A Multicriteria Evaluation by the Public Approval of Pesticides – A Case with the Plant-Growth Regulators in Grain

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A MULTICRITERIA EVALUATION BY THE PUBLIC APPROVAL OF PESTICIDES – A CASE WITH THE PLANT-GROWTH REGULATORS IN GRAIN

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ABSTRACT

Our object is to develop a method for the public approval and re-evaluation of pesticides that emphasises a wide evaluation of social benefits. This is done through the case for the three plant-growth regulators approved for use in Norwegian grain production at present: chlormequat chloride, ethephon and trinexapacethyl.

A multicriteria method is founded on the premises for an expert based model as opposed to e.g. a market based model. It seems to be a possible method that allows for the use of several incommensurable criteria in the approval process by National Agricultural Inspection Service (NAIS). Furthermore, it results in greater transparency, which may be an important quality in a public decision process. However, there are problems connected to a social benefit evaluation like this, some of these are:

- *There may be other criteria that also should be included*
- *Effects outside the agricultural sector are not considered*

The environmental effect and the health effect are estimated by NAIS, while a model for estimation of the economic margin is developed in this project.

The economic margin for a specific strategy is calculated for a specific species in a specific region and a specific lodging category. Afterwards the economic margin for each lodging category is multiplied with the probability of having that lodging category and finally the lodging categories are summarised. This leaves then together with the other evaluated criteria a multicriteria basis on a ha-basis. The modelled economic benefits and usage of growth regulators are the aggregated due to the registrered acreage of the different crops to a regional and national level corrected to absolute numbers by the total registered use of

every growth regulator.

A general problem is that such an approval has to be based on future behaviour and effects where the trial data is relatively scarce when it comes to the agronomic effect. The environmental and health effects are even less well documented and only the direct effects on health and the environment are considered by NAIS.

BACKGROUND

In the Plan of action for reducing the risks related to the use of pesticides (Ministry of Agriculture 1998) it is mentioned that 'a minimal and as small as possible risk associated with the use of pesticides should be an important quality requirement for Norwegian food production'. One of the attempts to ensure a reduced risk is the process of public approval. By the public approval of new pesticides and the re-evaluation of existing ones the Norwegian Agricultural Inspection Service (NAIS) is asked to emphasise a rather wide evaluation of the social benefits.

The Norwegian Agricultural Economics Research Institute has been contacted in this work to develop a model for use in the approval process. Further the Norwegian Crop Research Institute (NCRI) has contributed significantly to the project.

Today's regulation for approval of pesticides includes:

- Import, sale and usage of pesticides has to be approved by NAIS
- The approval includes documentation of:
  - The potential health risk for humans (human toxicological effect)
  - The effects for the environment (eco-toxicological effect)
  - The biological effect (agronomic beneficial value)
- A total evaluation where benefits are evaluated against risk associated with the use of the pesticide. The evaluation involves:
  - A substitution principle
  - A limited period of approval
  - A discussion in the 'Council for pesticides'

In practise this has resulted in a quantity regulation (prohibition, limited dosage) by the approval of a new pesticide. A variable fee, which depends on which health risk and environmental risk group the pesticide belongs to, is added to the price of the pesticide. Finally both the distributor and the user are required to have an authorisation.

In the future NAIS must focus on a broader evaluation of the social benefits in the approval and re-evaluation of pesticides than it has been done until now.

Today's uses include agricultural production, greenhouse production, public areas and private use. Generally the pesticides can be divided into four groups: herbicides, fungicides, insecticides and growth regulators. However, within each group different preparations w.r.t. the content of active matter and additives are found.

SCOPE OF STUDY

Our object is to develop a method for the public approval and re-evaluation of pesticides that emphasises a wide evaluation of social benefits. This is done through the case for the three plant-growth regulators approved for use in Norwegian grain production at present: *chlor-mequat chloride (CCC)*, *ethephon (Cerone)* and *trinexapacethyl (Moddus)*. Treating grain crops with growth regulators is an established way of preventing lodging (Erviö et al. 1995). *CCC* has to be applied at the 3-5 leaf stage. *Cerone* and *Moddus* are applied later, at the flag-leaf stage. At later application assessing the probability of future lodging are easier and farmers are able to make better-informed decisions about the need for growth regulators.

Lodging often leads to lower yields, deterioration of the grain quality and problems with harvesting the crop. With lodging, injuries caused by germination more easily occur. In injured grain, which has α-amylase activity, the starch quality decreases as measured by the Hagberg falling number. At a falling number <200 for wheat and <120 for rye, grain is accounted as feed grain instead of milling (breadmaking). The price difference between feed and milling is large. Further, mouldy grain may produce unhealthy mycotoxins.

Harvesting a field with lodging is much more time-consuming. The harvesting speed has to be reduced to avoid extreme grain losses and damages to the combine harvester. Still, the maintenance costs, tear and wear, and fuel consumption of the combine harvester increases. Increased grain losses at harvesting are also expected. After a rainfall lodging fields often dry slower, making the harvesting period shorter. Decreased harvesting capacity per day delay harvesting and the timeliness costs increases. In a worst case scenario, not all of the fields are harvested. The growing and harvesting season in Norwegian grain areas is short, and the climate is often humid in the harvesting period. Thus, time consumption at harvesting and prevention of lodging is of great concern to the grain farmers.

The project consists of the following steps:

- The development of a multicriteria decision model as a framework for:
  - An analysis of the economic net benefits at the farm level, on a regional level and on a national level
  - A mapping of the expected quantified health risk for the farmer and the consumer (toxicological effect) as well as the environmental risks for the natural environment (eco-toxicological effect)
  - An analysis and discussion of the decision process

Methodology

A social economic evaluation should ideally include all effects related to the use of growth regulators, among them, the health and environmental effects. However, they are external effects that are complex and therefore hard to identify and quantify. They do not have any direct effect on the price mechanism in a free market, implying that they are also difficult to value. This indicates that one cannot easily find an optimal level for the use of growth regulators without internalising these effects.

The multicriteria method is one of the methods that can be employed to deal with such problems (Munda 1995). The method may be based on expert evaluations (Jacobs 1997). An expert-based approach allows for the belief that some (the experts) are more capable of making decisions than others, or that there should exist some kind of division of labour, implying that we are all experts in different fields. The idea is that human resources are utilised most efficiently in this way. This may be an appropriate approach when it comes to complex problems with several criteria and information that is readily available. On the other hand, this approach will underestimate or obscure the issue of conflicting interests. Different decision-makers and experts undertake evaluations, even though the evaluation or weighting method is dependent on the comparability and commensurability between the criteria.

Cost-benefit analyses are often used to identify the optimal choice from two or more alternatives (Hanley & Spash 1993). It is often used for decisions in the short run and for limited projects. However, optimality depends on the perspective of the cost-benefit analysis, and the farmer's optimal level of pesticide application may differ significantly from that of the society as a whole. A cost-benefit analysis is an example of a rational choice model which is primary based on simulated markets where people are defined as consumers with preferences revealed through their willingness to pay (Jacobs 1997). This implies among other that values are assumed to be commensurable and can be measured in one common unit, and that choices are individual. The degree of commensurability is an important difference between cost-benefit and multicriteria analysis. This may be controversial in cases like this with a social evaluation of the approval of pesticides. Furthermore, there may be distortions in the market due to policy regulation through e.g. taxes or subsidies, resulting in a product price that is different from what it would have been if determined purely by the consumers WTP. The method does therefore not seem to be appropriate for use in this project in the case of decisions that are uncertain, unknown and where the decision-makers are hardly affected.

The multicriteria decision method seems to be an appropriate method in complex problems like the social economic evaluation of the approval of pesticides. Furthermore, the art of a public decision requires transparency of the decision process, which the multicriteria method leaves possibility for.

THE MODEL

Evaluations of growth regulators are carried out using a multicriteria method where the economic benefits are evaluated against the effects on health and environment at the farm level, regional level and national level. NAIS and an advisory committee of experts may then give a ranking of the different criteria. The ranking may be given either prior to or after the analysis of the effects of the specific growth regulator, and, where appropriate, with the use of an aggregation procedure as decision-aid.

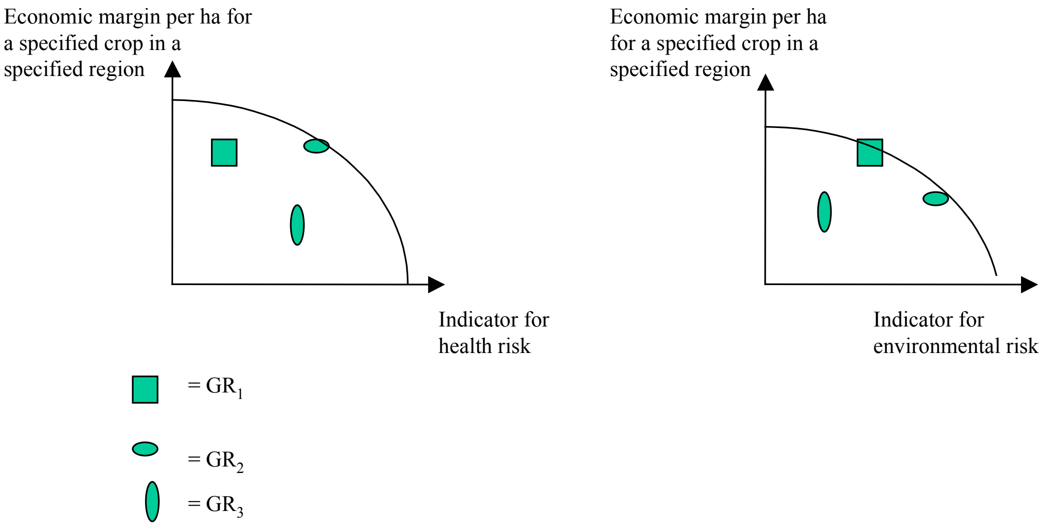

Figure 1: An example of a multicriteria evaluation of growth regulators

Through the use of this method we can obtain systematic information about different growth regulators, and thereby outline efficiency curves like in Figure 1. Over time, this could give an experience basis, i.e. a measure of what economic benefits accepting a given scale of risk will give us.

The margin at farm level

Between years the economic benefits of growth regulators at the farm level vary, depending on the farm's location in the country, cultivated grains and cultivars, growth season conditions with respect to rainfall, temperature, wind etc. in different periods. Use of growth regulators in a season with little rain normally has a small effect on the crop. On the other hand, much rain normally results in a large risk for lodging and income loss. Therefore the following categories were chosen:

- Region
- Crop
- Lodging
- Growth regulation strategy

Although the calculations are carried out at the farm level, they may be seen from the view of NAIS, who is the decision maker and the approver of specific growth regulators. The farmer is in another decision situation where he/she has to find out whether the use of an approved growth regulator results in a marginal economic benefit or not.

A year with average lodging

As mentioned, the effects of growth regulators for each crop within a region vary a great deal between years. To account for this aspect we have chosen a rather 'coarse' classification in lodging categories: heavy, medium and minor need for growth regulators (see Figure 2). To estimate the probabilities for heavy, medium and minor need for growth-regulators we used a combination of subjective expert beliefs and historical lodging data.

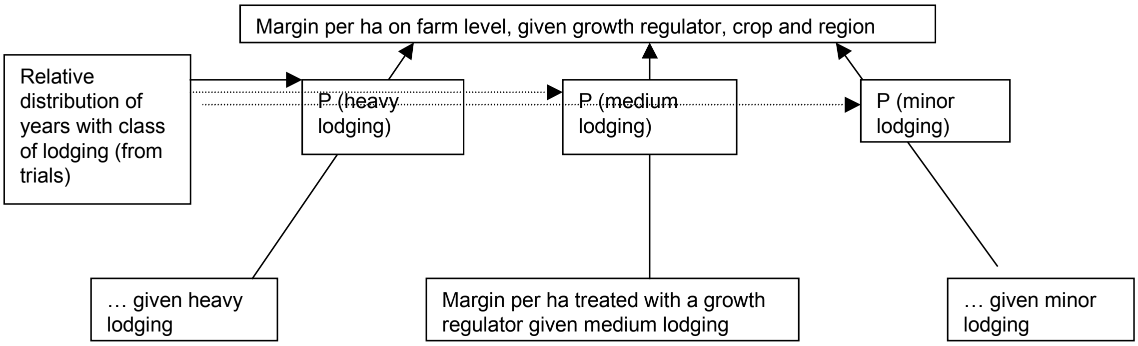

Figure 2: Economic margin at the farm level for a growth regulator

For the years 1984-2000 we calculated the average lodging per cent from crop experiments (NCRI 1985-2001) for each grain species within a region. For each grain species and region the time series of lodging per cent was considered as 'state of nature', i.e. this lodging percent time series of 17 years was assumed to give a good picture of the risk of lodging.

For each grain species and region, the time series 'state of nature' was then divided into three categories. An expert group (of crop scientists) made the following subjective limits:

- Under 5 per cent lodging = minor need for growth regulators
- Between 5 and 15 per cent of lodging = medium need for growth regulators
- Above 15 per cent lodging = heavy need for growth regulators.

These general limits for all types of species are very coarse and are chosen for simplicity. Combining the time series of lodging percent and the subjectively set application limits for growth regulators for each grain species and region, we simply counted the numbers of data points in each intervals to estimate the probabilities of the need for growth regulators. Since these probabilities sum to one, the margin per ha at the farm level represents an average with respect to the effect of growth regulators, see Figure 2.

The economic margin per ha

The economic margin for a specific strategy is calculated for a specific species in a specific region and a specific lodging category, see figure 2. We include only those variable costs and revenues that change between the categories, with the result that we do not calculate complete gross margins per ha. Afterwards the economic margin for each lodging category is multiplied with the probability of having that lodging category and finally the lodging categories are summarised.

Yield, grain quality parameters, lodging percent etc. are registered in crop research experiments, but the small plot trials are carried out under conditions that are different from those faced by the grain producers. Still, experimental results from NCRI with growth regulators are used in the calculations, but to some extent they are adjusted for farm results.

Revenues (per ha) for each of the specific strategies are calculated as follows: The absolute crop yield data are from farmers' registrations over the last seven years (Statistics Norway). These are used as proxies for the grain yields of untreated fields. Relative yield changes in growth regulator experiments conducted by NCRI determine the grain yield if treated with growth regulators. Trampling losses (100 kg/ha) are deducted from the revenues of flag-leaf stage treatments (*Moddus* and *Cerone*) in barley and oats.

Grain prices from year 2000 (Norwegian Agicultural Authority) are used in the models. Moisture content in grain at harvesting from the NCRI experiments is accounted for because of the drying costs. For spring wheat, winter wheat and rye the relationship between the proportion of grain for milling, and the lodging percent are estimated with regressions to get a proxy of the effect of lodging on the falling number.

Relevant costs include the cost of the growth regulator and spraying. In the economic evaluation, taxes on growth regulators are excluded. Furthermore, additional harvesting costs that arise because of lodging are included (labour, fuel, maintenance of the combine harvester, timeliness effects and harvesting losses). There is a lack of scientific knowledge regarding the rise in harvesting costs as lodging increases. In many cases subjective assessments are necessary to estimate harvesting costs as the lodging increases. The results should be interpreted in this context.

The lodging percent with different treatments are estimated as follows: For untreated fields the average lodging percent in each state of nature for each crop species from the 1984-2000 plots at NCRI are used. The relative changes in lodging resulting from the use of growth regulator are estimated by looking at the difference in the rate of lodging between treated and untreated plots in the same trial.

When water and other minerals are non-limiting, grain yields responds positively to N (nitrogen) application until a maximum yield is reached. At the same time, lodging tends to increase with increasing fertilizer-N. The interaction between growth regulator and application of fertilizer-N is not considered in the estimations. Treatment with fungicides to control diseases may be done at the same time as use of growth regulators and may reduce spraying costs. However, we have not considered these aspects.

Non-monetarian effects at the farm level

Risk evaluation is a professional evaluation of all data about the effects from the pesticides compared to information about exposure to predict the possibility for any harm to occur at a specific exposure. Two different risk evaluations are given at present by the NAIS (1999):

- Health risk
- Environmental Risk

Health risk

This is a toxicologic risk evaluation with the human being in focus. Since no standardised international or national guidelines exist for the evaluation of risk for users of pesticides, an indicator for health risk is based on the potential damage (the inherent qualities) and a simplified judgement of the exposure based on the formula and the spreading method. An index for health risk can then be calculated as shown in Table 1:

Table 1: The index for the health risk index for preparation per kg or litre preparation

Risk index for preparation				
Health	**Exposure class**			
	Under mixing			
	Low (1)		High (3)	
	Under spraying		**Under spraying**	
	Low (1)	High (2)	Low (1)	High (2)
Low (1)	1	2	3	6
Medium (2)	2	4	6	12
High (4)	4	8	12	24

Source: NAIS 1999

The index is calculated per kg or litre of preparation and does not consider the amount used of the pesticides. We therefore calculate an indicator for health risk on a ha-basis by multiplying the index for health risk with the dosage per ha.

Indicator for health risk/ha = Risk index for preparation × Dosage in kg/ha

Environmental risk

This is a toxicological risk evaluation dealing with the effects on the natural environment. An index for the environmental risk for every substance contained in the preparation is calculated by NAIS. The indexes are then added together to calculate the index for a given preparation. Different qualities are given scores for every matter in the formula, however the score for persistence is weighted double to consider the risk for chronic effects.

$$M_{matter} = (T + A + U + 2P + B + 1)^2$$

M = Index for environmental risk

T = Score for negative effects in the terrestrial environment

A = Score for negative effects in the aquatic environment

U = Score for leaching

P = Score for persistence

B = Score for bio-accumulation

As for health risk the index is calculated per kg or per litre of preparation and does not consider the amount used of the pesticide. The index for health risk is therefore multiplied with the dosage per ha to consider the consumption of the pesticide per ha.

$$\textit{Indicator for environmental risk/ha} = \textit{Risk index for preparation} \times \textit{Dosage in kg/ha}$$

Multicriteria evaluation at the farm level

The multicriteria method includes an evaluation or weighting of the three criteria (health risk, environmental risk and economic benefit) against each other by the NAIS and with consultancy by the Council for Pesticides.

For each growth regulator the economic margin per ha at the farm level is calculated for a year with average lodging, as illustrated in Figure 2. This economic margin is calculated without assuming any specific behaviour for the farmer about his preferences between the three criteria and can therefore at that level be compared to the indicator of health risk and the indicator of environmental risk. Thereby NAIS will receive a decision basis (an indicator) for each crop specified per ha and region. This may be necessary due to the fact that they give approvals for applications to species. The numbers can then be plotted as in Figure 1.

EVALUATION AT THE REGIONAL AND NATION LEVEL

For the evaluation at the regional and the national level we use as a basis:

a) The total registered use of every growth regulator

b) The modelled usage and economic benefit on a ha level for each crop and region

c) The registered acreage for each crop and region.

b) is then used as model for the economic benefit and use of growth regulator inside each category while c) is used as a rough measure for the aggregation of the crops and regions. Finally a) is used as a measure for the absolute quantities used on a national level. Thereby the modelized quantities of growth regulator and thereby economic benefits are corrected to reflect the actual use.

However to test in more detail how the use of growth regulators is divided between crops and regions we use questionnaires from local advisory services. They are important decision-makers in the diffusion of a "new technology" like growth regulators. Rogers (1995:11) states that: "Diffusion is the process by which an *innovation* is *communicated* through certain *channels* over *time* among the members of a *social system*. These elements are identifiable in every diffusion research study, and in every diffusion campaign or program."

MAIN RESULTS

This is a recently initiated project and there are at present no results to report. At the conference, results at a farm level and at a regional level for the economic benefits and the health and the environmental effects for plant growth regulators will be presented.

DISCUSSION

It is a demanding task to consider a method for a social benefit evaluation by the public approval and re-evaluation of pesticides. Ideally all effects arising from the use of growth regulators, among them the economic benefits, the health effects and the environmental effects, should be included. However, some of the effects are external and difficult to identify and quantify.

A multicriteria decision model seems to be a possible method that allows for the use of several incommensurable criteria in the approval process by NAIS. Furthermore, it results in greater transparency, which may be an important quality in a public decision process. However, there are problems connected to a social benefit evaluation like this, some of these are:

- There may be other criteria that also should be included
- Effects outside the agricultural sector are not considered

The environmental effect and the health effect are estimated by NAIS, while a model for estimation of the economic margin is developed in this project. There are many constraints on what it is possible to do in an analysis like this. Especially the lack of good crop experimental data and farming data has been a limiting factor in our work. Therefore this analysis is a kind of “art of the possible”. If we had more resources and better information available, a more thorough analysis would have been possible. Regarding the economic estimation the following issues are important to acknowledge:

- Data for the agronomic benefits are rather scarce
- Many assumptions are made about

- Categories
  - Cultivars differ in their resistance to lodging
  - Fertilizing level, fungicides and other categories may be decisive
- Harvesting costs

Attention should also be given to the offsetting or countervailing risks from banning some pesticides (Knutson 1999) like that untreated crops may produce natural toxins, (non-)use of growth regulators may have indirect environmental effects (e.g. nutrient leaching, consumption of fossil fuel) and changes that arise due to what, how much and where different crops are grown.

A general problem associated with the approval of pesticides is that such an approval has to be based on future behaviour and effects where the trial data is relatively scarce when it comes to the agronomic effect. The environmental and health effects are even less well documented and only the direct effects on health and the environment are considered by NAIS.

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