Farm Economic Consequences of a Reduced Use of Pesticides in Danish Agriculture

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FARM ECONOMIC CONSEQUENCES OF A REDUCED USE OF PESTICIDES IN DANISH AGRICULTURE

- Optimal adjustment to various pesticides scenarios for some typical farm types

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ABSTRACT

In 1997 the Danish Minister for Environment and Energy set up a committee to evaluate the possibilities of reducing the use of pesticides in Danish agriculture. As an important part of the evaluation the farm economic and macro economic consequences of a reduced use of pesticides in Danish agriculture was calculated. This article describes the farm economic consequences, as well as the agronomic background and the farm economic model developed to calculate these consequences. The analysis was built up around a set of farm types representative for Danish crop rotation regimes and a set of scenarios intended to show the consequences of different degrees of reduction of pesticide consumption in agriculture. For each scenario the crop yield losses, alternative cultivation techniques, and a number of overall restrictions on the crop rotation were estimated and incorporated in the farm economic model. By using the model the new optimal allocation of crops and pesticides was decided for the different farm types and scenarios. It was found that a total ban on the use of pesticides would have considerably economic effects on crop production and require severe adjustment of the crop rotation and cultivation systems. However, the present use of pesticides can be significantly reduced without any drastic economic losses.

KEY WORDS: *Pesticide scenarios, farm economic model, crop rotation regimes, and optimal land use.*

INTRODUCTION

In 1997 the Minister of Environment and Energy appointed a committee (The Bichel Committee) to assess the overall consequences of partial or total phasing out the use of pesticides and a transition to organic farming. A main committee was appointed with expert members from research, the agricultural industries, the ”green organisation”, the foodstuff and agrochemical industries, the trade unions and relevant ministries. In addition four sub-committees were appointed. Their task was to facilitate the main committee’s final reporting, by drafting specialist background reports in the following areas:

1) Agriculture (EPA 1999 b)
2) Production, economics and employment (EPA 1999 c)
3) Health and the environment (EPA 1999 d)
4) Legislation (EPA 1999 e)

The aim of the sub-committee for agriculture was to describe scenarios for the total and partial phasing out of pesticides and a restructuring to organic agriculture. Consequences for different types of cultivation systems in agriculture were to be assessed. As a reference the production achieved by agriculture today was used. The sub-committee should also illuminate alternative, non-chemical methods of controlling plant disease, pest and weeds. Based on these analyses the sub-committee on production, economics and employment evaluated the economic consequences of the various cultivation systems. The Danish Environmental Protection Agency (EPA) was coordinating the work of the committees.

Content

In this paper emphasis will be put on the economic analyses at farm level Effects on macro-economic factors and employment are dealt with in the report EPA (1999 c) and Jacobsen and Frandsen (1999); effects on environment and health in the report EPA (1999 d); effects on legislation in EPA (1999 e) and the restructuring to organic farming in EPA (1999 f). The EPS reports are available on www.mst.dk.

Method of analysis

The assessment of the economic consequences is based on three components 1) crop rotation analyses to determine the technical and biological relationships in arable farming if pesticides are phased out, 2) farm level economic analyses, and 3) sectoral and macro economic analyses.

The crop rotation analyses include estimates of the agronomically feasible crop production with pesticides phased out, while the farm level analyses focus on land use and the economic effects at farm level. The economically optimal crop production was estimated with unchanged livestock production and given price conditions. The sectoral and macro economic analyses, on the other hand, show the results for the entire sector and for the entire economy with full adjustment of production (including livestock production), taking into account economic effects on other sectors and feedback effects in the form of adjustment of product and factor prices. A more detailed description of the adopted conceptual framework is found in EPA (1999 c).

The main-committee selected 4 scenarios for total and partly phasing out pesticides defined as follows:

***0-scenario*:** No use of pesticides at all

***0+ scenario*:** (less than 5 percent of the present use). Pesticides are only allowed in order to satisfy specific legislative requirements on purity or described requirements for combating quarantine pests.

+ *scenario*: (approximately 20 percent of the present use). The use of pesticides is permitted for crops that would otherwise result in a big yield loss or where it is deemed impossible to maintain profitable production without the use of pesticides. For use of pesticides to be permitted, there must be a considerable yield loss (15-20 per cent) or the production is associated with such uncertainties that it must be expected to be discontinued or impossible to fit into the crop rotation.

++ *scenario*: (approximately 40-50 percent of the present use). Basically, significant economic losses from pests compared with present production are not expected in this scenario. The scenario assumes the use of all the present damage thresholds and mechanical weed control, where these methods can compete with the chemical methods. A larger number of man-hours for monitoring are assumed than in present production. Basically, the present cropping systems are economically optimised, but with the lowest possible use of pesticides.

AGRONOMIC BACKGROUND

Loss magnitudes

The sub-committee for agriculture evaluated alternative methods of reducing yield losses in case of a total or partial pesticides phase-out. The data used when estimating losses resulting from disease and pest attacks in case of a total ban on pesticides were mostly obtained from pesticide studies conducted by the Danish Farmers' Union and the Danish Institute of Agricultural Sciences. Several test-related factors are of significance to the loss percentages resulting from pest attacks. Thus, although the magnitudes of losses obtained from such studies cannot be representative of the losses that would occur in different farm types, there are no better sources on which to estimate losses caused by pests and diseases. Certain losses can only be calculated with difficulty, including effects on quality parameters. It is especially true of potatoes, malting barley and grass seed.

There are also large uncertainties in the loss magnitudes that would result from a switch to mechanical weed control. Only a few studies have been conducted, in which the effects on weeds and yield under a regime of mechanical weed control are compared with the effects of standard herbicide treatment. The loss estimates in grain were modified data from organic farms where weeds were recorded, after mechanical weed control was carried out. Losses resulting from the significant crop damage associated with mechanical weed control were also taken into account when estimating losses (Table 1).

Some of the alternative methods that can be used to prevent and minimise the problem of pests, diseases and weeds are linked to yield drawbacks. To minimise weed problems, postponed sowing of wheat and winter barley is recommended. To ensure a healthy, competitive crop, however, sowing in the second half of September is recommended. A minor yield loss (3-7 percent) can be expected as a result of the proposed delay in sowing compared to the practise used today. One of the other parameters that can reduce yield is the choice of the most resistant wheat varieties. Such varieties have a lower yield potential than the highest-yield varieties. According to data from 1995-1997 giving resistance priority over yield would cost 4-5 hkg per ha (Hovmøller *et al*., 1998).

Table 1. **Estimated direct yield losses resulting from a total ban on pesticides**

Crops	***Loss 1*** Delayed sowing	***Loss 2*** Diseases	***Loss 3*** Pest	***Loss 4*** Crop damage	***Loss 5*** Increase in weeds	***Loss sum*** Total loss	***Max. loss***
	Percent yield loss						
Wheat, 1 year, sand	8	7	2	7	6	27	45
Wheat, 1 year, clay	7	9	4	7	6	29	50
Wheat, 2 year, sand	9	7	5	7	6	30	68
Wheat, 2 year, clay	7	7	4	7	6	27	43
Spring barley, sandy soil	-	7	3	1	7	17	33
Spring barley, clay soil	-	6	6	1	7	19	30
Winter barley, sand	7	11	0	3	3	22	32
Winter barley, clay	7	10	0	3	3	21	28
Winter rye	3	4	3	1	2	12	28
Peas	-	2	9	5	7	21	26
Winter rape	-	2	5	0	0	7	26
Spring rape	-	2	17	0	5	23	48
Sugar beet	-	2	12	0	0	14	22
Fodder beet	-	2	12	0	0	14	22
Clover seed	-	0	50	0	50	75	100
Grass seed	-	1	0	?	50	50	100
Potatoes	-	38	4	0	0	42	100
Whole crop	-	3	2	1	8	13	16
Grass	-	0	0	0	?	3	4
Oats	-	5	3	1	8	16	25
Maize	-	0	0	5	8	13	16

Loss 1 covers losses due to cultivation practice which have been changed to minimise the risk of pest attacks, such as postponed sowing time and the choice of resistant varieties. **Loss 2** covers losses resulting for disease attacks. **Loss 3** covers losses resulting from pest attacks. **Loss 4** covers losses resulting from the crop damage caused by mechanical weed control and **Loss 5** covers losses resulting from the fact that more weeds remain after mechanical weed control than after the application of herbicides.

The total loss (**loss sum**) has been pieced together from five different loss magnitudes (**loss 1 – 5**), and the maximum loss has been calculated. The maximum loss (**Max. loss**) covers the situation in which one of the five loss functions gives the maximum loss and will, thus, establish a worst-case situation in the relevant crop. The maximum losses are often about twice as large as the average losses. Such losses can occur, e.g., if a potato blight attack develops very early in the growing season, or if wheat suffers a severe attack of stripe rust or *Septoria*. It is difficult to estimate the frequency at which such maximum losses will occur as they usually depend on the climate.

The various loss magnitudes can either be added or multiplied. For our task, we have chosen multiplication. This will prevent calculated crop yields from being negative. In the studies, losses are usually expressed as hkg per ha, which we have converted to loss percentages. It has not generally been possible to differentiate loss magnitudes according to crop yields. This was only possible for diseases in wheat.

Alternative treatments

For each crop, soil type and scenario the yield loss relative to the 0 scenario and the required treatment, e.g. pesticide use and mechanical weed control, has been determined. A pesticide treatment is described by an average dose, a probability expressing how often the treatment is needed, and an average number of required sprayings.

Through out the analysis the use of pesticides is measured by means of a so-called treatment frequency index (TFI). The index expresses the number of times the cultivated area may be treated with a normal dosage relevant to the task. For example a TFI = 1 corresponds to 3.5 litre Roundup (1.260 gram glyphosat), 1 litre Amistar (250 gram azoxystrobin), or 0.75 litre Dimethoat (300 gram dimethoat). Danish Agricultural Advisory Centre (2000).

As an example, alternative treatments and yield losses in first year winter wheat on clayey soil are shown in Table 2.

Table 2. **Alternative treatments and yield losses for different pesticides scenarios in winter wheat on clayey soil**

Crop Scenario	***Loss 1*** Delayed sowing	***Loss 2*** Diseases	***Loss 3*** Pest	***Loss 4*** Crop damage	***Loss 5*** Increase in weeds	***Loss sum*** Total loss	Average pesticide usage (TFI)	Probability (Percent)	Avg. no. of sprayings	Pesticide price DKK per TFI	€ per TFI	Extra harrowing
	------------------------- Percent ------------------------											
Diseases (present)							0.95	95	2.1	350	47	
++							0.58	95	1.6	400	54	
+		1.5				1.5	0.25	50	0.8	400	54	
0	3.5	9				12.5	-	100	-	-	-	
Pest (present)							0.65	65	0.7	65	9	
++							0.50	50	0.5	65	9	
+			2.5			2.5	0.09	10	0.1	65	9	
0			4			4	-	100	-	-	-	
Weeds (present)							1.40	100	1.3	112	15	0
++							1.00	100	1.3	112	15	0
+	1.5			3.5	3	6.5	0.10	100	1	112	15	2
0	3.5			7	6	16.5	-	100	-	-	-	3

It is shown that 95 percent of the winter wheat is sprayed with fungicides to prevent diseases in the present production. On average it is sprayed 2.1 times per seasons, with a total pesticide use equivalent to a TFI = 0.95 and at a price of DKK 350 (€ 47) per TFI.

In the ++ scenario use of new (more expensive) fungicides, optimum use of damage thresholds and warning systems will reduce the pesticide use from a TFI=0.95 to 0.58. At the same time the number of sprayings will be reduced from 2.1 to 1.6 per season. In the 0 scenario winter wheat will require four times extra harrowing. In the + scenario a TFI=0.1 will replace one harrowing and provide a 10 percent yield loss relative to the 0 scenario.

Farm types

The sub-committee on agriculture defined 12 farm types as being representative for the most common crop rotation regimes in Danish agriculture (Table 3). However, two of these farm types covering farms of less than 20 ha have not been analysed in more detail (type 6 and 12).

With the aid of the Danish Institute of Agricultural and Fisheries Economics' accounting statistics for 1995/96, we have estimated harvest yields, product prices, subsidies and cost structures for each individual farm type.

Table 3 **Farm types used in the farm level analysis**

Farm type	Farm acreage	Animal units	Grain yield	Use of pesticides
	------------- 1995/96	-------------	-------------	-- 1994 --
	-- Ha --	-- AU --	-- Hkg per. ha --	-- TFI --
Clayey soil				
1. Arable farms	104	16	97	2.6
2. Pig farms	64	104	101	2.5
3. Arable farms with beets	82	46	111	3.2
4. Arable farms with seeds	113	26	108	2.7
5. Dairy farms	50	72	94	1.9
Sandy soil				
7. Arable farms	121	19	108	2.4
8. Pig farms	62	109	104	2.3
9. Arable farms with potatoes	103	75	96	3.8
10. Dairy farms ext. prod.	66	77	92	1.5
11. Dairy farms int. prod.	49	81	94	1.4

The breakdown between clayey and sandy soil is based on counties with mainly clayey and sandy soil. Dairy farms on sandy soil are divided into two types. Dairy farms with the highest number of cows per ha and the highest ratio of fodder crops are defined as dairy farms with intensive production (type 11). The others are defined as extensive dairy farms (type 10). Farms on clayey soil growing seeds and sugar beets on at least 10 percent of the land are included in type 3 and 4. Farms on sandy soil with more than 10 percent potatoes are included in type 9. Finally, the residual farms with more than 20 ha are divided into arable farms (type 1 and 7) and farms with livestock, primarily pigs and thus called pig farms (type 2 and 8).

The livestock is measured in so-called animal units (AU). Of which 1 AU corresponds to one cow one year, or 30 pigs produced etc. Information on the pesticide use (TFI) is based on 1994 data.

For each of the farm types the sub-committee on agriculture set up a crop rotation corresponding to existing production practice and the 0 scenario. For a detailed description of these crop rotation analyses, readers are referred to the report from the sub-committee on Agriculture (EPA 1999 b), and Mikkelsen *et. al.* (1998).

THE FARM ECONOMIC MODEL

A linear programming model ("DØP", Danish acronym for "farm economic pesticide model") was developed to calculate the economically optimum acreage and pesticide utilisation. The model is a behavioural model in which it is assumed that in the long run the farm manager wants to optimise the economic profit (Ørum, 1999).

For each scenario and farm type, the model calculates the acreage utilisation, crop rotation and pesticide usage that gives the greatest total gross margin II from field cultivation. Gross margin II is defined as the amount available for covering the costs of buildings and land, when all other costs, including wages, have been deducted. In the present analyses, which focus only on arable farming, gross margin II can approximately be taken as a measure of land rent.

A number of assumptions were built into the model such as restrictions on pesticide use as well as several crop rotation restrictions, e.g. early crop effects, fodder balances and working capacity. Only the crops used in the present crop rotation were included in the calculations. Animal production was kept unchanged in the model and the aim was to sustain unchanged levels of feed production on the farms throughout the entire phase-out. Nevertheless the model allowed import of grain and protein fodder.

Accounts were not kept of plant nutrients although adjustments were made for the lower fertiliser costs in relation to the lower yields. One restriction was that set-aside land constituted a minimum of 10 percent and a maximum of 33 percent of the area with reform crops, including set-aside. The production of sugar beet, grass seed and clover grass was limited to the maximum quantity produced in 1995/1996 and a number of other assumptions were built into the model.

The alternatives to present production are calculated by adjusting the gross margin for yield losses and increases, changed costs for the purchasing and application of pesticides and changed costs for mechanical weed control. The value of the saved costs of pesticide application and the increased costs of mechanical weed control were determined on the basis of machine pool rates (Table 4) together with an hourly rate for manual weed control of DKK 130 (€ 14).

Table 4. **Machine pool rates**

Type of operation	-- DKK per ha --	-- € per ha --
Crop spraying (with 15 ha)	140	19
Harrowing (with 10-25 ha)	143	19
Row cultivator (25 ha with 12-row) machine	260	35
Gas-burning of weed (with gas DKK 150 (€ 20) per ha)	400	54
Crushing of potato tops	1,500	201

The costs of mechanical weed control were calculated for normal weed pressure. In the case of sugar beet and fodder beet, the costs were increased by the wages for 2 x 50 hours manual hoeing of weeds per ha. The costs of increased difficulty of harvesting and the increased need for drying were not included in the model and neither were costs of a more individual nature, such as difficulties with wild oat or special weed problems on low-level land, etc. It was assumed that the increased costs of pest monitoring in the + and ++ scenarios would amount to about DKK 150 (€ 20) per ha per year.

The chemical control of perennial grass (couch) was administered in the model as an independent use of pesticides common to the entire crop rotation regime. The mechanical control of couch grass demands a regime with several spring crops, where late crops or winter cereals could otherwise be cultivated. For the control of couch grass without chemicals, the model demands space for thorough mechanical couch grass control every three years and winter cereals could only be cultivated on a maximum of 40 percent of the land.

Winter wheat as an example

Figure 1 shows how the gross margin II in first year winter wheat on clayey soil is affected by the alternative treatments specified in Table 2.

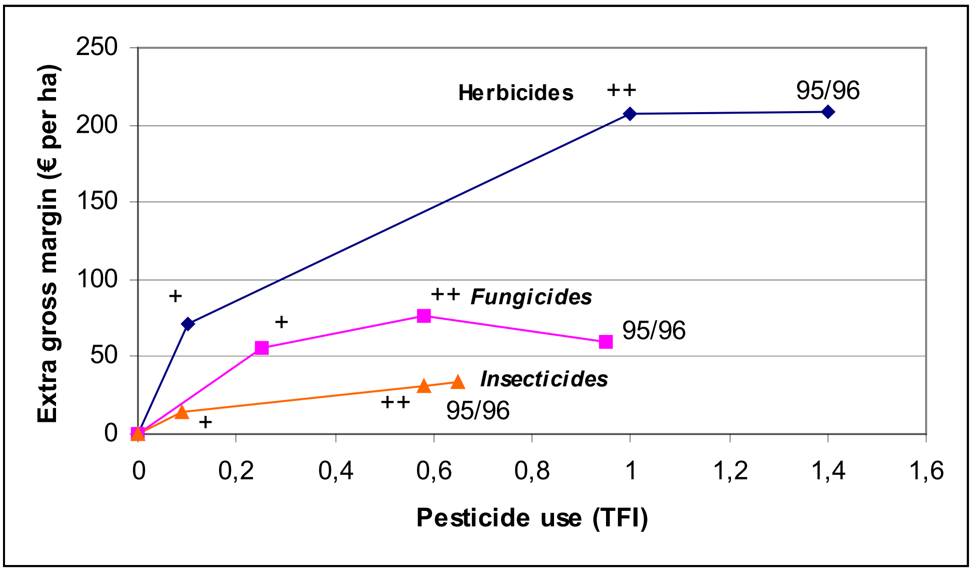

Figure 1. **Extra gross margin in winter wheat for alternative treatments**

It is shown, that the use pesticides and especially the use of herbicides are of big importance for the economic results in winter wheat. However, there are basis for significant reductions in the use of pesticides - at no cost.

Each graphic point is in fact matching a production alternative available in the farm economic model. In the case of more liberated scenarios, e.g. quota and tax scenarios, also linear combinations of the production alternatives matching the lines are available for the model.

FARM LEVEL CONSEQUENCES

A few results from the farm level analyses are summarised in Table 5 and 6.

Table 5. **Gross margin II for the different farm types and scenarios**

Farm type \ Scenario	Present production	Free [1)]	++	+	0
	----------------------------	€ per ha	--------------------------------		
Clayey soil					
1. Arable farms	444	458	460	373	307
2. Pig farms	389	412	412	339	273
3. Arable farms with beets	556	578	572	444	350
4. Arable farms with seeds	515	547	555	465	357
5. Dairy farms	291	346	307	257	227
Sandy soil					
7. Arable farms	298	307	304	283	227
8. Pig farms	295	311	310	261	223
9. Arable farms with potatoes	499	517	532	442	252
10. Dairy farms ext. prod.	252	300	277	255	228
11. Dairy farms int. prod.	271	324	288	280	257

1) Model calibrated economically optimised present production.

As shown in Table 5, a complete ban on the use of pesticides will reduce gross margin II ranging up to DKK 2,000 (€ 270) per hectare for farms specialised in potatoes, sugar beets and grass seed.

Table 6. **Pesticide usage for different farm types and scenarios**

Farm type \ Scenario	Present production	Free [1)]	++	+	0
	--------------- Treatment frequency index (TFI) -----------------				
Clayey soil					
1. Arable farms	2.4	2.3	1.5	0.4	0
2. Pig farms	2.5	2.1	1.3	0.4	0
3. Arable farms with beets	2.8	2.8	1.8	0.7	0
4. Arable farms with seeds	2.4	2.3	1.5	0.7	0
5. Dairy farms	1.9	1.6	0.9	0.3	0
Sandy soil					
7. Arable farms	1.8	1.1	1.0	0.3	0
8. Pig farms	1.9	1.7	1.3	0.3	0
9. Arable farms with potatoes	3.9	1.6	2.6	0.5	0
10. Dairy farms ext. prod.	1.4	1.0	0.6	0.2	0
11. Dairy farms ext. prod.	1	0.7	0.3	0.2	0

1) Model calibrated economically optimised present production.

For other types of farms on clayey soil the profit will decrease by DKK 1,000 (€ 135) per hectare and for the types on sandy soil by DKK 600 (€ 80) per hectare. The dairy farmers will experience the lowest decrease in profit, namely approximately DKK 500 (€ 65) per hectare on sandy soil and DKK 900 (€ 120) per hectare on clayey soil.

As shown in Table 6 the pesticide usage (TFI) differs for the different farm types and scenarios. Altogether, the TFI is around 0.5 in the + scenario (a reduction of about 80 percent) and around 1,5 in the ++ scenario (a reduction of about 40 percent).

Figure 2 shows gross margin II and pesticide usage (TFI) for farms without sugar beets and other specialised crops on different soil types.

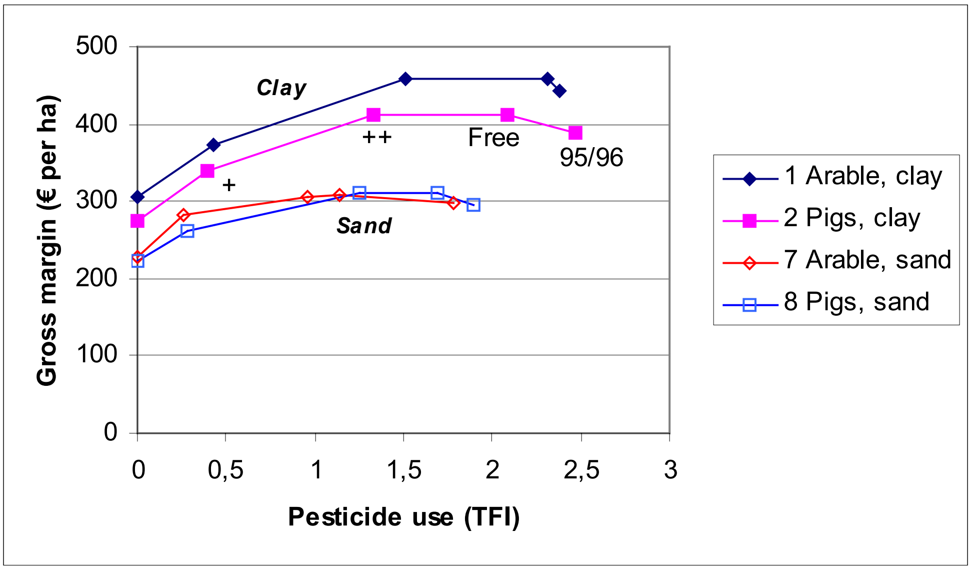

Figure 2. **Gross margins for conventional farms on different soil types for different pesticide scenarios**

The figure indicates that with optimum use of damage thresholds and warning systems (++ scenario), it would be possible to reduce pesticide usage to some extent without seriously reducing the economic return, but that earnings would soon fall if the treatment frequency index were reduced still further (+ and 0 scenarios). Farms on clayey soil would generally be worse affected than farms on sandy soil.

For a more detailed description of the resulting optimal land use and the resulting costs structures etc., readers are referred to Ørum (1999). Furthermore the optimal land use are compared to the land use determined by the agronomist in the sub-committee on Agriculture (EPA 1999 b) and Jørgensen *et. al*. (1999).

CONCLUSION

It is found that a total ban on the use of pesticides will have considerably economic effects on crop production and require severe adjustment of the crop rotation and cultivation systems. However, the present use of pesticides could be significantly reduced without drastic economic losses. The losses may be minimised through improvement of the monitoring systems and adjustment of the cultivation combined with a better education and extension service. The needs for adjustments will vary among the various farm types. However, if reductions in the use of pesticides have to be achieved, administrative and economical measures must be taken such as quotas, ban, prescriptions, and levies.

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BIBLIOGRAPHICAL SKETCH

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