q = f(x,z,t) \tag{3.15}$$

where: q = output
x = variable inputs (to be divided into pesticides and other variable inputs)
z = quasi-fixed inputs (labour, capital goods, land)
t = the level of technology

(Compared to the production function of (3.1) two categories of inputs are to be distinguished, each with several kinds of inputs).

It is assumed that in the relevant trajectory this function increases in all inputs and is concave in pesticides and other variable inputs, which means that for the variable inputs x, the matrix of second order derivatives (i.e. the Hessian) of f is negative semi-definite. On the basis of this the function f must comply with, e.g.:

$$\frac{\partial f}{\partial x} \geq 0,\ \frac{\partial f}{\partial z} \geq 0 \ \text{ and } \ \frac{\partial^2 f}{\partial x^2} \leq 0 \tag{3.16}$$

These conditions imply that the relation between input and output is characterized by diminishing returns. Only the production functions of Figure 3.1b (between point A and the top of the curve) fulfil these conditions.

The level of technology changes over time. By employing technological knowledge it is possible to produce more with the same inputs, or, the same production can be produced with less input. In terms of the production function this means that technological development is shifting the isoquant to the origin. An illustration of a technological advance (for a relatively low price level of pesticides) is given in Figure 3.1b with a shift from (1) to (2). Note that for high prices of pesticides, technological advance goes from (2) to (1). In our analysis technological development is represented by a trend term and develops in one direction only.

The production function incorporates the restrictions relating to the economic behaviour. But production is not the random assemblage of a quantity of inputs. On the contrary, the volume of production and the use of inputs are the result of economic reasoning. The production function, therefore, cannot be separated from the farmer's aim to maximize his income. This aim can be algebraically formulated as follows. Income is the difference between the revenues and costs. It is assumed that the prices of inputs and outputs are given for the producer. No costs are ascribed to the fixed production factors: capital goods, family labour and land. They are considered to be fixed on the short term. On the basis of this the income function can be written as:

$$\pi(p,r,z,t) = \max_{q,x}\ p\,q - r\,x \tag{3.17}$$

under the restriction: $q = f(x,z,t)$

where: π = income
p = price of output
r = price of variable input

There is a dual relationship between the production function and the income function on the basis of duality theory (Chambers, 1988; Thijssen, 1992a). Both the production function and the objective to maximize income are used to derive the income function (Equation 3.17). Conversely, is it also possible to derive the relevant production function from the income function. (A relevant production function is taken to mean the production function for inputs and outputs chosen by a farmer aiming to maximize his income). According to duality theory the optimizing behaviour of farmers constrained by technology can equivalently be represented by the income function π. The following conditions have to be fulfilled by the income function: it increases in the price of the output, decreases in the price of the variable input, is convex in prices, and is linearly homogeneous in prices. Hence, the income function has to comply with:

$$\frac{\partial \pi}{\partial p} \geq 0 \quad \frac{\partial \pi}{\partial r} \leq 0 \quad \frac{\partial^2 \pi}{\partial p^2} \leq 0 \quad \frac{\partial^2 \pi}{\partial r^2} \geq 0 \tag{3.18}$$

The production function and income-maximizing behaviour can be used to derive the well-known marginality conditions from which the supply and demand functions follow. These demand functions for the variable inputs and the supply function of the output comply with three conditions based on the assumptions made. The conditions are: homogeneity of degree zero in prices, restrictions on the coefficients of the prices and the symmetry restriction (Thijssen, 1989).

It is also possible to derive the supply and demand functions from the income function. This has the advantage that the supply and demand functions can easily be determined. Differentiating the income function to the prices gives the desired functions. This is known as Hotelling's Lemma.

$$q(p,r,z,t) = \frac{\partial \pi}{\partial p} \tag{3.19}$$

$$x(p,r,z,t) = -\frac{\partial \pi}{\partial r} \tag{3.20}$$

Given the duality relation, it is immaterial whether supply and demand relations are derived from a production function and income-maximizing behaviour or from an income function.

The quasi-fixed inputs are fixed in the short term (1 year). After this year the quantity adjusts partially. The demand function of quasi-fixed inputs can be determined using the 'partial adjustment' theory (Thijssen, 1992[b]). Here, the demand for quasi-fixed inputs is a function of the optimal quantity of quasi-fixed inputs and the quantity of quasi-fixed inputs in the previous period:

$$z_t = m\, z_t^* + (1-m)\, z_{t-1} \tag{3.21}$$

where: m = adjustment parameter (between 0 and 1)
z_t^* = optimal quantity of quasi-fixed inputs

A partial adjustment to the optimal quantity takes place. This is in contrast with the variable input, where the adjustment is complete within one year. The optimal quantity of quasi-fixed inputs follows from the marginality condition where the marginal profits of one unit of quasi-fixed input equals the marginal costs:

$$\frac{\partial \pi}{\partial z} = c_z \tag{3.22}$$

where: c_z = costs of one unit of quasi-fixed input

The costs of one unit of capital goods consist of depreciation and interest, to be adjusted for government policies which result in a reduction of these costs.

Adjustment of the quantity of capital goods, in turn, leads to a change in the use of pesticides, as shown by the demand function (3.20).

3.6 Risk models

In the preceding sections all relations have been derived under the assumption of certainty but there are various reasons why relations and variables are uncertain and this might influence optimal decision making. In a broad overview on risk and risk aversion with respect to pests and pesticides Pannell (1991) gives two sets of reasons why decision making differs between certain and uncertain situations: (1) for the 'risk neutral' decision maker the expected profit might differ from the profit derived from a model where parameters and variables are set at the expected or most likely value; (2) risk aversion causes the decision maker to evaluate uncertain profit levels lower (e.g. in terms of utility) than certain profit levels with the same expected value.

The first set can be illustrated by means of uncertainties in the threshold model, such as:
- the initial level of pest infestation;
- the development of pest infestation and the yield (or quality) of the product without treatment;
- the effect of pesticides on the development of the pest infestation, yield and/or quality of the product;
- the product price.

These uncertainties could have a large influence on generating maximum expected profits, compared with the certain situation. It is often believed that the more uncertainties there are, the more pesticide will be applied, although field research is inconclusive on this (Pannell, 1991).

The second set of reasons is based on the assumption that the decision maker is averse to risk. Decisions are based on the utility of income (or profit) and a risk-averse decision maker prefers a more certain set of income options above a more uncertain set with the same expectation of income. Interestingly, this framework gives rise to different conclusions.

- In the literature on the application of pesticides and integrated pest management, the risk aversion reason has been used to explain relatively *high* levels of pesticide use: above the optimal levels following from profit maximization (Carlson & Main, 1976; Feder, 1979; Zadoks, 1984);
- In neo-classical economics, risk aversion has been used to explain *low* levels of input use and therefore production (Sandmo, 1971; Anderson, et al., 1977; Andréasson, 1989).

We will elucidate those contradictory ideas later. We believe that differences in results follow from different assumptions about the production function.

The second set of reasons mentioned by Pannell (1991) can be developed further, using the framework of diminishing marginal utility of income and relative risk aversion (see Smidts, 1990, Ch. 3). This framework starts from the Bernoulli model where decisions are based on a utility function, which in turn is based on the assumption of diminishing marginal utility of income or net profit. Therefore in the Bernoulli model the utility of the same additional income at higher income levels is less than at lower income levels. Every decision maker with such a utility function of income is risk averse and prefers more certain outcomes above more uncertain outcomes with the same expected income level (see e.g. Smidts, 1990, p. 35). The relative risk preference can be defined on the basis of the Von Neumann-Morgenstern expected utility model (NM model). This model is not based solely on the diminishing marginal utility of income, and therefore a decision maker who receives certain, but fluctuating, incomes perceives a lower utility level than when his income is stable and of equal average size. The NM model incorporates the reactions to risky situations. The differences between evaluations according to the Bernoulli model and the NM model can be seen as a measure of relative risk aversion (Smidts, 1990, p. 49).

Because of the heated discussion in the literature about the concept of relative risk aversion (Smidts, 1990, Section 3.3) and the impossibility of measuring relative risk aversion directly (Smidts, 1990, p. 240), we will confine our discussion to the Bernoulli model.

To illustrate the consequences of incorporating risk in the analysis we start with a very simple example within the threshold model. It is also a good illustration of the intricacy of approaches incorporating risk. Therefore, the discussion in the rest of this section draws heavily on the literature.

Risk in a threshold model

The variable D_0 was important in the action threshold model. It was e.g. the initial level of a pest infestation. If this initial level is known with certainty, Equation (3.10) applies. But let us assume that the decision maker is uncertain about the level of D_0: it has a chance p_1

of being D_0^1 and a 1-p_1 change of being D_0^2. Now a decision maker who only looks at <u>expected</u> results uses the following rule. Apply pesticides if:

$$p_1.\pi(x^f,D_0^1)+(1-p_1).\pi(x^f,D_0^2) > p_1.\pi(0,D_0^1)+(1-p_1).\pi(0,D_0^2) \tag{3.23}$$

where: $\pi(a,b)$ = profit level with infestation level b and application of pesticides a

Left and right of the inequality there is the expected profit of an uncertain situation. Profit levels have also been illustrated (see Figure 3.5). We assume that in the situation where the standard dose of pesticide is applied the profit level does not depend on the initial level of pest infestation. This could be a reasonable assumption when infestation is detected at an early stage and a standard dose is sufficient to prevent any damage to the crop.

Defining $\pi_s = \pi(x^f,D_0^1) = \pi(x^f,D_0^2)$; $\pi_1 = \pi(0,D_0^1)$ and $\pi_2 = \pi(0,D_0^2)$, and observing that the difference between π_1 and π_s equals the costs of pesticide (including application costs), the expected results of using pesticides are better when:

$$p_1 < \frac{\pi_s - \pi_2}{\pi_1 - \pi_2} = p_1^* \tag{3.24}$$

Thus for p_1 smaller than p_1^*, the standard dose of pesticides is preferred. However, one can imagine that a particular farmer is not indifferent between the certain results when the standard dose is applied and the uncertain results of using no pesticides, when $p_1=p_1^*$. As a result of a concave utility function of income or profit, the certain situation might be preferred, as illustrated in Figure 3.6. Here, $v_c=v(\pi_s)$ is the utility level of the certain outcome, while $v_u=p_1.\pi_1 + (1-p_1).\pi_2$ is the utility that belongs to the uncertain situation[1].

An expected profit level of at least π_3 in the uncertain situation would be necessary for the farmer to decide to apply no pesticides. This is similar to a chance level of $p_1 = (\pi_3-\pi_2)/(\pi_1-\pi_2)$. Therefore, in this situation the assumption of a concave utility function of the decision maker implies a more intensive use of pesticides compared with making decisions on the basis of expected profits.

This example was only useful for illustrative purposes. It is intended to show why risk elements might be important. There are, however, many uncertain elements - even in decision making for one crop, as also mentioned in the introduction to this section:
- the level of infestation, as illustrated above;
- the development of an infestation if pesticide is not applied;
- the relation between the dose and the effect of a pesticide;
- the price level of the product.

[1] The expected utility in the uncertain situation is the linear interpolation of the two utility levels v_1 and v_2, which have weights p_1 and $(1-p_1)$ respectively.

a. Certain profit level (fixed dose) b. Uncertain profit level (no dose)

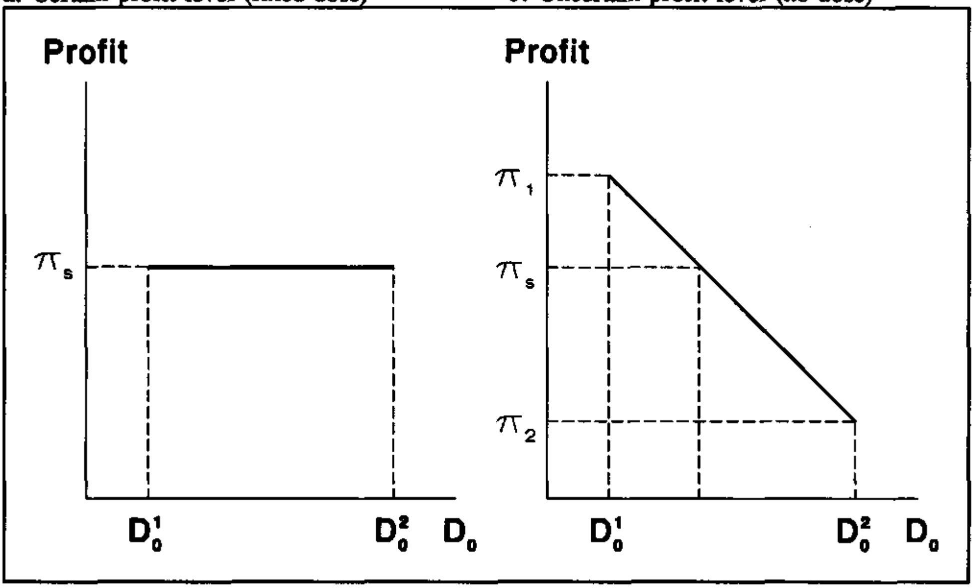

Fig. 3.5 Profit levels in the threshold model with uncertainty about the initial stage of pest infestation (D_0)

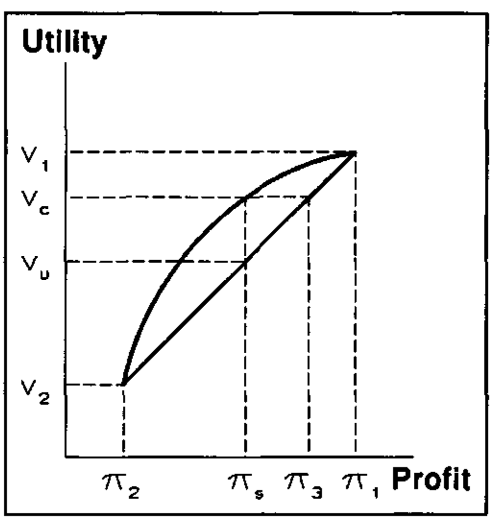

Fig. 3.6 Utility level of a certain and an uncertain profit level

Each of these elements might have different implications for optimal decision making based on maximizing utility rather than maximizing expected profits.

Moffitt (1986) gives an illustration in which a risk-averse decision maker (which is similar to a decision maker with a concave utility function), is uncertain about the initial level of infestation. As a result of this uncertainty, however, the actual level of production with and without pesticide is also uncertain, and the optimal dose of pesticide becomes a chance variable too. Moffitt derives that under such conditions both the standard dose and the threshold for applying this standard dose are larger than under risk neutrality. Therefore the effect of including risk in this situation is unclear.

In an uncertain situation farmers are reluctant to use pesticides, but if they decide to apply them, they will apply more than in a certain situation. Also, according to Pannell (1991), empirical studies indicate opposite reactions to more uncertainty, and there is no general justification for applying more pesticides in uncertain situations.

Incorporating all relevant risk elements, however, makes it very difficult to derive optimal results analytically. Therefore researchers either use many simplifying assumptions or they shift to simulation methods. Using simulation techniques makes it nearly impossible to derive general conclusions.

Risk in a whole farm programming context

Many uncertainties surround the optimal use of pesticides at farm level. Risk elements might be particularly important at farm level because the decision maker balances better expected results against a larger variance in the results. Recalling the optimization in (3.11), several elements within the whole optimization process might be uncertain. In practice, however, most researchers assume variability in the elements of the vector c (the net revenues per unit of activity), either because of price uncertainty or because of uncertainties in the input-output relation (Anderson, et al., 1977, Ch. 7).

If both expected net return and the variances and covariances of these returns can be specified for the activities in a programming context, one might generate a number of feasible cropping plans with different levels of expected profits and variances of those profits. A decision maker with a concave utility function of income and/or a risk-averse behaviour, has a utility function with respect to expected net revenue (E) and the variance of net revenue (V) as illustrated in Figure 3.7, where U links points with an equal utility level. The curve U_2 illustrates a higher level than U_1. This means that a cropping plan with a lower expected profit but also less variance might be preferred above cropping plans with a higher expected profit and greater variance. Different cropping plans can generate an (E,V) frontier, as illustrated in Figure 3.7. Such a frontier illustrates that better expected results might be generated by more risky production methods. Therefore the optimal cropping plan has a lower expected value than some other solutions on the (E,V) frontier.

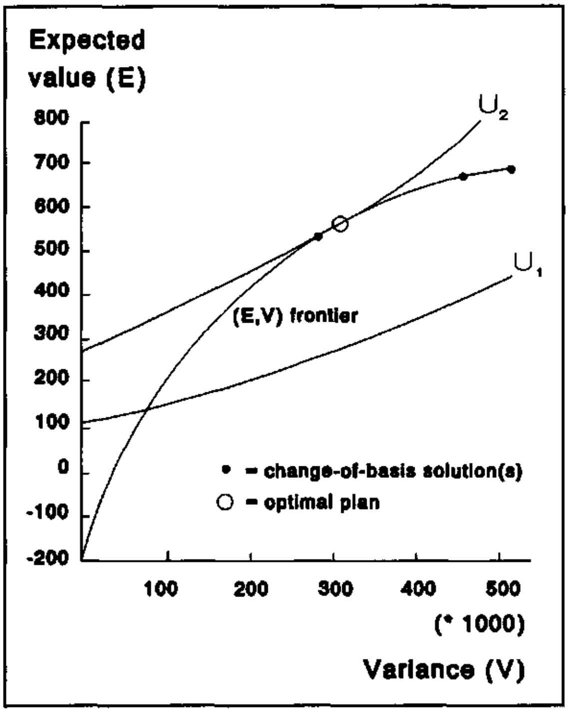

Fig. 3.7 Utility function and (E,V) frontier for a whole farm decision situation (Source: Anderson, et al., 1977, p. 201).

Because variance is not incorporated in the LP optimization, there is a tendency to incorporate activities that are too risky, especially if these activities are based on new and more environmental-friendly technologies. The same holds for pest management schemes and rotation schemes to reduce pesticide inputs. Therefore, the methodology applied in Chapter 6 will either underestimate the use of pesticides or overestimate the actual profit levels of farms. These conclusions will be reinforced if uncertainties about technical coefficients and restrictions were incorporated. Therefore a normative approach such as LP modelling underestimates the use of pesticides because uncertainty and risk are ignored.

Risk in a neoclassical economic model

Within the context of a neo-classical economic model producers are profit maximizers (see Section 3.5). However, one could incorporate the impact of risk on agricultural producers who are utility maximizers. The conclusions from such an approach are quite clear: if a producer is risk-averse he uses less input and produces less than in a situation without risk (Anderson et. al., 1977, Ch. 6; Andréasson, 1989, Ch. 2). As already mentioned, this conclusion is contrary to many results at the crop level, where uncertainty about parameters and variables and assuming risk-averse behaviour often give the opposite result.

If we check the assumptions in both approaches, we observe that neo-classical economics starts from a concave production function (such as in Figure 3.1b and even without the boundary point A). Models which start at crop level, however, could be based on quite different production functions such as illustrated in Figure 3.1a, which is not concave. Therefore we observe different conclusions from both approaches. The assumption of a concave production function, however, could be more justified at a higher level of aggregation of inputs and outputs.

The observation that uncertainty and risk-averse behaviour shifts the demand function of pesticides to the left (see Figure 3.2b) has little influence on the results of the empirical econometric analysis, as applied in Chapter 5. The demand function for pesticides was derived under the historical conditions and reflects the producers' reactions to these situations. Only in circumstances which imply an important change of risk do the historical relations have to be considered with care. Shifts in the level of technology (as illustrated in Figure 3.2b), however, might be more important than changes in the situations of uncertainty and risk.

3.7 Concluding remarks

Different approaches can be applied to derive the relation between the price of pesticides and the amounts used. Which approach is most relevant depends greatly on the particular questions, and the information available. Applying different methods makes it possible to compare the results of such methods. But a good understanding of the theoretical background is necessary to be able to interpret results.

Many uncertainties that might play a role in actual decision making could be mentioned, but it is very difficult to incorporate them in actual research. The discussion on uncertainties and risk clarified the conclusions that can be derived from approaches assuming certainty and ignoring risk-averse behaviour. The results of linear programming ignore risk elements and underestimate the application of pesticides. This underestimation could increase if the uncertainty surrounding the results increases as a result of technologies with a low use of pesticides. The results of an econometric approach, based on actual behaviour of farmers already reflect the effects of uncertainties. Here it is more difficult to incorporate new technologies.

In a survey of the literature on risk and risk aversion with respect to pesticide use, Pannell (1991, p.361) writes:

> "Risk can affect pesticide decision making either because of risk aversion or because of its influence on expected profit. It is concluded that risk does not necessarily lead to increased pesticide use by individual farmers. Uncertainty about some variables such as pest density and pest mortality, does lead to higher optimal pesticide use under risk aversion. However, uncertainty about other important variables, such as output price and yield, leads to lower optimal levels of pesticide use".

This demonstrates that the effects of risk and uncertainty are not completely resolved.

4. EXPERIENCES AND RESEARCH RESULTS

4.1 Introduction

The most important issue in the investigation of the economic results of levies is the analysis of the effects of price changes on pesticide use. This chapter gives an overview of the literature available on this topic.

One country that has some experience of imposing levies on pesticides is Sweden, where a system of product levies has recently been adopted. This system is discussed in Section 4.2 and the findings of the Swedish action programme for reducing health and environmental risks from pesticide use in agriculture are given. The role levies have played in this is indicated. Furthermore, a Swedish study on reducing pesticide use by assigning quotas is discussed.

Later sections contain an overview of economic research on the relationship between price changes and the amount of pesticides used. The studies discussed were done in the Netherlands (Section 4.3), Denmark (Section 4.4), and Germany (Section 4.5). It seems reasonable to assume that the situation in both Denmark and Germany does not differ very much from that in the Netherlands (see also Table 2.2). Among this group of three countries Denmark has most experience in reducing pesticide usage. In Section 4.6 we discuss the reduction targets of Sweden, Denmark and the Netherlands and draw conclusions on the effectivity of the price instrument in reaching such targets.

4.2 Levies and the Swedish crop protection policy

Overview

The total amount of pesticides used depends on the total area of crops and what crops are grown. Certain crops need specific sorts of pesticide. Table 4.1 shows the proportion of arable land in Sweden taken up by different crops as percentages of the total arable area (excluding fodder/feed crops). A notable difference from the Dutch situation is that a major part of the crop area in Sweden is under cereals, although less so in recent years. Rising prices for inputs and stagnation of grain prices have made it attractive to leave land fallow. This has resulted in 200 000 to 250 000 hectares of arable land being set aside in Sweden. Under current regulations, any land taken out of production in Sweden must be used for other purposes, for instance as a nature reserve.

Table 4.2 shows the total amounts of three categories of pesticide, as used on various crops over the period 1981-1985. Amounts are given as hectares treated, rather than kilograms of pesticides used. Figures shown in brackets are the average number of treatments per crop.

The greatest problem in crop protection in Sweden is the weed problem. This can be seen from the column 'herbicides' in Table 4.2. Fungus diseases and insects do not pose a big threat in the greater part of Sweden because of the climate. Nevertheless, fungicides are used in the south of Sweden, although this is not only because of the milder climate. A number of farms in the south of Sweden grow potato crops which are sprayed with fungicides an average of 5 to 6 times, as shown in Table 4.2.

Table 4.1 Crop areas in Sweden as a percentage of total arable land; total arable land (1000 hectares); excluding fodder/feed crops

Crop	1970	1975	1980	1985	1989
Cereals	82.7	79.4	79.8	78.5	70.8
Oilseeds	4.9	8.5	8.9	8.6	9.0
Sugarbeet	2.0	2.6	2.6	2.6	2.7
Potatoes	3.3	2.1	2.0	1.9	1.9
Other crops	3.4	3.5	3.6	4.7	4.5
Set-aside	3.8	3.1	3.2	3.6	11.1
Total area	1973	2037	2011	2007	1883

Source: Swedish Agricultural Market Board, 1990

Table 4.2 Area (1000 hectares) in Sweden treated with pesticides. Average for the period 1981-1985. Figures in brackets indicate average number of treatments per crop[1)]

Crop	Fungicides	Herbicides	Insecticides	Seed treatment
Winter wheat	100 (0.46)	200 (0.92)	68 (0.31)	217 (1.00)
Summer wheat	36 (0.45)	75 (0.94)	21 (0.26)	46 (0.58)
Winter rye	25 (0.44)	40 (0.70)	2 (0.04)	57 (1.00)
Barley	108 (0.16)	570 (0.82)	168 (0.24)	402 (0.58)
Oats	0 (0.00)	380 (0.80)	115 (0.24)	276 (0.58)
Oilseeds	7 (0.04)	55 (0.33)	164 (0.99)	140 (0.84)
Sugarbeet	2 (0.04)	150 (2.94)	45 (0.88)	51 (1.00)
Potatoes	212 (5.44)	16 (0.41)	11 (0.28)	-
Others	10	-	22	-
Set aside	-	50 (0.67)	-	-
Total	500 (0.27)	1546 (0.82)	616 (0.33)	1191 (0.63)

Source: Petterson et al. (1989)

1) Growth regulators were only used on grain, averaging 7% of the grain area.
Use of nematicides is prohibited in Sweden.

The Swedish action programme

In 1984 and 1985, the Swedish Parliament drew up directives for future crop production policy which, in 1986, led to the Swedish "action programme for the reduction of health and environmental risks posed by pesticides use in agriculture". To achieve a reduction of these risks, the following three groups of measures were proposed (Lantbruksstyrelsen, 1986):

1. A gradual change to treatments that are less dangerous to health and environment.
2. Measures to reduce overall use of pesticides.
3. More education, enforced legislature, and other measures aimed at protection of health and the environment.

The main purpose of the action programme is to reduce the risks related to pesticide use. In the mid-1980s, Swedish crop protection experts indicated that a 50% reduction in kilograms was feasible. This conclusion was incorporated as a clearly formulated objective in the action programme that targeted achieving a 50% reduction by 1990, relative to the 1981-1985 period (Swedish Board of Agriculture, 1992).

Levies

In Sweden, the levies are imposed on the way crop protection treatments are applied. There are two different types of levies: administrative charges required when registering pesticides, and levies on the use of pesticides (product levies). In Sweden, the fixed component of the administrative levy is higher than in the Netherlands: varying between 500 and 15,000 Dutch guilders per authorized chemical. Moreover, an additional amount of 1750 Dutch guilders must be paid annually for a chemical's authorization to be prolonged; this is higher than in the Netherlands (Reus, 1990).

Since 1986, two different use-related product levies have been effective: the environmental levy (not applicable to the agricultural sector only) and the surplus levy meant to finance exports of surplus production. The current environmental levy on pesticides entails a price increase of 8 Swedish Kroner (2.60 Dutch guilders) per kilogram of active ingredient, which results in an average price increase of 10%. The money acquired through this levy is used for more general purposes, as well as for research and information.

The surplus levy is the price that the farmer has to pay when buying any kind of pesticide, the basis of the levy being a fixed amount per standard dosage. By a standard dosage is meant the amount of a particular pesticide necessary to treat one hectare of crop. This standard dosage is indicated by the importer or manufacturer and has to be approved by the Swedish Agricultural Marketing Board[1]. This is also true for fertilizers. Funds resulting from surplus levies are used to subsidize exports of cereals and oil seeds. The surplus levy is related to the magnitude of the surplus to be exported. In 1986 the levy was 29 Swedish Kroner per treated hectare and it is currently 46 Swedish Kroner (14.70 Dutch guilders) per hectare. Using the standard dosage this is converted into a levy price per kilogram of active ingredient for each type of pesticide. Naturally, for chemicals that are applied in small dosages a higher levy is charged per kilogram of active ingredient than for those that are applied in large dosages (Swedish Agricultural Marketing Board, 1990; Eklöf, 1991 pers.comm.).

At the moment the total average levy on pesticides (environmental and surplus levies) amounts to about 40% of the average pesticide price. Since the main purpose of this levy is to finance exports, research and information, etc., the Swedish levy can be considered to be a financial levy, because reduction of pesticide use was the secondary objective. The size of the levy has not been adjusted in accordance with the environmental objectives to be met (Hasund, 1991, written comm.).

---

[1] Since 1 July 1991 the Swedish Board of Agriculture.

Preliminary results of the Swedish policy

Table 4.3 shows trends in pesticide sales (in kilograms) in Sweden from 1981 to 1990. In 1986, the announcement of the surplus levy (as per July 1, 1986) led to hoarding of pesticides. The result was that the sales figures given for 1986 and 1987 differed considerably from the amounts actually used. Therefore, since 1988, pesticide use can be derived from sales figures (Swedish Board of Agriculture, 1992).

Table 4.3 Sales of pesticides in Swedish agriculture, expressed in 10^3 kg of active ingredient

Years	Fungicides	Herbicides	Insecticides	Seed treatment	Growth regulators	Total
1981-85	599	3536	150	161	82	4528
1986	869	4207	160	199	243	5678
1987	470	1781	63	119	84	2519
1988	662	2029	112	101	75	2982
1989	445	1871	50	120	35	2521
1990	608	1658	38	97	49	2450

Source: Lantbruksstyrelsen et al. (1989); Swedish Board of Agriculture (1992)

According to the Swedish Board of Agriculture, the targeted reduction of pesticide use has been reached. For the evaluation, 1990 totals were compared with 1981-1985 averages. It was found that herbicides make up by far the biggest part of total pesticide use. Since the use of herbicides is relatively stable, it seems justifiable to take only one year (1990) as a reference year (Swedish Board of Agriculture, 1992).

Pesticide reduction achieved the following results. The total reduction in use (active ingredients) has been 48% or about 2200 tons compared with the average use between 1981 and 1985. A very large part of the reduction, 1900 tons, refers to the use of herbicides. Lower herbicide dose rates used against weeds in cereals correspond to about 900-1000 tons. The other 1000 tons consisted of prohibitions and restrictions and farmers' substitution by herbicides with the less active ingredient (e.g. phenoxy acids to sulfonylureas). The extension service which includes pest forecast and warning had a major impact on reduction of insurance spraying (Swedish Board of Agriculture, 1992).

However, other factors also contribute to the reduction of pesticide use. For instance, farmers' awareness of the negative effects of pesticides on the environment has been enhanced by educational programmes. Furthermore, Swedish farmers have been offered the opportunity of having their spraying equipment tested at a low cost, to improve the setting. Since January 1991 regulations have been enforced requiring mandatory testing of new sprayers (Swedish Board of Agriculture, 1992). Opinions differ about the set-aside schemes, which cover more than 10% of the Swedish arable area. Table 4.2 shows that although weed-killers are being used on land that has been taken out of production, they are applied much less intensively. On the other hand, the areas concerned are mainly in mid-Sweden where pesticide use was already very moderate. The set-aside programme may have had some influence though.

In Sweden levies at the current rate are believed to have been of minor importance in curtailing pesticide use and it is believed that adjusted crop protection would have become economically attractive to farmers even if no levies had been imposed on inputs. There is no consensus, however, on whether levies on herbicides have a different impact than levies on fungicides and insecticides.

Gummeson (1991, pers.comm.) believes that putting a levy on herbicides is pointless. To prevent the seedbank (stock of weeds in the soil) from posing future weed problems, a farmer cannot tolerate too many weeds in crops. In Sweden, no alternative reliable types of weed control, for instance mechanical weed killers, are yet available. Therefore, farmers have to stick to preventive spraying; a levy cannot change that. As mentioned previously, the relatively large percentage of cereals is important here.

As regards the application of fungicides and pesticides, in principle it is possible to use damage-threshold models (see Section 3.3). When product and input prices change, the damage threshold, or rather the economically optimal moment for treatment (damage threshold), will shift. As a result, levies on fungicides and insecticides will undoubtedly influence the use of these chemicals more than levies on herbicides (Sigvald, pers. comm.). A substantial rise in the levies on fungicides and insecticides was considered but was rejected on the grounds that product prices are expected to fall in Sweden. This will in itself bring about a reduction in the use of inputs, making an extra charge on fungicides and insecticides unnecessary (Johnsson, 1991, pers.comm.).

It is difficult to forecast the future level of levies in Sweden. What seems likely is that the surplus levy will be reduced because of reduced sales cost. The tendency in current Swedish agricultural policy is for import levies on agricultural products to gradually decrease and, as a result, for internal prices of cereals to fall too.

At present, research is being done on a levying system that distinguishes according to potential threat posed by the compound to the environment. The advantage of this approach is that a levy not only serves to reduce pesticide use but also stimulates the transition to less harmful treatments (Carlson and Dahl, 1991). The National Chemicals Inspectorate together with the Swedish Board of Agriculture are analysing this subject during spring 1992. The results will be published in an official report (Emmerman, 1992, pers.comm.).

Swedish research into further reducing the use of pesticides

By 1996, the use of pesticides must be reduced by a further 50% in Sweden, which means a reduction of 75% as compared with 1981-1985 (Swedish Board of Agriculture, 1992). The government believes this can be achieved without considerable yield losses, by more drastic technical improvements aimed at the reduction of kilograms of active ingredient in pesticides.

When considering pesticide use in arable farming in Sweden, however, one cannot but conclude that it has increased in recent years (Petterson et al., 1989). The report "Minskad bekaempning i jordbruket" (Kungl. skogs- och lantbruksakademien, 1989) discusses the potential for a further reduction of pesticide use and the repercussions of this as expressed in the treated area.

In that study, damage-threshold models were used, as described in Section 3.3, to establish the damage threshold for various crops, fungus diseases and insect infestations. Petterson and his colleagues distinguished three levels of product prices: the internal (Swedish) price, the world market price and the minimum price. The latter is the price corresponding to the most extensive level of pesticide use possible. At this level it is still possible to obtain a reasonable product yield (of acceptable quality).

The calculations were done on the basis of data gathered from a large number of experimental fields at different locations in Sweden where crop protection experiments were being done and data were available on a large number of diseases, infestations and crops. Using damage-threshold models it was investigated whether or not pest control for a certain crop/disease combination is feasible for these areas. For an example, see Table 4.4, which shows various thresholds for winter wheat. Low wheat prices imply high damage thresholds. Data similar to those in Table 4.4 were used to calculate on what part of the area pest control can be cost-effectively applied.

Table 4.4 Cost of pest control (in Kroner per hectare) and levels of damage threshold (in kilograms per hectare) for three product prices: figures in brackets related to the area treated (%); winter wheat (example)

Group of crop damagers and region	Costs of pesticides, Kroner/ha	Damage threshold, kg/ha		
		Swedish prices	World market prices	Minimum prices
Overwintering diseases	165	200 (30)	300 (20)	800 (4)
Foot rot	315	300 (15)	800 (4)	800 (4)
Insects				
Southern region	280	300 (40)	450 (30)	1200 (2)
Other regions	280	300 (20)	450 (10)	1200 (2)
Rust				
South Sweden	405	350 (40)	700 (10)	1200 (5)
North Sweden	405	350 (20)	600 (5)	600 (5)

Source: Kungl. skogs-och lantbruksakademien (1989)

This Swedish study did not use damage-threshold models for weed control. For weeds it was assumed that halving the number of treatments would result in a 5% yield reduction.

The Swedish researchers opted for quotas on pesticides (expressed in standard dosages) rather than levies. They did a quantitative analysis for one scenario. In this scenario, they halved the area treated with herbicides, and reduced the area treated with insecticides by 40% and the area treated with fungicides by 70%. In the calculation they also assumed that the producers would receive compensatory payments for income losses incurred from the imposition of quotas on pesticides. The compensation could take place by adjusting product prices. The result would be an increase in domestic prices for farm products.

An agricultural sector model was used to elucidate the aggregated economic effects of reduced application of chemical treatments. This model was an interregional, spatial linear programming model of Swedish food production. The results are summarized in Table 4.5. Table 4.5 shows that imposing quotas on pesticide use will cause production costs to increase by no less than 1000 Swedish Kroner per ha. Given that it was assumed that producers of cereals and rapeseed would be compensated for income losses, price increases were inevitable. Price increases for milk, meat and eggs were investigated. From Table 4.5 it appears that the prices of meat and eggs would have to be raised by 10% to 15%. The price increase of milk will be smaller, because of the reduced share of cereals in livestock feed. Large-scale price increases like this are unrealistic, though. The current international trend of ever-increasing liberalization in trade in agricultural products also influences Swedish policy-making. Price increases like the ones mentioned in Table 4.5, therefore, are politically unlikely.

Table 4.5 Summary of results from the sector analysis in Sweden; halving of the area treated with herbicides; the maximum area subjected to other treatments is 500 000 and 250 000 hectares for cereals and winter rape

	Basic situation	Quota on standard dosages of insecticides and fungicides	
		500 000 ha	250 000 ha
Net costs primary production (mln Kroner)	22 970	23 990	24 280
Budget costs of exporting grain surplus (mln Kroner)	650	230	100
Selling price (Kroner/kg)			
Milk	2.40	2.50	2.50
Meat	14.00	15.80	15.90
Eggs	7.80	8.50	8.50
Gain from treatment (Kroner/ha)	-	850	1180

Source: Kungl. skogs- och lantbruksakademien (1989)

Furthermore, the term "gain from treatment" in Table 4.5 means the additional revenue that can be obtained by applying additional treatment. Imposing a levy that is equivalent to the value of this additional revenue will bring about the targeted reductions in pesticide use. In terms of area sprayed, Swedish agriculture as a whole uses pesticides on about 4 million hectares (mean for 1986-1988). The economic evaluation considered a decrease of 1.3 million ha in the area sprayed. So, a levy of about 1000 Kroner per hectare (325 Dutch guilders per hectare) will lead to a reduction of about 33% in area sprayed. Note, however, that with a comparable levy on kilograms of active ingredient, the reduction in pesticide use measured in kg active ingredient will be more than 33%, because a change to chemicals with a low dosage would then be stimulated, which would be impossible when levying per treated hectare.

4.3 Results of Dutch research related to prices of pesticides

Although not much research has been done in the Netherlands into the effects of changes in pesticide price on pesticide use, some conclusions can be drawn from data acquired from various studies.

In a study on Dutch arable farming, Elhorst (1990) investigated the price sensitivity of fertilizers, pesticides and other variable inputs. He combined these inputs under the heading "non-factor inputs" and did not investigate them separately. The estimates were for the period 1980-1986. Elhorst (1990) found a price elasticity of -0.29 for non-factor inputs, which can be interpreted as being an underestimation of the price elasticity of pesticides for the following reasons:
- Neither the effect of a price change of non-factor inputs on the cropping plan nor the production per hectare were included in the analysis.
- Points of departure were a fixed amount of family labour and farm machinery. An increase in the price of pesticides is likely to affect the farm machinery.
- By lumping all non-factor inputs together, substitution of the individual inputs - for instance pesticides for contract work - is impossible.

The results found by Elhorst (1990) can largely be seen as a short-term adaptation to price changes. In view of the previous reasons, it seems likely that an increase in pesticide price of, for instance, 10% will reduce pesticide use by more than 3%.

Recent research by Oskam (1992) on the use of fertilizer and pesticides in Dutch arable farming reveals more about the price sensitivity of pesticide use. This research, concerning the 1970-1987 period, used data from a stratified sample of arable farms. A distinction was made between specialized arable farms (where more than 80% of the land is reserved for arable crops including feed crops), and farms where 50-80% is reserved for arable farming. Before discussing the price elasticities found we shall outline the factors which, according to Oskam (1992), determine the use of pesticides.

Table 4.6 sheds some light on the factors accounting for the use of pesticides. The analysis concerned the period 1970-1987. So, some of the differences can be ascribed to pesticide use increasing over time (Section 2.3).

The differences in pesticide use per farm per hectare relate to a large extent to the cropping plan. Reducing the share of onions, sugarbeet and potatoes in a farm's total area will considerably affect the use of pesticides, measured in guilders. Actual revenue per hectare and per crop consists of two elements:

- yield in kilograms per hectare;
- the price realized (as compared with the average price realized by farmers).

Higher revenue per hectare per crop play a role in explaining pesticide use. Factors such as increased quantity and improved quality of crops push up pesticide use. Regional differences in the use of pesticides are remarkably small. The differences that were found (see also Table 2.7) might be caused by differences in cropping plans.

Another conclusion to be drawn from the analysis is that pesticide use is more easy to explain than the use of fertilizer. This means that differences in use caused by, for instance, differences in farm management, individual factors, chance factors and the like, are less profound. Yet, as much as one-third of the differences in pesticide use (per hectare) belong to the category 'unexplained'. This category includes factors such as differences in management, individual factors, chance factors, measurement error, etc.

Table 4.6 Share (in percentages) of different factors in explaining pesticide use in guilders per hectare (against constant prices) over the 1970-1987 period in a sample of Dutch arable farms

Factors	Farms		
	All	Specialized	Mixed
Systematic differences during the period	19	21	7
Cropping plan	38	36	39
Quantity and quality of product	6	5	12
Regional differences	1	0	1
Schooling farmer, labour per ha, machinery, fertilizer, etc.	2	2	5
Unexplained	34	35	36

Source: Oskam (1992)

Table 4.7 Price elasticities of the demand for pesticides on two types of Dutch arable farms; the estimated standard deviations are given in brackets

Type of crop	Specialized farms	Mixed farms
Cereals, oilseeds, pulse crops, other marketable crops	-0.4 (0.4)	-0.5 (1.9)
Potatoes, onions	-0.5 (0.5)	-0.1 (0.3)

Source: Oskam (1992)

The price sensitivity of the different crops to the price of pesticides was determined, in the first instance, by an analysis that first estimated the volume (magnitude) of pesticide use per crop per year. With the help of regression analysis, these estimates were then used to determine to what extent pesticide use is increasing. In addition, the degree to which pesticide use is influenced by the prices of crops and pesticides was investigated.

Per crop, this method did not provide easily explicable results. Allocating crops to one of two groups, and assigning a special position to sugarbeet, gave the results shown in Table 4.7.

The results from Table 4.7 indicate a price elasticity of pesticide use in Dutch arable farming of about -0.4 to -0.5, although the price elasticity of potatoes and onions on mixed farms is slightly deviant. These price elasticities are to be regarded as medium-term results, since the specified relationship between pesticide use and pesticide price incorporates short-term as well as long-term effects. Given the relatively unreliable results, the figure for the price elasticity of pesticide use mentioned above must be treated with great care.

4.4 Results of Danish research on pesticide use

An overview

As illustrated in Table 2.2, pesticide use in Denmark is rather low, compared with other countries. Most important are herbicides and fungicides (see Table 4.8). Denmark has committed itself in the 'Action Plan' to reducing pesticide use. Both the volume and the number of treatments will have to be reduced by 25% in 1990, and by 50% in 1997 compared with the period 1981-85 (Dubgaard, 1990). The Danish government has opted for a system of administrative taxes or financial levies. Moreover, there has been a study on the effects of incentive or levies on pesticides (Dubgaard, 1991). The administrative tax is too low to have any measurable effect on pesticide use. In 1990 the financial levy amounted circa 3% of the expenses on pesticides and was mainly used for research, while part ended up in the government budget.

Table 4.8 Pesticide use in Denmark during the period 1985-1990 in 10^3 kg of active ingredient

Pesticide	1985	1986	1987	1988	1989	1990
Nematicides	113	101	48	73	86	85
Herbicides	4 244	4 031	4 117	3 988	4 276	3488
Fungicides	2 373	1 821	1 237	1 310	1 516	1660
Insecticides	337	311	215	223	306	313
Growth regulators	329	363	281	236	335	871
Others	12	11	9	17	11	10
Total	7 408	6 638	5 907	5 847	6 530	6427

Source: Miljostyrelsens Kemikalienspektion, 1990

Recently published statistics from the Environmental Protection Agency show that in 1990 the amount of active ingredients used dropped by 18% (compared to the period 1981-85), but the calculated number of treatments had increased by 33%. This illustrates that the initial objectives of the Action Plan have not been reached. This could be one of the reasons that the Danish government is now trying to have the targeted 50% reduction in the number of treatments removed from the Action Plan (Dubgaard, 1992, pers.comm.).

The study into the effects of incentive levies departed from a fixed levy per standard dose applied per hectare (Dubgaard, 1991). The amount of this levy can, by way of a standard dosage, be converted into a levy (amount) per kg of active ingredient. There are large differences in taxes per kg active ingredient. Toxicity and persistence might have been more likely candidate criteria for varying levies, but were disregarded. The Danish government's policy on authorizing chemicals has already succeeded in removing the most hazardous chemicals from the market. The environmental hazard posed by the remaining chemicals is less alarming.

In the Danish study (Dubgaard, 1987, 1991) two different economic approaches were chosen. The first was based on damage-threshold models. (For the theory behind this type of model, see Section 3.3). The second was an analysis using econometric models, which allow historical developments to be analysed. The essence of this method was discussed in Section 3.5. The method used in Denmark was based on an ad-hoc model.

Calculation using damage-threshold models

The principle of an economic damage-threshold is that it indicates the level of disease at which it becomes cost-effective to apply a treatment. To be able to work out the damage threshold, the product prices and the cost of chemical treatment must be known. These models can be used to assist farm management.

The Danish researchers used damage-threshold models to run simulations and interpreted the results on an aggregated level. To be able to do such an analysis, one needs to have data on the varying pressure of diseases and the effects of treatments on different crops. The data used for this had been collected from experimental fields throughout Denmark, similar to the research done in Sweden and described in Section 4.2.

Dubgaard (1991) sketches the conceptual model that combines the results of both the model simulations and the data on the experimental fields. Figure 4.1 shows this conceptual model. On the horizontal axis the area of a particular crop is given, in order of decreasing 'disease level' (which means the nearer to the origin, the more profitable the crop treatment). The costs and profits of the treatment per hectare are given on the vertical axis. Curve R gives the revenues acquired by treating an extra hectare. Line C represents the costs of treatment per hectare.

At the point where C and R intersect, the additional costs of treating one extra area unit equal the additional revenues. From the horizontal axis it can be read that in this situation it is economically profitable (cost-effective) to treat A_1 hectare of crop with chemicals. The imposition of a levy will result in higher treatment costs, which is reflected by line C + tax in Figure 4.1. This will cause the treated area (and the intersection) to shift from A_1 to A_2.

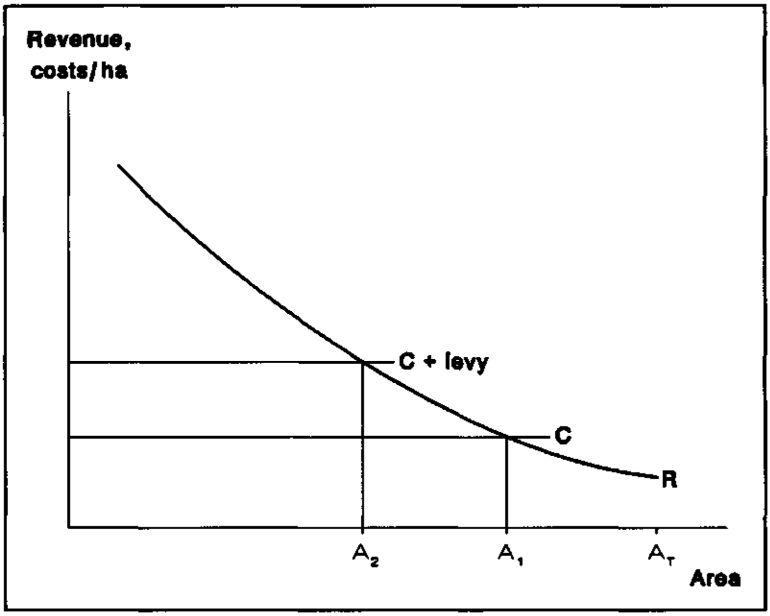

Fig. 4.1 Conceptual model used in Danish research to illustrate the effects of a pesticide tax on the area of application[1)]

1) Explanation:
A_T = total area under a particular crop
A_1 = area with pesticide application; no levy
A_2 = area with pesticide application; with a levy on pesticides
C = costs of pesticide application (per ha)
R = revenue from pesticide application (per ha)
Source: Dubgaard (1991)

In addition to the shifts, as shown in Figure 4.1, substantial price increases of pesticides will have other effects. For instance, they may be an incentive for farmers to take a different look at crops and consider adopting other methods, such as the use of management systems, or improving spraying equipment. Together, these effects are termed the "induced technological change". Because relevant data are scarce, it is impossible to calculate this change. To determine the induced technological change, the Danish researchers used estimates made by experts in crop protection.

Two levy amounts were investigated: 100 and 200 Danish Kroner per standard dose per hectare (30 and 60 Dutch guilders respectively). They caused the price of pesticides to increase by an average of 60% and 120% respectively. It turned out that the increase in insecticide price was about three times that of herbicides and fungicides (Dubgaard, 1987).

Crop protection experts 'guestimated' the reduction of pesticides use by 'induced technology change' to be 15% and 25% for price increases of 60% and 120%, respectively.

The results of the estimates and of the model calculations were combined, resulting in total reductions in pesticide use of 20-25% and 40-45% for price increases of 60% and 120% respectively, which comes down to a price elasticity of -0.3 for the demand for pesticides (Dubgaard, 1987). A recent recalculation indicated a price elasticity between -0.2 and -0.3, with rather low (absolute) values for herbicides (Rude, 1992, pers.comm.).

Calculation by way of econometric methods

The same Danish study used econometric methods to investigate the observed behaviour of farmers to obtain reference material for the above-mentioned findings. For that purpose regression equations based on annual data on prices and pesticide use in the 1971-1985 period were estimated. In the regression equations the average number of treatments per hectare were reflected as being a function of the index prices of pesticides and of a trend variable.

The price elasticities for herbicide and fungicide/insecticide were found to be -0.69 and -0.81 respectively. These price elasticities are substantially higher than the results found using the damage threshold models.

Dubgaard (1987; 1991) noted that the results were aggregated to two groups, because statistical data were only available on these two groups. Combining fungicides and insecticides was problematical, because the use of these chemicals did not increase equally. Moreover, estimation of the trend variable compounded the unreliability of the estimates.

Notwithstanding the doubts expressed by the researcher about the results (also in connection with the multicollinearity problems), the results must be regarded as being indicative of producers' long-term willingness to adapt to prices of pesticides: producers do react to price changes.

4.5 Results of German research on pesticide use

Pesticide use in West Germany is quite similar to Sweden and Denmark, although at an higher level. Moreover, reductions in amounts used are less clear in West Germany, especially for fungicides (see Table 4.9). The government is trying to reduce the number of authorized pesticides by applying more strict rules (Gifap, 1990).

Schulte (1983) investigated the effects of reduced application of fertilizers and pesticides on farmers' incomes. Among the instruments he studied were the tax on nitrogen in fertilizers and the tax on fungicides. He highlighted the interaction between the input of fertilizers and pesticides (see also Section 3.4).

Table 4.9 Pesticide use in West Germany during the period 1979-1987 in 10^3 kg of active ingredient

Pesticide	1979	1981	1983	1984	1985	1986	1987
Herbicides	20 510	19 507	19 339	18 843	17 390	18 630	16 967
Fungicides	7 112	7 012	7 572	8 546	8 491	8 689	9 206
Insecticides	2 341	2 405	2 152	2 331	1 566	1 456	1 220
Others	3 687	2 871	2 287	2 675	2 606	2 609	2 464
Total	33 650	31 795	31 350	32 395	30 053	31 384	29 857

Source: Industrieverband Pflanzenschutz, 1988

LP models were constructed for five farms, differentiating between factors such as farm size, region, etc. The farms were: three arable farms (in Rheinland, Bayern and Schleswig-Holstein), an intensive livestock farm in Südoldenburg, and a mixed farm in Hessen. Table 4.10 shows the figures resulting from the investigation on the tax on fungicides. Imposition of a 100% levy will substantially reduce the input of fungicides. For a mixed farm this would mean that fungicides will no longer be applied. The effects not only result in changes in cultivation methods but also in changes the cropping plan. Table 4.11 shows the impacts on incomes. In this table income loss is subdivided into the levy paid and the income loss caused by changes in yields and costs. The levy paid corresponds with the pesticide use (Deutsche Marks) shown in Table 4.10 multiplied by the appropriate levy (%/100).

Table 4.10 The effect of a levy on fungicides (in % of the price) on the use of fungicides (DM, per farm expressed in prices relating to no levy) for five German farms; the reduction in % is given in brackets

Model	Levy (%)								
	0	100		200		300		400	
Rheinland	8090	4490	(45)	4480	(45)	3440	(58)	1880	(77)
Bayern	7370	2400	(67)	2400	(67)	0	(100)	0	(100)
Schleswig-Holstein	13110	2570	(80)	520	(96)	520	(96)	0	(100)
Südoldenburg	2670	1490	(56)	360	(86)	360	(86)	360	(86)
Hessen	1250	0	(100)	0	(100)	0	(100)	0	(100)

Source: Schulte (1983)

From Table 4.11 it appears that the levy-induced losses are bigger for specialized arable farms than for the intensive livestock farm in Südoldenburg and the mixed farm in Hessen. The income losses of the arable farms vary with region. The input of fungicides appears to be most cost-effective on the farm in Rheinland: even when high levies are imposed, fungicide use remains high. For the farm in Rheinland this means that income losses caused by very high levies (from 200%) are higher than those found in other regions.

Table 4.11 The effect of a levy on fungicides (in % of the price) on the income[1] (DM per farm) for five German farms; total income losses as % of labour income before the levy is imposed; divided into levies paid and income loss after remuneration (DM)

Model	Labour income before levy	Income loss due to levy (%)			
		100	200	300	400
Rheinland	55 400	11%	19%	26%	31%
- levy paid		4490	8970	10310	7500
- effect on income		1500	1510	4040	9800
Bayern	64 300	7%	11%	13%	13%
- levy paid		2400	4800	0	0
- effect on income		2170	2170	8430	8430
Schleswig-Holstein	64 390	14%	16%	17%	17%
- levy paid		2570	1030	1550	0
- effect on income		6160	9570	9570	11180
Südoldenburg	57 330	4%	5%	6%	7%
- levy paid		1490	730	1090	1460
- effect on income		700	2400	2400	2400
Hessen	25 640	2%	2%	2%	2%
- levy paid		0	0	0	0
- effect on income		510	510	510	510

Source: Schulte (1983)
1) Effects on income after restitution of the levy

If the levy is excluded from the calculations, the income effects can be solely ascribed to changes in cultivation method and cropping plan as well as to the associated changes in input/output relations. These income effects are mentioned in Table 4.11 under the heading "effect on income". It appears that the arable farm in Schleswig-Holstein suffers the biggest income loss at all levy amounts. From Table 4.10 it appears that fungicide use in this model farm decreases dramatically even at a levy of 100%. Although this farm's income is obviously very dependent on fungicide use, the input of fungicides seems to become unprofitable fairly soon. This is to do with Schleswig-Holstein having less favourable conditions (particularly poor soil fertility) than the two other arable farming regions, which is why the input of nitrogenous compounds needs to be fairly high. In Schleswig-Holstein it appears to become attractive to reduce fungicide use substantially even at a low tax, because even then relatively much nitrogen is saved (Schulte, 1983).

4.6 Discussion and conclusions

It is interesting to compare the reduction targets and time schedule of Sweden, Denmark and the Netherlands. We will ignore soil disinfectants and the horticultural sector of the Netherlands. Both Sweden and Denmark have set the first round of reduction targets at the year 1990 and relative to the period 1981-85. However, the targets were quite different: 50% for Sweden and 25% for Denmark. These reductions had to be reached within a period of about 4 years. Moreover, it is remarkable that the country with the largest target reduction has the lowest use of active ingredient per hectare (2.3 and 2.9 kg a.i. per hectare for Sweden and Denmark, respectively). Future targets are a 75% reduction for Sweden and a 50% reduction for Denmark, both for the year 1997 and compared with the 1981-1985 level. This would bring these countries to application levels of respectively 0.56 and 1.45 kg a.i. per hectare in 1997.

By comparison, in the Netherlands the targeted reduction is 25% compared with the average of the period 1984-88. This target has to be reached in 1995 and within a period of four to five years. The next step is to have reduced the use of active ingredients by 39% (compared with the reference period 1984-88) by the year 2000. Because the Netherlands starts at a much higher level of active ingredient per hectare (7.7 kg a.i. on arable land), compared with Denmark and Sweden, it seems that it is not the level of pesticide use that is the most important factor determining the reduction percentages but 'reasonable targets' from a political perspective. The targeted level of pesticide use in the Netherlands (4.7 kg a.i. per hectare) is twice as high as the reference level for Sweden in the period 1981-85. Reductions are set without a clear insight in the actual environmental costs of pesticide use.

Although it is not absolutely clear from the reported research how much price changes will influence pesticide use, the results are certainly interpretable. The levies on pesticides being imposed in Sweden amount to an average price increase of 40%. The main purpose of the levies is to finance activities other than crop protection or conservation of the environment. The objective of the Swedish policy on crop protection was to halve pesticide use (in kilograms) by 1990, relative to the average use in 1981-1985. This objective was nearly reached. It is difficult to determine the influence of each individual factor. However, it seems that the levy has had only minor influence on pesticide use. Yet, in the Swedish situation the levy is thought to have more impact on the use of fungicides and insecticides than on herbicide use.

The Swedish study into the possibilities and effects of reducing pesticide use enables the level at which a levy will succeed in achieving a certain reduction to be determined. The effect of reducing the area treated with pesticides by about one-third was investigated. It was found that one additionally treated hectare should provide an increase of revenue equivalent to 325 Dutch guilders. Conversely, this means that a levy of 325 Dutch guilders per treated hectare (standard dosage) would reduce the area treated with pesticides by 33%. This comes down to an implicitly calculated price elasticity of circa -0.2.

On the basis of the information given in this chapter, the price elasticity of the demand for pesticides lies between -0.2 and -0.8, most results lying between -0.2 and -0.5.

Results deviating from this are either unreliable or less relevant in terms of the method used. The results found for Dutch arable farms indicate price elasticities of about -0.4 to -0.5. In a Danish study into the effects of levies on pesticides two approaches were followed. The first indicated a price elasticity of -0.2 to -0.3, whereas the second resulted in a price elasticity of about -0.7 for the demand for herbicides and -0.8 for the demand for fungicides and insecticides.

The German study focused, among other things, on the effects of taxes on fungicides on farm incomes. This was done using an LP model. The study, in which levies of 100%, 200%, 300% and 400% of the fungicide price were investigated, revealed that a levy of 100% will at least halve the use of fungicides. Implicitly, this is a price elasticity of -0.5. Specialized arable farms suffer most from the levy. Income losses for the arable farms within this group differ per region. This is largely attributable to differences in natural conditions.

5. ECONOMIC ANALYSIS WITH ECONOMETRIC MODELS

5.1 Introduction

The purpose of this chapter is to elucidate the influence of the price of pesticides on the demand for pesticides in Dutch arable farming and in Dutch horticulture. This relation is reflected in the own price elasticity of the demand for pesticides. Short-term (one year), medium-term (three years) and long-term (ten years) price elasticities will be investigated, using econometric models of the arable sector and the horticulture sector.

The econometric approach produces a model composed of the quantified relationships between the key variables of interest: price of pesticides, demand for pesticides, demand for other variable inputs (energy, seed, etc.), supply of the output, demand for capital. In Section 3.5 this model of the production behaviour of farm households was developed, starting from neoclassical theory. Therefore, all the relationships within the model have a causal interpretation. The model is quantified by applying statistical techniques to historical data. We developed two versions of this model, to describe how the production side of the Dutch arable sector and of Dutch horticulture are assumed to have worked in the past.

This chapter is organized as follows. In Section 5.2 the model is specified. Using the demand function for pesticides the effects of a pesticide levy on farmers' income can be calculated. This is described in Section 5.3. The models of the arable sector and the horticulture sector are described in Sections 5.4 and 5.5, respectively, paying particular attention to the data used. The price elasticities are given and discussed in Section 5.6. The most important conclusions are summarized in Section 5.7.

5.2 Specification of the model

Farmers are assumed to operate under short-term profit-maximizing behaviour, with respect to two variable inputs. The two inputs are pesticides and other variable inputs (energy, fertilizer, seed, etc.). In addition to the variable inputs, one quasi-fixed input and two fixed inputs are distinguished. The quasi-fixed input (capital) is fixed in the short term, but adjusts partially to the optimal level after one year. The fixed inputs (labour and land) are not subject to the profit maximization process. The labour input is not very sensitive to price changes; see Thijssen (1988). Therefore, we assume that labour is exogenous. The changes in the area of land used per farm are very sensitive to the availability of land in the neighbourhood of that farm. No information is available on the latter, therefore we also treated land as an exogenous variable.

According to duality theory the short-term profit function (or income function) represents the production technology for a given capital stock (see Section 3.5). We decided to use the quadratic form for empirical analysis. The profit function is normalized by the output price, to ensure that the profit function is linearly homogenous in prices. We also assumed that the profit function is linearly homogenous in the quasi-fixed input and the fixed input; therefore, using duality theory, the corresponding production function is linearly homogenous in inputs (Lau, 1978: 164). This assumption is necessary at the aggregate level, because only constant returns technologies satisfy linear aggregation (Chambers, 1988:188). The normalized profit function is written as:

$$\pi = \alpha_0 + \alpha_1 p_x + \alpha_2 p_v + \alpha_3 k + \tfrac{1}{2}\alpha_4 p_x^2 + \tfrac{1}{2}\alpha_5 p_v^2 + \alpha_6 p_x p_v + \alpha_7 p_x k$$
$$\alpha_8 p_v k + \alpha_9 p_x g + \alpha_{10} p_v g + \alpha_{11} g + \tfrac{1}{2}\alpha_{12} k^2 + \alpha_{13} p_x t +$$
$$\alpha_{14} p_v t + \alpha_{15} t + \alpha_{16} k t \tag{5.1}$$

where π is the profit normalized by the output price and the labour volume; p_x is the ratio of the price of pesticides to the price of the output; p_v is the ratio of the price of the other variable inputs to the price of the output; k is the quasi-fixed input (buildings and machinery) divided by the labour volume; g is land divided by the labour volume; t is technology. The profit function is specified in such a way that the resulting demand functions for pesticides, other variable inputs and capital are linear in all the variables. If the normalized profit function satisfies certain regularity conditions, it is dual to the production function and its parameters contain sufficient information to describe the farm's production technology at profit-maximizing points in the set of production possibilities (see Section 3.5). Testable conditions of regularity are: the profit function decreases in the normalized prices of the variable inputs; increases in the quasi-fixed input; is convex in the normalized prices of the variable inputs ($\alpha_4 > 0$ and $\alpha_5 > 0$) and is concave in the quasi-fixed input ($\alpha_{12} < 0$).

By Hotelling's Lemma, if we differentiate the profit function with respect to the relative price, we obtain demand functions for the variable inputs

$$x = -\alpha_1 - \alpha_4 p_x - \alpha_6 p_v - \alpha_7 k - \alpha_9 g - \alpha_{13} t \tag{5.2}$$

$$v = -\alpha_2 - \alpha_5 p_v - \alpha_6 p_x - \alpha_8 k - \alpha_{10} g - \alpha_{14} t \tag{5.3}$$

where x are pesticides per labour unit; and v are the other variable inputs per labour unit. The demand function for pesticides gives the relation between the demand for pesticides and the normalized prices of pesticides and other variable inputs, capital, land and technology. The demand function for the other variable inputs gives the relation between the demand for other variable inputs and the normalized prices of pesticides and other variable inputs, capital, land and technology.

Using the definition of the normalized profit ($\pi = q - p_x x - p_v v$), the optimal output for a normalized profit function is:

$$q = \pi - p_x \frac{\partial \pi}{\partial p_x} - p_v \frac{\partial \pi}{\partial p_v} \tag{5.4}$$

where q is the output per labour unit. The output supply function, therefore, is the sum of Equation (5.1), Equation (5.2) multiplied by p_x, and Equation (5.3) multiplied by p_v:

$$q = \alpha_0 + \alpha_3 k - \tfrac{1}{2}\alpha_4 p_x^2 - \tfrac{1}{2}\alpha_5 p_v^2 - \alpha_6 p_x p_v + \alpha_{11} g + \tfrac{1}{2}\alpha_{12} k^2 +$$
$$\alpha_{15} t + \alpha_{16} k t \tag{5.5}$$

The supply function of the output gives the relation between the supply of the output and the normalized prices of pesticides and other variable inputs, capital, land and technology.
The quasi-fixed input (capital) is fixed for the period of one year. After one year the quasi-fixed input adjusts according to the partial adjustment theory; see Section 3.5. The resulting demand function for capital at the end of the period is a function of the optimal capital stock and the capital stock at the start of the period.

$$k_{t+1} = m\ k_t^* + (1\text{-}m)\ k_t \tag{5.6}$$

where k_t^* is the optimal capital stock and m is the adjustment parameter, which should be larger than zero and smaller than one. The optimal capital stock can be calculated using the well-known static condition that the marginal return to capital is equal to the user cost of capital:

$$\frac{\partial \pi_t}{\partial k_t} = \alpha_3 + \alpha_7 p_{xt} + \alpha_8 p_{vt} + \alpha_{12} k_t + \alpha_{16} t = p_{kt} \tag{5.7}$$

where p_k are the costs of the quasi-fixed input. Combining Equations (5.6) and (5.7), we obtain the demand function for capital

$$k_{t+1} = m\ (p_{kt} - \alpha_3 - \alpha_7 p_{xt} - \alpha_8 p_{vt} - \alpha_{16} t)/\alpha_{12} + (1\text{-}m)\ k_t \tag{5.8}$$

The demand function for capital gives the relation between the demand for capital and the normalized prices of pesticides and other variable inputs, capital costs, capital, land and technology (all lagged by one year).

The models of the average farms of the two sectors consist of Equations (5.2), (5.3), (5.5) and (5.8). The demand functions are linear in the variables. Therefore the elasticities are not constant in time, but depend on the level of the variables. In agriculture there is usually a considerable time lag between the decision to produce and the actual realization of production. Hence, producers base production plans on price expectations. In this study the output price is used with a lag of one year. This implies that producers have a rather simple form of price expectation.

There are many cross-restrictions on the parameters of the model. This additional information is extremely useful because the models are estimated using aggregate data over a short period of time. Another advantage of the strong theoretical framework of the model is its internal consistency. For example, if the demand for pesticides and the capital stock are complements the parameter α_7 in Equation (5.2) should be negative. However, if pesticides and the capital stock are complements, the relation between the price of pesticides and the demand for capital stock should also be negative. The parameter of the price of pesticides in the demand function for the capital stock is equal to - m α_7/α_{12}. This parameter is negative if α_7 is negative and if the theoretical restrictions are satisfied ($0 < m < 1$ and $\alpha_{12} < 0$).

5.3 Effects on income

Using the econometric model of Section 5.2 the income effects for the farmers of a regulatory levy can be calculated directly from the profit function. This is the approach used in this chapter. Another approach is to calculate the effects on income by using the demand function for pesticides. That approach is unavoidable when the profit function is unknown. Other studies (see Chapter 4) mostly only give own price elasticities of pesticides. Using these elasticities and the amounts and prices of pesticides, and assuming a functional form, a demand curve for pesticides can be derived.

Assuming a linear relation between the demand and the price of pesticides (see also Equation (5.2)):

$$x = \beta_1 + \beta_2 \, p_x \qquad \beta_1 > 0, \ \beta_2 < 0 \tag{5.9}$$

where x is use of pesticides, and p_x is the price of pesticides relative to the output price. This relation is depicted in Figure 5.1 by the line DD'.

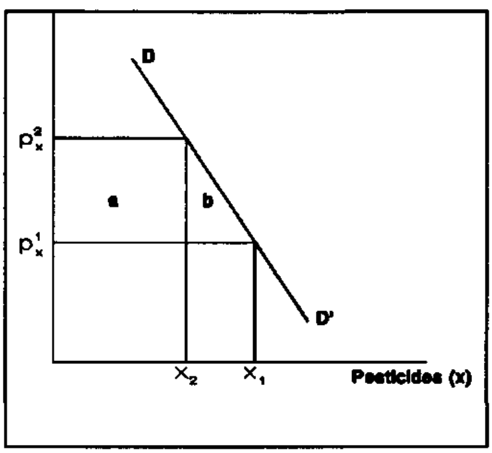

Fig. 5.1 The demand curve for pesticides

The computation of the two parameters β_1 and β_2 is straightforward when information is available on the average price elasticity (e), the average amount of pesticides used ($\bar{x}$), and the average price of pesticides ($\bar{p}_x$):

$$\beta_1 = \bar{x}\,(1\text{-}e) \text{ and } \beta_2 = e\,\bar{x} \,/\, \bar{p}_x$$

The effect of a price change of pesticides, say from p_x^1 to p_x^2 and assuming that output prices are constant, gives an effect on gross income that can be measured along the demand curve of pesticides, and is equal to areas a + b in Figure 5.1, because by Hotelling's Lemma the amount of pesticides is the first derivative of the profit function to the price of pesticides (see also Boadway & Bruce, 1984, pp.220-223). The total revenue from the levy (which is equal to area a), minus the administration costs will be returned to the producers. Therefore, the net income effect equals area b, if the administrative costs are ignored. This approach makes it easy to calculate the effects on income if only the own-price elasticity of pesticides and the amounts and prices of pesticides are known.

In this chapter we calculate the income effects using the estimated models for Dutch arable farming and horticulture. But these simulations give the same results in the short term as described by Figure 5.1. Differences could emerge in the longer term, because of a shift of the demand function for pesticides in response to adjustments in the capital stock.

5.4 The model of the Dutch arable sector

This model is based on data covering the period 1970-1988. Most of these data were derived from "Bedrijfsuitkomsten van de Landbouw (BUL)(farm results)" (LEI, various years). In the BUL six groups of average farms are described: large farms in four areas (northern clay area, the Peat Colonies and the northern sand area, central clay area, southwestern clay area) and small farms in two areas (clay area, the Peat Colonies and northern sand area).
We used the following data:
- calculated costs of pesticides
- calculated costs of other inputs
- labour (skilled farm workers)
- book value of assets
- area farmed

Data from the BUL were used to calculate the prices of crops per region. Prices of pesticides, prices of other inputs and prices of capital goods were derived from "Maandstatistiek van de landbouw"(Monthly Agricultural Statistics) (CBS, various years) and from "Landbouwcijfers" (Agricultural Statistics) (LEI, various years). Because the period which these data relate to was rather short (only 18 years), only one 'other variable input' was worked out. The price of this input differs per region because the share of various components in the total input is different. Because of the lack of data, only one input of pesticides was distinguished. All amounts were measured per unit of skilled labour.

We constructed a model with four equations that covers the Dutch arable sector as a whole. The equations are: demand equations for the amounts of pesticides, of other inputs and of capital goods, and a supply equation for the supply of end products (outputs). We opted for one model for the whole Dutch arable sector because the lack of information made it impossible to estimate a model for each separate group of farms. To make up for differences between the groups, we added a dummy variable to the various equations of each group. This type of model is known in the literature as the 'dummy variable model'. The model is estimated by a estimation technique (SUR) which takes account of the possibility that the error terms of the equations may be correlated (Judge et al., 1988).

The estimation results do not contradict the theoretical assumptions. The profit function is convex in both the price of pesticides and other variable inputs ($\alpha_4 > 0$ and $\alpha_5 > 0$) and concave in the quasi-fixed input ($\alpha_{12} < 0$). Therefore there is a negative relationship between pesticide price and the demand for pesticides; see Table 5.1. The adjustment parameter of the demand function for capital goods is equivalent to 0.54 (= 1 -0.46; see Table 5.1), and therefore also complies with the assumptions made.

The estimated model yields many relationships between inputs and prices and between inputs themselves. We used the model to calculate the price elasticities of pesticides. To illustrate how the model works, Table 5.1 shows key elasticities in the calculation of the price elasticities of pesticides for the average arable farm.

Table 5.1 Elasticities based on the model of the Dutch arable sector (standard errors in parentheses)

	Price pesticides		Capital lagged one year		Technical change	
Pesticides	-0.21	(0.15)	0.09	(0.09)	0.06	(0.01)
Other variable inputs	-0.03	(0.05)	-0.08	(0.06)	0.02	(0.01)
Supply	-0.02	(0.01)	0.01	(0.01)	0.03	(0.01)
Capital	-0.04	(0.05)	0.46	(0.10)	0.05	(0.02)
Income	-0.06	(0.03)	0.03	(0.01)	0.05	(0.01)

The relationship between the demand for pesticides and pesticide price is negative: -0.21. This means that a 1% rise in the pesticide price will lead to the demand for pesticides falling by about 0.21%. This figure is not completely reliable. However, the standard deviation sheds some light: the elasticity should lie between -0.06 and -0.36 (with a degree of certainty of about 66%).

The relationship between the demand for pesticides and the amount of capital goods on the average arable farm is found to be positive: there is complementarity. This means that an increase in capital goods leads to a greater pesticide use; however, the elasticity is small. Because of the complementarity observed, the demand for capital goods is negatively related to the price of pesticides. This elasticity is also small. The relationship between the demand for the other variable inputs and pesticides is also complementary. The amount of capital will adjust to price changes in about two years' time.

A rise in the price of pesticides will not only reduce the use of pesticides and of other variable inputs, but also the supply of the output and the farm income. If, however, the levy on pesticide use is restituted to the sector and the levy is low, income will remain stable.

Technological change greatly influences the demand for pesticides. Every year pesticide use per unit of family labour has increased by an average of 6%; this cannot be explained by changes in the price of inputs and outputs or by changes in the amount of capital goods and land available on the average arable farm.

5.5 Model of the Dutch horticultural sector

This model was also estimated on the basis of data for the period 1970-1988. Most of these data were derived from the publication "Rentabiliteit en Financiering"(Profitability and Financing) (LEI, various years), which is issued for the various categories in horticulture. This publication describes an average farm in six categories of horticultural farms: floriculture, growing of pot plants, field vegetable farming, greenhouse vegetable growing, fruit growing and flowerbulb growing. The following data were used:

- calculated costs of pesticides
- calculated costs of other inputs
  (mainly energy, fertilizers, plant material, seeds and hired labour)
- book value assets
- crop area

The prices of crops, pesticides, other inputs and capital goods were derived from "Maandstatistiek van de landbouw" (Monthly Agricultural Statistics) (CBS, various years) and "Tuinbouwcijfers" (Horticulture Statistics) (LEI, various years). Because the data cover a short period, only one output and one 'other variable input' were distinguished. The prices of these differ per category, because the share of the various components differ in the total output and total 'other variable input', respectively. Given the lack of data, only one input of pesticides was distinguished.

We estimated one model with four equations for the whole Dutch horticultural sector. The equations are: demand equations for the amount of pesticides, for the amount of other inputs and for the amount of capital goods, and a supply equation for the output. We applied the same estimation technique to the horticultural sector as we used for the arable sector (Section 5.4). Table 5.2 contains the relevant elasticities. The demand equation for pesticides in the model of the horticultural sector does not contain a trend variable for technological development. There are two reasons for this. Firstly, including of a trend variable in the demand equation would cause the price of pesticides to increase the demand for pesticides. This is a rather unrealistic connection that is the result of the correlation between the trend and the development of the pesticide price. Secondly, the data used in this study do not show an upward trend in the demand for pesticides.

The estimation results do not refute the theoretical assumptions. The profit function is convex in the price of pesticides and the price of the other variable inputs ($\alpha_4 > 0$ and $\alpha_5 > 0$), and concave in the quasi-fixed input ($\alpha_{12} < 0$). As a result, the relationship between the price of pesticides and the demand for pesticides is negative; see Table 5.2. The price elasticity of pesticides is -0.25, with a 66 % reliability lying between -0.06 and -0.44. The adjustment parameter in the demand function for capital goods is equal to 0.12, and therefore also complies with the assumptions made.

In horticulture there is also complementarity between the demand for pesticides and the amount of capital goods. Contrary to arable farming, in horticulture it is possible to substitute between the other variable inputs (energy, fertilizer and labour) and pesticides. A rise in the price of pesticides results in a rise in the demand for other variable inputs. Therefore, when there is a rise in pesticide prices the output will rise as well.

Table 5.2 Elasticities based on the model of the Dutch horticultural sector (standard errors in parentheses)

	Price pesticides		Capital lagged one year	
Pesticides	-0.25	(0.19)	0.49	(0.25)
Other variable inputs	0.04	(0.01)	0.49	(0.11)
Supply	0.01	(0.01)	0.48	(0.36)
Capital	-0.01	(0.01)	0.88	(0.07)
Income	-0.04	(0.03)	0.44	(0.61)

If a levy is imposed, farmers' incomes will fall. If, however, the levy is paid back to the sector, then a low levy will not change incomes in the sector. Contrary to the situation in arable farming, in horticulture the amount of capital goods is mainly determined by the amount of capital goods already available.

5.6 Short-term and long-term effects of a levy on pesticides in the Netherlands

With the help of the models discussed in Sections 5.4 and 5.5, it is easy to determine the short-term price elasticities of the demand for pesticides: they are equal to the price elasticities in the equations of the demand for pesticides. In the medium term, the amounts of capital goods will also partially adjust to a change in the pesticide price. This in turn influences the demand for pesticides. The medium-term price elasticity is therefore expected to be larger than the short-term price elasticity. In the long run, the amounts of capital goods will fully adapt to the changed pesticide price.

Before embarking on a discussion of the price elasticities found, we must stress that the findings have to be interpreted with great care. This study is a first attempt to gain some insight into the size of these price elasticities. The model of the horticultural sector pays relatively little attention to the large differences that exist between the various categories in the sector. For a more reliable result, all relevant data on individual farms will have to be thoroughly investigated. This is also true for the arable sector.

The short-term and the long-term price elasticities in the arable sector are -0.21 and -0.22, respectively; see Table 5.3. The difference is so small because a decrease in the amount of capital goods hardly influences the demand for pesticides. The elasticity is 0.09 (Table 5.1).

Table 5.3 Own-price elasticities of the demand for pesticides in the Netherlands (standard errors in parentheses)

	Arable sector		Horticulture sector	
	Pesticides	Income	Pesticides	Income
Short-term	-0.21 (0.15)	-0.06 (0.03)	-0.25 (0.19)	-0.04 (0.03)
Medium-term	-0.22 (0.15)	-0.06 (0.03)	-0.26 (0.19)	-0.05 (0.03)
Long-term	-0.22 (0.15)	-0.06 (0.03)	-0.29 (0.19)	-0.08 (0.03)

In his study on the arable sector, Aaltink (1992) based his models on a profit function and a cost function. The difference between these two functions is that a cost function assumes that the amount of production is fixed in the short term. In a year's time the amount of output will have partially adjusted. Aaltink used the same data set for determining the profit function, but normalized the prices and profits by the price of the other variable input. The profit function approach yielded a short-term price elasticity of -0.39 (0.16), and the cost function approach showed a price elasticity of -0.13 (0.10) (standard errors in parentheses). In the cost function approach the output is constant in the short term; this results in a lower price elasticity than when the profit function approach is used. In both approaches, the price elasticities remained more or less the same in the long term.

So, it became clear that the profit function approach is influenced by the way it is normalized, either by the price of the output (our strategy) or by the price of the other variable input (Aaltink's strategy). However, the differences between the short-term price elasticity of pesticides are not significant. Summarizing, the price elasticity of pesticides in the arable sector is small in both the short and long terms.

The same is true for the horticultural sector. Here the short-term and long-term price elasticities are -0.25 and -0.29, respectively; see Table 5.3. Because the influence of changes in pesticide prices on the demand for capital goods is practically negligible, the difference between short-term and long-term price elasticities is minimal. Table 5.2 shows an elasticity of capital for the price of pesticides of -0.01.

In the short term, the average farm income will decrease as a result of a levy on pesticides, both in arable farming and in horticulture. In arable farming the elasticity is -0.06, which means that a 1% rise in the price of pesticides will cause a 0.06 % drop in income. In horticulture, the short term elasticity is -0.04, whereas the income loss will increase slightly in the long term. However, if the levy on pesticides is restituted, a low levy will not change incomes in either sector.

5.7 Conclusions

In arable farming, the short-term and long-term price elasticities of pesticide use are -0.21 and -0.22, respectively. Small alterations to the model specifications result in a short-term elasticity of -0.39; the elasticity remains more or less the same in the long term. For the horticultural sector short-term and long-term elasticities are -0.25 and -0.29, respectively. The related standard deviations are reasonably high, so the findings will have to be interpreted with great care.

On the basis of these elasticities it is possible to calculate how much the average Dutch farmer will reduce pesticide use if a levy is introduced on pesticides. A long-term price elasticity of -0.22 for arable farming means that a 1% rise in pesticide price will result in pesticide use falling by 0.22%. According to the model calculations for the horticultural sector, in the long term a 1% price increase will lead to pesticide use falling by 0.29%.

This study used data from the arable and horticulture sectors in the Netherlands during the last two decades. Therefore, the elasticities calculated refer to relatively small price changes, and hence, to relatively small levies. In addition to trends in prices, there are other important differences between the past and present. For instance, the LCPP will encourage farmers to reduce pesticide use by means of education and information. Regulatory measures are also important. In potato growing, soil disinfection used to be compulsory treatment. Clearly, in such cases price changes are not the answer. In the future, soil disinfection will no longer be mandatory. It is likely that by means of persuasive measures the LCPP will lead to greater price elasticities than the ones given in this chapter.

The future importance of the role of technological development should also be considered. Technological development appears to be crucial to the demand for pesticides. For arable farming this can be seen in Table 5.1.

So far, every year there has been an average increase of 6% in pesticide use per unit of family labour, which is explained neither by changes in the price of inputs and outputs nor by changes in the amount of capital goods and land available on the average arable farm. If the price of pesticides is dramatically increased, there is likely to be a dramatic shift to technological development aimed at economizing on pesticide use. The technical possibilities for such a development are already available, as will be indicated in Chapter 6. By adopting innovative technologies, the long-term price elasticities of pesticides will become much greater than those given in Section 5.6.

In the short term the imposition of a levy will decrease average incomes both in arable farming and in horticulture. In the long term, income loss will increase slightly. If the levy on pesticides is restituted to the sector, however, a low levy will have little or no impact on incomes.

6. ECONOMIC ANALYSIS WITH LINEAR PROGRAMMING MODELS

6.1 Introduction

Linear programming (LP) is frequently employed to simulate the economic decision-making process at farm level (see Section 3.4). Environmental aspects of agricultural production can also be incorporated into this method (Kneese and Bower, 1979), for two reasons: linear programming provides an explicit and efficient optimum-seeking procedure; and once the program has been formulated, the results obtained by changing variables of interest can be rapidly calculated. This chapter presents the use of linear programming to assess the implications of a levy on pesticides. Familiarity with the basic characteristics of linear programming is assumed.

The individual farm was chosen as the starting point to develop the LP model used in this study, because it is at this level that the actual decisions are made about cropping pattern, production intensity, etc. The environmental effects of production can only be assessed in the context of rotation scheme and fertilization practice. Environmental impacts will be influenced by specific natural conditions, such as soil type and groundwater level (De Koeijer and Wossink, 1990). As well as the regular items of production, labour supply and requirements, cultivation operations, investments and financing, the model includes a component incorporating the environmental standards selected for the cropping activities.

The major advantage of using LP models for environmental economic research is that several activities producing the same product can be considered at the same time. In the present study each crop has variants ranging from an intensive to an 'ecological' production system. The environmental impact is represented in the technical coefficients of the process in the linear programming matrix. The financial results are given by means of the gross margin figures in the objective function. With this range of cropping variants it is possible to investigate the effects of a levy system on pesticides.

In Section 6.2 the structure of the linear programming model is presented. Section 6.3 focuses on the assessment of farms representative of the different crop-producing regions in the Netherlands and on the construction of the cropping variants. Afterwards, the results are presented (Sections 6.4 and 6.5) and discussed (Section 6.6).

6.2 Structure of the linear programming model

The general structure of the environmental economic LP model used is shown in Scheme 6.1. The activities x are shown across the top under five headings:
- production activities
- variable operations (options for weed control, late blight control etc.)
- seasonal labour supply
- 0/1 activities representing new machinery for chemical and mechanical crop care
- pesticide use.

The rows of the matrix indicate the type and form of the constraints included:
- total land
- rotation restrictions
- supply of fixed labour
- several coupling restrictions.

Thus, each unit (hectare) of a production activity requires inputs represented by its specific column in the matrix. Among the inputs, the type and amount of chemicals (in kg of active ingredients) related to a production activity is specified. Hence, the gross margin figures of the production activities do not include the costs of these inputs. These are given separately for every chemical, in guilders per kg of active ingredient, and are linked to the production activities by coupling constraints. In this way the linear programming procedure takes account of listing the total use of chemicals, and a levy on these inputs can easily be incorporated by raising their prices. The model also registers the total input of nitrogen. Here, the costs have not been separated, as a levy on N-fertilizer is not considered in the calculations.

As indicated in Scheme 6.1, the linear programming model covers the option of several investments in new machinery, namely: (a) a new spraying device, (b) a new mechanical technique for weed control in potato and (c) a mechanical technique for haulm killing in potato. The innovations considered provide for a reduction in the amounts of pesticides used and their costs. On the other hand, labour and tractor hours increase when the new machinery is adopted. Both effects are accounted for by linking the investments to specific cropping variants using the machinery. The capacity of the new machinery is assumed to be infinite, as expressed by the -999 figures.

The linear programming model optimizes the gross farm result, which is the difference between the total of the gross margins of the crops in the optimal plan minus the costs of pesticides, contract work, annual costs of additional investments and seasonal labour.

The matrix described contains about 200 activities and about 210 constraints. The initial farm situation is specified by about 70 non-zero right-hand side values, depending on the number of crops in the rotation scheme.[1]

We investigated how high the levies need to be to bring about a targeted/fixed reduction in pesticide use. This can be analysed with LP in two different ways: by gradually increasing the price of pesticides (a form of parametric programming; see Gal, 1979) or by including the restrictions in the model and then determining the shadow price of pesticides. We opted for the first approach. This enables optimization per farm per region.

---

[1] The software selected is XA-87, developed for solving linear programming problems on a personal computer. The XA system derives the LP problem formulations from LOTUS 123 files. This way, the advantages of the spreadsheet programme such as formulas, cell references etc., can be used. XA-87 includes a matrix generator option, called LTS (Look To Spreadsheet) which reads and combines spreadsheet files, covering all or part of the problem to be solved. Hence, the normal step of translating the linear programming solver input into MPS files can be omitted as the XA system can directly read a problem formulation from LOTUS 123. The XA programme was run on a 80386 pc with co-processor. Neither of the computations for the present study took more than about 4 minutes cpu time to solve the extended model.

Scheme 6.1 Structure of the LP model

Activities	Production activities	Seasonal labour	Variable operations: methods of control and own mechanisation or contract work	New machinery for crop care 0/1			Chemicals	Right-hand side
	1,...,n	1,...,m	1,...,p	a	b	c	1,...,q	
Constraints Max. hectares	+1							Total land
Rotation constraints	+1							Max. ha of each crop or group of crops
Fixed labour in periods of 14 days	$+a_{i,j}$	-1	$+a_{i,j}$					Available fixed labour in hours
Seasonal labour in periods of 14 days		+1						Available casual labour in hours
Coupling between production activities and var. operations	+1		-1					≤ 0
Coupling between production activities and new machinery	+1 +1 +1			-999	-999	-999		≤ 0 ≤ 0 ≤ 0
Coupling between production activities and chemicals	$+a_{i,j}$		$+a_{i,j}$				-1	≤ 0
Objective function	Gross margins excl. costs of chemicals	Costs per hour	Costs per hectare	Annual costs			Costs per kg a.i.	
				a	b	c		

Pesticide use depends not only on the crops grown, but also on the cultivation method. Therefore, for one particular crop, different cropping variants are distinguished and, in addition, "fallow land" is added. The cropping variants for a specific crop represent different crop protection methods; however, related factors such as cropping frequency, crop variety and fertilization can also be included. With reference to Section 3.4 it can be said that cropping variants form an extension to the 'technology set' (i.e. the 'activities' available at farm level). The extension represents the newest cropping variants, which are not yet widespread in practice. If sufficient data are available from research on cultivation methods, then a crop may have many cropping variants. To keep the model manageable, some cropping variants must be discarded. In the extended LP models each crop has cropping variants ranging from intensive to 'ecological'.

Cropping variants that imply the use of large amounts of pesticides will be made less attractive by levies than those that need less pesticide. Running the LP models with levies of different sizes reveals how much pesticide use will decrease. Each pesticide used, expressed in kg of active ingredients and price, is individually incorporated into the model. In this way, for each category of chemical (fungicides, insecticides, etc.) it can be determined at which level of the levy the LCPP objective is met. The starting point in this determination was the targeted reduction for arable farming for the year 2000 (see Table 2.13).

Each cropping variant has a certain gross margin. Aggregating the gross margins of farm areas of the cropping variants chosen via linear programming, yields the total gross farm result. This result does not equal the farmer's income because the fixed costs are excluded when it is calculated. Varying the size of the levy results in different gross farm results because of a shift to other cropping variants. These differences in farm balance indicate the shifts in incomes caused by the levy. Next, the calculations assumed that the levy paid per farm is fully restituted. Thus, the net income effect caused by the changed price ratio can be established.

6.3 Procedure and data

For the analysis, the Dutch arable farming area was subdivided into 4 regions on the basis of the LEI classification used in (Bedrijfsuitkomsten in de landbouw = BUL) the Farm Account Statistics (LEI, several years). The four regions are: the northern, central and southwestern clay areas, and Peat Colonies (peat area including the northern sandy area). According to the 1988 agricultural census (CBS, 1988), 81% of the crop-growing area (excluding fodder crops) falls within these areas. A distinction was made between large and small farms. One representative large model farm was distinguished per region. Two representative small model farms were selected: one for the clay areas (northern, central and south-western) and one for the Peat Colonies. All farms of 158 SFU (standard farm units) and above were considered to be large; the minimum for a small farm was 79 SFU. This classification resulted in six farm types which are considered to represent Dutch arable farming. Table 6.1 gives an overview of the different cropping areas per farm type, reflected as a proportion of the total cultivated area.

Table 6.1 1988 cropping patterns of 6 Dutch farm types; the most important individual crops expressed as percentage of the total area per farm type

Crop	Larger farms				Smaller farms	
	Northern clay area	Peat Colonies	Central clay area	South-western clay area	Clay areas	Peat Colonies
Cereals	45	18	24	30	38	26
Incl. wheat	30	4	18	23	25	6
barley	14	5	5	8	12	11
oats	1	7	1	0	1	8
Root crops	42	65	50	40	36	61
Incl. seed potato	16	10	13	1	3	3
ware potato	4	3	14	22	13	0
starch potato	1	33	0	0	0	36
sugarbeet	21	19	22	17	20	21
Other	13	17	26	30	26	13

The crops considered in the analysis were wheat (winter crop) from the category "cereals", ware potatoes, starch potatoes and sugarbeet from the category "root crops", and spring-sown onions, peas (to be dried) and seed grass from the category "other". In the study, the area under seed potatoes is included in the category 'area under ware potatoes' because no data are available on environmentally-friendlier cropping variants for seed potatoes. Central in the study is the use of pesticides, which is considered to be the same in ware and seed potato cropping.

In 1988, the crops selected for our study (excluding fodder crops) accounted for 71% of the total arable area in the Netherlands (CBS, 1988).

Table 6.2 presents the cropping patterns on which our study with LP models is based. It is a simplification of Table 6.1 (which was based on actual statistics) and uses the same classification into region and farm size as that table.

In the analysis the six farm types were incorporated in six LP models. To obtain data at a national level the totals of the 6 LP models have to be aggregated. As each model represents an average farm from a particular category, the individual totals per farm type can be multiplied by the number of farms in the category concerned. Dividing the product by the total number of farms considered, gives the average national outcome.

To determine present pesticide use, activities were formulated for all crops presented in Table 6.2, according to the current cropping practice. The data required were derived from "Handbook for Farm calculations" (PAGV, 1989). Subsequently, environmentally-friendlier cropping variants were formulated for the following crops: ware potatoes, starch potatoes, winter wheat, sugarbeet, peas, seed grass and spring-sown onions. For this we used De Buck's (1991) cropping variants for ware potato production in the Central clay area as well as Verschueren's (1991) variants for sugarbeet, winter wheat, peas and spring-sown onions in the same area. De Buck's variants were based on information from CABO-DLO in Wageningen (DLO Centre for Agricultural and Biological Research).

Table 6.2 Cropping patterns of six farm types; share of each crop in cropping plan in % (figures in brackets are hectares)

Crop	Larger farms								Smaller farms			
	Northern clay area		Peat Colonies		Central clay area		South-western clay area		Clay areas		Peat Colonies	
Winter wheat	45	(30)	18	(11)	24	(11)	30	(17)	38	(9)	26	(7)
Ware potato	21	(14)	-		27	(12)	23	(13)	16	(4)	-	
Starch potato	-		46	(28)	-		-		-		39	(11)
Sugar-beet	21	(14)	19	(11.5)	22	(10)	17	(10)	20	(5)	21	(6)
Spring-sown onion	-		-		15	(7)	9	(5)	11	(2.5)	-	
Peas	8	(5)	11	(6.5)	4	(2)	10	(6)	8	(2)	13	(4)
Seed grass	4	(3)	7	(4)	7	(3)	9	(5)	7	(1.5)	-	
Total	100	(66)	100	(61)	100	(45)	100	(56)	100	(24)	100	(28)

The integrated cropping variants for winter wheat, sugarbeet, peas and spring-sown onions, as used by Verschueren, were formulated according to data obtained from the OBS (Onderzoek Bedrijfssystemen/Research Farming Systems) experimental farm at Nagele (Vereijken, 1983-1988; Wijnands and Kroonen-Backbier, 1991). These data were collected during a number of years for comparing current variants with environmentally-friendlier cropping practices. The OBS data were corrected. The yields in kilograms were related to 1985-1989 averages (Janssens, 1991), thus adjusting for weather influences. Since actual yields are usually inferior to those from an experimental farm, they were multiplied by the fraction: "Handbook for Farm Calculations 89/90" to "current OBS". The data from OBS were used for the quantities of inputs; prices were obtained from the Handbook for Farm Calculations (PAGV, 1989). Note that pesticide use of the variants mentioned is not corrected and is thus related to the conditions prevailing on an experimental farm, i.e. to the expertise and insight available on such farms. De Jong (1991), derived the integrated variants for starch potatoes and for seed grass in a similar way from data from the OBS at Borgerswold (Boerma, 1989 and 1990).

Verschueren formulated ecological variants as well. The OBS data were unsuitable for this purpose[2]. For the 'ecological' variants of winter wheat, sugarbeet, spring-sown onions and peas we used the gross margin calculations formulated by Van Hall (1990). This source also provided quantities of inputs and outputs; prices are from the Handbook for Farm Calculations (PAGV, 1989). No data were available on labour requirements for ecological production. They were estimated by replacing the tractor hours required for chemical pest control by mechanical methods and additional manual work.

When feeding the LP models with data on integrated and 'ecological' cropping variants, we adjusted OBS yield data for regional differences. The adjustment was based on the relationship between current production on the OBS and yields, differentiated into regions, as stated in the Handbook for Farm Calculations (PAGV, 1989). Lack of trial data ruled out formulation of other, intermediate environmentally-friendly cropping variants. Therefore, to be able to calculate the physical yields of these "other" cropping variants, relations had to be formulated.

Cropping variants for ware potatoes were developed in close cooperation with CABO-DLO in Wageningen. The cropping variants formulated by CABO-DLO for the central clay area differ from one another in rotation, crop variety[3], fertilization, crop protection (weed and late blight control) and haulm- killing method. Each combination has its own specific input of means of production: soil, labour, seed material, fertilizers and plant protection treatment. We selected the 23 most interesting variants from the large number of combinations possible. The gross margins of these cropping variants were calculated and the 23 activities were then included in the LP models (De Buck, 1991; De Jong, 1991).

Besides the integrated and 'ecological' variants several extra variants that eschewed fungicides and the growth-controlling chemical CCC (Besseling et al., 1988, as well as sources mentioned) were distinguished at different stages of fertilization. In the case of sugarbeet, herbicide use could be drastically cut. For this purpose cropping variants with different spraying techniques and mechanical weed control were formulated (Marcelis, 1987; Van Schaijik et al., 1986). Appendix III gives an overview of the cropping variants for each crop formulated for the study.

After having extended the LP models with cropping variants, their optimal combination was determined without a levy. Subsequently, the price of pesticides was increased by adding on a levy. Successively increasing the levy (parametric programming), enabled the relationship between the size of the levy, choice of cropping variants, pesticide use and gross farm result to be assessed.

---

[2] The OBS experimental farm in Nagele investigates 'bio-dynamic' agriculture. Like ecological production, this type of farming eschews spraying but it is based on the concept of a mixed farm.

[3] To represent the so-called revised PS (potato sickness) regulation, variants for different rotation frequencies of the standard variety Bintje were required and also for the combination of Bintje and a PSR (=potato sickness resistant) variety. A fixed combination (50% Bintje and 50% PSR variety) was chosen, as it is expected that growing more of the PSR variety will stimulate the development of new pathotypes from the present nematode population in the soil.

6.4 Reducing pesticide use without a levy

In the LP models, actual farming practice is reflected by the cropping plans from Table 6.2, under the assumption that only current cropping variants apply. In the case of the optimal situation as presented by the LP calculations, all the cropping variants formulated were possible. This may deviate from the current situation. However, relatively profitable crops such as sugarbeet and potatoes were limited by the rotation restrictions necessary for agronomical reasons. The difference between these two situations (without levies) is shown in Section 6.5. Possible explanations are given for any differences. Section 6.5 also deals with the effect of levies.

Pesticide use

The difference in pesticide use between the economically optimal situation and the current situation is shown in Tables 6.3 and 6.4. The differences are given per LP model, and per crop. In reality, differences per crop can be subdivided into different cropping operations. This was not included in the tables (see De Koeijer and Wossink, 1992). Tables 6.3 and 6.4 help gain insight into the possibilities of reducing pesticide use in the present situation (without a levy).

Table 6.3 Pesticide use under the present and the optimal situation (kg of active ingredient per hectare and per farm)

Situation	Larger farms				Smaller farms	
	Northern clay area	Peat Colonies	Central clay area	South-western clay area	Clay areas	Peat Colonies
Current situation[1)]	9.9	67.4	32.6	10.0	10.4	58.1
Optimal situation[2)]	9.1	4.1	7.8	11.5	11.4	3.8
Difference per ha	-0.8	-63.4	-24.8	+1.6	+1.0	-54.5
Total difference per farm	-50	-3865	-1117	+88	+24	-1522

1) Resulting from optimizing a fixed cropping pattern (see Table 6.2) which includes current cropping activities only.
2) Resulting from optimizing the cropping pattern and after including environmentally-friendlier cropping variants. In Appendix IV this situation is indicated as "levy 0".

From Table 6.3 it appears that pesticide use can be reduced considerably. The shifts in cropping pattern mentioned in the table are largely attributable to the method of calculation. We shall return to this later.

In Appendix IV, the shifts in cropping pattern and resulting cropping techniques are given in two steps for each area. First, crops with a low profit margin, such as peas, seed grass (except for the Peat Colonies), and the 1:2 rotation of starch potatoes, disappeared when optimizing the cropping pattern. Next, the environmentally-friendlier cropping variants were added to the models; the results are given as the levy-0 situation. Changing from the 1:2 rotation with soil disinfection in the case of starch potatoes to the 1:4 rotation without soil disinfection (see Appendix III, Table 4) is of major importance to pesticide use. Soil disinfectants are used in large amounts but are cheap (see Table 2.6). Not all changes in cropping pattern bring about a reduction in the amount of active ingredients used: if the percentage of spring-sown onions in the cropping pattern increases, pesticide use rises accordingly (south-western clay area and clay areas).

Table 6.4 Differences in pesticide use in two situations: the optimal model situation and the present situation

Crops and explanatory factor	Larger farms				Smaller farms	
	Northern clay area	Peat Colonies	Central clay area	South-western clay area	Clay areas	Peat Colonies
Winter wheat	0	0	0	0	0	0
Sugarbeet	0	-32	-21	-16	-5	-17
Potato:						
- soil disinfection	-	-3815	-1062	-	-	-1498
- other pesticide use	-52	0	-11	-12	-4	0
Shifts in cropping pattern	2	-18	-23	116	32	-7
Total difference (kg a.i.)[1]	-50	-3865	-1117	88	24	-1522

1) By 'difference' is meant the difference in pesticide use that exists between the optimal and the current model situation.

The most significant changes in cropping variants take place in ware potatoes. The volume of active ingredients used in the optimal cropping pattern decreases especially dramatically in the central clay area. This is because in the optimal situation the model opts for a potato variant without soil disinfection (see Appendix IV, Table 3). This is possible because in this case the variety 'Bintje' is rotated with a variety that is resistant to potato sickness. In the central clay area, we assumed that in the basic situation only the Bintje variety is grown, and the soil is fumigated every six years.

A rotation frequency for potatoes needing no soil disinfection and/or the decision to grow potato sickness resistant varieties is crucial to total pesticide use. There are other (minor) measures that can lead to reduced use of active ingredients in potato growing, for instance mechanical crop control (by harrowing and late ridging) instead of chemical crop control (with metribuzin), and haulm killing mechanically with a haulm shredder instead of with chemicals (diquat). These two measures can bring about a reduction in the total amount of herbicides used (see Appendix III, Table 3). Finally, in sugarbeet growing, it is possible to curb spraying with herbicides (Appendix III, Table 2) by using weed harrows and row spraying equipment more frequently. Furthermore, the model results obtained show that in most areas hand weeding will have to be done twice as often per hectare as in the current situation.

Note that according to Table 6.3 average current pesticide use in the whole of the Netherlands is 27.1 kg of active ingredients per hectare, which is higher than the 18.6 kg mentioned in the LCPP for Dutch arable farming (see Table 2.12). This discrepancy arises because the average use mentioned in the LCPP, includes the area of fodder maize. Average pesticide use in this crop is 2.0 kg of active ingredient per hectare (MJP-G, 1991; see also Table 2.11), and if this is taken into account, the average use in the LCPP becomes about 25 kg of active ingredient per hectare. The remaining difference can be ascribed to the fact that in reality the whole crop area does not receive the treatments that are considered standard in the LP model (see Chapter 9 too). Another point is that the number of crops in the model is smaller than in reality.

Implications to incomes

From the LP results it can be concluded that applying environmentally-friendlier cropping patterns leads to higher farm incomes (see Table 6.5). Research by Verschueren (1991) on the Northeast Polder showed as much: where soil disinfection and the use of herbicides and fungicides decreased, incomes increased.

As suggested earlier, potato growing is the one activity where a change in cropping patterns is expected to provide the highest possible income improvement. This is mainly ascribed to omission of soil disinfection (the costs of this are about 500 Dutch guilders per hectare per annum). Moreover, there are cheaper ways of controlling late blight in potato varieties resistant to potato sickness, for instance by spraying less often, or by using maneb 80, which is cheaper. In the optimal cropping pattern, in the Peat Colonies the 1:2 rotation of starch potatoes is abandoned in favour of the 1:4 frequency which, in combination with leaving land fallow (yielding 1500 Dutch guilders per hectare per annum), is more profitable: the gross margin per hectare of the 1:4 cropping pattern appears to be 740 Dutch guilders higher than that of the 1:2 cropping pattern.

In other areas, besides the money-saving aspect of refraining from soil disinfection, the higher yields in kilograms when growing a potato sickness resistant variety are important (Appendix III, Table 3). The population (and related with it the pressure of diseases) of potato root eelworms is lower when Bintje is rotated with a PSR variety than when solely growing Bintje with soil disinfection. So, variety rotation will provide higher yields than growing Bintje exclusively (De Buck, 1991).

Other ways income can be improved in potato growing include mechanical weed control, mechanical haulm killing and economizing on nitrogen use (per hectare a dressing of 188 kg nitrogen by fertilizer according to petiole analysis, instead of 210 kg nitrogen by fertilizer plus 44 kg from 9 tons of organic manure).

Differences in incomes (Table 6.5) not only relate to different cropping variants, but partly result from changes in cropping pattern. As mentioned earlier, the latter are caused by the method used to compute the basic situation. The current cropping pattern has not been optimized, but is based on 1988 statistics from LEI. Since then, the gross margins of certain crops (for instance, seed grass and peas) have decreased relative to those of winter wheat, resulting in a lower percentage of these crops in the current cropping pattern. The 1989 prices were used for the calculations, so in the optimal situation these two crops are replaced by winter wheat, leaving land fallow (in the Peat Colonies, Appendix IV, Table 2) and spring-sown onions (southwestern clay area and small farms in the clay area, Appendix IV, Table 4 and 5, respectively), resulting in an increase in the total gross margin.

Table 6.5 Differences in farm incomes between the optimal model situation and the current situation: expressed per crop as percentage of total difference

Crop	Larger farms				Smaller farms	
	Northern clay area	Peat Colonies	Central clay area	South-western clay area	Clay areas	Peat Colonies
Winter wheat	1	0	0	0	0	0
Sugarbeet	15	16	8	20	26	24
Potato[1]:	62	65	89	33	43	51
- Bintje/PSR variety	40	-	70	-	30	-
- Weed control	4	-	3	5	-	-
- Late blight control	9	-	8	13	8	-
- Haulm killing	4	-	4	7	-	-
- N-dressing	6	-	5	1	5	-
Shifts in cropping pattern	22	19	2	47	31	26
Total difference (in %)[2]	100	100	100	100	100	100
Total difference (in guilders)	23 400	29 400	22 700	15 500	7 800	12 800

1) Soil disinfection was entirely ascribed to potato growing. Difference in income is subdivided into the selected cropping variant (Bintje/PSR) and "other" activities such as weed killing technique.
2) By 'total difference' is meant the difference in income between the optimal and the current situation.

To determine the extent of the income effect resulting from changes in cropping variants, the effects of the changes in cropping pattern must be adjusted. By adjusting for the percentages mentioned in Table 6.5, this can be approximated, resulting in the overview given in Table 6.6. The differences in income between the optimal and the current situation in all areas are largely the result of environmentally-friendlier cropping variants.

What causes the large difference between the current and the optimal situation? There are three main causal factors: (a) the assumptions made in formulating cropping variants, (b) the optimization objective and the knowledge available and (c) risk assessment.

As regards the change in income, the crucial assumption is that growing potato sickness resistant potatoes in combination with Bintje not only provides better yields per kg than for instance Bintje only (or in the case of starch potatoes: non-resistant varieties) but also achieves the same price. If this assumption is justified, current potato growing will disappear and farmers will get significantly higher gross margins. It remains to be seen, however, whether for instance the potato growing industry is willing to pay these prices, should this dramatic change in cropping variant take place. Another assumption made is that seed potatoes of potato sickness resistant varieties are available at prices comparable to those of other varieties.

When simulating with an LP model, full knowledge is assumed and profit maximization is the starting point. As already mentioned in the description of cropping variants, as far as knowledge of disease and infestation control is concerned, there might be a discrepancy between the know-how available on experimental farms and grass-roots know-how. That knowledge on economically optimal crop protection is sometimes lacking at farm level, as can be seen from the large differences in costs per hectare of pesticides use in arable farming (see Poppe, 1989). However, to be able to determine the economic optimum, the practising farmer needs to know the relationship between yields and the use of pesticides and other inputs.

As farmers do not have full knowledge of diseases, they cannot fully assess the risk involved in postponing spraying. Weather conditions are also an important issue. For instance, mechanical haulm killing is cheaper than the chemical method. A drawback of the first is, however, that 2 weeks must lapse before the potatoes can be lifted. This does not pose a problem when it is dry, but when it is raining a farmer will not easily take the risk (De Koeijer and Wossink, 1992; De Buck, 1991). Note that departing from LP solutions probably means underestimating pesticide use (see Section 3.6).

Table 6.6 Change in income when environmentally-friendly cropping variants are included in the LP calculations as well as current variants

Region	Change in income in guilders	
	Per farm	Per hectare
Larger farms		
- Northern clay area	18 300	280
- Peat Colonies	23 800	390
- Central clay area	22 200	490
- Southwestern clay area	8 200	150
Smaller farms		
- Clay areas	5 400	230
- Peat Colonies	9 500	340

6.5 Reducing pesticide use with a levy

The results given in this section reflect the influence of different levies on pesticide use and on income. The end result is a margin per category of pesticide within which, according to the LP calculations, the optimal levy lies. This is the amount at which the reduction targets from the LCPP for the year 2000 are just met.

Pesticide use

Table 6.7 gives an overview of the amounts of pesticides used as a total for the six LP models, for levies of different sizes. As a point of comparison, figures on current use are included. In Section 6.4, we already highlighted the possibility of reducing pesticide use without a levy by adopting environmentally-friendly cropping patterns. We also indicated that in some cases (large farms in the southwestern clay area and small farms in the clay areas) this reduction in use was negated by changes in cropping patterns (see Table 6.4).

From Table 6.7 it can be seen that levies bring about reductions in all areas. However, in each area either different cropping variant changes occur or these changes occur at different levies. Appendix IV gives a detailed overview.

Table 6.7 Amount of pesticide used (kg of active ingredient per hectare) at different levies (guilders per kg of active ingredients)

Area	Current situation	Levy in guilders per kg a.i.[1]							
		0	10	25	50	75	100	150	200
Larger farms									
- Northern clay area	9.9	9.1	4.5	4.5	3.1	3.0	2.5	2.4	2.4
- Peat Colonies	67.4	4.1	3.5	3.0	3.0	3.0	0.6	0.3	0.3
- Central clay area	32.6	7.8	6.4	6.4	5.4	5.0	4.3	4.1	4.1
- Southwestern clay area	10.0	11.5	6.3	5.4	5.2	3.0	3.0	2.1	2.1
Smaller farms									
- Clay areas	10.4	11.4	6.5	6.5	6.1	2.5	2.5	2.4	2.4
- Peat Colonies	58.1	3.8	3.3	2.8	2.8	2.8	0.7	0.3	0.3
Total	27.1	8.6	5.4	5.1	4.5	3.4	2.6	2.2	2.2

1) The calculations beginning with levy 0 refer to the LP models extended with new cropping variants.

In each area, a hundred per cent reduction of the use of nematicides can be observed in the levy 0 situation, i.e. when optimizing with all cropping variants included. Compared with the reduction that can be brought about by employing new cropping variants (for the whole of the Netherlands the use of nematicides will fall by 18.1 kg a.i. per hectare as a result of changes in cropping pattern and new variants) a levy does not have much power to induce reductions. This is because nematicides make up 66% of the total amount of active ingredients in the original situation. The targeted reduction (60%) for the total quantity of active ingredients is met even without a levy.

Table 6.8 Reduction of pesticide use at different levies (guilders per kg of active ingredients); reductions related to use in current situation (%); total Dutch arable farming

Pesticides	Current use in kg a.i. per ha	Levy in guilders per kg a.i.							
		0	10	25	50	75	100	150	200
Soil disinfectants	18.1	100	100	100	100	100	100	100	100
Herbicides	4.3	22	58	62	71	88	89	91	91
Insecticides	0.3	27	37	39	43	50	52	56	56
Fungicides	4.2	-6	24	27	31	39	55	63	63
Other[1]	0.2	-35	100	100	100	100	100	100	100
Total	27.1	68	80	81	83	88	90	92	92

1) Particularly growth regulators.

Table 6.8 shows the reduction percentages achieved by different levies for the Dutch arable farming sector, per category of pesticide. At a levy of 0, the increase in fungicides and in the category "other" is caused by the same factor as in Table 6.7: changes in cropping pattern. Considered per individual category of chemicals, a levy does bring about a reduction. The use of herbicides, fungicides, growth-controlling chemicals, 'other' and, to a lesser extent insecticides, diminishes particularly dramatically (see Appendix IV). When distinguishing into the targeted reductions for individual categories of pesticide, then it appears that levies are not needed to achieve the targeted 25% reduction of nematicides and insecticides. For herbicides (targeted reduction: 45%) and for growth-controlling chemicals (targeted reduction: 68%) the levy must be to 10 guilders, and for fungicides (targeted reduction: 25%) between 10 and 25 guilders.

The option of leaving land fallow plays an important role in the transition from 'current' to 'optimal' cropping pattern. It is also a useful tool when adjusting cropping patterns in the light of increasing tax levels (see Appendix IV). For instance, for the tax levels formulated, between 40 and 70% of the Peat Colonies is taken out of production. For the financial implications of this, see Chapter 8.

Implications to incomes

In Section 6.4 we indicated that a farmer can increase his income by applying environmentally-friendly cropping patterns as well as the current ones. Table 6.9 gives the levy-induced income effects. The figures stated relate to the situation in which the levy is 0 guilders and environmentally-friendlier cropping variants can be included in the cropping pattern. Per farm full restitution was assumed, implying that restitution differs among the arable regions considered. The restitution equals the sum of the amount of active ingredients used (per farm) and the levy (amount). This method implies that unless a farm introduces adaptations, there will be no effects on income. Note that farms here means the representative farm of the region.

From Table 6.9 it appears that the income losses resulting from a levy differ somewhat per region. At a low levy, income loss in the southwestern clay area is relatively large because of a reduction of the area under spring-sown onions. At a levy of 50 guilders, the northern clay area suffers substantial income losses compared with other areas because of the change to growing winter wheat ecologically. Further we noted that, at a levy of 75 guilders, incomes in the southwestern clay area are rapidly declining as a result of the change to ecological winterwheat growing. At a levy of 100 guilders no starch potatoes will be grown in the Peat Colonies any more, causing a dramatic income loss.

Table 6.9 Difference in income[1] compared to the situation with a levy of 0 guilders (optimal farm management); different levies per kg of active ingredients; in brackets, income effects in guilders per hectare

Region	Levy in guilders per kg a.i.							
	25		50		75		100	
Larger farms								
- Northern clay area	-1200	(-19)	-4100	(-62)	-4800	(-73)	-7200	(-109)
- Peat Colonies	-700	(-11)	-700	(-11)	-700	(-11)	-15000	(-246)
- Central clay area	-400	(-9)	-2500	(-57)	-3400	(-78)	-6100	(-136)
- Southwestern clay area	-3500	(-63)	-4000	(-72)	-11100	(-198)	-11100	(-198)
Smaller farms								
- Clay areas	-1000	(-43)	-1500	(-63)	-6700	(-279)	-6700	(-279)
- Peat Colonies	-300	(-11)	-300	(-11)	-300	(-11)	-6100	(-218)
Total	-1400	(-29)	-2600	(-52)	-5200	(-118)	-8700	(-188)

1) Income effect after full restitution; restitution differs per area. Restitution has been calculated on the basis of the amount of active ingredients used and in the amount of the levy.

6.6 Relation between levy and pesticide use

Table 6.8 indicates the relation between the size of the levy and the percentage reduction of pesticide use. When comparing these results with the targeted reductions in pesticide use (LCPP), margins for the optimal levy amounts can be formulated. Table 6.10 gives an overview.

According to the LP calculations, it is not cost-effective to use soil disinfection chemicals in the current situation. The policy proposed in the LCPP should be capable of bringing about the targeted reduction. The size of the levies for the other categories of chemicals do not differ much, except for the levy on fungicides, which is slightly larger. So, except for the difference between soil disinfection chemicals and the other chemicals, roughly speaking, there is no need for a possible levy to be differentiated according to types of chemicals. The results given in Table 6.10 suggest a levy ranging from 10 to 25 guilders per kg of active ingredient for the other categories of pesticide.

Table 6.10 Margin levy amounts (guilders/per kg active ingredient), differentiated into category of chemical; reduction (%)

Pesticides	Reduction goal LCPP for 2000 in %	Levy in guilders per kg a.i.	Use-reducing effect of levy
Soil disinfectants	70	0	100%
Herbicides	45	0-10	22 à 58%
Insecticides	25	0-10	27 à 37%
Fungicides	25	10-25	24 à 27%
Other (mainly for growth control)	68	0-10	-35 à 100%

6.7 Conclusions

The efficacy of levies of various sizes in achieving the LCPP targets was calculated. We found that the trajectory of 10 to 25 guilders per kg of active ingredient seems a reasonable levy margin for most types of pesticide, with fungicides at the top of the trajectory. The special position of fungicides was highlighted earlier in our discussion about the Swedish programme (see Section 4.2).

Another point is that the LP calculations indicate that in the current situation the use of soil disinfection chemicals is not cost-effective. In the case of nematicides, the LCPP policy is to be preferred to imposition of a levy for achieving the targeted reduction. Generally speaking, for the other categories of chemicals it seems unnecessary to differentiate a levy according to types of chemicals.

From Section 6.4 it can be concluded that the economically optimal model situation does not comply with the current situation, for various reasons. In some cases, merely changing to other cropping variants which enable dosages of pesticides to be reduced is already cost-effective. For a number of reasons this is not yet practised on a large scale. Model results do not accurately reflect the current situation because the farmer does not have full knowledge of how to interpret cropping variants and, moreover, because the risks involved in employing certain cropping practices were not included in the computations. The model computations indicated that changing cropping patterns could cause the average income of large farms to increase by 8200 to 23 800 Dutch guilders, that of small farms by 5400 to 9500 Dutch guilders.

If a levy is imposed, a farmer must know how best to adjust his farming practice. This is likely to cause problems because, as mentioned earlier, in many cases (including the present situation) crop protection is not economically optimal. On average, this leads to more pesticide being used than is economically optimal.

For a levying system to work successfully, much attention will have to be paid to matters such as educating and giving information to farmers and to doing research. As long as farmers' knowledge lags behind, it will be difficult to establish adequate levy amounts. As indicated above, the margins may prove insufficient in practice. With respect to this it is assumed that after levies have been imposed, more pesticides will be used than is economically optimal, as occurs at present.

Income effects (after restitution) occurring after the imposition of a relatively low levy have a minor impact on the Dutch arable farming sector as a whole. For the average farm a levy of 25 guilders per active ingredient will result in an income loss of 1300 guilders (29 guilders per hectare). At a levy of 50 guilders per kg of active ingredient this loss will be 2300 guilders (52 guilders per hectare). These sums do not include administrative costs.

7. THE LEVY: ITS LEVEL, ITS REVENUE AND HOW IT COULD BE SPENT

7.1 Introduction

The main reason for imposing a regulatory levy is to influence users (in this case, of pesticides) in such a way that a certain norm (in this case, environmental) is reached. From a social point of view it would be ideal if the regulatory levy equalled the social costs of a marginally used quantity (unit) of pesticides: it would then be a so-called Pigou levy (Baumol and Oates, 1988) and its main aim would be not to finance certain activities. However, if the levy is used to finance certain activities, it is called a financial levy, and the revenue it brings in has to be implemented for some purpose. If regulatory levies work effectively, the revenue they bring in will decrease over time.

A logical option is to use tax money to finance the administrative costs of the system of levying and refunding. According to the 'polluter pays principle', curative measures (i.e. those intended to mitigate the effects of pollution for instance, removing residues from groundwater used as a source of drinking water) could be financed by tax revenue. It seems very inefficient to spend all the money raised by the levy to cover the increased social costs per unit of pesticide (see Section 7.2). Another option would be to use this money to clean up previous damaging emissions. But the people or organizations who have to pay for the levy now, are not necessarily those responsible for the emissions in the first place. So, although in principle the revenues from a regulatory levy can be used to finance additional environmental measures, this may have its drawbacks. This is why in the NMP Plus (MVROM, 1990) the option of a regulatory levy is favoured, on the condition that revenues are redirected as much as possible to the sector that paid them. So, on the condition that the sector cooperates, restitution is the guiding principle.

In Sweden, a portion of the environmental levies is used to finance general governmental activities (see Section 4.2). In the Netherlands opinion on this is sharply divided. The government sees environmental levies as a useful additional source of income. Besides it would be inconvenient for the government if each levying system had a different spending pattern, because this would make it difficult to integrate the policies made by the various ministries (Donner, 1991). On the other hand, imposition of regulatory levies does have its negative side for the government. Since revenues are bound to decrease over time, levies are an unstable source of income for financing governmental activities. If, for instance, revenues from regulatory levies were to lead to reductions in other taxes, the price of government services would become too low.

The general philosophy environmental policy-making directed at the Dutch agricultural sector is that revenues from regulatory levies must be fed back to the sector as much as possible. In recent years, producers in this sector have invested in equipment and techniques that benefit the environment, some of which the government made mandatory. Therefore, they are unlikely to welcome a levying system without restitution. If levy revenues were restituted to the sector, the target group would be more ready to accept a levy because their income losses would remain limited. Indeed, depending on the restitution basis, individual farmers could even improve their income by using less pesticide than other farmers.

The target group's acceptance of a levy does not depend solely on how restitution is arranged. Also important is the degree to which income is transferred from one agricultural sector or subsector to the other via the system of levying and refunding. Other relevant factors are the system's fairness and transparency.

How this chapter is arranged

Section 7.2 discusses the theoretical relation between the magnitude of a levy and a) its revenues, and b) its effects on income. The determination of the optimum level of the levy and the possibilities for restitution are also discussed. Section 7.3 gives empirical information on pesticides in the Netherlands, and also deals with the efficiency of levies on pesticides from the government's viewpoint. Options for repaying levy revenues to the agricultural sector are dealt with in Section 7.4. Section 7.5 deals with income transfers from one sector to another under the assumption that a simplified form of restitution is employed. The last section (7.6) presents conclusions.

7.2 Theoretical relations between levies and restitutions

The size of the levy, its revenues, its restitution and its effects on income need to be analysed before we discuss the Dutch approach to levying and refunding. Figure 7.1 reflects the implications of a regulatory levy for a sector.

The upper diagram in Figure 7.1 illustrates the revenue (R) as a function of the levy (L). This is such that increasing the levy will lead to diminishing returns: the revenues increase less than the levy. If producers do not adapt their use of pesticides and other inputs, then revenue rises in proportion to the levy. Further it can be seen that there is a maximum revenue: R_{max}. If the levy exceeds L_m, the revenue will decrease. At a given moment (not indicated in Figure 7.1) the levy will be so high that pesticides will no longer be used. In the discussion we have assumed a levy of L_1 with a revenue level of R_1.

The lower diagram in Figure 7.1 depicts the income effects for the sector. The levy paid is the mirror image of the levy revenue from the upper diagram. Curve RS reflects the amount refunded to the sector after the costs of administration have been deducted. The administrative costs considered to be unrelated to the levy are equal to A. The income effects for the sector after full restitution (Y) are caused by farmers/growers switching to relatively more expensive inputs (in comparison with the situation without a levy) and/or by reduced yields. The higher the levy, the greater the effect on income. The point at which an extra levy will not change the use of inputs and the production of outputs is the point at which income will remain constant. Total income effect (YN) is the sum of income effect (Y) and administrative costs (A). Hence, at a levy of L_1 the total (negative) income effect for the sector equals YN_1.

As mentioned earlier, the situation for an individual producer may differ from what was stated for the sector. Not only the size of the levy paid by an individual farmer is important here, but also the basis for restitution.

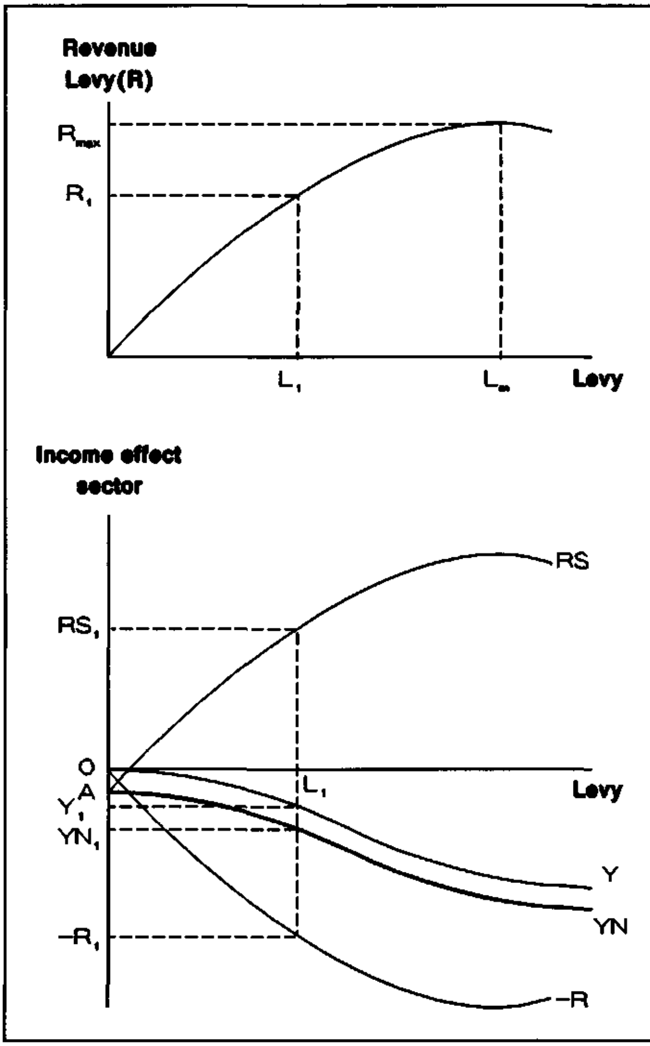

Fig. 7.1 The relation between the magnitude of a levy, its revenue and its effects on income

Optimal levy and destination of the levy

In theory, the levy should equal the marginal environmental costs (MEC in Figure 7.2) of the emission caused by an input. The optimal levy (L_{opt}) is where the marginal net private benefit (MNPB in Figure 7.2) of the input equals the MEC. Note that MNPB is another name for the marginal revenue curve of an input, which equals the demand curve of an input. For the farmer the optimal input level is where MNPB crosses the horizontal axis. If external effects of production are incorporated, the optimal level is x^*.

Although it might be easy to define a theoretical optimum input level and the related levy (Pearce and Turner, 1990, Ch.4-6), there are many practical problems because the relation between input and emission is unknown or uncertain and the marginal environmental costs of emission are unknown. These difficulties are especially relevant for pesticide, which is an input with non-point source pollution and for which very limited information is available about the costs of external impacts of emissions. In this study we use a limit (x^*) for the future use of input stipulated by the government. If we assume that this limit reflects the optimal level of pesticide application, here MPNB=MEC. The optimal levy can be derived from the MPNB curve.

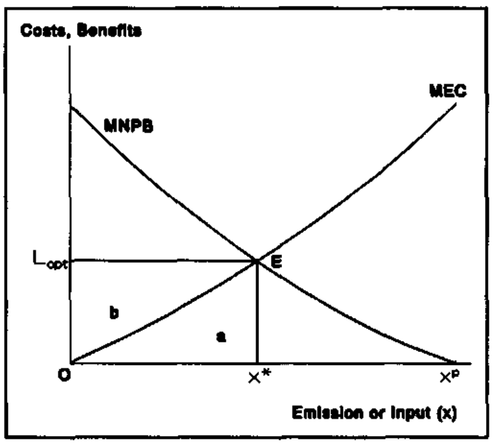

Fig. 7.2 Optimal levy derived from marginal external costs (MEC) and marginal net private benefit (MNPB) of an input

If x^* is the optimal input level induced by a levy L_{opt}, the total revenue from this levy equals $x^*.L_{opt}$ or areas **a** and **b**. Now the maximum amount to be spent on abating the emission to x^* is equal to area **a**, otherwise expenditure on abatement exceeds the total costs of emission (=area **a**). Therefore, the total amount of the regulatory levy exceeds the total costs of the emission. A sum that is at least equal to **b** is to be used for other purposes, such as:
- to cover administrative costs;
- to abate previous emissions;
- to stimulate technological developments to reduce emissions;
- to refund producers who pay the levy though in such a way that it does not influence the application of pesticides.

Within a system of regulatory levies it is common to return the total amount of the levy after subtracting administrative costs.

7.3 Regulatory levy with restitution: magnitude and efficiency

Having sketched the theoretical framework for the Dutch situation we will now indicate what revenues are to be expected in future at certain levy levels. According to DHV and LUW (1991), to achieve the reduction percentages mentioned in the LCPP, levies should be between 25 and 90 Dutch guilders per kg of active ingredient (a.i.) for all chemicals, except soil fumigants. If a levy system is introduced, DHV and LUW propose that the levy does not initially exceed 50 guilders per kg a.i. so as to confine the income loss within certain limits.

We did some computations using levies of 90, 50 and 25 guilders. The revenue was calculated on the basis of three variables: (1) current pesticide use (average for 1984-1988); (2) anticipated pesticide use in the year 1995, and (3) ditto for the year 2000. Figures for the years 1995 and 2000 refer to the pesticide use targets in the MJP-G (see Table 2.13). We assumed that the desired reductions would be achieved. The computations did not include soil fumigants. Table 7.1 shows the total levy revenues.

Table 7.1 Total levy revenues (million guilders) at 3 levy amounts (guilders/kg a.i.); current pesticide use (1984-1988); target use in the years 1995 and 2000; excluding soil fumigation chemicals

Levy (gld/kg a.i.)	1984-1988	1995	2000
90	680	500	410
50	380	280	230
25	190	140	120

On the basis of these revenues it is possible for the government to assess the suitability of a levy system. In this respect the National Taxation Department's unwritten criterion is that administrative costs (costs to the government) may not exceed 1.5 to 2 % of tax revenues. The magnitude of the administrative costs depends on the levy system. DHV and LUW (1991) distinguish two possible systems. The first (I) is based on a levy on imported pesticide use or on the production of pesticides in the Netherlands. The administrative costs are estimated to be about 3 million guilders. The second system (II) is based on a levy at farm level. It requires the pesticide user to keep records of pesticide use. The administrative costs of the second system are estimated to be 15 to 21 million guilders (excluding the costs of keeping records of pesticide use by farmers). Table 7.2 gives an overview. In this table we assumed the administrative costs to be 18 million guilders (DHV and LUW, 1991, p.147).

Table 7.2 indicates that a low price elasticity of the demand for pesticides (i.e. a high levy) implies a high efficiency rate for the government. However, this is only true for tax levying. The main purpose of a regulatory levy is to achieve a certain environmental norm. A tax levy, therefore, has a different purpose than a regulatory levy. The principle of taxation is to get the highest possible revenue at the lowest possible administrative cost. Although a regulatory levy minimizes administrative costs, the main goal is not to collect the highest levy revenue possible. On the contrary, attempts will be made to limit levy revenue, in order to avoid unnecessary circulation of money. From Table 7.2 it can be seen that relatively low administrative costs are involved when levying according to system I. System II would involve such high administrative costs that it is doubtful whether it could be maintained over time.

Table 7.2 Quotient of administrative costs and levy revenues (in per cent) under two administrative systems

Levy (gld/kg a.i.)	1984-1988		1995		2000	
	I	II	I	II	I	II
90	0.4	2.6	0.6	3.6	0.7	4.4
50	0.8	4.7	1.1	6.4	1.3	7.8
25	1.6	9.5	2.1	12.9	2.5	15.0

In this study the efficiency criterion must apply not only to the government but also to the target groups (transaction costs). These transaction costs consist of the administrative costs for the producers and the effects on their income. This is discussed in more detail in Section 8.5. However, it can already be postulated that the lower the price elasticity of the demand for pesticides (in which case administrative costs are relatively low) the higher the transaction costs will be. The pros and cons are difficult to weigh up; it might even be possible that additional administrative costs (for instance in system II relative to system I) easily outweigh the transaction costs.

7.4 Options for restitution

Levy revenues can be restituted in several ways. However, the following options must not be dismissed: subsidizing investments to benefit the environment; research on integrated crop protection or alternatives to pesticides; speeding up the authorization of 'better' pesticides; establishing a risk fund for farmers who dramatically reduce pesticide use. Excluding these options will probably not help to mitigate the environmental burden of pesticide use in arable farming but including them would undeniably pose several problems. For instance it will not be easy to determine how best to use pesticides without distorting economic competitiveness within the EC (DHV and LUW, 1991), or when implementing steering policies. When imposing levies on imports of pesticides it is difficult to refute accusations that the competition is being distorted, if the revenue is paid back to Dutch farmers and growers either directly or indirectly.

Other options for refunding money raised by taxes are: (1) restitution via the Agricultural Board levy, (2) restitution via the tax inspector (on wage and income tax), and (3) balancing the levy on pesticides. Factors such as practicability, limiting the opportunity for fraud, low administrative costs, limited transfers between sectors, are considered the most important objectives. So, what is at stake here is a political weighing up of the pros and cons. The various options already mentioned will be elaborated below.

Restitution via the Agricultural Board's levy

The levy imposed by the Agricultural Board (AB levy) is based on the number of SFUs (Standard Farm Units). The SFU is a standard measure of the net value added of farms. All (approx. 120,000) agricultural and horticultural enterprises in the Netherlands (excluding those smaller than 10 SFU) are liable to this levy. The AB levy fluctuates annually around 5 guilders per SFU (an average of thousand guilders per farm). The number of SFUs is established on the basis of the 'May census'. (This is the annual assessment of all agricultural enterprises carried out by the 'Dienst Uitvoering Regelingen' of the Ministry of Agriculture and is published by the Central Bureau of Statistics (CBS)). If restitution could be linked to the AB levy, the resulting system would largely cover agriculture and horticulture, and could be linked to an existing system.

Restitution through the AB levy need not invalidate the policy proposed in the LCPP (1991). In order to avoid income transfers, SFUs must be distinguished according to their pattern of pesticide use. Moreover, for many farmers the levy will turn into a net payment; this will limit administrative costs. Given that the Agricultural Board serves farmers' and growers' interests, it remains to be seen whether it is the most suitable organization to collect the levy. Furthermore, the May census might be unable to cope with the extra burden of supplying data on which to base restitution.

Restitution through wage and income tax

In this form of restitution a uniform rate of restitution is established per sector. The compensation per hectare depends on the size of the levy paid by the sector. Identical amounts of restitution will be paid for crops in that same sector. This enables restitution to be achieved by deducting from the wage and income tax or corporation tax.

Restitution can thus be easily and reasonably cheaply organized on the basis of the farm size per potential levy payer and per sector. Crop areas can be obtained form the May census. Income transfers between sectors can easily be avoided. However, in this system the tax department would have to make use of these data. Furthermore, here the same disadvantage applies against using data from the May census as applies to restitution by the Agricultural Board.

In certain sectors the imposition of a pesticide levy might cause farmers to change to cropping schemes that require less pesticides. Restitution by the tax department based on the number of hectares will not influence this. Whether a farmer will switch to crops from another sector and/or to more extensive cropping practice depends on the sums restituted in that sector.

Balancing the levy on pesticides

If a levy is incurred by the users then it is possible to regulate both the levy and the restitution through the same institution (for instance the Levy Bureau in Assen, which also regulates the levy on manure). Although this implies extensive administration for the government and the user, the advantage of this system is that it is open and fair to both

(Zachariasse, 1991). Under such a system farmers will be well informed about ways of economizing, for instance via advice based on observation of pesticide use and the best crop/cultivation combination. The system as a whole provides extensive opportunities for refinement (for instance levying on the basis of emissions in a closed system) as well as for research into the causes of differences in pesticide use.

The most difficult point in the levying system will be the monitoring of pesticide use; however, this does not play a role in considerations about restitution. Restitution can be based either on the levies of the previous year or on estimates of amounts levied in the current year.

7.5 Transfers of income; a pilot study

Pesticide use is an important criterion in the classification into sectors. Clearly, however, the use of pesticides per crop category can differ considerably within these sectors. The criterion 'no transfers within sectors' is therefore relative.

For obvious reasons we departed from the classification into sectors used in the LCPP (MJP-G, 1991) (see sector classification A below). The classification concerns is based on type of cropping rather than types of farms.

Classification A
- arable farming
- field vegetables
- bulb and flowers from bulbs
- nursery stock industry
- pastures
- public parks and gardens
- floriculture
- vegetables under glass
- mushrooms

However, more workable classifications are conceivable, for instance:

Classification B
- public parks and gardens
- pastures
- closed cultivations; floriculture and vegetables under glass, and mushrooms
- other cultivations; e.g. arable farming, field vegetables and floriculture, bulbs, fruit growing and nursery stock industry

Unlike classification B, restitution according to classification A can avoid income transfers taking place between the different sectors. An illustration of the income transfers according to the 2 categories is given in Table 7.3.

Table 7.3 reflects the income transfers according to the above-mentioned classifications. Calculations were based on a levy of 50 guilders per kg of active ingredient (excluding soil disinfectants) covering average use in the 1984-1988 period. Administrative costs (system costs) were fixed at 5 million guilders.

In classification B, the restitution in the sectors arable farming, nursery stock industry and vegetables under glass is larger than the levy. This is remarkable, given that the levy revenues are not fully paid back because of the administrative costs. For these sectors the restitution per hectare according to classification B is higher than that according to classification A. The sectors at a disadvantage under classification B are bulbs and flowers from bulbs, floriculture under glass, and mushrooms. The mushroom sector shows a remarkably high restitution amount per hectare according to classification A, but is much worse off in classification B. It is questionable, however, whether a restitution per hectare is the right option for closed cultivations. The magnitude of the restitutions for these cultivations is likely to lead to incorrect reporting about the size of the area under cultivation. Moreover, in this sector there are often several harvests per year. In the future restitutions might be linked to the emission level.

Table 7.3 Net levy and hectare restitution at a levy of 50 guilders per kg of active ingredient (excluding soil disinfection); net levy is the difference between restitution and levy revenue; amounts based on average use over 1984-1988 period

Sector classification	Net levy (mln gld)		Restitution (gld per ha)	
	A	B	A	B
Arable farming	-3.2	56.7	293	373
Field vegetables	-0.2	-0.7	384	373
Bulbs growing and flowers	-0.7	-45.0	2845	373
Fruits	-0.3	-16.2	2786	373
Nursery stock industry	-0.1	1.0	324	373
Pastures	-0.5	-0.5	30	30
Public parks and gardens	-0.1	-0.1	8	8
Field floriculture	0.0	-0.3	533	373
Floriculture under glass	-0.2	-4.5	2892	1986
Vegetables under glass	-0.1	4.5	941	1986
Mushrooms	0.0	-0.3	5696	1986
Total	-5	-5		

7.6 Conclusions

Although in theory it seems easy to fix the optimum rate of a levy on pesticides, the lack of factual information makes it impossible to establish the amount. Therefore we based our study on the norms the government laid down for the reduction of pesticide use. Once the levy rate has been fixed, additional variables can be determined (restitution, income effects).

Restitutions are an important part of regulatory levies. Although the effectiveness of an environmental policy in which restitution is not based on its environmental merits is open to question, restitution can add considerably to the willingness of sectors to cooperate in the system of regulatory levies.

If a regulatory levy works properly, levy revenues will be limited. After deducting the costs the government incurs from implementing the levy system, the ratio of administrative costs to revenues can be unfavourable. Limited levy revenues indicate that the financial instrument can be useful in the quest for reducing pesticide use.

Tax money can be refunded to pesticide users in different ways and by different institutions. Although keeping on-farm records of pesticide use is expensive to implement and monitor, it is clear that this strategy has far better prospects for levying and refunding (as well as for counselling) than other strategies.

8. REGULATORY LEVY: FUNCTION, LEVEL AND INCOME EFFECTS

8.1 Introduction

The following discussion of the regulatory levy is based on arguments used in Chapter 7 as well as on results from empirical research (see Chapters 5 and 6) and experiences in other countries (see Chapter 4). Because insufficient information was available to enable us to determine the optimal size of the levy, we took the targeted reductions for pesticide use formulated in the Long-Range Crop Protection Plan (LCPP), as starting points. This resulted in levies of different sizes, which made it possible to determine upper and lower limits for the levy. On the basis of assumptions discussed in Chapter 3, we shall investigate which factors are responsible for the large differences, after first discussing the calculated levies, income effects in agriculture, and other related subjects.

Section 8.3 deals with the levy for the arable sector, giving the results of two different approaches. In that sction we also describe the experiences gained by other countries in studying how levies on pesticides affect pesticide use in arable farming. Price elasticities derived from both the econometric research (Chapter 5) and the literature (Chapter 4), hint at relatively large levies, thereby providing the upper limit for a levy. The LP study (Chapter 6) yielded relatively small levies, indicating the lower limit.

Section 8.4 focuses on horticulture, in particular on the results available from the econometric analysis. Because of the diversity in horticulture, the estimated elasticity is an average of various heterogeneous subsectors.

The income effects of levies are discussed in Section 8.5. These effects are crucial to the industry's willingness to cooperate in bringing about policy changes. Therefore much attention is paid to the income issue. We used a sensitivity analysis to investigate the assumptions that most influence the calculated income effects. In this section we compare the income effects following from our analyses with those in the LCPP.

Chapter 6 indicated that a levy on pesticides increases the total area left fallow. The LP models showed that in certain areas a sizeable area is left fallow even without a levy on pesticides. Section 8.6 deals with the budgetary consequences of leaving land fallow, and indicates its impacts on the total area used for arable production.

In Section 8.7 we return to the theory to study the consequences of price changes of pesticides, as discussed in Chapter 3. Section 8.8 contains some concluding remarks.

8.2 Basic principles in determining the size of a levy

As indicated in Chapter 7, from the point of view of the allocation of production factors it is desirable to finetune the levy to the marginal external effects (i.e. the marginal environmental damage) of the types of pesticides in question. Such an approach would require determining the damage level for each type of pesticide. However, this method will pose great problems, for three reasons.

1. Although some effects of pesticide use are known (Van der Vaart, 1987; see also Section 2.4), albeit within wide margins of uncertainty, they cannot as yet be converted into sums of money equivalent to negative external effects (Eitjes and De

Haan, 1987).

2. In some environmental components (for instance drinking water) it takes a long time from the moment the pesticide is used until the damaging effects show up (RIVM, 1991, pp. 324-327). The benefits of pesticides, therefore, become visible much sooner than the disbenefits.
3. The negative external effects of a particular type of pesticide may partly depend on the extent of other polluting substances (other types of pesticide, for instance). The existing EC norm for drinking water of 0.5 μg of total pesticides per litre acknowledges this (Richtlijn 12, July 1980 No. 80/778/EEC).

The first reason speaks for itself, but the others show that we know too little about the negative external effects of pesticide use to base a levy on them. This means that, for the time being, a levy on pesticides must be based on other facts; for instance, on reaching quantitative objectives, as formulated in the LCPP (see Table 2.13). Another point is that a certain reduction in pesticide use does not necessarily lead to a proportional reduction of damaging emissions. If there is a threshold above which emissions become harmful, the percentage of emission reduced is greater than the reduction in pesticide use.

The result of focusing on the amount of active ingredients used in pesticide could be a cut back in the use of chemicals containing the most active components (measured in kilograms) rather than in the use of pesticides that are the most damaging. This problem is discussed in more detail in Chapter 9.

8.3 A levy for arable farming based on experience and research

Examination of the situation in Sweden has shown that it is difficult to indicate the individual influence of the factors causing a reduction in pesticide use in Sweden. The influence of levies - which led to the price of pesticide increasing by about 40% - appeared to be limited. However, it seemed that the levy affected the use of fungicides and insecticides more than the use of herbicides (see Section 4.2).

Research on the Dutch and Danish arable farming sectors produced price elasticities of the demand for pesticides of between -0.2 and -0.8 (see Sections 4.3 and 4.4). Given these results it seems justified to conclude that the long-term effects are more significant than the short-term effects. The price elasticities for the Netherlands were found to be -0.4 to -0.5.

Two methods were used in our research on the Netherlands: (1) econometric analysis (see Chapter 5), and (2) linear programming (see Chapter 6). The econometric analyses yielded low short-term price elasticities of the demand for pesticides of -0.21 and -0.39 (depending on the model specifications). These price elasticities appeared to increase hardly at all in the long term. Only if the price of pesticides is raised considerably is modern technology likely to be used to cut back pesticide use. Therefore the long-term price elasticities will be considerably higher than those mentioned above. The literature, discussed in Chapter 4, also contained higher price elasticities than the ones we found in our econometric research of Chapter 5.

Many studies have shown that technology rather than price is the factor determining input use in agriculture. Sections 2.3 and 4.3 concluded that there has been a considerable increase in pesticide use per hectare in arable farming in the Netherlands, even after adjusting for the share of the various crops. There have been signs, however, particularly in the late 1980s, that this trend was levelling off. The econometric analysis also showed an upward trend in pesticide use (see Table 5.1). After conversion, this increase appears to be 4% per annum and per hectare over the period 1970-1988. Another important factor is the size of the area used for arable farming: if arable farming increases at the expense of pasture, pesticide use will rise considerably. The total arable farming area in the Netherlands (excluding fodder crops) increased by 1.6% per annum in the period 1985-1990 (LEI/CBS, 1991, p. 61). It is uncertain whether this trend will continue. So, when technological development and expansion of the crop area reach a point where total pesticide use in arable farming remains constant, then the upward trend in pesticide use will have come to a halt.

With the data on the Netherlands mentioned above - and given a price elasticity relating to average prices and average amounts of pesticides in the period 1970-1988 of -0.3 - we are able to calculate the maximum levy. Converting the data to that of the reference period gives a price elasticity that is only slightly different.[1]

In 1987, the average price of pesticides used in arable farming (excl. soil disinfectants) was approx. 78 Dutch guilders per kilogram of active component (Vijftigschild, 1991; see also Table 2.6). This price includes VAT. So, to reach the targeted reduction in the year 2000, and taking into account the -0.3 price elasticity and the 39% reduction percentage (excl. soil disinfectants, see Table 2.13), a levy of 99 guilders per kg of active component will be required.[2] This is the upper limit for a regulatory levy on pesticides. Following the same procedure for soil disinfectants, we arrived at a levy of 12 Dutch guilders per kilogram of active ingredient.

The economic analyses with LP models also provided the upper and lower margins within which a levy should lie if it is to achieve the targeted reductions for the year 2000 set in the LCPP. The LP models showed that soil disinfection is no longer cost effective.

[1] When using a linear demand curve for pesticide use (see Section 5.3) it is necessary to convert the price elasticity of pesticides in the estimation period into that of the reference period. In our study we had to adjust for amounts of pesticides used, crop prices and pesticide prices. We derived the amounts from the LCPP covering the period 1984-1988. Differences in pesticide use can be caused by different weather conditions. Prices of arable products also fluctuate over the years (see Table 2.3). Therefore we used a rather long reference period for the prices of arable products: 1985-1989. Pesticide prices in the database (Vijftigschild, 1991) relate to 1987 prices. Conversion gives a price elasticity of -0.31 for the demand for pesticides in the reference period.

[2] In this calculation we did not take into account possible changes in pesticide use resulting from policy incentives, technological development and changes in the area of arable land. Furthermore, we considered the relation between prices of pesticides and prices of arable products over the period 1970-1988 to be the same as that over the period 1990-2000. We will return to this in Section 8.5.

Abolition by the Dutch government of regulations that demand soil disinfection in the 1:2 cultivation of starch potatoes - in the case that varieties resistant to potato sickness are grown - is sufficient to achieve the targeted reduction. For the other categories of pesticides it seems unnecessary to differentiate into types of chemicals. The LP models suggest that differences between various types of pesticides are not very clear.

According to the LP calculations, the levy for pesticides (excluding soil disinfectants) should lie within the trajectory 10 to 25 Dutch guilders per kg of active ingredient, which seems rather low. The studies mentioned in the literature and our analysis using econometric models showed price elasticities that imply much larger levies. The LP calculations are based on the assumption that the average farmer is able to apply a crop protection technique that is economically optimal. However, this is not so at the moment. In Section 6.4 more explanations have been given on why an LP model tends to underestimate pesticide use. All in all, it is likely that the levy margins indicated by the LP model underestimate the levy really required. On these grounds we consider a levy of 25 guilders per kg of active ingredient (excluding soil disinfectants) to be the lower limit for a levy.[3]

If the policy objectives (DHV-LUW, 1991, p. 128) are to remain feasible, differentiating a levy on pesticide use into types of chemicals for reasons other than protection of the environment and public health must be avoided as much as possible. The calculations done in Chapter 6 do not clearly indicate that differentiation is necessary. However, an exception must be made for the use of soil disinfectants. For this category of chemicals the targeted reduction is likely to be reached without a levy, because of the severe regulations proposed in the LCPP. Chapter 6 also concluded that the use of soil disinfectants is not cost effective from an economic point of view. According to the econometric approach, the large price difference per kg of active component between soil disinfectants and other pesticides does justify differentiation of a levy.

8.4 Effects of a levy on pesticides in horticulture and in other sectors

Although the arable sector is responsible for the greater part of total pesticide use in the Netherlands, this does not necessarily mean that the levies calculated for this sector would have the same effect in other sectors. The LCPP formulated different objectives for the other sectors (see Table 2.13). So the question is, should levies in other sectors differ from levies in agriculture, and if so, to what extent? To answer this question we have only the indications from the econometric analysis for the horticultural sector at our disposal; see Section 5.4.

The sectors fodder crops, livestock farming and public parks and gardens have not been taken into account. Fodder crops, of which green maize is the most important, have been left out of the analysis. Green maize has been excluded from the LP models altogether and has only incidentally been considered in the econometric analysis, because only 10% of green maize is grown on specialized farms (LEI/CBS, 1991, p. 21). Pesticide use in

[3] Price changes in the period 1989-2000 have not been taken into account. The prices used in the LP calculations were standardized 1989 prices (see Section 6.3).

fodder maize production is about 1.8 kg per hectare, whereas other arable crops use almost 7 kg per hectare (excluding soil disinfection) (see Appendix II).

Livestock farming primarily uses herbicides on pastures (80% of expenditure for pesticide) and cleaning agents. Herbicides are often used to improve the quality of the sward. For green maize that is not grown in specialized arable farming and for livestock farming the price elasticity of the demand for pesticides is assumed to be -0.25. The public parks and gardens sector mainly uses herbicides with a low content of active ingredient. The price of this type of chemical is high. Since responsibility for this sector is largely in the hands of local authorities, we ignored income effects in this sector.

The econometric method indicated a short-term price elasticity of -0.25 for the horticultural sector. Although the price elasticity appears to increase slightly in the long term (-0.29), we took a price elasticity of -0.25 as a starting point. As a result, the price elasticities for the horticultural sector are somewhat lower than the average price elasticities for arable farming. Price elasticities differ in the horticultural subsectors. The data used in the analysis in Section 5.4 were not suitable for examining the separate subsectors in more detail, therefore we will now discuss two relevant groups of factors.

Determining factors in explaining differences in price elasticities between sectors are:
1. The availability of alternative methods of crop protection. The fewer the alternatives, the smaller the price elasticity.
2. The share of pesticide costs in total revenues. If this share is large, a rise in the price of pesticides will have a relatively large impact on revenues, probably resulting in a relatively high price elasticity.

For an indication of the first factor see Table 2.13, which gives feasible reduction percentages. The differences in reduction percentages largely depend on the availability or absence of possible alternatives. Intensity of pesticide use (= use per hectare, see also Appendix II) is another aspect possibly playing a role. When these aspects are examined, it appears that price elasticities in the nursery stock industry, fruit growing and mushroom sectors are relatively small.

Chapter 2 deals with the relationship between costs of pesticides and total yields (factor 2) (see Table 2.7 and Appendix II). Fruit growing and flower bulb growing are the sectors with the highest share of pesticides in total yields. In all sectors the relationship between costs of pesticide and total revenue fluctuated around 1.5% in the period 1984-1988. It is also possible to concentrate on the value added per unit of pesticide (Stolwijk, 1991). A high added value signifies that it is difficult to reduce pesticide use by way of a levy. From the aforementioned it can be concluded that price elasticities will be relatively small in greenhouse systems and in the nursery stock industry.

It seems likely that price elasticities in the nursery stock industry, in vegetable growing under glass, floriculture and mushrooms are lower than in arable farming. This does not pose a big problem in the nursery stock industry and fruit-growing sectors, since the targeted percentages of pesticide reduction in these sectors are also smaller than in arable farming. However, in the other three sectors reduction percentages are comparable to those in arable farming. This means that vegetable growing under glass, floriculture and mushroom growing may require larger levies if a reduction similar to that in horticulture is to be achieved.

A calculation based on a price elasticity of -0.25 for the horticultural sector as a whole, indicates that to attain the reduction percentages required in the years 1995 and 2000, levies need be only slightly higher than those in arable farming (see Tables 8.1 and 8.2). For this reason it seems unnecessary to differentiate between the levies for arable farming and horticulture.

8.5 Effects on income

Overview

By income effects we mean the effects of a regulatory levy in combination with restitution - after deduction of administrative costs - on incomes in agriculture. Two things are at issue here. On the one hand there is a certain levy on pesticide use, expressed in Dutch guilders per kilogram of active ingredient. On the other hand there are the targeted reductions of pesticide use formulated in the LCPP. The levies required to attain these targets are derivatives: the size of the levy depends on the model used. The price level - another variable in our calculations - is also liable to changes and therefore needs to be considered.

To get a better overview, the income effects are often subdivided into subsectors. In the case of the analysis based on LP models, this is absolutely necessary because in this analysis only specialized arable farming in the most important production areas has been taken into consideration. To be able to compare the calculated income effects with one another, it is important to know which data the analyses are based on.

This chapter focuses on the size of a levy. We used the same standards for both restitution and administrative costs. Restitution was based on method B in Section 7.5, with the distinction that we did differentiate between arable farming and field horticulture. Note further that the public parks and gardens sector is not restituted. Administrative costs, based on the principle that pesticide users pay levies, have been estimated to be approx. 18 million guilders (DHV-LUW, 1991, p.147). The distribution of administrative costs is based on the share of pesticides in total expenditure in the period 1984-1988 (see Table 2.14).

Income effects derived from the demand function for pesticides

First of all we simulated the effects of a regulatory levy that would be sufficient to attain the targets set for 1995 and 2000. We used the assumptions mentioned above. The targets were derived from Table 2.13. Because there is a large difference in the targets for soil disinfectants and other pesticides, these two groups of pesticides have been distinguished. Moreover, a subdivision has been made into arable farming (including green maize) and horticulture. Because of important differences between horticulture under glass and in the field, both these types of horticulture have been distinguished, although the empirical research gave no separate information on elasticities.

The levies and income effects for 1995 and 2000 are shown in Tables 8.1 and 8.2, respectively. For larger reductions to be achieved in 2000, levies and income effects will have to increase substantially between 1995 and 2000. The income effect is a quadratic function of the levy (see also Section 5.3). We calculated regulating levies in 2000 of about 12 and 100 guilders for soil disinfectants and other pesticides, respectively. For soil disinfectants in field horticulture and other pesticides in closed horticultural systems (greenhouses) a higher levy is indicated. Because of the quality of the information, however, these differences are too small to justify a general subdivision of levies between different agricultural sectors.

Table 8.1 Levy for two different types of pesticide to attain the targeted reduction in 1995 and its income effects

Sector	Levy in gld/kg a.i.		Income effects in gld/ha			Income effect sector (mln gld)
	Soil disinfectants	Others	Soil disinfectants	Others	Total	
Arable farming	7.7	63	25	58	83	63
Horticulture						
- Field	12.0	74	84	255	339	32
- Under glass	7.9	130	165	938	1104	12

Table 8.2 Levy for two different types of pesticide to attain the targeted reduction in 2000 and its income effects

Sector	Levy in gld/kg a.i.		Income effects in gld/ha			Income effect sector (mln gld)
	Soil disinfectants	Others	Soil disinfectants	Others	Total	
Arable farming	11.7	99	55	122	178	130
Horticulture						
- Field	15.3	108	133	496	630	59
- Under glass	9.9	197	253	1994	2246	25

Total income effects for the agricultural sector are circa 110 mln guilders in 1995 and circa 210 mln guilders in the year 2000. The levy on 'other pesticides' is most important. Moreover, there are large differences in the income effects per hectare between the three sectors.

Sensitivity analysis

Because we had to make several assumptions (see Section 8.3 and Table 8.3, note 1) in estimating the consequences of a regulating levy on pesticides, it might be interesting to investigate the influence of each of these assumptions. We limit the analysis to four sets of assumptions. Each set has to be compared with the results of the basic assumptions[4]. We calculated the aggregate results for horticulture.

Table 8.3 Levy required to attain specified reductions (for the year 2000) in the use of pesticides (except soil disinfectants) in arable farming and horticulture under different assumptions, and its income effects

Variable	Assumptions					
	Basic[1)]	Other elasticities[2)]	Other model[3)]	Other prices[4)]		Other technological development[5)]
				Pesticides +2%/year	Arable products -3%/year	
Arable farming						
Levy	99	119	390	72	54	40
Income effect (gld/ha)	125	146	299	73	48	34
Total income effect (mln gld)	94	110	220	55	39	26
Horticulture						
Levy	120	150	554	100	120	54
Income effect (gld/ha)	621	762	1562	444	621	172
Total income effect (mln gld)	65	79	160	46	65	18

1) Period 1970-88 annual growth in the amount of pesticides used (because of technological change) is 4% in arable farming and 0% in horticulture. Price elasticity of demand for pesticides is -0.30 in arable farming and -0.25 in horticulture. During the period 1988-2000 annual price changes of pesticides, arable products and horticultural products are 2.6%, 1.2% and 3.1% respectively. During that period the annual change in the amount of pesticides (assuming constant prices) is 0%.
2) Period 1970-88: price elasticities of demand for pesticides in arable farming and horticulture are -0.25 and -0.20 respectively.
3) Log-linear demand function for pesticides with constant price elasticities of demand for pesticides as in the basic scenario.
4) Period 1988-2000: additional annual increase of the price of pesticides of 2% per year; additional price decrease of arable products of 3% per year.
5) Period 1988-2000: annual shift of minus 2% in the demand curve for pesticides.

The column 'other elasticities' in Table 8.3 illustrates the effects of a smaller reaction in pesticide use on prices of pesticides. The reactions show a nearly inverse relation with the absolute value of the price elasticity.

[4] Income effects under the basic assumptions are slightly different from Table 8.2, because of small differences in refunding the levy.

In the third column a log-linear demand function for pesticides has been assumed, with the same elasticity as the linear demand function in the estimated period. Here differences are very large. A log-linear demand function with an elasticity of -0.3 is rather extreme and cannot exist over a large range of prices (Deaton and Muellbauer, 1980, p. 17).

The higher the price of pesticides, the lower the levy required. Similar reasoning can be used to explain the effects of a reduction in the prices of arable products. Both developments are probable: large reductions in the use of pesticides could increase the marketing margin and the EC is already discussing lowering prices of arable products (Commission, 1991).

The importance of technological development is substantial. If there is an autonomous shift of -2% per year in the demand function for pesticides, the regulating levies required would be much lower (and vice versa). This illustrates the importance of interpreting historical trends in pesticide use. The sensitivity analysis makes clear that the results greatly depend on the assumptions.

Estimated reductions and income effects of different regulatory levies

To make the information comparable with the results of the LP model, we give some information of the reduction in the application of pesticides (excluding soil disinfectants) achieved by some levies by 2000. Here the same assumptions as for Table 8.2 have been used. The difference is that the levy on soil disinfectants is zero. Moreover, calculation starts from a particular levy and results in a percentage reduction.

Table 8.4 Income effect and reduction percentages for different levies in the year 2000 (excl. soil disinfectants)

Levy (gld/kg a.i.)	Income effect (gld/ha)	Reduction (%)	Income effect sector (mln gld)
	Arable farming		
25	23	10	17
50	44	20	33
75	79	30	59
100	127	39	95
	Field horticulture		
25	74	9	7
50	147	19	14
75	265	29	25
100	438	38	41
	Horticulture under glass		
25	161	6	1.8
50	251	13	2.8
75	401	19	4.4
100	611	25	6.7

Table 8.4 shows the results for four different levies in arable farming and horticulture. As might be expected from Table 8.2, the effects for closed horticultural systems (greenhouses) are limited.

DHV-LUW (1991, p. 128) advises a levy of 50 guilders per kg a.i. as the starting value. The effects of such a levy for different subsectors of agricultural production in the Netherlands are shown in Table 8.5. Because price elasticities were not estimated separately for the subsectors of horticulture, the results are only indicative.

Table 8.5 Income effect of a levy of 50 gld per kg a.i. (excl. soil disinfectants) for different agricultural sectors, year 2000

Sector	Total expenses pesticides/ha av. 1984-1988	Income effect (gld/ha)	Reduction (%)	Income effect sector (mln gld)
Arable farming	414	44	19.7	33
Field vegetables	874	53	10.9	2.4
Bulbs	2672	485	26.6	8.7
Nursery stock	2511	161	11.5	1.1
Fruit	859	121	23.0	2.8
Floriculture	4067	223	10.2	1.4
Vegetables under glass	2797	229	14.6	1.0
Mushrooms	22313	5643	33.0	0.5

Income effects derived from the LP models

In an LP model, the calculation of the income effects of a regulating levy is straightforward. Differences in the balance between revenues and variable costs determine the income differences between two different situations; for instance, when there are price differences between different types of pesticides. This way the average changes in income per farm and/or per hectare can be determined.

The economic analysis with LP indicated that current crop protection methods are not economically optimal in some respects. The model calculations showed that incomes could rise substantially if cropping patterns were changed.

As was shown in the analyses with econometric methods, the LP calculations also indicated that relatively small levies will cause only minor income losses to take place in the arable sector (see Table 8.6).

We assumed full restitution. The income effects in Table 8.6 relate to a situation where the levy is zero and all environmentally sound cropping patterns formulated can be applied. This situation is 'optimal' and is difficult to achieve in practice. Therefore, income loss in the real situation may differ slightly from the income loss calculated. In reality, the levy-induced income loss will probably be slightly greater.

Table 8.6 Income effects per farm and in guilders per hectare (arable farming) of a regulatory levy

Levy (gld/kg a.i.)	Per farm	Per hectare
0	0	0
25	1400	29
50	2600	52
75	5200	118
100	8700	188

A comparison with other calculations

The LCPP estimated the costs that will be incurred in crop protection in the Netherlands in the coming years as a result of reducing pesticide use (MJP-G, 1990, Background documents). Appendix V gives a brief overview of the costs for the arable sector. For the period 1990-2000 an income loss of 328 guilders per hectare per year for the whole arable sector has been calculated. Both the econometric and the LP approaches indicate income losses that are considerably smaller (see Tables 8.2 and 8.7). Even if large levies were imposed (for instance 100 guilders per kg a.i.; excluding soil disinfection for which a levy of 12 guilders per kg a.i. is required) income loss would be smaller. The econometric method yields an income loss of 178 guilders per hectare, including administrative costs. The method with LP models gives an income effect of 188 guilders per hectare (see Table 8.6), and therefore remains well below the 328 guilders per hectare. The LP calculations also show that a considerable increase in incomes is possible without a levy. The difference is largely to do with the assumptions made about expected losses in yield. The assumptions made in the LP calculations are more moderate than those made in the LCPP. Furthermore, the LCPP estimates a number of essential costs. We did not do this in the LP analyses; instead, we calculated these costs afterwards (see Appendix V). If these additional costs were included, then the total costs calculated would still be far behind the estimates in the LCPP.

For the horticultural sector, the differences between the costs stated in the LCPP and those following from our method, are even bigger. The LCPP arrives at total annual costs of 587 million guilders (see Table 8.7), whereas our calculations on the basis of a demand function for pesticides show a sum of 84 million guilders in the year 2000. This substantial difference is probably because in the LCPP estimates of all investment costs involved in transforming horticulture under glass into closed systems are included in the cost calculations. The aim of introducing this new technology is not only to cut pesticide use, but also to prevent emission of minerals (nitrate, phosphate, etc.). The introduction of new technologies may also be helpful in saving labour and reducing energy costs.

Notwithstanding the enormous increase in the financial burden calculated in the LCPP, it is assumed this policy can be pursued without any additional economic instruments, such as, for instance, a regulatory levy. This seems inconsistent with assumptions about the behaviour of arable farmers and horticulturalists.

If we compare our results for the bulb sector with De Vroomen et al. (1991, p. 28,79) and take South Holland as representative for the Netherlands, differences are small because Vroomen's estimate is 33 million guilders.

Table 8.7 Income effects of a reduction in the use of pesticides in mln guilders

Sector	LCPP		Demand function		LP
	1995	2000	1995	2000	2000
Arable farming	230	263	63	133	31.0[1]
Horticulture	498	587	46	84	-
- Floriculture	184	210	11	22	-
- Bulbs	45	60	21	30	-
- Nursery stock	23	39	1.7	5.0	-
- Mushrooms	3	5	0.1	0.1	-
- Fruit	35	45	2.9	8.5	-
- Vegetables under glass	153	160	3.8	8.0	-
- Field vegetables	55	68	5.2	10	-
Total	728	850	109	217	-

Source: MJP-G (1990), Background documents; own calculations
1) Excluding administrative costs. Based on a levy of 50 guilders per kg a.i. (see Appendix V)

8.6 Consequences of set-aside

The LP model includes set-aside as one of the options. A large share of the representative farm area has been put under set-aside in the Peat Colonies and the Northern sand area. The share of land under set-aside decreases with the availability of new cropping variants and increases with the levy on pesticides (see Appendix IV). As levies increase, set-aside (as one of the activities in the LP model) produces a substantial reduction in the application of pesticides and a relatively small income reduction. The reduction in pesticide use is partly caused by the assumption that no herbicides are required for fallow land (see Appendix V).

Two consequences of set-aside require more attention: the effects on the budget and on the delivering and processing industry. The budgetary consequences are quite easy to compute. The amount per hectare is 1500 guilders, three-quarters of which is to be paid by the national government and one-quarter by the EC. There are, however, differences between actual set-aside rules and the ones used in the LP model. Actual set-aside is restricted to areas for cereals, whereas in the LP model all land can be taken out of production. The results of the calculations are shown in Table 8.8. Here the area represented by the six LP farms has been multiplied by the factor 1.5 to give a complete representation of all arable land except the area under fodder maize. It will be clear that the budget costs of taking land out of production are quite high. With a regulatory levy of 50 guilders per kg a.i. the budget costs are more than three times the income effects.

Table 8.8 Set-aside area in the Netherlands and national budget costs under different conditions of optimization

Conditions		Set-aside	
		Area (* 1000 ha)	Budget costs national government (* 10^6 glds)
Actual[1]		0	0
Optimal[2]		93.3	105
Levy[3]	0	63.4	71
	10	63.4	71
	25	92.0	104
	50	94.6	106
	100	144.9	163
	150	158.0	178
	200	158.0	178

1) Here a simplification of the actual area has been used, see Chapter 6.
2) Optimal cropping pattern under the present technology, see Chapter 6.
3) Optimal cropping pattern with new cropping variants included; levy in guilders per kg a.i. (excluding soil disinfectants).

Table 8.9 Relative production levels (in percentages) of different products in the Netherlands compared with the actual situation

Crop	Optimal	Levy		
		0	25	50
Cereals	116	116	122	126
Sugarbeet	100	100	100	100
Ware and seed potatoes	100	100	100	100
Starch potatoes	0	27	27	27
Onions	119	119	78	55
Other crops	23	23	0	0

The consequences of set-aside for the delivering and processing industries as well as for trade and transport might be substantial. Here, figures compared with actual production levels have been given for a number of crops included in the analysis of Chapter 6 (see Table 8.9). The reduction in the production of starch potatoes is especially dramatic. Input prices and product prices here will probably adjust if such changes take place. Moreover, part of the increase in pesticide costs could be shifted to the delivering and processing industries, implying that a levy would have less effect than predicted by modelling. This is another illustration of the rough methodology of LP modelling.

8.7 Evaluation of the methods applied in calculating the effects of a levy

In Chapter 3 several methods were introduced to analyse the effect of a regulatory levy on pesticides. Assuming no uncertainty, three different methods were introduced: crop management models, cropping plans at farm level and neo-classical economic models at average farm or sector level. Each approach requires different information and (as might be expected) gives different empirical results.

One of the useful aspects of using different models is the range of results that are obtained. If one could interpret the reasons behind such results, it would give at least an indication of the levy required to attain a particular reduction in the application of pesticides.

The results of crop models have been used only indirectly (through the literature and by preparing new cropping variants for the LP models) in this research. The methodology is very labour-intensive and often gives incomplete results, unless very broad information on many crops, types of soil and other conditions is available. If we interpret the results in the literature, crop models often indicate that levies on pesticides are not very efficient. This might be because of the limited context in which the problem was studied. Switching to new technologies, other crops or other cropping variants is beyond the standard methodology of these models.

LP models provide the opportunity to study problems at farm level and to introduce new technologies that still have to be applied in practice. One of the main problems of the LP models is the large difference between the actual situation and the model (under the same conditions). In our research this difference was very large and made it difficult to derive reliable results for the effects of regulating levies. It could be argued that the LP models indicate a lower limit for the required levy. Moreover, the models give no indication about the time-lag between imposing a levy and the result of such a levy. The final results depended heavily on the assumption of set-aside and of constant product prices. Ultimately, both assumptions seemed unrealistic.

The neoclassical economic model resulted in the most useful results, although one might question the basic assumption of a concave production function for pesticides. The data, however, did not indicate problems in this respect. Effects of new technologies that differ from the normal development are difficult to incorporate. Moreover, it is very questionable whether a model that has been estimated on a very small range of pesticide prices can be used to calculate the effects of levies that more than double the price. Sensitivity analysis illustrates large uncertainties.

Given the rather wide range of results and the important uncertainties with respect to models, coefficients, technological development, etc., it seems unjustified to give too much attention to the problem of incorporating risk explicitly in the analysis. Therefore we restricted ourselves to some reasoning from approaches and models that incorporated risk elements.

8.8 Concluding remarks

Given the lack of information on the negative external effects of pesticides, fixing a levy on the basis of the LCPP objectives is the only possible way to examine the levy that is required. Considering the margins of uncertainty in this study, it seems that a levy of 25 to 100 guilders per kg a.i. (excluding soil disinfection) will lead to the desired reduction of pesticide use by the year 2000.

It seems delusory to believe that the policy instruments proposed in the LCPP will achieve the formulated reductions in pesticide use, (except for soil disinfection), unless an extensive list of bans and authorizations in combination with a severe policy towards chemicals are pursued (see Chapter 9). The calculations indicate that even if new cropping variants are introduced on all Dutch farms, the targeted reductions in pesticide use will not be achieved. It is likely that arable farmers and horticulturalists will gladly adopt new technologies that lead to a net cost reduction as soon as these technologies become available. Starting from the cost calculations in the LCPP, the arable and horticultural sectors will suffer considerable income losses. It is inconsistent to assume that under such conditions new technologies will be easily adopted. As noted in Section 8.5, the income losses mentioned in the LCPP have probably been overestimated. Nonetheless, the principle still stands that technological changes will be easily accepted only if this benefits those who take the decisions (i.e. the farmers and growers).

A regulatory levy might be an important tool in the process of achieving the technological developments proposed in the LCPP work. Imposition of a regulatory levy, in conjunction with measures taken by (and information given to) individual farmers and growers will provide a useful basis, and will enable policy instruments to be directed more precisely and therefore more effectively in the future. The introduction of a regulatory levy will probably give new impetus to the investigation of the value of the negative external effects of pesticides in money terms. So far, this assessment has not taken place. The task set in the LCPP was primarily to concentrate on reduction percentages that were technologically feasible.

9. ASPECTS OF THE POLICY ON COMPOUNDS

9.1 Introduction

The previous chapters extensively discussed the feasibility of cutting pesticide use by means of a regulatory levy. We investigated this levy option as a supplement to the battery of measures put forward in the Long-term Crop Protection Plan (LCPP) (see Section 2.5). The proposed regulatory levy increases the chance that the amount of pesticides used, expressed in kg active ingredients, will be reduced to an acceptable level. Imposing a regulatory levy would, therefore, enforce the "volume policy" pursued by the Dutch government.

The volume policy hardly distinguishes between different types of active ingredient. Its main aim is to cut overall pesticide use. The less pesticide used the better: 8600 tonnes per year in the Netherlands is better than 20 260 tonnes. In this approach it does not really matter which active components are involved. The policy on compounds, however, pays less attention to the quantities used but focuses on two categories of compounds: chemicals thought to be harmful and those that are harmless or less harmful.

So, in previous chapters the volume policy was central. This final chapter complements the discussion in Chapter 2 and focuses on the policy on compounds (by way of the policy on authorized compounds). Sections 9.4 and 9.5 discuss likely consequences of the intended policy on compounds for arable farming and horticulture, respectively. In the preceding section (9.3), the way of handling data and information are briefly discussed. Finally, in Section 9.6, the joint implications of both the volume and compound policies for arable farming are given and the extent to which pesticides mentioned in the volume policy are involved in the policy on compounds is investigated. The chapter ends with some conclusions.

9.2 Policy on compounds

In Section 2.4 problems in current pesticide use were listed. The diffusion of chemicals into the environment and the effects of this on flora and fauna led to proposals for banning these chemicals. The Dutch government can withdraw authorization for using certain compounds if they have unacceptable damaging side-effects. Assessing pesticide use reveals that a considerable proportion of the pesticides currently used fulfil the qualifications for being banned: 65% of the group of chemicals investigated (195 compounds/active ingredients) are harmful to the environment (see Section 2.5). In this and the following section we will deal with this fraction only. Although it is conceivable that other problems in agriculture (e.g. resistance to pesticides) might also give rise to proposals to ban chemicals, we have not heard of any such proposals (see Sections 2.4 and 2.5).

In a study preceding the LCPP, Ruiken (1990) and Ottenheim et al. (1989) examined pesticides that can cause environmental damage. Both studies based their conclusions about whether or not a pesticide is damaging to the environment on a synthesis of existing lists of criteria. Ruiken listed 278 harmful compounds, 10 of which should be banned immediately, 104 within one year, and 164 within five years. Ottenheim et al. estimated total pesticide use to be 19 660 tons of active ingredient per year in the Netherlands; 60% of which (11 832 tons; 110 components) they deemed to be 'harmful to the environment'. They investigated the availability of biotechnological alternatives. The Long-term Crop Protection Plan proposes banning certain chemicals on the grounds of environmental criteria by tightening up the policy, on authorizing chemicals. This should be done in two stages: before 1995, and before 2000.

The criteria for the first stage are:
- The presence of the compound has been demonstrated in the upper groundwater (up to 10 metres below ground level) in a concentration exceeding 0.1 μg/l.
- The model computations show that the compound leaches out from the upper groundwater (up to 2 metres below ground level; up to 10 metres below ground level according to additional model computations) in concentrations above 10 μg/l.
- As a result of application to one or more crops, the compound exceeds the acute toxicity limit of 0.1 LC50 for fish and L(E)G50 for algae or crustaceans.
- The compound exceeds the persistence limit of DT50 of 180 days. This implies that 50% of the original quantity is still in the soil after 180 days.

The criteria for the second stage are:
- The model computations show that the compound leaches out into the upper groundwater (up to 2 or 10 metres below ground level) in concentrations above 0.1 μg/l.
- As a result of application to one or more crops, the compound exceeds the acute toxicity limit of 0.1 LC50 for fish, algae and crustaceans.
- The compound exceeds the persistence limit of DT50 in the soil after 60 days.

The results of this policy on compounds largely depend on how it is pursued.

Environmental groups strongly support a ban on all compounds that do not comply with the above criteria (see Vogelezang-Stoute and Matser, 1991). Agricultural circles, however, support fine-tuning the policy on compounds with the volume policy (Ritsema, 1991), because this would also take account of consequences for agriculture. Economic effects of banning compounds have to be balanced with information about the harmful effects of these compounds. Study groups in the different sectors are currently working on this. Because of the important economic consequences, clarity is called for (Simons-Vinkxs, 1991).

A cutback in pesticides can also be brought about without the policy on authorized pesticides or in addition to that policy. Banning of pesticides could be based on information similar to the criteria and data used for authorization. This would imply a reduction of the amount of harmful compounds applied.

To support growers and extension officers, three types of "environmental yardsticks" are currently being developed (Reus, 1991):
- one for leaching to groundwater;
- one for the risk to soil organisms;
- one for the risk to water organisms.

The acceptability of an environmental burden can be brought on a one-dimensional scale (see e.g. De Vroomen et al., 1991, p. 136-141). In the future this could be an important step to solving the problem, but it is not discussed in this chapter any further.

9.3 Working method to determine the consequences of a policy on compounds

In this chapter "banning" means withdrawing authorization for all compounds listed by the LCPP.

We discussed soil disinfectants in earlier chapters. Soil disinfectants have been used in such large amounts in the Netherlands that a different banning regulation has been proposed for them. Starting 1995, or possibly earlier, liquid soil disinfectants will only be available on prescription if a number of conditions are satisfied (see LCPP; Appendix 2). In this chapter we assume that these compounds (dichloro propane, metham-sodium and dazomet) will be dealt with in this way.

Before discussing the influence of the LCPP policy on compounds, we shall first consider the inventory of pesticide use compiled by Berends (1988). Looking more closely at the different Dutch inventories on pesticide use, including the one in the LCPP, they all appear to originate from this source. Berends's report obviously contains the best information available. He gives information on the intensity of pesticide use in 1987 for 37 crops, and per crop for 7 regions at most (for sugarbeet). He selected these using two criteria: (1) districts where crop protection experts from the extension service are stationed, and (2) soil type (sand, clay). The latter is important for weed control. These regions differ from the agricultural regions distinguished by the LEI/CBS. The cooperation of these experts is especially important in assessing the likelihood of application (the part of the area treated), the period of application (months) and the application frequency (number of treatments per year). Drawing on this expertise Berends was able to make a valuable inventory of the potential burdens to surface water, which was only partly made use of in subsequent inventories, including ours.

So, how have the consequences of the policy on compounds been determined? By using the same database as used for the volume policy. In this database the active components involved in each amount of pesticide have been determined (see Chapter 2). So the components to be banned can be deleted from this list, to leave an amount of pesticides, expressed either in kg active ingredient or in guilders. There is no substitution assumed by other compounds that are still on the list. To be able to compare the volume policy with the policy on compounds, the effect of the volume policy has been expressed in percentages of reduction, related to the use in the period 1984-1988. We have not examined whether crops can actually be grown under these circumstances.

The range of pesticides that will remain in the year 2000 determined in this way is both too narrow and too broad. It is too narrow because:
- authorized substances, applied in unknown amounts, have not been included in the database;
- compounds authorized after 1987 have not been taken into account;
- no account has been taken of the list of pesticides that have to be excluded for agricultural reasons (see Section 2.5);
- combinations of active ingredients are deleted if one of the ingredients is banned.

The range is too broad because it does not take account of additional environmental criteria which have recently been announced (MVROM, 1991a).

9.4 The policy on compounds and arable farming

In this section we pay attention to the effects of the intended policy on compounds upon arable farming, see Table 9.1. In the period prior to 1990 the effects of a ban on dinoseb were far-reaching (see 'other pesticides' and several types of potatoes).

Table 9.1 Anticipated reduction in annual use of pesticides (excluding soil disinfectants) in the Dutch arable sector resulting from the proposed policy on compounds. Data give percentual reduction in kg a.i. and in guilders for each category of pesticide and with 1984-88 as reference period

Category	Realized compound policy[1]	First phase compound policy (1995)[2]		Second phase compound policy (2000)[2]	
	kg	kg	guilders	kg	guilders
Total	14	76	44	88	60
Pesticide					
- soil treatment	13	74	70	100	100
- herbicides	8	68	38	77	52
- fungicides	0	93	69	98	92
- insecticides	0	54	22	76	63
- others	78	80	23	86	26
Crop					
Ware potatoes[3]	20	96	46	98	50
Pulses	15	57	38	79	51
Starch potatoes	23	98	91	100	100
Barley	0	86	61	97	96
Grass seed	0	30	15	83	44
Caraway	0	12	13	12	13
Rapeseed	0	30	21	76	62
Fodder maize	2	88	74	92	80
Seed potatoes	50	92	45	99	98
Sugarbeet	2	46	29	51	34
Winter wheat	0	27	12	78	70
Field beans	5	83	41	89	54
Onions	0	58	37	90	68
Others	0	95	84	95	84

1) Compound policy realized in the years 1988 and 1989 (CTB/BB, 1991)
2) Compound policy intended in the government decisions for 1995 and 2000 (MJP-G, 1991)
3) Crops printed in italics are included in the LP models in Chapter 6

From Table 9.1 it can be concluded that in both stages the relatively cheap chemicals will be banned: the reduction percentage in guilders is less than the percentage expressed in active ingredients. This means that most of the pesticides banned as a result of the policy on compounds will be the relatively cheap ones.

As a general tendency, a policy with a regulatory levy per kg of active ingredient parallels a compound policy, because compounds that are banned bear the highest levies per kg a.i. This does not imply that this parallel between reduction volume and compounds holds for all pesticides. A trend towards producing and applying pesticides with a low content of active ingredient has been observed (see Chapters 2 and 4).

The first stage will see a considerable increase in reduction percentages. For the period after the ban (in the year 2000) the following can be anticipated:
- hardly any soil treatment compounds and fungicides are applied anymore;
- the reduction in the use of herbicides and insecticides is relatively small;
- pesticide use is minimal in potato and barley, and very low in green maize and onions;
- no major changes in pesticide use in caraway seeds are necessary, whereas in sugarbeet only minor reductions are necessary.

The reduction percentage of active ingredient (measured in kilograms) in the year 2000 is equal to 88%. This number can be compared with the results of a similar calculation made by NEFYTO (1991, p.4), where they conclude that the banning of pesticides concerns 84% of the total amount of pesticide used in 1990. Table 9.1, however, refers to 1984-88 and only to the arable sector.

Comparing Tables 2.13 and 9.1 reveals that this compound policy for arable farming works more drastically (larger reduction percentages) than the volume policy (for soil treatment compounds 100% instead of 50%; for herbicides 77% versus 45%, etc.).

9.5 The policy on compounds and horticulture

The LCPP distinguishes seven subsectors in horticulture. In the following we restrict ourselves to fruit growing, field vegetable farming and greenhouse horticulture. From the analysis, the consequences of the policy of compounds for the whole horticultural sector can be derived.

Table 9.2 elucidates the effects of the policy on compounds (excl. soil disinfectants) in the horticultural subsectors mentioned above. The part of the authorization policy that has already been implemented has not yet proven effective. Therefore, this period has not been mentioned separately in the table (compare with Table 9.1). Only the three main crops have been included in the table.

Table 9.2 shows that (similar to arable farming) in field horticulture it is the relatively cheap chemicals that are banned. The opposite seems true for greenhouse vegetable growing. Note that as far as prices of pesticides are concerned, the database is more complete for arable farming than for greenhouse horticulture. For both arable farming and horticulture it holds that the amounts applied are reduced considerably in the period 1990-1995. For the period after the year 2000, when the ban will have become fully effective, it can be predicted that:
- in fruit growing, soil treatment compounds and herbicides are prohibited; insecticide use is still considerable;
- in field vegetable growing, treatment compounds are no longer used; fungicides are still relatively widely used;
- in greenhouse vegetable growing no single category of chemicals has been completely

banned; soil treatment compounds and herbicides are still used on a relatively large scale;
- in apple and pear growing a much smaller volume of chemicals is applied;
- no big changes in pesticide use are necessary in carrot growing.

Table 9.2 Anticipated reduction in annual use of pesticides (excluding soil disinfectants) in the Dutch horticultural subsectors fruit, field vegetables and vegetables under glass resulting from a policy on compounds. Data give percentual reduction in kg a.i. and in guilders for each category of pesticide and with 1984-88 as reference period

Category	Compound policy first phase[1]		Compound policy second phase[1]	
	kg	guilders	kg	guilders
Total Fruits	82	66	84	69
Vegetables (field)	51	33	67	57
Vegetables (under glass)[2]	30	52	34	59
Ditto, excl. formalin	53	52	60	59
Fruits				
Soil treatment	100	100	100	100
Herbicides	99	99	100	100
Fungicides	92	91	92	91
Insecticides	27	24	41	33
Other	21	21	21	21
Vegetables (field)				
Soil treatment	100	100	100	100
Herbicides	51	33	67	57
Fungicides	46	31	46	31
Insecticides	36	40	56	67
Others	0	0	0	0
Vegetables (under glass)				
Soil treatment	13	32	13	32
Herbicides	12	32	16	35
Fungicides	55	47	60	50
Insecticides	66	60	79	72
Others	0	0	0	0
Crops[3]				
Apple	83	70	85	72
Pear	82	51	83	53
Carrots	23	25	23	25

1) Intended compound policy with a first phase for 1995 and a second phase for 2000 (MJP-G, 1991).
2) Including 62 040 kg formalin out of a total of 144 706 kg active ingredient.
3) Only the three crops with the greatest use of active ingredient are included.

Comparing Tables 2.13 and 9.2 reveals that for field cultivations the policy on compounds could be more drastic (higher percentages of reduction) than the volume policy. This is illustrated by herbicide use (in fruit growing 100% versus 55%, in field vegetable growing 67% versus 31%). For cultivations under glass the opposite seems true: here the volume policy is sometimes more drastic than the policy of compounds (a 50% reduction in herbicide use in greenhouse vegetable growing versus 16%; for the category 'other' a reduction of 50% versus 0%).

A complication arises in the category greenhouse disinfectants and glass cleansing treatments. In Table 2.12 these chemicals were excluded from the inventory. However, they are included in the scheme of the greenhouse horticulture subsector. The plan for the greenhouse horticulture subsector aims at a reduction that includes these chemicals (Table 2.13; other). In the database only the disinfectant that can be transformed into the active ingredient formalin is included. This chemical is characterized by its high content of active ingredient and its low price. In a small sector like greenhouse vegetable growing these characteristics can greatly influence the effect of the policy on compounds and the volume policy (as can be seen in Table 9.2). Without formalin the quantitative reduction percentage in greenhouse vegetable growing is comparable to that in field vegetable farming. An analysis at crop level (not included in Table 9.2) shows that crops such as plums, greenhouse strawberries, cauliflower, broccoli, salsify, spinach and chicory, as well as carrots (included in the table) have to undergo relatively few changes as a result of the policy on compounds (reductions of less than 40% in the year 2000).

9.6 A synthesis of the volume and compound policies

Table 9.1 shows which crops have been included in the economic study using linear programming (Chapter 6). After the policy on compounds proposed in the LCPP has become effective, only 18% (expressed in number of active ingredients; see De Jong, 1991, Bijlage III) of the group of pesticides we originally started with in the study remains. These active ingredients are chloridazon, difenoxuron, ethofumesate, fenmedifam, fluaziflop-p-buthyl glyphosate, metobromuron, iprodion, vinclozolin and chlormequat. The question is: are these chemicals used in current arable farming or will they be used in future arable farming (based on models) under a high levy per kg active ingredient?

We will now analyse the situation for the central clay area in the Netherlands. Similar conclusions may probably be drawn for other areas in the country. We determined the possible effects of the policy on compounds for levies of different sizes (see also Section 6.5; Table 6.7). Strictly speaking, we should have excluded cropping variants in which a certain chemical is banned: such variants will simply become impossible. However, we did not do so. We determined the influence of the policy on compounds by deleting the amounts of future banned pesticides that are applied presently (see Section 9.3). No substitution has been assumed. Data are derived from the optimal solutions of the LP model.

Table 9.3 indicates the effects of the policy on compounds for levies of different sizes. The degree to which a chemical is used at a levy of 50 guilders has been estimated to be

5.7 kg active ingredient per hectare, which means a 29% reduction in use (see Table 9.3 a and c).

Table 9.3 Anticipated effect of a policy on compounds and of some levels of regulatory levies for large farms in the central clay area of the Netherlands. Effects are in percentages of reduction compared with no levy and no compound policy

Policy	Levy in guilders per kg active ingredient		
	0	25	50
a) Reduction (%) compared with zero levy and no compound policy			
No compound policy	0[1)]	17	29
Compound policy first phase	77	86	92
Compound policy second phase	93	98	99
b) Reduction compared with situation without compound policy			
No compound policy	0	0	0
Compound policy first phase	77	83	88
Compound policy second phase	93	98	99
c) Reduction compared with zero levy			
No compound policy	0	17	29
Compound policy first phase	0	38	63
Compound policy second phase	0	69	86

1) Total amount of active ingredient is 723 ton for an area of 90 200 ha (see also Table 6.7).

The effect of the policy on compounds seems to be levy-dependent. Similarly, the effect of the levy seems to depend on the policy on compounds (see Table 9.3b and 9.3c). Ideally, an increasing levy would diminish the effect of the policy on compounds, because then both policies (policy on compounds and the volume policy) would be complementary. However, the opposite is true. Measured in amounts of active ingredient, nearly all pesticides used at a levy of 50 guilders appear to be candidates for banning under the proposed policy on compounds. Ultimately (i.e. by the year 2000) an amount of 0.1 kg of active ingredient per hectare will be used in the central clay area.

This brings us to the question of which substances survive in the final situation and which do not when a levy of 50 guilders is imposed in the context of the policy on compounds. In sugarbeet and seed onions the herbicides difenoxuron and fenmedifam will still be used in the final scenario. A 99% reduction would be achieved by withdrawing the following types of pesticide:

- Herbicides: mecoprop, metamitron, paraquat, pendimethalin, chloropropylate and metribuzin;
- Fungicides: maneb/chlorothalonil, maneb/vinclozolin, maneb and maneb/fentin-acetate;
- Insecticides: pirimicarb, parathion;
- Other: carbofuran and maleic hydrazide.

However, these chemicals are essential in the cropping variants for winter wheat, seed onion, sugarbeet and potato, selected by the LP model.

Unfortunately, the conclusion to be drawn from this analysis is that the use of chemicals harmful to the environment is not reduced by imposing a levy of 50 guilders. The opposite is true: a stringent volume policy increases the proportion of pesticides harmful to the environment.

9.7 Conclusions

The policy on compounds, proposed in the Long-Term Crop Protection Plan, may have a dramatic effect on the amounts of pesticides applied. If banning in the policy on compounds means withdrawing authorization for all substances harmful to the environment (excluding soil disinfectants), then higher reduction percentages can be achieved in arable farming and in horticulture than by pursuing the volume policy. In the period before 1995 the amounts applied will be reduced considerably under the assumptions of a full application of the reduction and no substitution by remaining or new pesticides. The amount of pesticides decreases faster than the money value, because chemicals harmful to the environment appear to be relatively cheap. Because of the relative low price of substances harmful to the environment, a uniform levy per kg a.i. works in the same direction as a policy on compounds.

Field horticulture shows results similar to arable farming. Different conclusions are to be drawn for greenhouse horticulture: here volume policy and policy on compounds do not work in the same direction. The effects of different categories of pesticides differ per subsector.

Analysing the effects of a levy in relation to the policy on compounds (for arable farming in the central clay area of the Netherlands) indicates that the higher the levy the more dramatic the impact of a policy on compounds. A number of herbicides, fungicides and insecticides are irreplaceable in the volume policy and will have to be banned in the policy on compounds.

SUMMARY

The application of pesticides in the Netherlands - measured in active ingredient per hectare - is very much higher than in other countries. This became clear from the Long-term Crop Protection Plan (LCPP) that made a detailed inventory of the application of pesticides in the Netherlands. Additional information from other sources like OECD, FAO, and individual countries illustrates the exceptional position of the Netherlands.

Several reasons can be given for the high application of pesticides. One is the intensive cropping scheme, with a large share of potatoes which use large quantities of soil disinfectants and fungicides. Moreover, the important share of horticulture in total plant production leads to large amounts of pesticides being used per hectare, although not per unit of production or value added.

Trends in pesticide application are not very easy to derive, but sources indicate that in the 1970s there was a substantial increase in the use of pesticides in arable farming. Although this increase seems to have levelled off there is still a slight upward trend.

The LCPP sets out the objectives of future crop protection policy in the Netherlands. It sets reduction targets for each group of pesticides and for each sub-sector of agricultural production. These targets are mainly based on reductions that can be achieved by technological change, and on an understanding of the best practices and assumptions about the application of integrated production in arable farming and closed systems in greenhouses. Most of the targets have a technical basis and it is not clear how farmers will adopt these major reductions in pesticide applications if production costs increase substantially. As well as aiming to reduce the amounts of pesticide used by about half, the LCPP also advocates a policy related to chemical compounds; this involves prohibiting any more pesticides whose benefit to agricultural production is outweighed by the threat they pose to the environment.

This study investigates the policies to reduce the amount of pesticides used and the policy related to chemical compounds. We considered two questions. The first is whether a regulatory levy on pesticides could be a useful instrument to attain the targeted reductions in the LCPP. To find the answer, the analysis concentrates on the relation between the quantity and price of pesticides, e.g. the demand function of pesticides. Experience from other countries, literature research, econometric models and linear programming models are used to elucidate this relation. The second question is: What are the effects of the policy related to chemical compounds. The LCPP contains a long list of pesticides that will not be authorized for use in the Netherlands in the future. Therefore, applying this list and comparing it with present application of pesticides in arable farming and a number of sub-sectors in horticulture indicates the effect of this compound-related policy. The central element of this study is the analysis of the first question; the second question is analysed in the last chapter.

According to economic theory the optimal levy is equal to the marginal social costs of emission at the optimal level of pollution. Unlike revenue oriented taxes, which are aimed at financing the implementation of policy, the main objective of a regulatory levy is to encourage behavioral change. Because of lack of information and because pesticides lead to

so-called "non-point source pollution", we study the efficacy of a levy on pesticides to achieve the goal set in the LCPP.

Remarkably, there is no uniform economic theory on the optimal application of pesticides; several models have been applied to different questions. We have tried to reconcile these different approaches on the basis of two different production functions. Production functions describe the relation between the input of pesticides and the product output under different conditions. It has been shown that different approaches such as threshold models, programming models and neo-classical economic theory assume particular type of production functions and concentrate on specific aspects of the question of optimal use of pesticides under different conditions.

Because risk elements play an important role in many analyses on the application of pesticides, we discuss the effect of introducing uncertainty in the different models and also the consequences of the risk-averse behaviour of agricultural producers. Different models can give contradictory conclusions on the consequences of introducing uncertainty in such models, but we explain that these conclusions depend on the form of the production function that has been assumed.

Experience from other countries (mainly Sweden) is considered, when evaluating the effects of regulatory levies. The information is limited and sometimes rather scattered, but there are some indications about the price elasticity of demand for pesticides. It appears that if a substantial reduction is necessary, the levies should be high.

To analyse the relation between the quantity and price of pesticides in the Netherlands, two different approaches are developed. Both are based on the assumption of rational behaviour of producers, maximizing the difference between revenue and variable costs, and that the farmer is a price taker in the output and variable inputs markets.

The first approach is econometric, based on historical data on prices and quantities. The basis is a profit function for both arable farming and horticulture, together with the related demand functions for inputs (in this case, pesticides and other variable inputs) and the supply function of output. Long-term adjustments in the application of pesticides are partly based on a partial adjustment model for capital investments. With such a model based on economic theory, a demand function for pesticides can be estimated, and the consistency of the assumptions can be tested. Price elasticities of demand can be derived. They indicate a short-term price elasticity of about -0.3 for the arable sector. This means that a 1% rise in the price of pesticides will reduce the application of pesticides by 0.3%. Long-term price elasticities are not very different, because investments in capital goods are only slightly affected by prices of pesticides. The econometric approach yields short-term and long-term price elasticities for horticulture of -0.25 and -0.29, respectively.

The other approach is based on linear programming (LP). It enables the effects of different levies for different pesticides to be investigated. The LP approach indicates that even without a regulatory levy a considerable reduction in pesticide use is possible without any loss of income. This is particularly true for soil disinfectants, whose use is already unprofitable under current circumstances according to the LP calculations. Obviously there is a large difference between the actual behaviour of arable farmers and optimal behaviour according to the LP models. This difference between model and reality has been considered, but it is difficult to give a clear explanation. The LP approach indicates that for pesticides (except soil disinfectants) a levy between 10 and 25 guilders per kg of active ingredient would suffice to reach the target level in the year 2000. There were no clear differences between the various categories of pesticides. The levies calculated via the LP approach appear to be quite low compared with other experiences and studies. This is because of the model and the empirical information we used.

A regulatory levy always gives a surplus revenue above the optimal costs of abatement. One of the principles of a regulatory levy - as formulated in the Dutch National Environmental Policy Plan - is to return the revenue of the levy (after deducting administrative costs) to the sector. Several ways of levying pesticides and returning the levies are discussed. The most feasible in the long term seems to be to levy and restitute each individual producer. This requires much administration, however, with attendant high costs and the need for intensive checking.

To attain the reduction targets set in the LCPP for the year 2000 without a restrictive compound-related policy, a regulatory levy on pesticides is a useful and even an unavoidable instrument. Experience from other countries, literature research, econometric models and linear programming models indicate how big the regulatory levy should be. The LP model provides a lower limit for the levy (25 guilders per kg of active ingredient), because optimal behaviour and full information are assumed. The results depend heavily on the assumption of set-aside and constant product prices and, as already mentioned, there is a great difference between actual behaviour of arable farmers and optimal behaviour according to the LP models. The econometric model provides an upper limit to the levy (100 guilders per kg of active ingredient), because the effect of a probable increase in technological change is not taken into account. However, it is very questionable whether a model that has been estimated on a very small range of prices of pesticides can be used to calculate the effects of levies that more than double the price.

Sensitivity analysis illustrates the large uncertainties. Clearly, there is a large difference between soil disinfectants and other pesticides. Because the first category has a very low price per kg of active ingredient and because regulations about the use of soil disinfectants have been changed, it seems probable that a large reduction in application can be achieved with a very small levy.

The acceptability for the agricultural sector of a regulatory levy on pesticides depends on the income effects this levy would have in the sector. For a given demand function of pesticides it is easy to derive the income effects for producers. The total income effects for the agricultural sector are 110 mln guilders in 1995 and about 220 mln guilders in the year 2000. A sensitivity analysis indicates that the results greatly depend on the assumptions. We also calculated income effects and reduction percentages for different levies in the year 2000. The LP model indicates that the income effects for the arable sector of a particular regulatory levy are quite similar. However, the econometric study and the LP model indicate income effects that are substantially smaller than in the LCPP. This suggest that a regulatory levy is more efficient than other types of policy in achieving particular target levels.

The compound-related policy is investigated in the last chapter of the book. For all sectors this policy will reduce the application of pesticides quite severely. Here we assumed no substitution between different pesticides; therefore this might be considered as a maximum estimate of the effects of a compound-related policy. The percentual reduction in active ingredient is much larger than the reduction in the money value of pesticides. Cheaper pesticides are more often on the 'black list'. This illustrates that a levy per kg of active ingredient is more in line with a compound-related policy than a percentual levy on the price of pesticides. In this chapter the pesticides applied in new cropping variants and in optimal production plans under a levy are compared with the pesticides that will be authorized in the future. Here we found that a large part of the pesticides that will not be authorized in the future are incorporated in the optimal production plans. This illustrates the different effects of a volume policy and a compound-related policy. If the main purpose is to reduce the environmental burden of pesticides, a policy directed at the volume of pesticides will not always work in the right direction.

LITERATURE

Aaltink, A.J. (1992). Economische gevolgen van de beperking van het bestrijdingsmiddelengebruik in de akkerbouw. LUW, Wageningen (Thesis, Department of Agricultural Economics).

Agrofarma (1990). Gli Antiparassitari e l'Agricoltura. Associazione Industrie Difesa Produzioni Agricole, Milano.

Anderson, J.R., J.L. Dillon and B. Hardaker (1977). *Agricultural decision analysis*. Iowa State University Press, Iowa.

Andréasson, I.M. (1989). *Costs of controls on farmers' use of nitrogen*. Economic Research Institute, Stockholm.

Anonymous (1988). Die wirtschaftliche Entwicklung der Pflanzenschutzmittel-Industrie war 1987 weniger befriedigend. *Gesunde Pflanzen* 40 (9): 379-382.

Baumol, W.J. and W.E. Oates (1988). *The theory of environmental policy*. Cambridge: Cambridge University Press.

Berends, A.G. (1988). Bestrijdingsmiddelen en oppervlaktewaterkwaliteit; Een inventarisatie van het gebruik van bestrijdingsmiddelen in de akker- en tuinbouw. DBW/RIZA.

Besseling, P., C. Kusters, T. de Koeijer, M. Pebesma and A. Pronk (1988). Produktiebeperking in de akkerbouw door middel van extensiveren. LUW Wageningen (Project thesis).

Boadway, R.W. and N. Bruce (1984). *Welfare Economics*. Basil Blackwell, Oxford.

Boer, H.B.P. and L.J. van Keulen (1992). Een inventarisatie van het gewasbeschermingsbeleid en het gebruik van bestrijdingsmiddelen in EG-landen en Zweden. (Thesis, Department of Agricultural Economics).

Boerma, J. (1989, 1990). Jaarverslagen 1987 en 1988 proefproject Borgerswold, PAGV, Lelystad, Verslag 90 en 105.

Buck, A.J. de (1991). Milieu-economische modellering: De gevolgen van milieurestricties op de teelt van consumptieaardappelen in de Noord-Oostpolder. LUW, Wageningen (Thesis, Department of Farm Management).

CAD Gewasbescherming (1986). Handleiding 1987; De chemische bestrijding van ziekten, plagen en onkruiden in landbouwgewassen. CAD-G, Wageningen.

CAD Gewasbescherming/Plantenziektenkundige Dienst (1987). Gewasbeschermingsgids; Handboek voor de bestrijding van ziekten, plagen en onkruiden en de toepassing van groeiregulatoren in de akkerbouw, veehouderij, tuinbouw en het openbaar groen. CAD-G and PD, Wageningen.

Carlson, G.A. and C.E. Main (1976). Economics of diseaseloss management. *Annual Review of Phytopatology* 14: 381-403.

Carlson, I. and B. Dahl (1991). Swedish government bill on environmental policy 1990/91:90; A living environment - main proposals. Riksdagen, Stockholm.

Carson, R. (1962). *Silent spring*. Fawcett Crest, New York.

CBS (1989). Afzet van chemische bestrijdingsmiddelen t.b.v. landbouwkundig gebruik. *Kwartaalbericht Milieustatistieken* 6(1): 26-30.

CBS (1990). Afzet van chemische bestrijdingsmiddelen t.b.v. landbouwkundig gebruik. *Kwartaalbericht Milieustatistieken* 7(3): 11-14.

CBS (1991). *Milieufacetten*. Staatsuitgeverij, Den Haag.

Centraal Bureau voor de Statistiek (1987, 1988). CBS Landbouwtelling 1987, 1988. CBS, Den Haag.

Centraal Bureau voor de Statistiek (several years). *Maandstatistiek voor de landbouw*. Staatsuitgeverij, Den Haag.

Chambers, R. (1988). *Applied production analysis, a dual approach*. Cambridge University Press, Cambridge.

Commission of the European Communities (1991). The development and future of the Common Agricultural Policy. COM (91) 258, Brussels.

CTB/BB (1990). Verslag van de werkzaamheden van de Commissie Toelating Bestrijdingsmiddelen en het Bureau Bestrijdingsmiddelen over 1988/1989, Wageningen.

Curatorium Landbouwemissie (1980). Rapport over emissies vanuit de landbouw. MLV, Den Haag.

Deaton, A. and J. Muellbauer (1980). *Economics and consumer behavior*. Cambridge University Press, Cambridge.

DHV and LUW (1991). De mogelijkheid van een regulerend heffingensysteem voor bestrijdingsmiddelen in de landbouw; eindrapport. Amersfoort/Wageningen.

Dillon, J.L. and J.R. Anderson (1990). *The analysis of response in crop and livestock production*. Pergamon Press, Oxford (third edition).

Donner, J.P.H. (1991). Discussiebijdrage, 18 oktober 1991. Den Haag.

Drenth, H. and W. Stol (1990). EPIPRE-adviesmodel. PAGV-verslag 97, Lelystad.

Dubgaard, A. (1987). Anvendelse af afgifter til regulering af pesticid forbruget (Taxation as a means to control pesticide use). Statens Jordbrugsokonomiske Institut, Copenhagen, Report 35.

Dubgaard, A. (1990). Danish policy measures to control agricultural impacts on the environment. Statens Jordbrugsokonomiske Institut, Copenhagen, Report 52.

Dubgaard, A. (1991). Pesticide regulation in Denmark. In: N. Hanley (ed.) *Farming and the countryside: an analysis of external costs and benefits*. CAB International, Wallingford, p. 48-58.

Eitjes, H. and E. de Haan (1987). Indirecte kosten van bestrijdingsmiddelengebruik. Wetenschapswinkel VU-Amsterdam, rapport 8705-223.

Eklöf, P. (1991). Personal communication.

Elhorst, J.P. (1986). Een schatting van de produktiefunctie en de winstfunctie voor de landbouw in Nederland. *LEI-Onderzoekverslag* 25, Den Haag.

Elhorst, J.P. (1990). De inkomensvorming en de inkomensverdeling in de Nederlandse landbouw verklaard vanuit de huishoudproduktietheorie. *LEI-Onderzoekverslag* 72, Den Haag.

Emmerman, A. (1991, 1992). Personal communication.

FAO (1989). Production Yearbook, Volume 42, Rome.

Feder, G. (1979). Pesticides, information and pest management under uncertainty. *American Journal of Agricultural Economics* 61: 97-103.

Feeley (1991). Written communication.

Gal, T. (1979). *Postoptimal analyses, Parametric programming and related topics*. Mc Grawhill, New York.

Gifap (1990). Agrochemical Country Markets. Country Natwest WoodMac, Edinburgh.

Goewie, E.A. (1990). Gewasbescherming in een veilige, duurzame en concurrerende landbouw. In: F.M. Brouwer en A.J. Reinhard (red.). *Landbouw, milieu en ruimte; symposiumverslag*. LEI Mededeling 432 (Band 1), Den Haag.

Gummesom, G., B. Olofsson, H. Hallqvist, A. Bengtsson, H. Fogelfors (1988). Kan kemis bekämpning minskas? Aktuellt från lantbruksunivesitet 370. Sv. lantbruksuniversitet, Uppsala.

Hall, V. van (1990). Duurzame landbouw in Flevoland. Verslag Vakgroep Alternatieve Methoden in de Land- en Tuinbouw, Wageningen.

Harris, J.M. (1990). *World agriculture and the environment*. Garland, New York.

Hasund, K.P. (1991). Written communication.

Hegeman and Vos (1989). Prikkel of pressie?; Beleidsinstrumenten voor het terugdringen van bestrijdingsmiddelen. VU, Rapport 8908-427, Amsterdam.

Hekstra, G.P. and F.J.M. van Linden (red.) (1991). Flora en fauna chemisch onder druk. Verslag symposium 10/1990, Pudoc, Wageningen.

Hoeksema, A. (1987). Bestrijdingsmiddelenwetgeving in Nederland. VU, Amsterdam.

Hoppenbrouwer (1991). Personal communication.

Janssens, S.R.M. (1991). Personal communication.

Jong, W. de (1991). Inkomens- en bedrijfsvoeringseffecten van een heffing op bestrijdingsmiddelen voor de akkerbouw in Nederland. LUW, Wageningen (Thesis, Department of Farm Management).

Johnsson, E. (1991). Personal communication.

Judge, G., R. Carter Hill, W. Griffiths, L. Lütkepohl and T. Lee (1988). *Introduction to the theory and practice of econometrics*. Wiley, New York.

Just, R.E. and N. Bockstael (1991). *Commodity and resource policies in agricultural systems*. Springer, Berlin.

Kneese, A.V. and B.T. Bower (1979). *Environmental quality and residuals management*. J. Hopkins University Press, Baltimore.

Koeijer, T.J. de and G.A.A. Wossink (1990). Emissies van meststoffen en bestrijdingsmiddelen in de akkerbouw. LUW, Vakgroep Agrarische Bedrijfseconomie, Wageningen.

Koeijer, T.J. de, G.A.A. Wossink and J.A. Renkema (1991). De zorg voor het milieu in economisch perspectief (3). *Landbouwkundig Tijdschrift* 103 (5): 24-26.

Koeijer, T.J. de, and G.A.A. Wossink (1992). Integratie van milieuaspecten in bedrijfsmodellen. LUW, Vakgroep Agrarische Bedrijfseconomie, Wageningen.

Landbouw Economisch Instituut (several years[a]). Bedrijfsuitkomsten in de landbouw (BUL). LEI, Den Haag.

Landbouw Economisch Instituut (several years). Landbouwcijfers. LEI/CBS, Den Haag.

Landbouw Economisch Instituut (several years). Rentabiliteit en financiering van.... (different categories of horticulture). LEI, Den Haag.

Landbouw Economisch Instituut (several years). Tuinbouwcijfers. LEI/CBS, Den Haag.

Landbouwschap (1989). Integraal Milieu Actieplan voor de Land- en Tuinbouw. Landbouwschap, Den Haag.

Landbouwschap (1990). Integraal Milieu Actieplan voor de Land- en Tuinbouw. Voortgangsrapportage 1990. Den Haag.

Landbouwschap (1991). Integraal Milieu Actieplan voor de Land- en Tuinbouw. Voortgangsrapportage 1991. Den Haag.

Lantbruksstyrelsen, statens naturvardsverk, kemikalieinspektionen en arbetarskyddsstyrelsen (1986). Minskad kemisk bekämpning. Jönköping/Stockholm.

Lantbruksstyrelsen (The National Board of Agriculture) (1989). Swedish programs to reduce the environmental problems related to agriculture. Lantbruksstyrelsen, Jönköping.

Lau, L.J. (1978). Applications of profit functions. In: M. Fuss and D.McFadden (eds.). *Production Economics: a dual approach to theory and applications*. North-Holland P.C., Amsterdam.

Lichtenberg, E. and D. Zilberman (1986). The econometrics of damage control: why specification matters. *American Journal of Agricultural Economics* 68: 261-273.

Marcelis, R.A.L. (1987). Zuinig spuiten- een gids voor akkerbouwer en loonwerker, Centrum Landbouw en Milieu, Utrecht.

MJP-G: Ministerie van Landbouw, Natuurbeheer en Visserij (1990). Meerjarenplan Gewasbescherming; Beleidsvoornemen + Achtergrondsdocumenten. MLNV, Den Haag.

MJP-G: Ministerie van Landbouw, Natuurbeheer en Visserij (1991). Meerjarenplan Gewasbescherming; Regeringsbeslissing. Tweede Kamer, vergaderjaar 1990-1991, 21677, nr. 3-4. Staatsuitgeverij, Den Haag

Ministerie van Landbouw, Natuurbeheer en Visserij (MLNV) (1990). Structuurnota Landbouw; Regeringsbeslissing. Tweede Kamer, vergaderjaar 1989-1990, 21148, nr. 3, Den Haag.

Ministerie van Landbouw en Visserij (MLV) (1983). Nota: Gewasbescherming in Nederland. Tweede kamer, vergaderjaar 1983-1984, 18100, nr. 3, Den Haag.

Ministerie van Landbouw en Visserij (MLV) (1987). Naar een taakstellend meerjarenplan voor de gewasbescherming. MLV, Den Haag.

Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer (MVROM) (1986). Indicatief Meerjarenprogramma Milieubeheer 1987-1991. TK 86-87, 19707, nrs. 1-2.

Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer (MVROM) (1989). Nationaal Milieubeleidsplan. Tweede Kamer, vergaderjaar 1988-1989, 21012, nr. 1-2.

Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer (MVROM) (1990). Nationaal Milieubeleidsplan Plus. Tweede Kamer, vergaderjaar 1989-1990, 21137, nr. 20.

Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer (MVROM) (1991a). Milieucriteria ten aanzien van stoffen ter bescherming van bodem en grondwater. Vergaderjaar 1990-1991, 21012, nr.8, Tweede Kamer, Den Haag.

Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer (MVROM) (1991b). Milieukwaliteitsdoelstellingen bodem en water; Notitie. Tweede Kamer, 21990, nr. 1, Den Haag.

Moffit, L.J. (1986). Risk-efficient tresholds for pest control decisions. *Journal of Agricultural Economics* 37: 69-75.

Nadiri, I. (1982). Producer theory. In: K.J. Arrow and M.D. Intriligator(eds.) *Handbook of Mathematical Economics*, Volume II. North Holland P.C., Amsterdam.

NEFYTO (several years). Landbouw en gewasbescherming in cijfers. Den Haag.

OECD (1991). *Agricultural policies, markets and trade; monitoring and outlook 1991*. Paris.

Oskam, A.J. (1991). Weather indices of agricultural production in the Netherlands 1948-1989, 1. General methodology and the arable sector. *Netherlands Journal of Agricultural Science* 39: 149-164.

Oskam, A.J. (1992). Economic analysis of the use of fertilizer and pesticides in Dutch arable farming. (forthcoming).

Ottenheim, J.J.G.W., P.H. Smits, A.K. Minks en H. Huttinga, (1989). Milieuvoordelen bij de toepassing van biotechnologische gewasbeschermingsmethoden, Instituut voor Plantenziektenkundig Onderzoek, Wageningen.

Pannell, D.J. (1991). Pests and pesticides, risk and risk aversion. *Agricultural Economics* 5: 361-383.

Pearce, D.W. and R.K. Turner (1990). *Economics of natural resources and the environment*. Harvester Wheatsheaf, New York.

Petterson, O., J. Petterson, V. Johansson, H. Fogelfors, R. Sigvald and B. Johnsson (1989). Minskad bekämpning i jordbruket; möjligheter och konsekvenser. *K. Skogs- och Lantbruksakademisk Tidskrift* 128: 379-396.

Pimentel, D. et al. (1980). Environmental and social costs of pesticides. *OIKOS* 34: 126-140.

Poppe, K.J. (ed.) (several years). Bedrijfsuitkomsten en financiële positie (BEF); Samenvattend overzicht van landbouwbedrijven. LEI, PR-13, Den Haag.

Proefstation voor de Akkerbouw en de Groenteteelt in de Vollegrond (PAGV) (1989). Kwantitatieve informatie voor de Akkerbouw en Groenteteelt in de Vollegrond 1989/1990. PAGV, Lelystad.

Reus, J.A.W.A. (1990). Naar een stimulerend beleid voor geïntegreerde gewasbescherming. CLM, Utrecht.

Reus, J.A.W.A., (1991). Milieumeetlat voor bestrijdingsmiddelen. CLM, Utrecht.

Ritsema, P., (1991). Meerjarenplan Gewasbescherming. In: Beleid en Universiteit 2, Landbouwuniversiteit, Wageningen, p.58-69.

RIVM (1991). *Nationale milieuverkenning 2, 1990-2010*. Samsom, Alphen aan den Rijn.

Rude, S. (1992). Personal Communication.

Ruiken, M.J., (1990). Bestrijdingsmiddelen zwart gemaakt!, Milieudefensie, Amsterdam.

Sandmo, A. (1971). On the theory of the competitive firm under price uncertainty. *American Economic Review* 61: 65-73.

Schaijik, L. van, E. van de Wiel, T. Terwisscha van Scheltinga, A. Schokker, N. Roozen and R. Kerkmeester (1986). Onkruidbeheersing in de suikerbietenteelt, LUW, Wageningen (Project thesis).

Schulte, J. (1983). Der Einfluss eines begrenzten Handelsduenger- und Pflanzenbehandlungsmitteleinsatzes auf Betriebsorganisation und Einkommen verschiedener Betriebssysteme. Rheinischen Friedrich-Wilhelms-Universität, Bonn (Dissertation).

Sigvald, R. (1991). Personal communication.

Simons-Vinkx, M.W.L., (1991). Toelating van gewasbeschermingsmiddelen. *Agrarisch Recht* 51: 265-272.

Smidts, A. (1990). Decision making under risk. *Wageningen Economic Studies* 18, Landbouwuniversiteit, Wageningen.

Stolwijk (1991). Milieubeleid in de landbouw. In: H.J. Silvis, et al. (red.) *Landbouwpolitiek tussen diagnose en therapie*. Landbouwuniversiteit, Wageningen, p. 88-103.

Swedish Agricultural Market Board (1990). Facts about the Swedish food and agricultural sector. SAMB, Jönköping.

Swedish Board of Agriculture (1992). Programme to reduce the risks connected with the use of pesticides in Sweden. Jönköping.

Thijssen, G. (1988). Estimating a labour supply function of farm households. *European Review of Agricultural Economics* 15: 67-78.

Thijssen, G. (1989). Produktietheorie en melkveehouderijbedrijven. *Wageningse Economische Studies* 14, Landbouwuniversiteit, Wageningen.

Thijssen, G. (1992a). A comparison of production technology using primal and dual approaches: the case of Dutch dairy farms. *European Review of Agricultural Economics* 18: 49-65.

Thijssen, G. (1992b). Microeconomic models of Dutch dairy farms. *Wageningen Economic Studies* 25, Landbouwuniversiteit, Wageningen.

Vaart, L. van der (1987). Indirekte effekten van bestrijdingsmiddelen. Wetenschapswinkel VU-Amsterdam, rapport 8707-223.

Vereijken, P.H. (1985-1988). Verslag over 1983 t/m Verslag over 1985. Proefbedrijf Ontwikkeling Bedrijfssystemen, OBS Publicatie nr. 4 t/m 6, Lelystad.

Verschueren, L.A.L.R. (1991). De effecten van een heffing op bestrijdingsmiddelen voor de akkerbouw in de NOP. LUW, Wageningen (Thesis, Department of Farm Management).

Vijftigschild, R. (1991). Database bestrijdingsmiddelen. LUW, Vakgroep Algemene Agrarische Economie, Wageningen.

Vogelezang-Stoute, E.M. and E.J. Matser (1990). De toelating van bestrijdingsmiddelen. Centrum voor Milieurecht en Chemiewinkel, UvA, Amsterdam.

Vogelezang-Stoute, E.M. and E.J. Matser (1991). De toelating van bestrijdingsmiddelen: landbouwbelangen versus milieubelangen? *Agrarisch Recht* 51: 550-557.

Vroomen, C. de, N. de Groot, B. v.d. Ploeg and C. Vernooij (1991). Op weg naar een milieuvriendelijke bollenteelt. *LEI-Onderzoekverslag* 91, Den Haag.

Vulpen, L. (1991). Het pesticidenbeleid van de Verenigde Staten in relatie tot de voedselveiligheid. Bureau van de Landbouwraad, Washington D.C.

Wijnands, F.G. and B. Kroonen-Backbier (1991). Verslag over 1986. Proefboerderij Ontwikkeling Bedrijfs-Systemen, OBS-publicatie nr. 7, Lelystad.

Zachariasse L.V. (1991). Bruikbaarheid van financiele prikkels in het landbouw-milieubeleid. Discussiebijdrage, 18 oktober 1991, Den Haag.

Zadoks, J.C. (1984). Schade. Syllabus t.b.v. doctoraalcollege G 200-10, Wageningen.

APPENDIX I. PRICES OF PESTICIDES AND AGRICULTURAL PRODUCTS

Trends in pesticide and in product prices are important when analysing the effect of regulatory levies. Here, we present a number of price series (see Table I.1). Different sources give very different prices for pesticides. Because these series are not easily accessible, we give them here (see Table I.2). The prices shown in the first column of Table I.2 have been used in Section 4.2 (analysis for the Netherlands) and in Chapter 5. Prices of pesticides, according to recent information from the CBS are different (see Table I.1).

Table I.1 Price indices (base year is 1980) of pesticides, arable products, horticultural products and general prices in the Netherlands

Year	Pesticides[1]				Arable products	Horticultural products	General prices
	Fungicides	Insecticides and Nematicides[2]	Herbicides	Total			
1970	73	79	71	78	76	66	46
1971	66	77	67	74	67	71	50
1972	67	79	65	75	74	72	54
1973	66	75	67	72	85	74	59
1974	77	81	73	80	85	74	64
1975	91	93	90	91	98	82	71
1976	89	93	95	93	138	89	79
1977	84	93	95	92	112	95	85
1978	85	96	92	91	91	92	89
1979	87	97	95	94	93	89	94
1980	100	100	100	100	100	100	100
1981	103	103	107	105	104	107	106
1982	114	116	113	114	105	102	110
1983	114	119	118	117	129	109	113
1984	121	122	122	121	130	118	115
1985	129	128	122	125	103	121	117
1986	128	133	123	126	99	109	116
1987	123	134	123	125	93	117	116
1988	121	127	117	120	94	115	118
1989	118	128	112	116	103	114	119
1990	119	128	117	119	102	118	122
Annual increase (%)							
1970-80	3.2	2.4	3.5	2.5	2.8	4.2	8.1
1980-90	1.8	2.5	1.6	1.8	0.2	1.7	2.0

Source: CBS, Maandstatistiek van de Landbouw, several years
CBS, Nationale rekeningen, several years
CBS, private information, 5 January 1992

[1] Before 1975 prices are based on price indices used by Eurostat (EC indices of purchase prices 1968-1977)
[2] Before 1975 insecticides only

Table I.2 Data on pesticide prices, from different sources: indices relative to prices in 1980

Year	Price of pesticides[1]	Prices for farmers (excluding TVA)[2]				Prices of domestic sales (excluding TVA)[3]			
		Pesticides	Fungicides	Insecticides	Herbicides	Pesticides	Fungicides	Insecticides and acaricides	Herbicides
1970	68.4	76	69	81	76	65	64	65	64
1971	70.0	72	62	79	72	65	62	67	64
1972	71.6	73	63	81	70	68	64	70	67
1973	72.5	70	62	77	72	69	65	70	67
1974	79.3	78	73	83	79	75	74	76	73
1975	90.9	93	86	95	97	86	88	84	88
1976	92.7	95	89	94	99	89	89	87	91
1977	91.8	95	87	112	95	88	86	89	88
1978	90.9	94	88	100	96	89	85	92	87
1979	93.6	95	92	96	97	91	89	93	89
1980	100	100	100	100	100	100	100	100	100
1981	105	105	104	105	106	112	112	115	104
1982	114	112	108	115	112	117	114	124	112
1983	117	114	100	118	116	124	122	129	113
1984	121	119	102	121	122	129	130	132	120
1985	125	120	108	130	120	134	137	132	123
1986	126	125	113	139	123	138	142	135	123
1987	125	124	109	138	123	137	141	137	119
1988	108	123	108	136	123	137	140	139	119
1989	116	123	108	136	123	135	136	140	123
1990	-	124	114	141	122	137	136	143	124

1) CBS, Maandstatistiek van de Landbouw, several years (period 1980-89); Elhorst (1986, p. 26) period 1975-79; CBS, Maandstatistiek van de prijzen, several years (period 1970-74).
2) EC indices of purchase price, several years; EC agricultural price indices 1973-1980; Data provided by CBS, letter 5 January 1992.
3) CBS, Maandstatistiek van de prijzen; see CBS, letter 5 January 1992.

APPENDIX II. DATABASE ON PESTICIDE USE IN THE NETHERLANDS: 1984-1988

Outline

The database contains information on types of pesticides used in the Netherlands. A pesticide has been defined as follows: an active ingredient or combination of active ingredients authorized by the Dutch government for a certain type of disease or pest control whose price can be estimated relatively accurately. Using the database, data relevant for tackling pesticide use in terms of certain compounds can be generated.

The classification according to application that has been used in the database largely conforms with that of the LCPP: soil disinfection, soil treatment, weed control and other types of crop protection. The database is based on the pesticides authorized per 1 January 1987. Pesticide prices are therefore 1987 prices (excl. 5% VAT). Some of the compounds mentioned in the LCPP inventory of active ingredients are absent; this results in a 1.3% deviation (compare Tables 2.5 and 2.12). The database comprises all sectors and crops (and livestock) in Dutch agriculture and horticulture distinguished in the LCPP. Although data were available for some regions, no regional subdivision has been made.

The data presented in Chapters 2 and 9 have been derived from the database and are aggregates for sectors (crops), applications and a phased-in ban (see Tables 2.5, 2.6, 2.11, 2.14, 9.1 and 9.2). This appendix provides more details on the database. Three tables containing data in a more disaggregated form have been included.

The basis of the database: a compound and a crop

Table II.1 depicts the use of benomyl. Similar information can be given for other compounds. What we have done here is to take the pesticide we wish to use for the database from the Crop Protection Guide and quantify it. We have listed the two authorized formulations of the pesticide benomyl, both with the same application, ignoring differences in brands. Benomyl seems to be applied in five sectors: arable farming, flowers from bulbs and bulb growing, mushrooms, fruit growing and field vegetable farming. The amounts of benomyl used as a soil treatment have not been registered. The presentation of the data differs per sector, because the data were collected by different study groups. Thus, for example, from the presentation of the Study Group on flowers from bulbs it can be derived whether the compound is in liquid or solid form, whereas the Study Group on arable farming did not make this distinction. In general we only included formulations in the database if their price was known. In two cases, fungicides, insecticides and other chemicals from the LCPP were not included in the database: if they were not authorized per 1 January 1987 (excl. methyl bromide); and if it was unclear what is the active ingredient. The sectors for which it is difficult to determine the amounts used are discussed below.

The Study Group for Bulb Flower Growing used the terms 'carbamate mix' and 'BCM chemicals', where BCM obviously stands for butyl carbomyl (pers. comm. Weggemans, 1992, PD). Our database uses the terms zineb/maneb (50/20) and 1/3 benomyl (50), 1/3 carbendazim (50) and 1/3 thiophanate-methyl (50) respectively, which are arguable but also justifiable.

For apple and pear growing, the Study Group for Fruit Growing mentions only total amounts of active ingredients (herbicides, fungicides and insecticides/acaricides). According to the 'Background Document') the estimates have been derived from the Berends Report. The results of our enquiries among members of the Study Group (Van der Scheer, Van Maurik) suggest that the Berends method is debatable. It is thought that Berends did not ask all the specialists the same questions. The Study Group made a better estimate. It is in the files of the Secretariat of the LCPP. Though the database does use the Berends estimates, wherever possible it is based on the amounts given in the LCPP.

The only sector that did not include an appendix listing pesticide use is the Study Group for Floriculture. According to De Goeij, the data available are unreliable because the sector has very many crops and there might be an overlap with, for instance, the sector "flowers from bulbs". The database uses the Berends estimates (1988) for roses, chrysanthemums, gerberas and gypsophila.

The Study Group on Growing Vegetables under Glass makes frequent reference to Berends (1988). The chemicals used to clean glass have not been included in the database.

The Study Group on Livestock Farming does not distinguish soil treatment, although soil-borne pests can be a major problem in pasture management. In accordance with the LCPP, disinfectants have not been included in the database.

Table II.1 The use of benomyl in several crops (in agriculture and horticulture) in the period 1984-1988

Crop	Application[1]	Name[2]	Quantity of active ingredient (kg)[3]	Factor [2]	Quantity of compound (kg)	Price[4] (gld/ kg a.i.)	Value (guilders)
Wheat	3	82	325	2	650	58.5	38 025
Anemone (bulb)	3	82	31	2	62	58.5	3 627
Gladiolus (bulb)	3	82	155	2	310	58.5	18 135
Hyacinth (bulb)	3	82	138	2	276	58.5	16 146
Iris (flower)	3	82	190	2	380	58.5	22 230
Iris (bulb)	3	82	7	2	14	58.5	819
Crocus (bulb/corm)	3	82	52	2	104	58.5	6 084
Lily (bulb)	3	82	849	2	1 698	58.5	99 333
Narcissus (bulb)	3	82	565	2	1 130	58.5	66 105
Tulip (flower)	3	82	3 695	2	7 390	58.5	432 315
Tulip (bulb)	3	82	737	2	1 474	58.5	86 229
Other flowers from bulbs and bulb growing	3	82	27	2	54	58.5	3 159
Mushrooms	3	82	238	2	476	58.5	27 846
Cherry	3	82	50	2	100	58.5	5 850
Fruit tree growing	3	82	67	2	134	58.5	7 839
Brussels Sprouts	3	82	2 861	2	5 722	58.5	334 737

Notes:
1) 3 = other crop protection: fungicides and bactericides.
2) 82 = benomyl spraying powder containing 50% active ingredient; the latter was chosen because the price was known and the authorized use is identical to that of benomyl spraying powder containing 75% active ingredient = 81; to convert active ingredient to formulated product, multiply by 2.
3) Data derived from study group reports to the LCPP as well as from the Report "Pesticides and Surface Water"; the best country-wide estimate available, also serving as a basis for the targeted percentages of reduction in the LCPP.
4) Price derived from the "Handleiding 1987".

The Study Group on Arable Farming lists per crop only the total amount of active ingredient applied in controlling above-ground fungi and insects, and weeds. The Berends report contains specification of the active ingredients concerned. For sugarbeet, winter wheat, peas, summer and winter barley it specifies per region whether they are grown in clay or sandy soil. The correspon-ding sub-areas have not been specified, however. In the database it has been assumed that the pesticide use in these areas are similar to the shares with respect to ware potatoes. Table II.2 shows the use of pesticides in sugarbeet. A similar overview can be given for other crops. From this table it can easily be seen which data were used for Table II.3: in general, totals from Table II.2 are incorporated in Table II.3. The prices are known for sectors (notably arable farming) in which price used to be considered as influencing the choice of pesticides. In fruit growing (pers. comm. Van Maurik, 1992), however, pesticide prices hardly play any role.

Table II.2 Applications of different types of pesticides in sugarbeet in the period 1984-1988

Application[1)]	Name[2)]	Quantity a.i. (kg)	Factor	Quantity of compound (kg)	Price (gld/kg)	Value (guilders)
0						
1	178	4 600	20	9 200	14	1 288 000
1	649	14 500	7.1	102 950	17	1 750 150
2	237	154 466	1.5	231 699	53.75	12 453 821
2	450	30 239	5	151 195	44	6 652 580
2	451	8 437	7.1	59 903	34.8	2 084 614
2	483	94 478	6.4	604 659	44.75	27 058 499
2	513	1 877	8	15 016	108.5	1 629 236
2	559	512	2.8	1 434	74.75	107 162
2	735	207 910	1.4	291 074	59.75	17 391 672
2	880	35 452	2	70 904	11.25	797 670
2	971	1 407	5.3	7 457	70.5	525 726
2	1 064	21 533	2.5	53 833	25.75	1 386 187
3	1 045	613	2	1 226	8	9 808
4	726	766	2	1 532	85	130 220
4	828	4 500	4	18 000	9	162 000
4	864	97 602	2	19 520	102.5	2 000 800
5						

Notes:

1) 0 = soil disinfection (no distribution among individual crops); 1 = soil treatment; 2 = herbicides; 3 = fungicides and bactericides; 4 = insecticides and acaricides; 5 = others

2) 178 = carbofuran granulate 5%
649 = lindane spraying poweder 14%
237 = chloridazon spraying powder 65%
450 = liquid ethofumesate 200 g/l
451 = liquid ethofumesate/fenmedifam 50/90 g/l
483 = liquid phenmedipham 157 g/l
513 = liquid fluazifop-p-butyl 125 g/l
559 = liquid glyphosate 360 g/l
735 = metamitron spraying powder 70%
880 = propham spraying powder 50%
971 = liquid sethoxydim 190 g/l
1064 = liquid tri-allate 400 g/l
1045 = thiram spraying powder 50%
726 = liquid mercaptodimethur 500 g/l
828 = parathion spraying powder 25%
864 = pirimicarb spraying powder 50%

Table II.3 Pesticide use and productivity (yields) per crop; division among categories, quantity of active ingredient (a.i.) per hectare, price per kg of a.i. and share of pesticide costs in total output value

Crop sector[1]	Quantity a.i. (kg)	Categories[2] (in %)						Quantity in kg a.i. per ha	Price in guilders per kg a.i.	Share (%)
		0	1	2	3	4	5			
Ware potatoes	1 278 855	0	0.4	1.5	75.2	0.8	22.1	17.0	59.0	12.8
Peas	166 617	0	0	59.5	27.1	13.4	0	4.7	100.2	18.0
Starch potatoes	459 395	0	0	27.7	72.3	0	0	7.9	34.2	5.3
Barley	134 122	0	0	90.0	9.0	0	0.9	2.7	89.5	11.0
Grass seed	55 331	0	0	100.0	0	0	0	2.5	90.4	1.6
Caraway	5 545	0	0	74.1	14.4	11.5	0	3.5	90.2	n.a.
Rapeseed	17 451	0	0	52.2	19.5	28.3	0	1.8	194.8	14.2
Green maize	367 799	0	1.5	88.5	1.9	8.0	0	1.9	67.7	3.6
Seed potatoes	364 243	0	11.3	3.8	31.5	2.5	51.0	10.6	52.7	5.8
Sugarbeet	591 050	0	3.2	94.1	0.1	2.5	0	4.6	127.6	9.4
Wheat	329 158	0	0	56.4	22.6	5.4	15.6	3.1	79.6	7.2
Field beans	62 411	0	0	29.5	59.0	11.5	0	6.1	73.7	25.5
Onions	306 657	0	0	33.2	53.3	3.1	10.5	19.8	57.4	14.2
Gladiolus (flower)	16 200	85.8	0	0	13.8	0.4	0	324.0	12.3	0.9
Gladiolus (bulb)	311 606	64.8	1.3	3.6	29.5	0.8	0	134.2	18.6	n.a.
Hyacinth (bulb)	368 861	76.2	15.8	1.0	6.3	0	0.7	360.2	8.4	n.a.
Iris (flower)	4 200	0	69.0	0	31.0	0	0	32.3	95.2	0.8
Iris (bulb)	156 987	62.7	14.7	3.2	18.3	0.4	0.8	163.7	29.3	n.a.
Crocus (bulb)	21 320	47.4	5.8	9.2	36.1	0	1.5	46.6	28.1	n.a.
Lily (flower)	30 800	0	88.6	0	11.4	0	0	48.7	126.6	3.6
Lily (bulb)	364 986	23.7	3.6	7.2	20.8	44.3	0.3	197.0	23.0	n.a.
Narcissus (bulb)	190 300	71.5	0	5.6	16.8	0.1	5.9	115.8	11.6	n.a.
Tulip (flower)	71 414	0	15.7	0	84.3	0	0	297.6	54.6	2.1
Tulip (bulb)	516 443	39.2	24.6	6.1	28.9	1.2	0	70.1	41.8	n.a.
Rose	104 676	31.0	11.6	0	52.8	4.6	0	126.1	63.1	1.3
Gerbera	4 292	0	7.4	0	13.2	78.9	0.5	19.0	139.8	0.4
Gypsophila	2 122	0	5.4	0	12.6	82.0	0	27.9	329.9	1.3
Chrysanthemum	140 159	0	30.5	0	52.3	17.2	0	224.3	134.1	4.0
Forest and hedging plant material	131 611	84.6	0	2.8	7.3	5.3	0	74.5	15.2	n.a.
Avenue and park trees	43 446	48.8	0	2.8	21.3	27.1	0	31.5	48.3	n.a.
Rose rootstock	77 588	79.8	0	1.2	18.9	0.1	0	384.1	9.0	n.a.
Roses	79 211	73.8	2.6	0.9	22.3	0.5	0	155.9	15.1	n.a.

Ornamental conifer	75 403	48.6	28.4	3.6	2.4	17.1	0	83.1	80.9	n.a.
Rhodondendron and azelea	9 833	16.0	33.6	2.7	1.3	46.5	0	75.6	122.0	n.a.
Heathers	26 358	46.8	52.1	0.4	1.3	0.6	0	488.1	19.0	n.a.
Climbers	3 313	73.0	10.7	1.2	6.0	9.2	0	58.1	60.4	n.a.
Perennials	36 340	92.8	4.7	0.6	1.4	0.5	0	91.5	22.0	n.a.
Mushrooms	53 449	0	0	0	6.1	13.2	80.6	578.5	35.5	n.a.
Apple	263 116	7.2	0	17.4	60.2	10.4	4.8	17.4	48.3	6.5
Pear	99 279	0	0	15.6	67.1	5.5	11.9	19.1	50.4	7.2
Plum	3 894	0	0	23.4	0	9.9	66.8	6.0	51.4	2.4
Cherry	3 624	0	0	23.2	67.4	9.4	0	6.0	82.8	10.5
Soft fruit (excl. strawberry)	2 995	0	0	37.8	53.4	8.8	0	6.6	200.3	7.2
Fruit trees	91 857	80.6	1.9	1.0	14.3	2.2	0	79.1	18.5	n.a.
Strawberry (greenhouse)	3 626	0	66.8	0.3	27.6	5.3	0	19.1	110.3	2.2
Cucumber	9 732	0	11.0	0.9	23.1	65.0	0	16.2	215.8	0.5
Paprika/peppers	6 307	0	14.1	0.7	6.3	77.2	2.3	14.3	126.8	0.3
Tomato	22 349	0	17.7	0.4	40.3	37.1	4.5	14.0	228.2	0.5
Lettuce and endive	29 926	0	0	3.2	91.2	5.6	0	12.9	80.2	1.0
Radish	5 819	0	0	0	45.1	54.9	0	43.8	68.7	n.a.
Pasures management	704 702	0	0	82.7	0	17.3	0	0.6	76.6	n.a.
Strawberry	387 085	93.7	0.5	1.0	3.2	1.5	0	200.6	15.5	10.7
Asparagus	47 604	44.0	0	9.4	39.6	7.0	0	17.4	44.1	3.8
Cauliflower/broccoli	17 642	0	9.8	20.2	60.6	9.4	0	7.4	158.7	4.4
Celeriac	9 467	0	12.8	12.7	57.8	16.7	0	7.8	73.9	19.6
Leek	77 180	45.0	0	7.4	44.1	3.5	0	25.5	57.0	7.1
(Cabbage) lettuce; iceberg lettuce and endive	148 628	69.4	0	21.9	7.5	1.2	0	77.1	13.5	4.4
Salsify	59 728	79.3	0	4.8	15.9	0	0	51.0	8.4	57.2
Cabbage	10 696	0	45.0	35.0	0	20.0	0	3.2	112.2	n.a.
Spinach	5 527	0	0	88.4	0	11.6	0	3.4	126.7	9.2
Brussels sprouts	31 608	0	28.1	6.8	27.2	34.4	3.6	5.5	186.7	8.2
French climbing and string beans	18 008	0	0	58.1	31.9	10.0	0	3.1	166.6	13.4
Chicory	36 821	0	0	35.6	55.9	8.5	0	7.1	95.1	n.a.
Carrots	341 328	80.6	4.5	3.0	4.5	7.5	0	67.2	28.4	n.a.

Notes: 1) Grouping per subsector of agriculture
2) See note 1, Table II.2.

Outcome of the database: a disaggregated overview

Table II.3 gives an overview of the use of pesticides per type of crop. The picture is somewhat confused because in the sectors "arable farming" and "growing vegetables under glass" soil disinfectants have been ascribed to the sector as a whole rather than to individual crops. In some crops, estimated pesticide use is far too low. The table indicates ratios only. The database differs from previous inventories by showing the relationship between the amount of active ingredient used and its costs (the estimated price of an amount of active ingredient per crop). These data largely depend on the composition of pesticide use. Finally, the table shows the relationship between costs of pesticides and output value. A high proportion means that if pesticide prices rise, profitability will decline markedly and a pesticide use is also likely to decline.

Sources

Adviesprijzen over 1991, CEBECO Agrochemie B.V., 7/1991, Rotterdam.

Bestrijdingsmiddelen en oppervlaktekwaliteit, A.G. Berends, Instituut voor Onderzoek Bestrijdingsmiddelen, 1988, Wageningen, 110 p. plus bijlagen.

Gewasbeschermingsgids 1987, CAD Gewasbescherming/Plantenziektenkundige Dienst, Wageningen, 575 p., in particular p.81-167.

Handleiding 1987. De chemische bestrijding van ziekten, plagen en onkruiden in landbouwgewassen, december 1986, CAD Gewasbescherming, Wageningen, 76 p., in particular p.71-76.

Meerjarenplan Gewasbescherming, beleidsvoornemen augustus 1990, Ministerie van Landbouw, Natuurbeheer en Visserij (LNV), Den Haag, 138 + 133 (bijlagen) p., in particular p.36-40 and p.80-94.

Meerjarenplan Gewasbescherming, regeringsbeslissing juni 1991, Ministerie van Landbouw, Natuurbeheer en Visserij (LNV), Den Haag, 298 p., in particular p.35-39 and p.85-102.

Rapportage werkgroep Akkerbouw, november 1990, LNV, Den Haag, 103 p., in particular p.34-36 and p.85-88.

Rapportage werkgroep Bloembollenteelt, november 1990, LNV, Den Haag, 124 p., in particular p.29-42 and p.81-99.

Rapportage werkgroep Bloemisterij, november 1990, LNV, Den Haag, 79 p., in particular p.26-28.

Rapportage werkgroep Boomteelt, november 1990, LNV, Den Haag, 112 p., in particular p.21-28 and p.51-72.

Rapportage werkgroep Eetbare paddestoelen, november 1990, Den Haag, 51 p., in particular p. 15/16 and p.37-39.

Rapportage werkgroep Fruitteelt, november 1990, LNV, Den Haag, 76 p., in particular p.32-33 and p.61-64.

Rapportage werkgroep Groenteteelt onder glas, november 1990, LNV, Den Haag, 69 p., in particular p.26-27 and p.56-61.

Rapportage werkgroep Openbaar Groen, november 1990, LNV, Den Haag, 55 p., in particular p.24-27 and p.44-60.

Rapportage werkgroep Veehouderij, november 1990, LNV, Den Haag, 70 p., in particular p.21-27 and p.44-60.

Rapportage werkgroep Vollegrondsgroenteteelt, november 1990, LNV, Den Haag, 102 p., in particular p.27-35 and p.60-98.

Verslag van de werkzaamheden van de Commissie Toelating Bestrijdingsmiddelen en het Bureau Bestrijdingsmiddelen over 1988/1989, CTB/BB, 8/1990, Wageningen.

APPENDIX III. CROPPING VARIANTS

In the LP analysis, "cropping variants" which differ in economic and environmental value are defined for every crop. The variety of the cropping variants with regard to environmental parameters is represented in the technical coefficients in matrix A. Financial differences are given by means of the gross margin figures (excl. costs of pesticide use) c in the objective function (see Scheme 6.1 in Chapter 6).

For ware potato, 23 cropping variants had to be distinguished to account for the different cropping frequencies and for the combination with a variety resistant to potato sickness. For the other crops there are fewer alternatives: 4 for starch potato, 8 for sugarbeet, 14 for winter wheat, 3 for peas and 3 each for seed grass and spring-sown onions.

The cropping variants range from intensive to the ecological production system, representing a discrete set of production alternatives which cover both: (a) consecutive points on a non-linear production function (Table III.1), and (b) points on different production functions using different technology (Tables III.2 to III.7).

Table III.1 Winter wheat cropping variants

variant	yield (kg/ha)	straw (kg/ha)	nitrogen (kg/ha)	pesticides (kg a.i./ha) F	CCC	H	I	total	gross margin (gld/ha)	labour (h/ha)
1	7500	4700	160	2.475	0.9	2.24	0.125	5.74	2526	14.1
2	7430	4656	130	2.475	0.9	2.24	0.125	5.74	2533	13.5
3	7290	4568	100	2.475	0.9	2.24	0.125	5.74	2512	13.5
4	6760	4236	50	2.475	0.9	2.24	0.125	5.74	2362	12.9
5	6270	3929	20	2.475	0.9	2.24	0.125	5.74	2205	12.9
6	5880	4685	-	2.475	0.9	2.24	0.125	5.74	2075	12.3
7	6480	4061	160	-	-	2.24	0.125	2.365	2294	13.1
8	6720	4211	130	-	-	2.24	0.125	2.365	2422	12.5
9	6880	4312	100	-	-	2.24	0.125	2.365	2518	12.5
10	6600	4136	50	-	-	2.24	0.125	2.365	2466	11.9
11	6110	3829	20	-	-	2.24	0.125	2.365	2309	11.9
12	5740	3597	-	-	-	2.24	0.125	2.365	2187	11.3
13	6629	4154	140	-	-	0.829	-	0.829	2386	12.6
14	5500	3447	-	-	-	-	-	-	1866	9.8

Source: Verschueren (1991), modified

Remarks:

- Per hectare, variants 1-12 require 150 kg seed, variant 13 requires 180 kg and variant 14 requires 175 kg.
- The output price is 0.41 guilders per kg for all variants.

F = fungicides
CCC = growth control
H = herbicides
I = insecticides
D = others (see Table III.7)
Gross Margin = output in guilders per ha minus variable cost including pesticides but excluding the costs for contract work, i.e. harvesting and straw removal.

Table III.2 Sugarbeet cropping variants

variant	yield kg/ha	nitrogen kg/ha	pesticides (kg a.i./ha) H	I	total	gross margin gld/ha	labour[1] h/ha
1	61000	140	5.81	0.38	5.56	4441	29.7
2	61000	140	3.63	0.38	4.01	4610	29.2
3	61000	140	2.07	0.38	2.45	4730	28.7
4	61000	140	2.60	0.38	2.98	4731	45.7
5	61000	140	1.03	0.38	1.41	4807	45.2
6	61000	140	2.88	0.38	3.26	4648	30.7
7	53483	93	1.80	0.30	2.10	4059	37.7
8	50000	142.5[2]	-	-	-	3898	77.7

Source: Verschueren (1991), modified.

[1] In variants 2, 3 and 5, all requiring row spraying, there are two options: (a) contract work or (b) investment in own machinery. In the latter case the labour requirements for row spraying (1 h/ha for one treatment) should be added.

[2] For the ecological variant the manure used (142.5 kg/ha) is translated into cost of the equivalent amount of N fertilizer.

Table III.2a Differences in method of weed control and use of herbicides for the sugarbeet cropping variants

variant	pre-emergence	post-emergence	harrowing (# treatments)	manual weeding (h)	herbicides (kg a.i./ha)
1	total	total	2 times	15	5.18
2	total	row	2 times	15	4.63
3	row	row	3 times	15	2.07
4	total	—	3 times	30	2.60
5	—	row	3 times	30	1.03
6	50 %	LD	2 times	15	2.88
7	—	row + total	4 times	20	1.80

Source: Verschueren, 1991.

Remarks:

Total = spraying total field (0.5 hours/ha)

Row = row spraying (1.0 hours/ha)

LD = low dosage system, treatments repeated (2 to 3 times) with a reduced dose of herbicides plus mineral oil

Table III.3 Ware potato cropping variants

variant	variety	rotation	yield kg/ha	soil fumigation	bait crop	nematicides (kg a.i./ha)	gross margin[1] (gld/ha)
1:3 variants:							
1	Bintje	1:3	49400	1:3		174	4813
2	Bintje	1:3	46960	1:6		87	4780
3	Bintje	1:6	50980	1:6		174	5065
	PSR var[2]	1:6	53520	—		0	6298
4	Bintje	1:6	50690	infected areas		34.8	5373
	PSR var	1:6	53220	—		0	6250
5	Bintje	1:6	50490	—		0	5699
	PSR var	1:6	53010	—		0	6217
6	Bintje	1:6	50770	—	1:6	0	5744
	PSR var	1:6	53310	—		0	6265
1:4 variants:							
7	Bintje	1:4	53000	1:4		174	5387
8	Bintje	1:4	51320	1:8		87	5475
9	Bintje	1:4	50290	—	1:4	0	5667
10	Bintje	1:8	54090	1:8		174	5561
	PSR var	1:8	56790	—		0	6820
11	Bintje	1:8	53890	infected areas		34.8	5884
	PSR var	1:8	56580	—		0	6786
12	Bintje	1:8	53750	—		0	6219
	PSR var	1:8	56440	—		0	6764
13	Bintje	1:8	53930	—	1:8	0	6251
	PSR var	1:8	56640	—		0	6796
1:5 variants:							
14	Bintje	1:5	56410	1:5		174	5931
15	Bintje	1:5	55260	1:10		87	6104
16	Bintje	1:5	52690	—		0	6050
17	Bintje	1:5	54180	—	1:10	0	6288
18	Bintje	1:5	55200	—	1:5	0	6451
19	Bintje	1:10	57020	infected areas		34.8	6383
	PSR var	1:10	59870	—		0	7313
20	Bintje	1:10	56930	—		0	6726
	PSR var	1:10	59770	—		0	7298
21	Bintje	1:10	57060	—	1:10	0	6747
	PSR var	1:10	59920	—		0	7321
1:6 variants:							
22	Bintje	1:6	56580	—		0	7237
23	Bintje	1:12	59450	—		0	7128
	PSR var	1:12	62430	—		0	7721

Source: De Buck (1991) based on information from DLO Centre for Agrobiological Research (CABO, Wageningen) and on KWIN 89/90 (PAGV, 1989).

[1] Gross margin considering the first method for each operation as presented in Table III.3a.

[2] PSR: resistant to potato sickness, in this case to nematode pathotype A. Note that a fixed combination of 50% Bintje and 50% PSR variety is chosen, as it is expected that growing more of the PSR variety will stimulate the development of new pathotypes from the present nematode population in the soil.

Table III.3a Ware potato cropping variants (continued)

Optional methods for N dressing, weed control, haulm killing and late blight control				
Options			**kg a.i./ha**	**labour h/ha[1]**
N dressing:				
method 1	current practice (210 kg N and 44 kg N by 9 tons manure per ha applied in autumn before potato growing)			0.6
method 2	"Neeteson" fertilizer only (185 kg N per ha)[2]			0.6
method 3	split fertilization supported by petiole analysis (188 kg N per ha)		0.8	
Weed control:				
method 1	1 kg metribuzin per ha total field spraying		0.70	2.5
method 2	0.5 kg metribuzin per ha under-leaf spraying[3]		0.35	3.0
method 3	late ridging + hoeing + 0.125 kg metribuzin per ha[4]		0.0875	3.0
Haulm killing:				
method 1	chemical : 5 l diquat per ha		1.00	0.5
method 2	mechanical[5]		-	2.8
Late blight control:				
method 1	Bintje :	27 l per ha maneb/fentin	11.88	6.0
	PSR var:	20.25 l per ha maneb/fentin	8.91	4.5
method 2	Bintje :	14 l maneb 80% + 4.5 l maneb/fentin per ha	13.18	4.5
	PSR var:	10 l maneb 80% + 2.25 l maneb/fentin per ha	8.99	3.0

[1] Excluding contract work.
[2] Yield reduction of 750 kg/ha compared with option 1 which is accounted for in the costs.
[3] In the case of own mechanization, row spraying accessories are required: annual costs 612 guilders per farm. The option of contract work is also offered at 70 guilders per hectare.
[4] To account for the risk of unsuccessful mechanical weed control it is assumed that over four years a chemical treatment is required once. Investment in earther/ridge hoe: annual costs 756 guilders per farm.
[5] Investment in a haulm shredder: annual costs 2415 guilders per farm.

Source: De Buck (1991) based on information from DLO Centre for Agrobiological Research (CABO, Wageningen).
Remarks: In the reference situation (standard cropping variants) it is assumed that for every operation the first method mentioned is applied; hence, the level of pesticide use is high.

Table III.4 Starch potato cropping variants

variant	rotation frequency	yield kg/ha	planting material (kg/ha)	nitrogen (kg/ha)	pesticides (kg a.i./ha) H	F	I	N	total	gross margin (gld/ha)	labour (h/ha)
1	1:2	45000	2200	200	1.85	5.94	0.25	131	139.04	1788	27.7
2	1:2	45000	2163	215	1.5	9.95	-	126	137.45	2024	31.5
3	1:4	41868	2250	197	1.5	11.23	-	126	138.73	1585	34.4
4	1:4	42315	1975	204	-	11.20	-	-	11.20	2527	34.4

Source: KWIN 88/'89 (PAGV, 1989) and Boerma (1989 and 1990).
Remarks:
- Output price: 113 guilders per 1000 kg.
- Variants 1 and 2 require soil disinfection 1:2

Table III.5 Pea cropping variants

variant	yield (kg/ha)	straw (kg/ha)	nitrogen (kg/ha)	pesticides (kg a.i./ha) F	H	I	total	gross margin (gld/ha)	labour (h/ha)
1	4900	2000	20	0.5	2.47	0.75	3.72	2350	14.16
2	4223	1724	-	0.15	2.15	0.21	2.51	1974	15.8
3	3500	1429	-	-	-	-	-	1888	26.8

Source: Verschueren (1991), modified.
Remarks:
- Sowing rate for variants 1 and 3: 140 kg seed/ha; variant 2: 175 kg seed/ha.
- Output price: 0.65 guilders per kg.

Table III.6 Seed grass cropping variants

variant	yield (kg/ha)	seed (kg/ha)	nitrogen (kg/ha)	pesticides (kg a.i./ha) H	I	total	gross margin (gld/ha)	labour hours per ha
1	1300	8	130	6.13	0.25	6.38	2586	14.4
2	1300	11	181	2.855	-	2.855	2559	16.1
3	1162	10	159	2.515	-	2.515	2360	17.2

Source: KWIN 88/'89 (PAGV, 1989) and Boerma (1989 and 1990).
Remarks: Output price 2 guilders per kg.

Table III.7 Onion cropping variants

variant	yield (kg/ha)	nitrogen (kg/ha)	pesticides (kg a.i./ha) F	H	I	D	total	gross margin (gld/ha)	labour (h/ha)
1	51000	120	10.05	5.6	0.75	2.25	18.65	4142	48.3
2	38773	32	3.42	2.5	-	2.25	8.17	3053	69.1
3	25000	-	-	-	-	-	-	2005	126.2

Source: Verschueren (1991), modified.
Remarks:
- Sowing seed variant 1: 6.0 kg/ha; variants 2 and 3: 6.7 kg/ha as against 6.0 kg/ha.
- Output price 0.13 guilders per kg.

APPENDIX IV. CHANGES IN CROPPING PATTERNS AND CROPPING VARIANTS PER REGION

The cropping patterns under the heading "current situation (fixed)" correspond to the situation derived from statistical information (see Table 6.2). This situation differs from the optimal cropping pattern, given under the heading "current situation (optimal)", which is assessed by LP computations accounting for agronomical constraints, to the rotation. The difference between both situations with respect to pesticide use is presented in Table 6.3. In both instances only standard cropping activities were included.

Next, model computations were done for all cropping variants for the various crops included (zero levy situation). This zero levy situation expresses the changes in farming practice if the most modern techniques were to be introduced on the representative farms. Further, the changes in cropping patterns and in the selected variants that would occur in response to a levy increasing from 10 to 200 guilders per kg a.i. are presented.

Table IV.1 Changes per farm in cropping pattern and cropping variants in hectares, Northern Clay Area (larger farms)

Crop and variant no.	Current situation		Levy in guilders per kilogram active ingredient								
	Fixed	Optimal	0	10	15	25	50	75	100	150	200
Winter wheat 1	30	33									
Winter wheat 2			33								
Winter wheat 13 integrated				33	33	33					
Winter wheat 14 ecological							33	33	33	33	33
Sugarbeet 1	14	14									
Sugarbeet 4			14	14	14	14	14				
Sugarbeet 5b								14	14	14	14
Green peas 1	5										
Seed grass 1	3										
Ware pot.16 Bintje	14	14									
Ware pot.20 Bintje			7	7	7	7	7	7			
Ware pot.20 AM-var.			7	7	7	7	7	7			
Ware pot.23 Bintje									5.83	5.83	5.83
Ware pot.23 AM-var.									5.83	5.83	5.83
Set-aside		5	5	5	5	5	5	5	7.33	7.33	7.33
Total	66	66	66	66	66	66	66	66	66	66	66

Table IV.1a Ware potato: changes in variable methods, Northern Clay area (larger farms)

	Current situation		Levy in guilders per kilogram active ingredient								
	Fixed	Optimal	0	10	15	25	50	75	100	150	200
N Dressing 1	x	x									
N Dressing 2											
N Dressing 3			x	x	x	x	x	x	x	x	x
Weed control 1	x	x									
Weed control 2											
Weed control 3			x	x	x	x	x	x	x	x	x
Late blight contr.Bintje 1	x	x								x	x
Late blight contr.AM 1											
Late blight contr.Bintje 2			x	x	x	x	x	x	x		
Late blight contr.AM 2			x	x	x	x	x	x	x	x	x
Haulm killing 1	x	x									
Haulm killing 2			x	x	x	x	x	x	x	x	x

Table IV.2 Changes per farm in cropping pattern and cropping variants in hectares, Peat Colonies (larger farms)

Crop and variant no.	Current situation		Levy in guilders per kilogram active ingredient								
	Fixed	Optimal	0	10	15	25	50	75	100	150	200
Winter wheat 1	11										
Sugarbeet 1	11.5	11.5									
Sugarbeet 4			11.5	11.5	11.5	11.5	11.5	11.5	11.5		
Sugarbeet 5b										11.5	11.5
Green peas 1	6.5										
Seed grass 1	4	10	10								
Seed grass 2				10	10						
Starch pot.1 1:2	28										
Starch pot.4 1:4			14	14	14	14	14	14			
Set-aside		39.5	25.5	25.5	25.5	35.5	35.5	35.5	49.5	49.5	49.5
Total	61	61	61	61	61	61	61	61	61	61	61

Table IV.2a Changes per farm in cropping pattern and cropping variants in hectares, Peat Colonies (smaller farms)

Crop and variant no.	Current situation		Levy in guilders per kilogram active ingredient								
	Fixed	Optimal	0	10	15	25	50	75	100	150	200
Winter wheat 1	7										
Sugarbeet 1	6	6									
Sugarbeet 4			6	6	6	6	6	6	6		
Sugarbeet 5b										6	6
Green peas 1	4										
Seed grass 1		4.5	4.5								
Seed grass 2				4.5	4.5						
Starch pot.1 1:2	11										
Starch pot.4 1:4			5.5	5.5	5.5	5.5	5.5	5.5			
Set-aside		18	12	12	12	16.5	16.5	16.5	22	22	22
Total	28	28	28	28	28	28	28	28	28	28	28

Table IV.3 Changes per farm in cropping pattern and cropping variants in hectares, Central Clay area (larger farms)

Crop and variant no.	Current situation		Levy in guilders per kilogram active ingredient								
	Fixed	Optimal	0	10	15	25	50	75	100	150	200
Winter wheat 1	11	17.5									
Winter wheat 2			17.5								
Winter wheat 9				17.5	17.5	17.5	20.1	21.2	22.5	22.5	22.5
Sugarbeet 2a	10	10									
Sugarbeet 3b			3.29	2.51	2.51	2.51					
Sugarbeet 5b			6.71	7.49	7.49	7.49	10	10	10	10	10
Green peas 1	2										
Seed grass 1	3										
Onion 1	7	5.5	5.5	5.5	5.5	5.5	2.87	1.84			
Ware pot.2 Bintje	12	12									
Ware pot.5 Bintje			6	6	6	6	6	6	6	6	6
Ware pot.5 AM-var.			6	6	6	6	6	6	6	6	6
Set-aside								0.5	0.5	0.5	
Total	45	45	45	45	45	45	45	45	45	45	45

Table IV.3a Ware potato: changes in variable methods, Central Clay Area (larger farms)

	Current situation		Levy in guilders per kilogram active ingredient								
	Fixed	Optimal	0	10	15	25	50	75	100	150	200
N dressing 1	x	x									
N dressing 2											
N dressing 3			x	x	x	x	x	x	x	x	x
Weed control 1	x	x									
Weed control 2											
Weed control 3			x	x	x	x	x	x	x	x	x
Late blight Bintje 1	x	x								x	x
Late blight AM 1											
Late blight Bintje 2			x	x	x	x	x	x	x		
Late blight AM 2			x	x	x	x	x	x	x	x	x
Haulm killing 1	x	x									
Haulm killing 2			x	x	x	x	x	x	x	x	x

Table IV.4 Changes per farm in cropping pattern and cropping variants in hectares, Southwestern Clay Area (larger farms)

Crop and variant no.	Current situation		Levy in guilders per kilogram active ingredient								
	Fixed	Optimal	0	10	15	25	50	75	100	150	200
Winter wheat 1	17	24.47									
Winter wheat 2			24.47								
Winter wheat 13 integrated				28.5	28.5	28.5	28.5				
Winter wheat 14 ecological								28.5	28.5	28.5	28.5
Sugarbeet 2a	10	10									
Sugarbeet 3b			9.42	3.07	3.07						
Sugarbeet 5b			0.58	6.90	6.90	10	10	10	10	10	10
Green peas 1	6										
Seed grass 1	5.5										
Onion 1	5.5	9.5	9.5	5.47	5.47	3.13	2.38				
Ware pot.12 Bintje	6.52	6.52	6.52	6.52	6.52	6.52	6.52	6.52	6.52		
Ware pot.12 AM-var.	6.52	6.52	6.52	6.52	6.52	6.52	6.52	6.52	6.52		
Ware pot.23 Bintje										4.33	4.33
Ware pot.23 AM-var.										4.33	4.33
Set-aside						2.33	3.08	5.47	5.47	9.83	9.83
Total	57	57	57	57	57	57	57	57	57	57	57

Table IV.4a Ware potato: changes in optional methods, Southwestern Clay Area

	Current situation		Levy in guilders per kilogram active ingredient								
	Fixed	Optimal	0	10	15	25	50	75	100	150	200
N dressing 1	x	x									
N dressing 2											
N dressing 3			x	x	x	x	x	x	x	x	x
Weed control 1	x	x									
Weed control 2											
Weed control 3			x	x	x	x	x	x	x	x	x
Late blight Bintje 1	x	x								x	x
Late blight AM 1											
Late blight Bintje 2			x	x	x	x	x	x	x		
Late blight AM 2			x	x	x	x	x	x	x	x	x
Haulm killing 1	x	x									
Haulm killing 2			x	x	x	x	x	x	x	x	x

Table IV.5 Changes per farm in cropping pattern and cropping variants in hectares, Clay Areas (smaller farms)

Crop and variant no.	Current situation		Levy in guilders per kilogram active ingredient								
	Fixed	Optimal	0	10	15	25	50	75	100	150	200
Winter wheat 1	9	9									
Winter wheat 2			12								
Winter wheat 13 integrated				12	12	12	12				
Winter wheat 14 ecological								12	12	12	12
Sugarbeet 2a	5	5									
Sugarbeet 4			5	5	5	5					
Sugarbeet 5b							5	5	5	5	5
Green peas 1	2										
Seed grass 1	1.5										
Onion 1	2.5	3	3	3	3	3	2.92				
Ware pot.22 Bintje	4	4									
Ware pot.23 Bintje			2	2	2	2	2	2	2	2	2
Ware pot.23 Am-var.			2	2	2	2	2	2	2	2	2
Set-aside							0.08	3	3	3	3
Total	24	24	24	24	24	24	24	24	24	24	24

Table IV.5a Ware potato: changes in variable methods, Clay Areas (smaller farms)

	Current situation		Levy in guilders per kilogram active ingredient								
	Fixed	Optimal	0	10	15	25	50	75	100	150	200
N dressing 1	x	x									
N dressing 2											
N dressing 3			x	x	x	x	x	x	x	x	x
Weed control 1	x	x									
Weed control 2			x	x	x	x	x	x	x	x	x
Weed control 3											
Late blight Bintje 1	x	x								x	x
Late blight AM 1											
Late blight Bintje 2			x	x	x	x	x	x	x		
Late blight AM 2			x	x	x	x	x	x	x	x	x
Haulm killing 1	x	x	x	x	x	x	x	x	x	x	x
Haulm killing 2											

APPENDIX V. ADDITION TO THE LP COMPUTATIONS

The LCPP outlines the strategy to reduce pesticide use and estimates the costs this entails per agricultural sector. This Appendix presents a comparison of the LCPP estimates for arable farming with those obtained by the LP computations.

The total changes in costs as given in the LCPP are made up of increased expenditure and yield reductions as well as savings on inputs. The cropping variants used in the LP models usually cover several of these aspects. Hence, changes of costs and returns are difficult to separate. The items listed under the heading 'LP results 2000' - which means resulting differences between total revenue and variable costs - do not add up to the 31.0 mln guilders given as the 'total'. Furthermore, as the LP approach is restricted to farm level some costs mentioned in the LCPP are omitted. For example, the costs of implementing an information system and additional costs of inspecting sprayers. These are indicated by '-'.

The quantification of the additional costs for the LP computations pertains to the situations with a levy of 50 guilders per kg active ingredient (except soil disinfection). There were no unambigous data on 'yield and quality reduction attributable to additional mechanical operations' that could be included in the cropping variants. The costs of shredding small potatoes left in the field and transporting soil wastes were left out, as they are irrelevant for a levy imposed on pesticide use. Finally, reduction in the quality of seed potato is disregarded, as in the LP models growing seed potatoes is considered to be equivalent to growing ware potatoes (see Section 6.3).

In the LP result set-aside plays an important role. For example, in the case of a levy of 50 guilders per kg a.i., set-aside accounts for more than 50 per cent of the arable land in the Peat Colonies (see Appendix IV). A premium of 1500 guilders per hectare set-aside is assumed in the computations. Without this premium the cropping patterns change; more seed grass is grown in the Peat Colonies. The major part of the former set-aside area remains fallow, however, and income losses caused by a levy become more dramatic.

Table V.1 Comparison of the annual additional costs of the LCPP for the arable sector according to MJP-G (1990) and a regulatory levy of 50 guilders per hectare according to LP results (all amounts in million guilders)

	MJP-G (1990) 1990-1995	1995-2000	LP results 2000
Infestations of the soil			
Ware potato:			
higher costs seed material			
PSR varieties	2.0	1.3	4.0[1]
lower product prices PSR variety	8.1		0.0[2]
separate storage	15.0	15.0	-
Starch potato:			
lower yields	7.0		- [3]
Sugarbeet:			
lower yields	6.6	6.6	0.0
All root crops:			
pesticide applications			
and operation methods	15.0	14.0	0.0[4]
shredder (remnant potatoes)	12.5	12.0	-
transport of soil wastes	15.0	15.0	-
nematode bait crops		4.2	- [5]
soil sampling (nematode control)	36.0	24.0	- [5]
Diseases due to fungi/viruses etc.			
Ware potato:			
reduction of N dosage	-3.2	-3.2	- [6]
risks of rotting in storage	7.0	7.0	- [7]
lower yields caused by reduced			
N dose	4.2	4.2	0.0
lower yield because of greater			
damage		4.9	- [7]

[1] Assuming 50% Bintje and 50% PSR variety.

[2] The PSR variety has a higher yield per hectare that compensates for the lower product price.

[3] The change-over from a 1:2 cropping frequency to 1:4 without soil fumigation results in lower yields; as the 1:2 rotation is not profitable according to the LP computations this is not regarded as additional costs.

[4] Also used without imposing a levy.

[5] In the LP computations the common method of soil fumigation is preferred to the innovative techniques of growing a bait crop or disinfecting of the infected areas.

[6] According to the LP computations the current practice of manuring and supplementing with fertilizer is abandoned in favour of a split application of N-fertilizer supported by petiole analysis.

[7] This is accounted for in the cropping variants, see Appendix III.

Table V.1 (continued)

	MJP-G (1990)		LP results
	1990-1995	1995-2000	2000
Starch potato:			
reduction of N dosage	-1.7	-1.7	- [3]
lower yields caused by reduced N dose	2.0	2.0	- [3]
Onion:			
reduction of N dosage	-0.6	-0.6	0.0 [8]
risks of lower quality	1.3	1.3	0.0 [8]
Cereals:			
yield reduction	24.0	43.0	22.1
reduction of N dosage	-6.0	-10.8	<- 0.1
Weeds			
All crops:			
commitment of casual labour	30.0	50.0	0.0
additional investments in machinery	36.0	42.0	- [9]
reduction of yield and quality by additional mech. treatments	99.0	150.0	-
Growth regulation			
Seed/ ware and starch potato:			
additional investment in machinery	19.0	19.0	- [10]
reduced quality of seed potatoes		3.5	-
more expensive germination control		11.7	- [7]
Adaptations of spraying techniques	18.7	18.7	- [11]
Cost of inplementing information system	4.3	4.3	-
Savings on pesticide use	-121.2	-191.4	-85.6 [12]
Total	230.0	263.0	ca. 31.0 [13]

[8] The share of onion in the cropping patterns is reduced (see Appendix IV) the method of growing onions is unchanged.

[9] The LP computations assume availability of a weed harrow and a hoeing machine in the basic situation. The innovative combination of earther/ridge hoe for environmentally friendlier weed control in potato is used without imposing a levy (see results levy 0 computations, Appendix IV).

[10] The investment in a haulm shredder is profitable without imposing a levy (see results levy 0 computation runs in Appendix IV).

[11] Includes the annual costs of the row-spraying machinery.

[12] Assessed by multiplying the savings on pesticide use (from comparing cropping patterns and cropping variants of the levy 0 with the levy 50 situations for the representative farm per region, see Appendix IV) by a representation factor (hectares under arable crops per region divided by the the hectares represented by the model) and summing the results.

[13] Resulting from multiplying the costs per hectare (see Table 8.6) by total hectares under arable crops, viz. 597 700 ha.

Some more English-language titles in this series

The world coffee market and the international coffee agreement
M.Th.A. Pieters and H.J. Silvis
1988, paperback, Wageningen Economic Studies 9. Price US$ 18.00

Farmers and finance: experience with institutional savings and credit in West Java
H.A.J. Moll
1989, paperback, Wageningen Economic Studies 11. Price US$ 24.00

The idea of environmental welfare economics
J.J. Krabbe
1989, paperback, Wageningen Economic Studies 12. Price US$ 11.00

Decision making under risk
A study of models and measurement procedures, with special reference to farmer's marketing behaviour
A. Smidts
1990, paperback, Wageningen Economic Studies 18. Price US$ 43.00

Foot-and-mouth disease and export
P. Berentsen, A.A. Dijkhuizen and A.J. Oskam
1990, paperback, Wageningen Economic Studies 20. Price US$ 13.00

Depletable resources and the economy
W.J.M. Heijman
1991, paperback, Wageningen Economic Studies 21. Price US$ 37.00

Issues of environmental economic policy
W.J.M. Heijman and J.J. Krabbe, editors
1992, paperback, Wageningen Economic Studies 24. Price US$ 33.00

Micro-economic models of Dutch dairy farms
G.J. Thijssen
1992, paperback, Wageningen Economic Studies 25. Price US$ 19.00