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THE ECONOMIC IMPLICATIONS OF CHEMICAL USE RESTRICTIONS IN AGRICULTURE

by

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1 Introduction

1.1 Problems to Be Investigated and Objectives of the Study

Modern agriculture is increasingly coming under fire from the public. It is held responsible for the agricultural surpluses and all their attendant problems and it is increasingly regarded as the principal culprit for growing damage to the environment.The increase in intensification and specialization in farming are believed to be the main causes of the problem. Reservations exist especially with respect to the use of mineral fertilizers and pesticides as means of increasing and stabilizing yields. The actual reasons for using agrochemicals, namely to provide plants with nutrients and to protect them from attack by weeds, pests and diseases, has long been relegated to the status of secondary issues and anxiety that irreversible damage is being done to water, soil, air and the living world and to human health has become the prominent issue in the debate. Many critics even go so far as to demand a complete ban on the use of mineral fertilizers and pesticides.

There is certainly some cause for concern about our environment and health. There is plenty of evidence that nature has already been damaged and that there are limits to the amount of stress the environment and the human beings can tolerate. Therefore, an important task for society in the near future will be to check all aspects of production and consumption in the national economy for their impact on the environment. Already in 1985, the German Council of Experts for Environmental Issues (Rat von Sachverständigen für Umweltfragen) dealt at length in a special report with the specific environmental problems posed by agriculture. The Council made the point that the production methods used on the majority of farms in Germany are at, and in many cases actually exceed, the thresholds of environmental tolerance (Deutscher Bundestag, 1985, p. 302). The conclusions and recommendations in this report are, however, far more specific and comprehensive than those currently being debated in practical economic policy, some of which have already been put into action. Many approaches aimed at solving the problems of agriculture and environmental policy fail to take account of the complex pattern of cause and effect which is characteristic for environmental problems. Instead, they look at only one aspect of the environment. This tunnel-vision approach is often echoed in proposals for economic policy, such as an across-the board reduction in the use of mineral fertilizers and pesticides in agriculture. This is done without carefully considering all the relevant environmental factors or weighing the benefits against the costs of the measures. Therefore, advocates of a modern, but environmentally acceptable, form of agriculture warn against the consequences of a strategy of imposing a total ban

1) This paper is the summery of the book: Schmitz, P.M. und M. Hartmann (eds.), "Landwirtschaft und Chemie". Kiel 1993.

on the use of agrochemicals. In the light of this controversial debate and the resulting uncertainty in policy and practice, it is necessary to pay as much attention as possible to the potential implications of proposals on a chemical reduction in agriculture.

This is the starting point of this contribution. In fact, our knowledge of the effects of sector-based strategies involving reductions in the methods used to boost and stabilize agricultural yields, is limited. Certainly, many reliable experiments have been carried out over the years to investigate the effect of fertilizer and pesticide application on yields of various crops. There are also reports on organic farming at individual-farm level. What is lacking, however, is a systematic, quantitative assessment of the benefits and costs of pursuing a sectoral strategy of reducing the use of mineral fertilizers and pesticides, taking into account many different and complex adjustment processes. We hope that this study will contribute to setting us an objective basis for the debate by considering four aspects of the problem, namely:

- the effects at the micro-economic level;
- sectoral and/or regional effects;
- the significance as regards the national economy;
- implications as regards international trade.

The specific impetus for the study, and its objective, was to apply the same policy scenarios to the four relevant levels of the economy, by carrying out simulations. This should fill a gap in research and provide a more objective basis to evaluate the demand for political action which is clearly needed. The priority of the study is not primarily normative, i.e. making recommendations for or against reduction strategies in general or making recommendations for selecting the best means of achieving reductions and the extent of reductions. The study is rather designed as a positive analysis, i.e. a pure analysis of effects. Nonetheless, many results obtained in the course of the study speak for themselves and imply certain conclusions as regards the shaping of economic policy.

1.2 Method and Design of the Study

Given the ambitious terms of reference of the study, it was not possible to work with an integrated model based on system theory. Nevertheless, the coherence between the four levels of economic analysis in the study is produced by basing each on the same four scenarios which can be described as follows:

Scenario 1: Starting situation = general politico-economic conditions, production and consumption structures, product and factor prices as in 1991/92 (abbreviation: **status quo**);

Scenario 2: 50% reduction in the use of mineral nitrogen fertilizers at the micro-economic level (abbreviation: **N halved**);

Scenario 3: General ban on the use of pesticides, including plant treatments (abbreviation: **ban on pesticides**);

Scenario 4: General ban on the use of mineral fertilizers and pesticides (abbreviation: **ban on chemicals** or zero option).

In some sections, these four basic scenarios are occasionally modified slightly for data availability reasons, or intermediate steps are deliberately added so that a better estimate can be made of the sensitivity of the results with respect to different levels of reduction. However, in principle at all four levels of analysis, there is an attempt to ascertain the effects of these four scenarios on the topics of interest. In concrete terms, the implications of each of these policies is evaluated with respect to

- the level of, and fluctuation in, the yields per hectare;
- the structure of cultivation and production of plant products and animal production;
- income and employment of farmers;
- supply, demand, imports and exports of agricultural and food products;
- international agricultural trade and the position of third countries;
- the sectors of the economy closely related with agriculture;
- overall welfare in the national economy and with respect to the means of public finance.

The four economic models used in this study are as follows: the starting point is a **written survey** (Hartmann and Wiegand, 1993, pp. 34) Addressees are agricultural advisers in the Federal Republic of Germany (section 2.2) who advise mainly on crop production and farm management. The information obtained from these experts are the anticipated effects of the different strategies in reducing the use of mineral fertilizers and pesticides on yields per hectare (level, volatility). The time base, i.e. the short-term basis (less than one year) and medium-term basis (two to five years) is a particularly important aspect of the analysis. Secondly, the advisers are to point out possible adjustment processes in production and factor use, so that the total amount of the primary and the secondary effects can be quantified. This makes it possible to draw conclusions about the effects on production value, production costs and revenues. To check the reliability, the results obtained in the survey are compared with published information about crop production and farm management effects of chemical reduction, so as to obtain a rough idea of the spectrum of the results.

The second approach used in the study is a dynamic **production and factor demand model** for agriculture in the Federal Republic of Germany (Becker, 1993, pp. 128). It differentiates between the German *Länder* and is linked with a nutrient-balance model (section 2.3). On the basis of an elasticity matrix, derived from duality theory, with own-price and cross-price elasticities, it is possible to quantify the production effects for a total of 18 agricultural products, the impact on factor demand for 5 variable inputs, and the short-term and medium-term effects on farm incomes. Additionally, the nutrient balances for nitrogen, phosphorus and potash are calculated. Beyond analyzing the effects of the reduction strategies, the production and factor demand model is also utilized to quantify the effects of the agricultural reforms passed by the EU in the summer of 1992.

The third model refers to the level of the national economy (Brockmeier, Ko and Schmitz, 1993, pp. 190). The macro-economic effects of a reduction in the use of agrochemicals are quantified on the basis of a **computable general equilibrium model** or CGE (section 2.4). The special feature of such CGE models is their ability to give a consistent picture of all across-sector allocational and distributional effects of a political intervention and/or economic change in a national economy. All interdependences and feedback effects are fully incorporated. The features of the model used in section 2.4 are as follows:

- input coefficients in production are price-dependent rather than constant;
- takes account of the existence of heterogeneous goods and production factors and intra-industry trade flows in goods;
- takes account of the existence of unemployment;
- takes account of agricultural reform policies which have a cumulative effect as regards the reduction strategies;
- portrays four sectors of the national economy, namely agriculture, food economy, chemical industry, and all other sectors combined.

However, the reduction scenario considered with this model goes beyond the simulations with the other models in so far as it analyses not only the reduction of fertilizers and pesticides, but also takes into account all chemical products used in agriculture including, for example, all veterinary medicines.

Finally, the fourth and last model deals with the effects of chemical reduction strategies on international agricultural trade and their repercussions on farmers, consumers, and taxpayers in the European Unity (EU), in Germany, and in non-member countries (section 2.5, Hartmann, 1993, pp. 229). One aspect investigated is the differences which would arise if Germany reduced the use of agrochemicals unilaterally, or if such a policy were pursued throughout the EU. Section 2.5 is based on a **multi-output multi-input world agricultural trade model**. The original version of this model, the 'SWOPSIM' model (Static World Policy Simulation Model), was created by the U.S. Ministry of Agriculture. For the purposes of this study, however, essential aspects of the model have been changed to produce the TEPSIM model (Trade and Environmental Policy Simulation Model). It comprises four countries or groups of countries, 15 agricultural products and three agricultural inputs.

To conclude, we should mention that the survey of agricultural advisers is relevant in two of the four models. Firstly, all micro-economic effects (e.g. yield effects, income effects, etc.) have been inferred solely from the results of the survey, so they represent estimates made by experts rather than figures obtained from farm management models. Secondly, together with the data base of the U.S. Department of Agriculture on production, consumption and trade volumes and on levels of protection in the various countries, the survey results regarding the yield effects are entered and processed in the model of international agricultural trade. All the other parts of the model operate with independent sets of data which have nothing to do with the survey. This approach appeared to be an appropriate method to increase the reliability of the results.

1.3 Limitations of the Study

As with all scientific investigations, some worthwhile topics had to be left out due to staff shortages, shortage of time and lack of data. In particular, it would have been desirable to:

- extend the survey to other groups, such as farmers, administrators and scientists, and to other regions, e.g. other EU countries;
- supplement the components of the model by normative farm management models on an LP (Linear Programming) basis;
- consider alternative policy instruments for implementing and evaluating the reduction scenarios;
- include the latest trends in the shaping of agricultural and environmental policies;
- consider relevant factors other than the reduction in the use of agrochemicals, such as the GATT negotiations, the EU common market and the opening up towards Eastern Europe, which may have a lasting impact on agriculture and whose effect may be cumulative;
- supplement the results obtained in the economic context by including ecological and nutritional data in a single evaluation system to achieve a cost/benefit analysis.

Research in this last field has only just begun. The monetary evaluation of environmental effects and quality changes and the adjustment of the basis on which the national product ist calculated, are still in their infancy. There is a great deal left to be done.

2 Results of the Economic Analysis

The economic analysis is based on the four models already explained. They cover the micro-economic, sectoral or regional, macro-economic and international effects of a reduction in the use of mineral fertilizers and pesticides in agriculture. However, before these are reported in detail, the principal adjustment reactions as a result of restricting factor use are to be inferred on a theoretical basis.

2.1 Theoretical Basis

Reducing the use of a variable means of production results in comprehensive adjustments in farm inputs and outputs. Empirical knowledge of the production function, which defines the relationship between factor uses and production level, is not in itself enough to characterize the structural changes. That is to say, not only is there a movement on the existing production function of a farm (short-term reaction), but there is also a shift in the production function, in the sense of choosing a different production process or another organization structure (long-term reaction). Consequently, on the basis of historical data it is difficult to identify quantitative relationships between input and output resulting from a policy of extensification. This was one of the reasons for the procedure selected here, that is to use not only models with ex-post data, but also the pooled knowledge of experts and their forecasts.

Despite the problems in characterizing the adjustment reactions with sufficient accuracy, it is, however, possible to show one phenomenon of agricultural chemical reduction clearly. This is the cost-increasing effect in agricultural production when restrictions on the use of a factor are imposed externally, regardless of the implications of minimum-cost accounting.

In circumstances in which factor prices are constant and production is maintained at the previous level, an external enforced reduction of agrochemical use results in an increased use of other inputs such as labour (substitution effect) and at the same time in a marked increase in the variable costs of the farm. Thus, the new factor combination implies a departure from the firms' cost-minimizing expansion path. Departures of this sort also result in an increase in the marginal costs of production from the level at which the factor limitation becomes restrictive. Since the new marginal costs exceed the product price at the original production volume, there is a tendency for a profit-maximizing farmer to reduce volume in order to satisfy the 'price = marginal costs' equation. Assuming that all other variables are constant, the reduction in production volume results in turn in a reduction of factor use. By this, some of the cost-increasing effects are offset.

In principle, all subsequent economic changes can be inferred from this basic idea. To start with, there is on the one hand the production-reducing effect of a reduction in agrochemicals which, directly and indirectly via the market price, induces all the adjustment processes on the markets and on trade. On the other hand a suboptimum combination of resources is induced which not only adds to the producer's costs, but also represents waste of productive capacity in the economy. On the basis of this brief theoretical analysis, we shall now look in detail at the effects of an agrochemical reduction at the various levels of the economy.

2.2 Effects at the Micro-Economic Level

The following results are taken from a survey and concentrate on the yield effects and the impacts on the structure of crop production in the sample farms. The effects on the production value and costs, on revenues and on the level of compensation payments needed are as well examined. The analysis is based on 111 evaluable questionnaires from a survey of 745 agricultural advisers (response rate: about 15%), whose main area of consultation are crop production and business management. In the analysis of this representative sample a total of 124000 pieces of information has been utilized.

In the short-term, without consideration of adjustments in production and organization structures, the yield reductions are (see Table 1):

- 18% to 25% if N is halved (exception: field beans);

- 23% to 35% if pesticides are banned (exceptions: potatoes, meadows and pastures);
- 35% to 47% if chemicals are banned (exceptions: potatoes, field beans, meadows and pastures).

The reduction in the yields of field beans as well as meadows and pastures are well below the average of all products, while potatoes show above average yield losses in particular if pesticides (-41%) or all chemicals (-54%) are banned. There are also large reductions in the yields of sugar beet, rape and wheat.

In contrast, the reductions in the yield of oats and maize are, in comparison, moderate. The percentage reductions in yields are much more pronounced in the old German *Länder* than in the new *Länder*. However, after the reduction scenarios the yields are at a similar level.

Table 1: Short-Term Effects (%) on Yields per Hectare

Crop	N Halved	Ban on Pesticides	Ban on Chemicals
Winter Wheat	- 22	- 28	- 43
Winter Barley	- 22	- 29	- 41
Spring Barley	- 22	- 24	- 40
Oats	- 21	- 23	- 35
Rye	- 23	- 27	- 42
Maize	- 18	- 27	- 39
Field Beans	- 4	- 24	- 29
Rape	- 25	- 35	- 45
Sugar Beet	- 20	- 35	- 47
Potatoes	- 24	- 41	- 54
Silage Maize	- 21	- 25	- 41
Meadows and Pastures	- 22	- 8	- 30

Source: Written Survey

The farms react to the forced restriction in the use of agrochemicals by making extensive adjustments in production structures and organization structures (see Table 2). The proportion of cereals grown decreases from just under 56% (Status quo) to about 38% (chemical ban). Reductions of the area grown are particularly pronounced with respect to wheat, barley, sugar beet and rape. Oats, rye and leguminous gain in relative importance. There is also a marked increase in the set-aside area to almost 17% of the total area in cultivation. The proportion of arable land utilized in intercropping increases from 31% to 43%. Adjustment measures take also place in animal production. In general, cattle stocks decrease (bulls: -42%; dairy cows: -28%) and pig stocks increase (fattened hogs: 43%; breeding sows: 20%) if there is a total ban on the use of agrochemicals. This is the result of two opposing effects: reducing stocks as a result of falling yields from fodder crops and increasing stocks to produce organic fertilizer.

Table 2: Structure (%) of Land Use

Crop	Status quo	N Halved	Ban on Pesticides	Ban on Chemicals
Total Cereals	55,7	49,0	46,0	37,8
Winter Wheat	30,2	24,4	19,2	15,6
Winter Barley	15,1	11,5	10,9	8,0
Spring Barley	2,6	3,9	4,0	2,7
Oats	0,9	1,0	3,3	3,1
Rye	5,3	6,5	6,7	6,9
Maize	1,2	1,3	1,6	1,2
Leguminous Crops	0,5	4,4	2,2	7,3
Rape	8,8	7,4	6,1	3,8
Sugar Beet	12,2	12,1	8,8	8,1
Potatoes	3,3	3,3	2,9	2,7
Silage Maize	2,6	2,8	2,6	1,4
Meadows and Pastures	6,7	7,1	7,1	7,3
Other Areas	9,3	7,8	14,8	15,3
Set Aside	1,3	6,5	9,8	16,6
Total Area	100,0	100,0	100,0	100,0

Source: Written Survey

It would be reasonable to assume that, after these adjustments, the revealed short-term reductions in yields will slightly diminish in the medium run. In fact, however, after two to five years there is on average a further decline in the yields per hectare. This decrease can be explained by the fact that in the medium-term the supply of plant nutrients in the soil declines markedly while the conditions for weeds, wild grasses, and pests improve considerably. Table 3 shows the reductions in yield which can be anticipated in the medium-term for each crop.

The only crops for which the medium-term yield reductions are smaller than short-term ones are maize as well as meadows and pastures. Especially, maize appears to absorb organic fertilizer from the increased pig production better than other crops. However, yield reductions are not the only result of reducing the use of agrochemicals.

Table 3: Medium-Term Effects (%) on Yields per Hectare

Crop	N Halved	Ban on Pesticides	Ban on Chemicals
Winter Wheat	- 28	- 35	- 48
Winter Barley	- 28	- 36	- 47
Spring Barley	- 27	- 31	- 43
Oats	- 28	- 29	- 36
Rye	- 26	- 31	- 44
Maize	- 15	- 17	- 27
Field Beans	- 8	- 26	- 26
Rape	- 31	- 39	- 52
Sugar Beet	- 26	- 37	- 46
Potatoes	- 28	- 48	- 55
Silage Maize	- 25	- 31	- 49
Meadows and Pastures	- 17	- 5	- 24

Source: Written Survey

The increasing variations in the yields per hectare also have a major impact on farm profits (see Table 4). A rule of thumb for German agriculture is that, ceteris paribus, a variation in the yields per hectare of X% results in a fluctuation of income of slightly less than 2·X%. Consequently, yields variations have marked effects on the stability of farm income.

Starting with the status quo, with a yield variation around the mean of about 20%, the instability increases to about 25% if N is halved, to about 30% if pesticides are banned and finally to an average of 35% if there is a total ban on chemicals. The effect on potatoes (just under 54%) and winter rape (43%) is particularly pronounced. In contrast, the increases in instability with respect to spring barley, oats, rye, silage maize as well as meadows and pastures are insignificant.

Despite the increase in the relative variation, the absolute variation of the yields per hectare decreases slightly for most products. Only with respect to maize and potatoes there is a small increase also in the absolute variation of the yields.With the ban on pesticides, the yield-securing function of this input is lost and the yields become very dependent on the vagaries of local conditions and the weather. The adjustments in yield and area structure have an enormous impact on farm profits. The changes in production value approximately track the reductions in yields per hectare.

Table 4: Variation (%) in Yields per Hectare*)

Crop	Status quo	N Halved	Ban on Pesticides	Ban on Chemicals
Winter Wheat	20	24	32	37
Winter Barley	21	24	30	35
Spring Barley	24	26	28	29
Oats	24	26	24	29
Rye	23	25	28	34
Maize	19	24	28	37
Field Beans	29	29	35	37
Rape	23	27	36	43
Sugar Beet	21	24	32	33
Potatoes	21	27	47	54
Silage Maize	20	23	26	24
Meadows and Pastures	18	21	19	23

*) Coefficient of variation calculated from an approximation of the standard deviation and the mean of the yields

Source: Written Survey

The costs for chemical inputs, which in the initial scenario account for about 50% of all the variable costs, decrease markedly from scenario to scenario. The results confirm that there is a complementarity between the use of fertilizers and pesticides. If the use of pesticides is banned, the use of nitrogen decreases by 30% and the use of other fertilizers decreases by 15%. If nitrogen use is reduced by 50%, the use of pesticides decreases by 15%. Especially the reduction in fungicides is considerable. There are no obvious trends with respect to the other variable costs. As a total, the variable costs decrease by about 10% to 15% if N is halved, by about 30% if pesticides are banned and by about 40% to 50% if there is a total ban on chemicals. The change in quasi profits in the sample farms are shown in Table 5.

If nitrogen is reduced by about 50%, quasi profits fall by more than 40% for all crops but sugar beet, for which the decline is only 28%. If pesticides are banned, the effects on quasi profits are on average similar. Spring barley, rye and rape are less sensitive, but there is an above-average fall in quasi profits for sugar beet and potatoes. The same holds if all chemicals are banned. In this case, however, the loss in quasi profits rises on average to 50%.

Table 5: Effects (%) on Quasi Profits

Crop	N Halved	Ban on Pesticides	Ban on Chemicals
Winter Wheat	- 41	- 44	- 55
Winter Barley	- 43	- 42	- 56
Spring Barley	- 43	- 28	- 58
Oats	- 53	- 45	- 55
Rye	- 44	- 34	- 47
Rape	- 47	- 32	- 44
Sugar Beet	- 28	- 44	- 56
Potatoes	- 42	- 57	- 70

Source: Written Survey

Table 6 below shows the payments in DM, which the experts regard as necessary to compensate farmers in the old German *Länder* for the loss of profits resulting from the restriction on the use of agrochemicals.

Table 6: Necessary Compensation Payments in the Old German *Länder*

Scenario	Compensation in DM per Hectare of Land Used for Agricultural Production	Compensation per Farm (in 1000 DM)
N Halved	498	47,1
Ban on Pesticides	767	72,5
Ban on Chemicals	1184	111,9

Source: Written Survey

Finally, it is interesting to obtain from the results information about the regional income effects of reducing the use of mineral fertilizers and pesticides.

The regional results, obtained when utilizing a simple, comparative static agricultural sector model are shown in Table 7. This short-term analysis is based on the given quantity structure and cost structure of German agriculture. The effects on income are calculated from the short-term yield effects summarized in Table 1 assuming constant producer prices and input prices. The calculation is based on the specific yields and the crop structure relevant in the specified region. Owing to a lack of data, the only products considered in the model were winter wheat, winter barley, spring barley, oats, rye, winter rape, sugar beet and potatoes. The analysis also neglects adjustment measures in the farm organization or in the crop structure resulting from a reduction in the use of chemical inputs. The results demonstrate that with respect to the considered product markets, German farmers would have to bear a 13% loss of income if the use of nitrogen were halved. This loss would increase to 14% if pesticides were banned and to 17% if all chemicals were banned. There is a trend towards greater income losses in Lower Saxony and Hesse. Evidently, a reduction in the use of chemical input has a particularly marked impact in these regions.

As the data in Table 7 do not include the complete range of products, the reductions in income shown can only be regarded as the lower limit of the short-term losses actually sustained by agriculture. With respect to the medium-term income losses the results are even less reliable. Those can be expected to be much larger, firstly because the reductions in yields increase further in the medium term and secondly, because major adjustment occur in the structure of farming. In particular, crops with high quasi profits per hectare are taken out of the rotation.

Table 7: Effects (%) on Income Analyzed by Region

	Scenario		
Region	N Halved	Ban on Pesticides	Ban on Chemicals
Schleswig-Holstein	-13	-13	-15
Lower Saxony	-15	-18	-20
North Rhine-Westfalia	-13	-15	-17
Hesse	-18	-18	-20
Rhineland-Palatinate	-10	-10	-12
Baden-Würtemberg	-11	-11	-13
Bavaria	-13	-14	-17
Saarland	-13	-10	-12
West Germany	-13	-14	-17

Source: Own calculations based on regional statistics and the results of the survey

Finally, the important question to ask is how reliable are the results reported here? Comparison with published data from experiments confirm that the results derived from the survey of experts are entirely plausible as regards both the direction and the scale of the trends they indicate. They may therefore give an important preliminary indication of possible effects at the micro-economic level of a reduction in the use of agrochemicals.

2.3 Effects at the Sectoral/ Regional Level

Models, based on duality theory, at the micro-economic or sector level are an excellent means of portraying simultaneous adjustment processes in production and factor use in agriculture. Becker's calculations are therefore important in bringing state-of-the-art international methodological research to bear on the problem we are investigating. However, the lack of time-series data, the nature of the product list and the consideration of 10 subregions do not allow Becker to self-estimate all own-price and cross-price elasticities simultaneously in a multi-equation system. Instead, they are constructed on a plausibility basis, from information about single-equation estimates from the literature and from restrictions inferred from theory. Since the elasticity matrix is important as regards the results of the analysis, there is no doubt that more econometric research will be necessary[2].

The following results can be obtained from Becker's analysis[3].If the use of mineral fertilizers is halved, the production of all crops but sugar beet falls in West Germany by between 7% and 10% and animal production (exception: milk) falls by 1 % to 3.6%. Banning the use of pesticides has no effect at all on animal production, but reduces arable crops by on average 13% to 18%. Finally, a total ban on agrochemicals results in a 24% to 35% reduction in crop production. The reduction in animal production is only slightly greater than if exclusively mineral fertilizer use is halved.

The static income losses in the three scenarios, namely 12.1% (mineral fertilizer halved), 14.8% (ban on pesticides) and 28.5% (ban on chemicals), correspond in the first and second scenario fairly closely to the projections at the regional level based on the results of the survey (see Table 7). Only in the case of a total ban on chemicals the income losses in Becker's study are markedly higher (almost 30%).

It is also interesting to analyse the cumulative effect of the simultaneous implementation of agricultural reforms and an enforced agrochemical reduction (see Table 8). The effects described above greatly increase by the reforms. For example, under the zero option (a total ban on chemicals), crop production decreases by between 11% and 60%, and animal production decreases by between 5% and 14%. The corresponding losses of income are about 40% (static) and 36% (dynamic).

2) For an estimation of this sort, based on a product list and factor list shorter than that used by Becker see Dubberke, H. und P.M. Schmitz, Ökonometrische Schätzung von Eigenpreis- und Kreuzpreiselastizitäten im Produkt- und Faktorbereich der deutschen Landwirtschaft auf der Basis einer Translog-Gewinnfunktion. In. Schmitz, P.M. und M. Hartmann, Landwirtschaft und Chemie, Kiel 1993

3) In contrast to the survey, Becker's analysis considers a 50% reduction in all mineral fertilizers, not just nitrogen fertilizer.

Table 8: Effects (%) on Production and Income in West German Agriculture*)

Variable	Status quo		Mineral Fertilizer Halved		Ban on Pesticides		Ban on Chemicals	
Cereals	0	(-12,9)	-9,8	(-21,0)	-17,9	(-29,7)	-35,4	(-46,7)
Legumes	0	(-24,4)	-6,7	(-30,1)	-12,2	(-36,0)	-24,4	(-48,8)
Potatoes	0	(-2,1)	-6,7	(-7,8)	-13,0	(-14,4)	-25,1	(-25,4)
Oil-Producing Plants	0	(-27,2)	-9,7	(-35,0)	-16,9	(-42,9)	-33,7	(-60,3)
Sugar Beet	0	(0)	0	(0)	0	(0)	0	(0)
Vegetables	0	(0,1)	-7,5	(-6,2)	-8,3	(-7,7)	-22,2	(-19,7)
Fruit	0	(0)	-2,9	(-2,4)	-6,8	(-6,5)	-12,0	(-10,9)
Vines	0	(0)	-4,2	(-3,6)	-6,3	(-6,0)	-13,9	(-12,7)
Beef	0	(-5,3)	-3,6	(8,3)	0	(-5,3)	-6,7	(-13,7)
Pork	0	(-2,6)	-1,0	(-3,4)	0	(-2,6)	-1,9	(-8,0)
Mutton	0	(-3,1)	-2,0	(4,8)	0	(-3,1)	-3,8	(-7,9)
Poultry	0	(-4,1)	-0,3	(-4,3)	0	(-4,1)	-0,5	(-9,1)
Eggs	0	(-4,3)	-0,3	(-4,5)	0	(-4,3)	-0,5	(-4,6)
Milk	0	(0)	0	(0)	0	(0)	0	(0)
Income (static)	0	(-22,0)	-12,1	(-31,6)	-14,8	(-35,3)	-28,5	(-40,2)
Income (dynamic)	0	(-17,2)	-4,8	(-25,8)	-7,2	(-29,2)	-23,5	(-35,8)

*) The figures in parantheses are the percentage changes resulting from the reduction in the use of agrochemicals together with the effect of the EC agricultural reforms of May 1992.

Source: Results obtained using the regional production and factor demand model of Becker

The effects on cereal production, analysed by region, in West Germany, are shown in Table 9. Analogous to the results of the survey (see Table 7), there is a trend towards more marked decreases in producion and losses of income in the northern Länder and in Hesse than in the southern Länder. Finally, it is interesting to see the effect on the nitrogen excesses in each scenario (see Table 9).

According to Becker, in West Germany in 1989/90 nitrogen application amounted to 198 kg per hectare of agricultural land. 125 kg (63%) of this was applied in the form of mineral fertilizer and 73 kg (37%) in the form of organic fertilizer. In the reference situation, the crops assimilate on average 122 kg N for growth, leaving an excess of 76 kg. The excess differs markedly from Land to Land, ranging from 99 kg in North-Rhine Westphalia to 58 kg in Hesse.

Assuming, as Becker does (1992, p. 40), a 50 % denitrification and a quantity of 2000 m^3/ha leakage water, a nitrate concentration of 50 mg/l will be exceeded if more than 46 kg of the excess nitrogen per hectare gets into the leakage water. In the reference situation, this threshold value is exceeded in all German *Länder*. Also, the agricultural policy reform only results in an insignificant reduction of these nitrogen excesses, with the result that, according to the Becker model, the environmental improvement is at best only marginal. The same applies if pesticides are banned. In none of the German *Länder* does the nutrient excess fall below the threshold of 46 kg N/ha.

The nutrient excess falls markedly below this threshold if the use of mineral nitrogen fertilizers is halved. If chemicals are banned completely, the nutrient excesses disappear completely; in many regions even shortages of nutrients occur, which inhibit crop growth. Thus, the problem of the contamination of ground water with nitrates can be solved both by halving the use of mineral N fertilizers and by completely banning chemicals. However, these results must be qualified by pointing out that, for political fine-tuning, nutrient audits at district level, rather than at German *Land* level, are required. The result of this would presumably be that recommendations would differ markedly from district to district. Also, the nutrient audit model does not distinguish between excesses arising from mineral fertilizers and excesses arising from organic fertilizer. There is some evidence that, in terms of time and rates of application, mineral fertilizers are easier to use selectively and crop-specifically than organic fertilizers. As a project for future research, it might certainly prove a rewarding exercise to extend the nutrient balance model to include these factors.

It would be equally helpful to estimate econometrically a system of all own-price- and cross-price elasticities of Becker's comprehensive list of agricultural products and inputs, subdivided into the 10 subregions of the Federal Republic of Germany. There is some evidence to suggest that Becker's reaction coefficients in the product and factor area represent lower limits of the actual, sectoral behaviour. For example, the estimates of Dubberke and Schmitz for the Federal Republic of Germany and for eight West German Länder based on a translog profit function all show higher elasticities (Dubberke and Schmitz, 1993, pp. 169). This applies in particular to the own-price elasticities of demand for fertilizers and pesticides, whose values are of great relevance for the results. Accordingly, the introduction of taxes would lead to a substantial reduction in demand for these inputs. At the regional level, there is an elastic reaction with respect to fertilizers in at least seven of eight German Länder (exception: Saarland). The same applies to the demand for pesticides; only in Lower Saxony the results show a weak reaction to tax-induced price changes. Additionally, the econometric estimates indicate that changes in the prices of mineral fertilizers and pesticides result in more marked reactions in agricultural production than are assumed in Becker's analysis. This applies particularly to fertilizers and, in terms of regions, to Schleswig-Holstein und Saarland. Finally, the level of the elasticities is also relevant as regards the extent to which reductions in agricultural prices are reflected in a change in the demand for agrochemicals. Here again, Becker assumes that the reactions are inelastic, whereas the estimates of Dubberke and Schmitz indicate high elasticities, particularly with respect to animal production and, in terms of regions, again in Schleswig-Holstein and Saarland. Precisely, this means that reductions in support prices as part of reform measures would result in a greater decrease in intensity than had previously been assumed.

Table 9: Regional Effects (%) on Cereal Production, Income and Nitrogen Excesses (kg N/ha of Land Used for Agricultural Production) in West Germany

German *Land*	Cereal Production			Income (Statistic)			Nitrogen Excess*)			
	N Halved	Ban on Pesticides	Ban on Chemicals	N Halved	Ban on Pesticides	Ban on Chemicals	Status quo	N Halved	Ban on Pesticides	Ban on Chemicals
Schleswig-Holstein	-10,1	-18,8	-34,5	-12,2	-15,6	-27,7	67 (53)	18	49	-14
Lower Saxony	-11,0	-21,3	-42,0	-12,9	-17,2	-32,2	85 (80)	39	78	8
North Rhine-Westphalia	-9,9	-23,6	-41,7	-11,8	-19,3	-32,5	99 (93)	48	89	13
Hesse	-11,0	-18,4	-38,1	-13,0	-15,0	-30,1	58 (50)	13	51	-16
Rhineland-Palatinate	-8,9	-11,3	-27,7	-10,6	-9,1	-21,9	66 (59)	16	57	-20
Baden-Württemberg	-8,5	-14,1	-29,5	-10,1	-11,6	-23,6	69 (65)	25	63	-4
Bavaria	-8,8	-13,1	-28,5	-14,0	-13,8	-29,3	71 (67)	30	62	4
Saarland	-10,9	-15,4	-34,6	-13,1	-12,8	-28,0	69 (64)	22	61	-11
West Germany	-9,8	-17,9	-35,4	-12,1	-14,8	-28,5	76 (70)	31	67	1

*) Figures in paranthesis are the nitrogen excesses after the agricultural reforms have been put into effect.

Source: Results obtained using the regional production and demand model of BECKER

It is not the purpose of this study, nor is it possible, to state here whether Becker's elasticity values are closer to reality than the estimated values of Dubberke and Schmitz. Clearly, there is a need for further research in this area. Rather, the objective here is to demonstrate the implications of the level and structure of the elasticity values for agricultural and environmental policies.

2.4 Effects at a Macro-Economic Level

Partial sectoral models are not able to illustrate the structural adjustment processes in the whole national economy, particularly the feedback effects of governmental interventions. For this reason, a computable general equilibrium (CGE) model is needed. Although many CGE models have been developed in the last decade, as yet, there are no CGE models for Germany, in particular there is no model which will explicitly consider the agribusiness sector (e.g. agriculture, food economy, chemical industry). A model of this sort has been developed specifically for this study. The policy scenarios discussed so far had to be modified in the CGE model because the high level of aggregation does not allow for any subdivision of agrochemicals into mineral fertilizers and pesticides. Instead, the model goes through four levels of reduction in the overall use of agrochemicals (including veterinary medicines), namely -25%, -50%, -75% and -95%. Agricultural reform measures, comprising a 30% or 100% cutback in agricultural protection in Germany, are also taken into account.

Table 10 shows the main results obtained for the Federal Republic of Germany, using the CGE model. A successive proportional reduction in the use of agrochemicals results in a disproportionately large decline in agricultural production. For example, a 95% chemical reduction results in a decrease in overall production of 36.3%. This is a more pronounced production decline than in the Becker model. This difference can be explained by the fact that the CGE model also includes veterinary medicines and other chemical products used in agriculture. Thus, a ban on chemicals affects both crop and animal production. The fall in production is accompanied by a cutback in agricultural employment. If the reduction is 95%, about 183 thousand jobs are lost in agriculture. In reality, the CGE model assumes that standard wage levels can not decline. Thus, the model is able to simulate the phenomenon of unemployment; the agricultural workers who have lost their jobs are not taken up by the labour market. Additionally, the policy of extensification reduces employment in other sectors, so in total 430 thousand jobs are lost and unemployment rises by this number.

The maximum losses of income (25.5%) are somewhat smaller than in the Becker model because, in contrast to the latter, this model allows for cost-induced price rises in individual sectors. There are enormous changes in foreign trade, particularly in exports. Agricultural exports fall by almost 55% and there is an increase in agricultural imports of nearly 30%. The agricultural budget deficit, defined here as the expenditure on export subsidies minus the income from import levies, decreases by 1.4 billion DM as a result of the induced effects on trade. Finally, overall welfare decreases by a maximum of 16.3 billion DM. An important point to note is that as the use of agrochemicals is reduced the welfare loss grows disproportionally.

Table 10: Effects of a Reduction in the Use of Agrochemicals in Agriculture in West Germany*)

Economic Variable (Expressed in Real Value)	Reduction in the Use of Agrochemicals				
	0%	25%	50%	75%	100%
- Agricultural Production (%)	0	-4,2	-9,8	-18,7	-36,3
- Agricultural Employment (%)	0	-2,7	-6,5	-12,5	-25,5
- Agricultural Employment (1000 Persons)	0	-19,6	-46,3	-89,9	-182,8
- Total Employment (1000 Persons)	0	-41,7	-98,7	-190,9	-430,1
- Farm Incomes (%)	0	-2,7	-6,5	-12,5	-25,5
- Volume of Agricultural Imports (%)	0	2,8	6,8	13,7	29,3
- Volume of Agricultural Exports (%)	0	-7,3	-16,7	-30,5	-54,6
- Agricultural Budget Deficit (Billion DM)	0	-0,2	-0,4	-0,8	-1,4
- Overall Welfare (Billion DM)	0	-1,7	-3,9	-7,5	-16,3
- Gross Domestic Produkt (%)	0	-0,1	-0,2	-0,5	-1,2

*) The figures in the Table are the absolute or percentage change from the reference situation before the introduction of the policy. They are therefore the departures from the baseline of the general equilibrium model.

Source: Results obtained using the computable general equilibrium model

The effects described above increase if the agricultural reform measures of May 1992 are included. However, the increase is comparatively moderate because, in the baseline year selected for the CGE model, the level of protection for agricultural products in Germany was rather moderate.
The reduction in the use of agrochemicals also affects those sectors of the economy closely related to agriculture. These include in particular the food economy and the chemical industry. Table 11 shows the effects of a policy of extensification on these two sectors.

All in all, the overall impact on those two sectors is rather moderate, leading in general to changes of less than 10%. Only the reduction in the volume of exports in the food economy is slightly greater (12.5%). The effects on employment, i.e. job losses of 19 000 and 27 000 respectively in the extreme scenario, are also fairly insignificant relative to the total number of jobs in the chemical industry and food economy. The reason for these rather minor effects is that agrochemical production is only a comparatively small sector of the chemical industry, and agricultural raw materials are accounting for an ever-dwindling proportion of turnover in the food economy. The results are therefore somewhat distorted. To gain a more accurate picture of the effects, an analysis of the data by subsector is necessary. If the simulated changes indicated by the CGE model are considered solely in terms of agrochemicals and the para-agricultural food economy, the effects are much greater (see Table 11, figures in parentheses). For example, if chemicals in agriculture are reduced by 50% or 95% and assuming that agrochemicals account for about 10% of total chemicals, the agrochemical industry suffers an income loss of 20% or 35%, respectively. Thus, for subsequent runs of the model, it would be desireable to characterize the particular partner of agriculture in sufficient detail to give as sophisticated an answer as possible.

Table 11: Effects of a 50% and 95% Reduction in the Use of Agrochemicals on Sectors Closely Related to Agriculture*)

Economic Variable	Chemical Industry				Food Economy			
(Expressed in Real Value)	50%		95%		50%		95%	
- Production (%)	-1,9	(-19,0)	-3,0	(-30,3)	-1,7	(-5,6)	-6,7	(-22,4)
- Employment (1000 Persons)	-10,7		-19,1		-6,9		-27,3	
- Volume of Imports (%)	-2,2	(-22,8)	-4,4	(-43,3)	-0,5	(-1,7)	-2,1	(-6,7)
- Volume of Exports (%)	-1,6	(-16,0)	-1,9	(-18,9)	-3,3	(-10,4)	-12,5	(-41,5)
- Income (%)	-2,0	(-19,8)	-3,5	(-34,7)	-0,9	(-3,0)	-3,6	(-12,3)

*) The figures in the Table are the absolute or percentage change from the reference situation before the introduction of the policy. They are therefore the departures from the baseline of the general equilibrium model. The figures in parantheses are estimates, determined outside the model, for the agrochemical industry and for the para-agricultural food economy. These estimates were made assuming that agrochemicals account for about 10% of total chemicals, and that the para-agricultural food economy accounts for about 30% of the total food economy.

Source: Results obtained using the computable general equilibrium model

2.5 Effects at the International Level

The fourth and last component used evaluates the national and international effects of imposing quotas on the use of nitrogen and/or pesticides in Germany and in the European Community. The multi-input multi-output world trade model TEPSIM has been developed for this purpose. TEPSIM is one of the small group of agricultural trade models which take explicitly account of agricultural inputs. It is also the only model of its kind in which Germany is characterized as a region in its own right in the international context.

An interesting approach was adopted to calibrate the model. The own-price and cross-price elasticities for the integrated inputs were specified in a way that the model reproduces the effects on production of a 50% reduction in the use of nitrogen and of a ban on pesticides, as ascertained in the survey of advisers. Plausibility considerations and restrictions inferred from the theory were also taken into account in selecting the elasticities.

The analysis focuses on the national and international effects of imposing a 50% quota on the use of nitrogen or a 95% quota on the use of pesticides on production, trade, prices and welfare in Germany and Europe. It is also interesting to look at the effects of a successive reduction in the use of an input from the status quo to a virtual ban. Thus, the effects of a reduction in eight stages, from 0% to 80% in the use of nitrogen were analysed, as well. In all, twelve different policy options are considered.

The results show that, as regards most agricultural markets, restricting the use of chemical inputs in German agriculture leads to a substantial fall in production. As a result, Germany's net exports as well as the importance of German agriculture in the European context decline. For some products, Germany actually changes from a net exporter to a significant net importer. This holds particularly if environmental policies in agriculture result in a very great reduction in the use of chemical inputs. In these cases, German agriculture becomes appreciably less competitive in Europe and internationally. The results with respect to a stepwise reduction in the use of nitrogen are also interesting. They indicate that, as restriction on the use of chemical inputs increases, the decrease in supply and in net exports in most product markets grows disproportionally.

However, imposing quotas on the use of chemical inputs in German agriculture has more than just internal effects. These policies also lead to changes in world prices and affect prices, volumes and welfare in non-member countries. In general, restricting the use of mineral fertilizer and pesticides in Germany causes world prices to rise. Reducing the use of nitrogen by 50% increases world prices for cereals by about 5%, but increases world prices for animal products by less than 1 %. The European Union has a far greater impact on the world markets for agricultural products, so the effects on world prices are many times greater if the input policies are implemented throughout the EU.

Table 12 shows the effects on quantity and price of reducing, respectively the use of nitrogen or pesticides by the same percentage. The sign of the effect on supply, trade and world prices is the same in both scenarios for virtually all products. However, this does not apply to the magnitude of the effects. Restricting nitrogen use causes much greater changes in volumes and prices than reducing the use of pesticides by the same percentage.

Losses in farm incomes resulting from the imposition of quotas on chemical inputs are significant particularly if the use of one input is reduced very markedly. The model does not give an unequivocal result with respect to the overall welfare effects in Germany. The level of quota imposed on inputs is evidently a key determinant of these effects. Accordingly, reducing nitrogen use by 10% or 20% results in net welfare gains. However, a greater restriction on the use of this input results in welfare losses to society as a whole; these losses increase exponentially with the percentage reduction in nitrogen use. Finally, it is interesting to consider the net welfare trends in non-member

Table 12: Effects of an 80% Reduction in the Use of Nitrogen Fertilizers (N) or Pesticides (P) in Germany*, on the Supply , Net Export and World Prices of Selected Agricultural Products

Product or Product Group	Effect [%] on Supply		Effect [in 1000 Tonnes] on Net Exports		Effect [%] on World Prices	
	80% Reduction in N Use in FRG	80% Reduction in N Use in FRG	80% Reduction in N Use in FRG	80% Reduction in N Use in FRG	80% Reduction in N Use in FRG	80% Reduction in P Use in FRG
Beef	-24,14	-9,22	-380	-145	1,68	0,75
Pork	57,78	6,45	1410	157	-1,59	0,34
Mutton/Lamb	-0,04	-0,02	0	0	1,07	0,48
Poultry	19,80	3,12	84	13	1,05	0,63
Eggs	19,81	3,12	142	22	0,75	0,59
Milk	-12,32	-6,03	-2986	-1461	4,43	2,09
Wheat	-71,11	-38,30	-8259	-4161	9,23	4,50
Maize	-16,80	3,27	-394	76	3,94	1,93
Other Feed Grains**	-60,14	-20,17	-8945	-2616	9,79	3,77
Rape/Other Oil Seeds***	-73,65	-38,30	-1459	-566	6,13	2,68
Sugar	-52,09	-36,28	-1564	-1089	6,31	4,28

*) The results for the new Federal *Länder* cannot be regarded as representative because the sample was too small, so the figures in Table 12 are for the Federal Republic of Germany as defined by its boundaries before the 3rd of october.

**) Barley, millet, mixed cereals, oats, rye, sorghum.

***) Copra, cottonseed, linseed, palm kernels, groundnuts, safflower, sesame (not soybeans).

Source: Own calculations based on the multi-input/multi-output world trade model TEPSIM countries. Table 13 shows that the European Union benefits from a unilateral reduction in the use of chemical inputs in Germany, but welfare losses are inevitable if these policies are implemented throughout the EU.

Table 13: Changes in Overall Welfare in Selected Countries and Regions (in Million DM)*)

Scenario	Germany	EC-11	U.S.A.	Rest of World	World, Total
50% Reduction in N in Germany	-1017	951	771	-2735	-2030
50% Reduction in N in EC	-875	-7182	5646	-19887	-22298
95% Reduction in Pesticides in Germany	-26201	1407	907	-3695	-27582
95% Reduction in Pesticides in EC	-26086	-166922	8585	-24477	-208900

*) Overall welfare is defined as the sum of the real incomes of all market participants; as a rule these comprise consumers, producers and taxpayers.

Source: Own calculations based on the multi-input/multi-output world trade model TEPSIM.

Implementation of environmental agricultural policies in Germany or the European Community results in an increase in welfare in the U.S.A., which is a net exporter of agricultural products. In contrast, welfare decreases in the rest of the world, which is a net importer. Finally, it is interesting to look at the implications as regards global trends in welfare. The results of all simulations demonstrate that on a global basis substantial decreases in welfare are inevitable.

Two important factors are missing from this analysis of welfare. Firstly, the empirical analysis takes no account of unproductive rent-seeking activities or of the substantial cost of the bureaucracy needed to introduce, push through and monitor an additional political measure. Failure to take these into account means that the actual welfare losses are underestimated or the possible welfare gains overestimated. Secondly the conventional welfare analysis only includes changes in real incomes. It takes no account of the non-monetary benefits in terms of improving the quality of the environment which accrue from implementing environmental agricultural policies. As the restriction on input use becomes tighter, the cost of the environmental agricultural policies discussed increases exponentially, but there is some evidence to suggest that the additional non-monetary benefits of reducing environmental pollution decline.

3 Conclusion

This paper is a synopsis of a comprehensive preliminary study in which several methods were used to make quantitative estimates of the effects of reducing the use of agrochemicals. This effort must and will be followed by others. The Advisory Committee on Science of the Federal Ministry of Food, Agriculture and Forestry, in its latest report on the strategies for an environmentally acceptable agriculture, announced that the comments made hitherto are shortly to be supplemented by analyses of the reduction in the use of yield-enhancing agricultural inputs, and by recommendations regarding specific environmental problems and policies relevant to the environment (Wissenschaftlicher Beirat, 1992, p.2). The principal objectives are to examine as many aspects of the problem of extensification as possible, but with particular emphasis on the economic audit, the ecological audit and food quality, and to draw comparisons with the results of this study.

Without going through the results in detail again, it can be stated that the economic input of a strategy of across-the-board reduction in the use of chemical fertilizers and pesticides are on the whole negative. This is evident in all four components of the study. In particular, they appear to tally in that they indicate that, with each step in the reduction in agrochemical use, the cost, at both the micro-economic and macro-economic level, of an across-the-board strategy of extensification grows disproportionally. This is illustrated in Figure 1. To evaluate the net eco-social effects, the disproportionate increase in costs as quantified by the conventional method of welfare measurement has to be compared to the effects, quantified in financial terms on the quality of the environment and on food quality. On the subject of food quality, with some exceptions, reducing the use of agrochemicals does not essentially alter the value of the food with respect to its contribution to the health and nutrition of the consumer (Deutsche Gesellschaft für Ernährung [German Food Association], 1988 and 1992). Thus, there is little risk of compromising the relatively high quality already achieved.

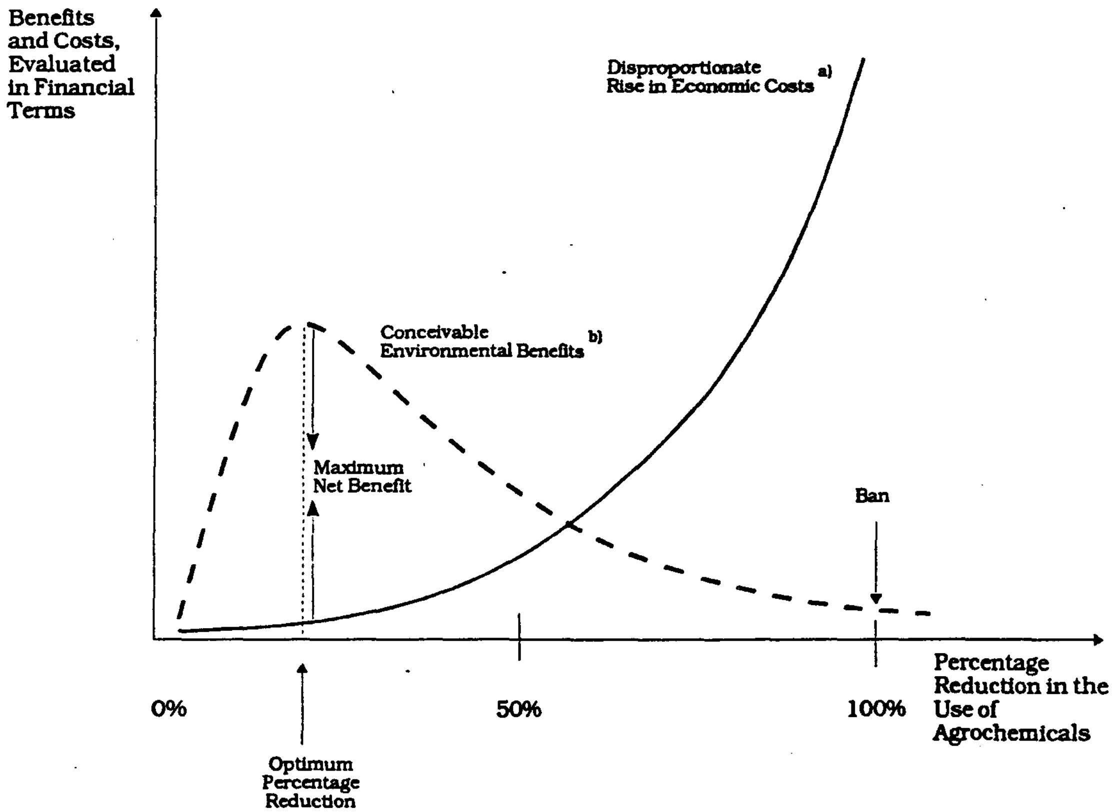
This result is confirmed by Senauer's report on experience in the U.S.A. (Senauer, 1993): although 76% of the consumers surveyed expressed concern and anxiety about pesticide residues in food, their revealed preferences told another story. Almost three-quarters of those asked had confidence in the products on sale at their supermarket, there was little willingness to pay for additional food safety and the demand for ecological products was only marginal. It was concluded from the results of a recent study carried out by researchers at the University of Berkeley (U.S.A.) that the risk of contracting cancer as a result of pesticide residues in food has been vastly overestimated and that faulty techniques in the preparation of food are a greater potential hazard. The Deutsche Gesellschaft für Ernährung (1988 and 1992) also states that microbiological contaminations of food, the presence of natural toxins and widespread malnutrition pose a greater risk to human health. Accordingly, residues from mineral fertilizers and pesticides in food are of little significance.

It is therefore more likely that the monetary evaluation of quality are confined to the environment. Research in this field has as yet produced little in the way of quantitative data. Also, the changes in the quality of the environment would have to be determined, separately for every single environmental resource, they would have to be weighed according to their perceived value to society, and then added up. This can give rise to conflicts between the environmental resources themselves. In Figure 1 there is a conceivable, but unconfirmed, profile of benefit plotted vs. percentage reduction of agrochemical use. This is not a product of the study reported here, but it should stimulate debate. There are three comments to be made about this diagram. **Firstly**, ecological benefits are achieved fairly rapidly, i.e. for small reductions. With more far-reaching, more vigorous, across-the-board extensification, the gains fall to zero or may even turn into losses. The conventional meaning of extensive farming is land-intensive production, specifically with on-going price support for agricultural products. However, if production becomes land-intensive there is the risk of an attendant reduction in areas such as woodlands and wetlands which provide the ecological balance. Hence, as mentioned above, conflicts between different environmental audits may well arise. Thus, **secondly** the maximum net benefit is achieved with only a small reduction (see Figure 1). With this in mind, a strategy of drastic extensification on all farms poses not only economic problems but must be questioned also from an interdisciplinary standpoint. **Thirdly**, and finally, it is possible to achieve an even greater net benefit by avoiding the imposition of bans and controls which force farmers across the board to respond in a uniform manner by adopting extensive farming methods, as this may also prevent possible positive ecological contributions of land management. The best policy would be to tackle evident environmental damage in a targeted way and on a site-specific basis, and to take steps to avoid environmental damage by providing more training, advice and information. Especially given the global food shortage and the ecological constraints on using more land in agricultural production, the implementation and development of integrated production systems appear to be the only sensible approach to solve the environmental problems.

Figure 1

Cost/Benefit Analysis of an Across-The-Board Strategy of Extensification

- Stylized Diagram -



a) Profile of the conventional macro-economic costs of a reduction in the use of agrochemicals, which is confirmed by the empirical results of this study.

b) Conceivable profile (not quantfied in this study) of the environmental effects in financial terms. Environmental effects of this sort will have to be quantified in later studies. Research on this topic is still in its infancy.

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