PESTICIDE MANAGEMENT AT FARM LEVEL

Mariane Hansen

Danish Institute of Agricultural and Fisheries Economics, Denmark

ABSTRACT

In this paper a simulation model is constructed whereby it is possible to evaluate economic consequences of various applications of pesticides at farm level. The estimations are based on dose response functions for pesticide use for different crops with respect to fungus, insects and weeds. The loss of each type of pesticide is added to get a total estimate of the loss at field level. Finally gross margin at crop level and farm level are estimated with respect to loss and the optimal treatment frequency index.

INTRODUCTION

During the last decades Danish agriculture has reached a high level of efficiency like many other West European countries. This efficiency is mostly regarded as positive with respect to farmers' economy, use of better technology and inputs. However, this efficiency also have some negative effects. Pollution of groundwater with pesticides and nitrate are considered some of the main negative effects. In Denmark concern about the groundwater is especially high as more than 95 per cent of the drinking water source is based on groundwater.

THE DANISH ACTION PLAN TO REDUCE PESTICIDE APPLICATION

Great public concern about the increased use of pesticides lead to the fact that the Danish politicians implemented the "Action Plan to Reduce Pesticides Application" in 1986. The aim of the Action Plan was a 50 per cent reduction in the use of pesticides in Danish Agriculture before 1997, relative to the average consumption from 1981-1985, and measured by a) the use of active ingredients and b) the number of standard treatments per hectare of arable land. The decrease in use of active ingredients has been reached, while the decrease in treatment frequency index has not. Increases in the area grown with winter crops, where higher treatment are required, is the main reason to the last partial goal has not been reached. The applied policy were rules like: all persons who use pesticides professionally should pass a test in handling and applying pesticides and from 1994 a plan of pesticide use should be made on farms larger than 10 hectares. These rules should include pesticide products and amount applied, differentiated on crops and area. Furthermore, there was a claim to make a revaluation of the registered pesticides, using new criteria. The tax is often assumed to be the best economical tool to change persons behaviour in a wanted direction. Therefore, in 1996 a low tax at 13 per cent on herbicides and fungicides and a tax on 27 per cent on insecticides were legislated.

In figure 1, the treatment frequency index is shown for the period 1981 to 1995, divided in the four common types of pesticide: herbicides, growth regulators, fungicides and insecticides. The size of the columns is an average of the treatment frequency index per hectare of arable land in Denmark.

The definition of the treatment frequency index (TFI) is "the average number of times it is possible to treat the total area of a certain crop during the growing season with pesticides, that are sold for that purpose in the specific year".

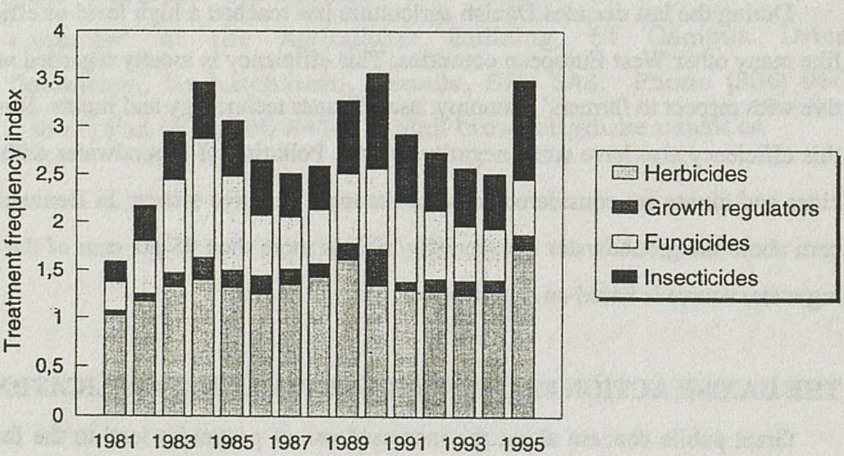

Figure 1: Treatment frequency index (TFI) per hectare in Denmark in the period 1981-1995.

Since the treatment index is a constructed figure, it does not necessary show the actually use of pesticides. From figure 1, it looks like more pesticides were used in 1995 after four years with a TFI at 3 or less. However, 1995 may have been influenced by the tax legislation and the increase in 1995 may be due to hoarding. Such a hoarding was also seen in the late 1980'es due to the strengthened approval procedures, (Schou, 1996). The policy has primarily been to prohibit pesticides or put a high tax on these, so that farmers will tend to lower their use of pesticides.

However, any policy tool implemented to lower the use of pesticides will in general have some negative effects on the economy of crop production. At the same time will changes in the use of pesticides affect crop yields, which are also strongly related to many biological aspects. This complexity makes it difficult to estimate the economical effects of a changed use of pesticides at the farm level.

MODEL CONCEPT

The aim of this paper is to show the effects on gross margin at crop and farm level as a function of changes in treatment frequency index (TFI). An overall model diagram is shown below.

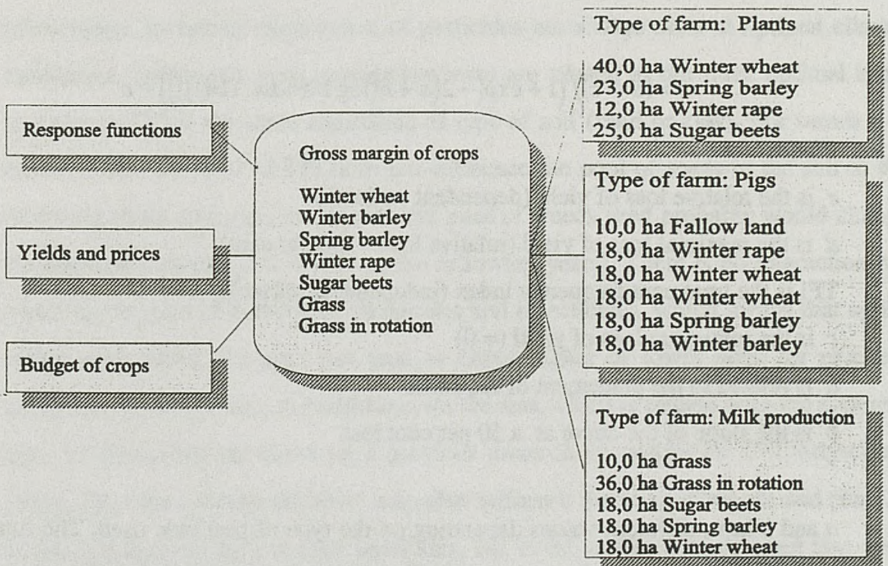

Figure 2: Diagram of model

The model is build on response functions for weeds, fungus and insects, (Secher, 1997). These functions are estimates of the loss of a crop to a given treatment frequency index. On field level there has been done much research comparing yields at different levels of pesticide use. However, there are several pesticide products and some of them are only on the market in few years, either because they are prohibited or because better substitutes are developed. The response functions for weeds and fungus are estimated on basis of field trials by the Danish Institute of Plant and Soil Science. Functions have been estimated with respect to two types of herbicides, used at grass weeds and weeds with two seed leaves, respectively. A function with respect to fungicides has been estimated as an average of the used fungicides and finally response functions with respect to insecticides are estimated as an average of used insecticides to the respective crops. The functions with respect to insects are still only based on parameters. For all response functions the treatment frequency index is the independent variable, whereas the yield loss in relative number is the dependent variable.

The response functions represent data for 3-4 years. If data was selected for only one year, the response functions might vary considerably from year to year due to climate conditions and weeds and pests populations. The mathematical expression for one of the response function estimated for grass weeds is shown below:

$$e = (d - c) / \left(1 + \exp\left(-2\left(a + b\left(\log 10(\text{dose TFI})\right)\right)\right)\right) + c$$

where,

e is the relative loss of yield (dependent variable)

d is the maximal loss of yield (relative loss =100 per cent)

TFI is the treatment frequency index (independent variable)

c is the minimum loss of yield (= 0)

a is related to the placement of the curve

b is the slope of the curve at a 50 per cent loss

a and b have different values depending on the type of pesticide used. The function, which has the b-value at -1, represent the loss that can be expected when winter grain crops are applied by sulfonylurea products. When the b-value is -3 the function represent pesticides used against grass weeds. The sulfonylurea products are used on 75-100 per cent of the land, whereas the other herbicides normally are used on less than 50 per cent of the land.

Further there is data on yields and prices which is used for calculating gross margin for the respective crops. Data on each crop like amount of seeds for sowing, amount of fertiliser and machinery costs are taken from the "The Danish Agricultural

Advisory Centre" (Landbrugets Raadgivningscenter, 1996). By combining the three data sets, it is possible to estimate gross margin with respect to different TFI for the following five crops: winter wheat, winter barley, spring barley, winter rape and sugar beets. The model is simulated for the three types of farms, cf. figure 2. The total area for each type of farm is set to 100 hectares, which means that the area of each crop also represent the area in per cent. The farm models represent typical crop rotations for the three types of farms.

Based on the estimated gross margins with respect to the TFI for each crop, the total gross margin for three farms representing plants, pigs or milk production is simply estimated by multiplying the area with the specific crop by the optimal gross margin and adding the values for each crop together. The optimal gross margin is defined at that TFI where marginal value of the production equal marginal costs.

The model is based on a wide range of assumptions with respect to biological relationship, including: application of pesticides are always done at optimal climate conditions, weeds and pests population level are treated at the most optimal time, loss due to TFI is the same regardless of type of soil (sand or clay). For weeds it is assumed that the level of TFI does not influence the pool of seeds in the soil in the following years (since an increase in the pool of weeds seed probably would change the response functions for weeds in the following years). There is no interaction between application of herbicides, fungicides and insecticides, which means that application with herbicides does not lead to either higher or lower need for example spraying with fungicides. Assumptions on the area which is treated with the different types of pesticides are based on a previous research on pesticides, (Miljøstyrelsen, 1995). The crop rotation schedule may also influence the level of weeds and pests in a crop and thereby the need for pesticides, but in the model it is assumed that need for pesticide application is the same for each crop no matter of the crop rotation schedule.

RESULTS

For each of the five crops the gross margin has been calculated. Gross margin at permanent grass land and grass in rotation is assumed fixed since the use of pesticides is set to zero. From a farmer's point of view the expectations on future prices and yields may affect how the farmer makes decisions in his production, regarding the use of pesticides and other inputs. In the simulation model it is therefore possible to change the levels of yield and price.

Table 1 shows optimal values for gross margin for winter wheat per hectare, percentage change from base situation and optimal treatment index, when changes have been made on sale price of wheat and/or if pesticide prices have been increased. The changes in pesticide prices could be a consequence of higher taxes on pesticides. Taxes on pesticides has already been introduced at a low rate, so it will be quite simple to turn on that "bottom". In the simulations changes on pesticides prices are set at the levels: +50, +100 and +200 per cent.

As the base situation for the simulations has been chosen: average yield of crops grown in soil of clay, recommended use of other inputs than pesticides, Danish prices of outputs and inputs in 1996. The result of the base simulation in table 1 is a gross margin of 4415 DKK and 3864 DKK at the wheat price 87 DKK/hkg and 78 DKK/hkg, respectively. The variable inputs include seeds, fertiliser, pesticides, machinery and man hours.

Table 1: Optimal gross margin and TFI in winter wheat

	Sales price wheat 87 DKK/hkg (1996 price)			Sales price wheat 78 DKK/hkg (1996 price - 10%)		
Pesticide price (DKK/ ha)	Gross margin (DKK/ha)	Percentage change (%)	Treatment freq. Index (TFI)	Gross margin (DKK/ha)	Percentage change (%)	Treatment freq. Index (TFI)
Base run (1996)	4715	0,0	3,33	3864	0,0	3,16
Base run +50 %	4489	-4,8	2,85	3650	-5,5	2,66
Base run +100 %	4294	-8,9	2,50	3460	-5,8	2,33
Base run +200 %	3956	-16,1	2,00	3143	-18,7	2,00

The figures are calculated without incorporating any substitutions effects although some kind of substitution when decreasing pesticide use probably would be carried out in practical farming. This could for example be mechanical weeds harrowing.

The results of the price changes and the optimal gross margin for winter wheat and spring barley are shown in table 1 and table 2.

Table 1 shows that a tax on + 200 per cent at pesticides costs leads to a 16,1 per cent decrease in gross margin in winter wheat. The decrease in gross margin for spring barley can be seen in table 2 and is less than 5 per cent. The decrease in treatment frequency index is more obviously for winter wheat than spring barley, changing from 3,33 to 2,00 and from 1,96 to 1,73, respectively.

Percentage changes (%) in gross margin are approximately the same when the sale price of winter wheat are lowered from 87 DKK/hkg to 78 DKK/hkg and the same taxes on pesticides are assumed. The difference in gross margin, when pesticide costs have not been changed, is about 18 per cent due to the change in wheat price.

Table 2: Optimal gross margin and TFI in spring barley

	Sale price spring barley 87 DKK/hkg (1996 price)			Sale price spring barley 78 DKK/hkg (1996 price -10%)		
Pesticide price (DKK/ ha)	Gross margin (DKK/ha)	Percentage change (%)	Treatment freq. index (TFI)	Gross margin (DKK/ha)	Percentage change (%)	Treatment freq. index (TFI)
Base run (1996)	3616	0,0	1,96	3025	0,0	1,96
Base run +50 %	3573	-1,2	1,84	2983	-1,4	1,84
Base run +100 %	3533	-2,3	1,84	2944	-2,7	1,73
Base run +200 %	3456	-4,4	1,73	2869	-5,2	1,73

A decrease from 87 to 78 DKK/hkg in sales price of spring barley results in a decrease in gross margin from 3616 DKK to 3025 DKK or 15 per cent. The same changes in pesticide prices as for winter wheat are made for spring barley, but the reductions in gross margin are much lesser than for winter wheat. The percentage changes ranges from -1,2 to -4,4 at the 1996 price level. Almost the same changes are seen when the sales price level is 78 DKK/hkg (price in 1996-10 per cent).

The same calculations as shown in table 1 and 2 have been made for the other crops: winter barley, winter rape and sugar beets. Based on these gross margin calculations for the different crops, the total gross margin at farm level for three types of farms have been estimated. For a certain price level the gross margin for a crop is multiplied by the area grown with that crop. The total gross margin for the three types of farm comes up by adding the gross margins for the respective crops.

In a similar way the total TFI has been calculated for each type of farm. Table 3 shows the total gross margin and TFI for the three types of farms and shows relative total change in gross margin and TFI measured in per cent.

From table 3 it can be seen that due to a change in pesticide price, the total gross margin decreases with 8-11 per cent for the three types of farms. However, the decrease in total TFI is about 33-35 per cent. When the sale price for crops is lowered the gross margin decreases, but the percentage changes, when also the pesticide price has been increased, is approximately the same by the range 9-13 per cent. Regarding the total TFI, the figures show also the same changes, ranging 32-33 per cent.

It should be noticed that the changes in the income of the farm may be underestimated in table 3, because fixed costs are not included in the calculations. These costs may differ considerably in each farm model.

Due to the simplicity in the model the focus has only been on the changes in gross margin and TFI. However, other aspects should be mentioned briefly. For example there may be more uncertainty on the expected yield when pesticide applications are lowered. Increasing pesticide prices may also lead the farmer to switch to less pesticide demanding crops. How the farmer values this risk and eventually decide to change his crop rotation in response to price changes needs a more intensive analyse.

Table 3: Gross margin and treatment frequncy index (TFI) for three types of farms

Sales price for crops	Pesticide price per TFI	Plants		Pigs		Milk	
DKK/ hkg	DKK/TFI	Gross margin in DKK (1000) and %	TFI and %	Gross margin in DKK (1000) and %	TFI and %	Gross margin in DKK (1000) and %	TFI and %
Base run (1996)	Base run (1996)	596 / 0	405 / 0	394 / 0	250 / 0	480 / 0	245 / 0
	Base run + 50 %	576 / -3,3	351 / -13	384 / -2,7	212 / -15	469 / -2,5	212 / -14
	Base run + 100%	559 / -6,2	318 / -21	375 / -5,0	191 / -24	458 / -4,6	192 / -21
	Base run + 200%	529 / -11,2	272 / -33	359 / -9,0	163 / -35	440 / -8,3	164 / -33
Base run -10%	Base run (1996)	497 / 0	386 / 0	330 / 0	233 / 0	423 / 0	234 / 0
	Base run + 50 %	479 / -3,8	335 / -13	320 / -3,0	200 / -14	412 / -2,6	203 / -14
	Base run + 100%	462 / -7,1	302 / -22	311 / -5,7	179 / -23	402 / -5,0	183 / -22
	Base run + 200%	434 / -12,8	261 / -32	296 / -10,2	159 / -32	385 / -9,0	156 / -33

The estimated results on the decrease in TFI can be compared to previous research (Rude,1992). Rude estimated the effects on TFI when an additional tax per used TFI unit was added. A levy at 100 DKK was equal to 60 per cent of the pesticide price in 1992. A levy at 200 DKK was equal to 120 per cent. The decrease in TFI for the two levies at 100 and 200 DKK was estimated by Rude to be 13-19 per cent and 20-28 per cent, respectively. The percentage changes in TFI are within the same range in the two studies although the estimation procedures are quite different.

CONCLUSIONS

Several European countries have set up action plans to reduce impacts on the environment by pesticides. In Denmark the target of a 50 per cent reduction in the use of active ingredients has been reached. However, the target of a 50 per cent reduction of the TFI has not yet been reached, due to increases in the area grown with winter crops, where higher treatment are required. This paper has been focusing on a model, which makes it possible to estimate the economic effects and effects on pesticide use of changes in prices at farm level. The model is based on response functions and application of the model shows that a 200 per cent increase in pesticide price may lead to a decrease in treatment frequency index at approximately 30 per cent at the farm level, and may lead to a loss in income for the farmer of more than 10 per cent.

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