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GMO NEIGHBOURHOODS – WILL CO-EXISTENCE BE A GEOGRAPHICALLY REALISTIC POSSIBILITY?

by
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ABSTRACT. In Denmark, there has been widespread opposition to the use of genetically modified organisms (GMOs) as a result of which rules have been developed relating to the co-existence of GM, conventionally and organically produced crops. This has been in the form of a spatially elaborated implementation of the precautionary principle adopted in the Maastricht Treaty from 1992 by the EU.

We concretized these rules in relation to actual landscape practices among primary producers of sugar beet in Denmark, and simulated the co-existence of GM and conventional sugar beet in an area of intensive sugar beet production in Lolland, South Eastern Denmark. The theoretical basis for our work finds three major sources of inspiration; namely Ulrich Beck's theory of the 'risk society', Torsten Hägerstrand's concept of 'the process landscape' and its relation to the social practices of land users, and Brian Wynne's studies of the discrepancy between theoretical and practical knowledge related to environmental risk.

The farmers, who were involved in the study, were interviewed concerning their opinions on land-use practices in cases of co-existence. Interviews were carried out both before and after the study took place. It is concluded that although the farmers are positive towards the possibility of introducing GM sugar beet, it is not realistic to expect the rules of co-existence to be observed, which makes the risk assessment behind the new rules unrealistic. Further studies of social practice in relation to trends and geographical variations in the distribution of structure, size and fragmentation of agricultural holdings are recommended in order to investigate possibilities for realistic co-existence.

Key words: GM crops, GMO, co-existence, neighbourhood relations, process landscape, simulation, regulation, practical knowledge

Background

It is well documented that there is considerable resistance from the European population to the introduction of GM crops, and consumers have stated that they do not wish to purchase them (EU Commission, 2002, pp.1–2, 13–14).

There is no direct international regulation of growing GM crops; it is not to be found in the UN (Codex Alimentarius), in WTO rules. A certain degree of indirect international regulation has been included in the Convention on Biological Diversity, which was signed by 155 states in 1993, and came into force in 2003 through the Cartagena Protocol on Biosafety, which the European Union has signed. In relation to GMOs, the protocol states that the signatory countries must be supplied with enough information to enable them to make risk assessments. In addition, they must receive documentation concerning the origin of GMOs. The extensive resistance to GM crops in the European Union caused a five-year de facto moratorium between 1999 and 2004. During this period, important decisions were taken in the EU, influencing the situation after the moratorium came to an end. A stricter directive concerning risk assessment was agreed (The European Parliament and the European Council, 2001). This explicitly states that the regulation of GM crops must be based on the precautionary principle. The precautionary principle states that when there is reasonable suspicion of harm, lack of scientific certainty or consensus must not be used to postpone preventive action (Andersen 2000). Consequently, the EU has introduced a labelling system (The European Parliament and the European Council, 2003) with the intention of ensuring that consumers are given a 'free' choice. For the labelling system to work, the food has to be controlled in the food chain.

An important geographical problem exists in relation to free choice between GMOs and non-GMOs. To prevent contamination, GM crops have to be adequately separated from conventional and organic crops as well as from wild species able to cross with grown cultivars. However, the production of GM crops is related to an open landscape system displaying material spatial processes, both natural and human, at different scales. Nature disseminates pollen and seeds. Pollen from the sugar beet *Beta vulgaris L.* is dispersed up to 5 kilometres by winds (Tolstrup *et al.*, 2003); however, the effects seem to be less than 1% at a distance of more than 200 metres (Eastham and Sweet, 2002). Practical experience gained from seed production and dispersal experiments with *Beta vulgaris L.* in Denmark indicate that dispersal declines at a distance of more than 50 metres (personal communication, Göran Kjellsson, National Environmental Research Institute), although the dispersal of pollen also extends beyond this distance (Madsen, 1994), which is the proposed minimum distance between GM and conventionally grown sugar beets (Tolstrup *et al.,* 2003). Humans make mistakes when producing seeds: conventional seeds may be mixed with GM seeds during growth, packaging, transportation and so on. During beet growth, humans walk around the fields and move the seeds in the soil from one field to another.

In a situation of co-existence, farmers will, to a greater extent than before, have to co-ordinate their activities and obey social rules limiting their freedom to grow crops as they wish within the territory of their holding. According to the new Danish Act on Co-existence (Lov nr. 436, 2004), a farmer choosing to grow a GM crop will have to co-ordinate the crop rotation with neighbouring farms having fields located within the separation distance depending on the type of crop. For sugar beet, this distance is 50 metres if it is a conventional beet and 100 metres. if it borders an organic field. This means that there will be a need for adjusting the crop rotation at one or more of the farms to comply with the distance requirements.

Thus a number of conflicting but interrelated questions arise. The following describes three ways of presenting the problems forming a framework for the subsequent empirical analysis of the geography of GMO co-existence.

Theoretical background

Different, contemporary, social scientists have theorized about problems of environmental readjustment relevant for the introduction of co-existence between GM and non-GM crops. The German sociologist Ulrich Beck has analysed the ever-growing social problems and challenges related to the distribution of risks connected to technological innovations. Of special relevance for the geographical focus of this paper has been the work of the Swedish time-geographer Torsten Hägerstrand who has emphasized the growing need – but also the still very limited social ability – to master the complexity related to innovations being implemented in a cultural landscape which is under constant transformation due to both nature and man. The British nature scientist and sociologist Bryan Wynne has studied the different concepts of risk related to scientific expertise and specialist lay knowledge and the communication gaps between these when it comes to the evaluation of risk consequences.

Ulrich Beck and modern reflexivity

Ulrich Beck's book *Risikogesellschaft*, published in 1986, analyses how modern industrial society is increasingly transforming itself into a risk society. Beck argues that the basic division in society is no longer based on material goods, but on risks which are the result of industrialization and the environmental problems it has produced (Beck, 1986). The risk society is also characterized as being reflexive due to its very complex construction, which demands that a society's citizens think and act reflexively in both their professional and daily lives. In relation to land users growing GM sugar beet, this demand for reflexivity is very time consuming, difficult to handle and control. Furthermore, the social relations between neighbours are challenged, complexities which will be discussed and illustrated below.

The scientific and technological development existent in risk society becomes full of contradictions; on the one hand it creates solutions to problems, and on the other hand it creates new problems elsewhere in society or nature. For example, the conventional cultivation of sugar beets demands a high input of, in particular, herbicides that provide benefits but also create problems such as polluting drinking-water. Pesticides have been found in a number of water analyses from drills of drinking-water – lowering the input of herbicides could perhaps solve this problem. The GM sugar beet is resistant to the herbicide Round-up, which makes it easier to use, since it is only necessary to spray the fields a few times during the season. Both the environment and the land users seem to win. However, new problems of co-existence result from this solution; for example, the unknown risk from annual flowering weed beets (bolters), which can become problematic dispersal sources if GM outcrossing occurs (Tolstrup *et al.,* 2003).

In summary, according to Beck, science in risk society solves problems with solutions that create new problems, which science also tries to solve, and so it goes on. One might postulate that science keeps itself busy and has a double-sided role – as a troublemaker and a rescuer.

Torsten Hägerstrand and the material character of geographical reality

In his more recent publications, Torsten Hägerstrand often linked the growing environmental problems to the unfitness of most scientific disciplines to express the fundamental dynamics of cultural landscapes as concrete expressions of man–nature-relationships (Hägerstrand, 1993a, 1993b, 1995a, 1995b). As a framework for regional studies that also includes environmental relations, he introduced the concept of 'the process landscape'. The process landscape contains all which is present within its given boundaries, including all that moves in and/or out of its borders within a chosen period of time, examples of which are animals, humans and machines, as well as crop rotation.

The state of the landscape is not the focus of attention (as, for instance, in the case of seeing the landscape as scenery). The goal is rather to study landscape dynamics and to make clear which types of process produce a transformation of landscape, seen in different time perspectives.

Within the process landscape, the bodies of both nature and society compete for space in a limited budget relating to space, time and energy. Thus the question of cause and effect is not just a question of 'before-after', as in a laboratory, but also a matter of a possible expansion in the space budget due to resistance from neighbours or their willingness to give way to new processes. As an example, the establishment of a GM sugar beet-producing agricultural holding under the conditions of co-existence will not depend solely on the economically favourable command of a number of new production and control processes, but the producer will also be confronted with a variety of neighbour-related considerations, in reality obstructing the new production methods, if the neighbours will not co-operate because they judge the new production method to imply a risk to their own production or livelihood strategy.

To understand the nature of the landscape processes and changes, it is not enough to distinguish between different types of processes (such as abiotic, biotic and social/cultural); they have to be presented in their connection within the framework of the budget conditions of the process landscape.

This demands a usage that will balance the abiotic, biotic and social/cultural processes, which is not the case if concepts and terms are taken from the existing geo-sciences, biology and social/cultural sciences. The latter type in particular is often not at all suited to landscape studies due to their traditional ignorance of the material character of life, including such qualities as volume, form, resistance and capacity of different 'bodies', and their neighbourhood relations.

Social and cultural sciences often concentrate on goals and ideas, but suppress action as a material form. Thus, the goal of enforcing a precautionary principle and even developing it into a principle of co-existence will not necessarily be confronted with the current material geographical realities.

Thus, for Hägerstrand, the overall purpose of introducing the concept of 'process landscape' was to overcome the blindness of current, modern regional planning and management concerning nature and the environment. This blindness is due to the abstract social scientific character of much modern planning, in practice alienating basic concepts from the material character of reality as well as detaching them from their ever-present material neighbourhoods. Neither nature, nor ecosystem, habitat, society, establishment and so on are abstract categories drifting in a natural or cultural space. On the contrary, they are material bodies and multitudes, located in specific places, entering into more or less co-ordinated activity, since, as Hägerstrand puts it, *contact is the most elementary relation of existence* (Hägerstrand 1993a, p. 34).

Thus the co-existence of GM crops and non-GM crops means regulated contact in the form of stable or at least controlled borders between the two types of crop. This contact is primarily maintained and supported by neighbours among the different producers who respect the continuous parallel production forms, and interfere actively in natural processes threatening dissemination crossing the spatial borders separating GM and non-GM crops.

Neighbourhoods are a very concrete manifestation of this elementary contact. All human management of the environment is, in general, based on a clear partition of competences of given geographical domains. The lowest primary domain is the unit of property within which the owner has the right to change the landscape within certain general rules laid down by society. This right is strongly protected in almost all contemporary societies. Hägerstrand calls this exceptional right to manage and change the primary domain the right to exercise *territorial competence*. This is contrasted with the much more limited *spatial competence* of all power holders of domains at higher levels, namely municipalities, regions, nation-states and the EU, which are typically represented by politicians and the public services related to these domains. They certainly have competence within their strictly defined domains, but only enough to establish general rules and conditions concerning what should or could be done within the domain, or to designate sub-domains and establish special conditions for these areas.

The importance of a transparency of territorial and spatial competences for GMO has been illustrated by the situation of co-existance in Spain, where GM-crops have been grown since 1998, but, with no public information on where the crops were grown nor information to neighbouring non-GM farmers. Contamination of conventional and organic products has been observed, and it has been realized that without information especially to non-GM-producing neighbours, any co-existence must be considered an illusion (Spendeler, 2004).

The power holders of higher order domains cannot directly physically change the landscape, but only manage *symbolic transactions:* political deliberations, rule setting, control, tax collection, subsidy provision and so on. Symbolic transactions at the social level are vital for the transformation of society and for its ability to unite to attain common goals in the future. However, their power to produce a direct transformation of the rural community is very limited, as well as to act physically in a situation, where the holders of territorial competence do not respect or conform to the symbolic transactions of the holders of spatial competence.

The implementation of a principle of co-existence is a symbolic transaction, intended to be materialized at the landscape level by the actors of territorial competence. However, their local actions are regulated by a variety of specific conditions rather than by general guidelines, which means that these conditions for action have to be the focus of any serious evaluation of the efficacy of general guidelines:

> At the global level social and economic facts are by necessity expressed in terms of statistics. But what actually happens among actors in the landscape is more properly understood in terms of logistics. To be able to judge effects and potential side effects of management operations one would need conceptions in which the perspectives of concerned actors on the micro level has a place. Global change is after all not the outcome of a few human actions of an immense scale. It is the nearly incalculable number of small actions which pile up to major changes in space and over time.
>
> The complexities of human action can be approached along two different roads. One is to try to interpret the driving forces behind observable behaviour. The other is to try to identify constraints of various kinds which define the limits of the potential choice space of the actor. From a management point of view both aspects are clearly relevant. But the second is of particular interest because management is to a large extent a question of defining general limits to actions rather than prescribing what people should do. The limits of action spaces in the terrain are of fundamental importance from both regional policy and environmental policy perspectives. It is primarily within these limits that other regulations or influences can make themselves felt.
>
> Hägerstrand 1993a, p. 44; cf 1995b p.2

This second path will be followed in the simulations of GM sugar beet production presented in the empirical section of this paper.

Bryan Wynne and practical knowledge versus theoretical knowledge

Risk assessment undertaken by the introduction of new technologies is closely related to the interaction between theoretical and practical knowledge. There is a great difference between the two – yet we cannot do without either of them.

In the analysis of production-related environmental problems, Brian Wynne has been investigating the linkage between theoretical and practical knowledge (Wynne, 1996). Based on a number of cases, he has theorized, in general, about the failure to including practical and local knowledge in experts' considerations when producing theoretical knowledge. Laymen will often include ethical and social consequences in a risk concept which is broader than that usually used, differing from experts and authorities representing another rationality and blind to the rationality of the layman. Experts often have vague and unrealistic assumptions as to the nature and extent of private and public competences (e.g. of the different spatial types of competences regulating and implementing legal and expert rules).

– scientific expert knowledge embodies assump-

tions and commitments of a human kind, about social relationships, behaviour and values;
- it also embodies problematic 'structural' or epistemic commitments, for example about the proper extent of agency, control and prediction, or of standardisation;
- it neglects and thus denigrates specialist lay knowledge;
- at a secondary level it then defines lay resistances as based on ignorance or irrationality rather than on substantive if unarticulated objections to these inadequate constructions of lay social identity which the expert discourses unwittingly assume and impose;
- thus a further reinforcement takes place, of tacit public ambivalence about being dependent on social actors (experts) who engender such alienation and social control;
- hence the fundamental sense of risk in the 'risk society', is risk to identity engendered by dependency upon expert systems which typically operate with such unreflexive blindness to their own culturally problematic and inadequate models of the human.

(Wynne, 1996)

In this study of the co-existence of GM and conventional crops, it has been a surprising discovery that although both scientists and practical agriculturalists seem to acknowledge the importance of a linkage between theoretical and practical knowledge, when it comes down to it, there is, nevertheless, only a week connection. As documented in the following section, the Danish Working Group on the Co-existence of Genetically Modified Crops with Conventional and Organic Crops (henceforth the Working Group) has handled the practical knowledge of farmers as a condition related to a defined 'good farming practice' whereas the actual knowledge and experience of farmers has not been considered important and has not been used as a source of information for risk assessment. Although important new types of farming practice by GM sugar production have already been implemented for organic GM sugar production (cleaning machines and the separation of seeds and beets from conventional types), such practice has not been evaluated as a part of the risk assessment. At the same time, the farmers interviewed during this investigation did not, in the first series of interviews, consider their own experience as important for the scientific investigation of the co-existence of GM and conventional crops. Only through the discussion of detailed practice-related rules for co-existence, based on a simulation of such co-existence, did it prove possible to overcome this contradiction and establish a realistic connection between rules for co-existence and a probable agricultural practice related to co-existence.

Co-existence and cultivation practice – an empirical approach

In November 2003, the Danish Working Group on the Co-existence of Genetically Modified Crops with Conventional and Organic Crops published a report discussing co-existence for a wide range of crops – among these sugar beet (Tolstrup *et al.*, 2003). For each crop, the Working Group described the geographical distribution, present cultivation practice, experiences with GM and the dispersal sources through the entire production process. This was followed by a list of the important control measures for managing crop purity below a certain level of GM content (in accordance with EC Directive 2001/18/EC) related to adventitious percentage presence scenarios of GM seed and crop of 0%, 10% and 50%. For conventional sugar beet farming, a GM content of <0.3% or <0.4%, depending on the scenario, has been anticipated. Finally, the need for further scientific knowledge concerning each crop is listed.

The conclusions are given in the form of expert knowledge closely related to scientific statements emphasizing the preconditions for the investigation. In a general section on production practices describing the great influence on the co-existence of farm management at the individual farm, it is clearly stated that the Working Group generally assumes 'good farming practice' as described by the Danish Farmers Association and Danish Family Farms Union (2000). To make this assumption more precise, the Working Group *defines* 'good farming practice' in crop production as:

- Compliance with cropping practice, including compliance with time limits for spraying, application of fertilizers and manure, as well as spraying, and manure-free zones in accordance with the current legislation.
- Management of volunteers and wild oats and the cleaning of machinery in connection with seed production in accordance with the current legislation.
- Bookkeeping of accounts for fertilizer, manure

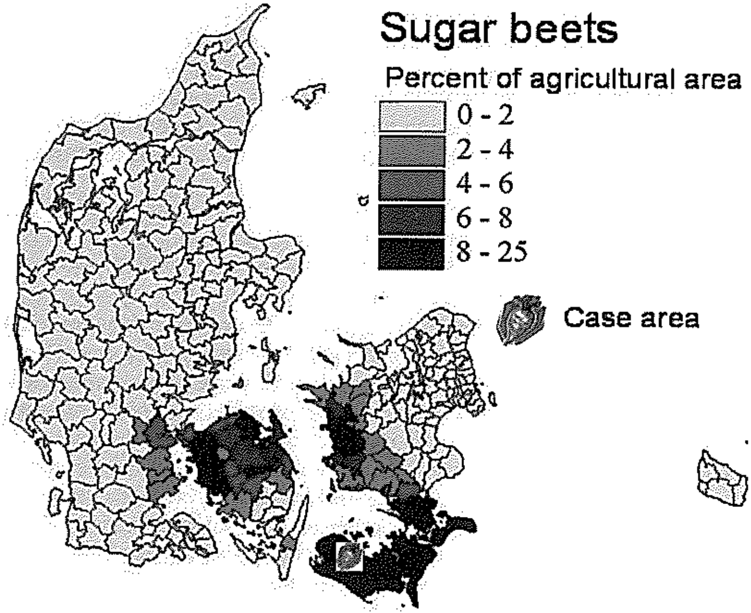


Fig. 1. The distribution of beet (*Beta vulgaris* ssp. *vulgaris*) in Denmark, 2002 (Dalgaard and Kristensen, 2003), and the location of the area under investigation. Approximately 85% of the beet area is grown for sugar, the rest for cattle feed. The variation in distribution reflects the distribution of beet for sugar production, concentrated around areas with sugar processors.

and spraying records in accordance with the current legislation.

- Entering into a good dialogue with neighbours with adjoining production areas.
- Trading with quality seed, and cereal processors who take care to avoid mixing seed lots.
- Choosing varieties and establishing crop rotations that also take problems with weeds into account, including volunteers, diseases and pests.'

(Tolstrup *et al.*, 2003)

The report does not discuss how far these rules of good farming practice are likely to be observed by farmers, in contemporary cultivation practice as well as in future practice related to the production of GM crops.

The empirical section of this study tries to shed light on farmers' actual practice and how this practice will be transformed with GM production.

Methodology

Based on a simulation of co-existence between GM and conventional sugar beet production, agricultural practice and management has been investigated among farmers from nine neighbouring agricultural holdings situated in the middle of one of the main sugar beet-producing areas in Denmark, comprising a total area of 2,166 ha, (Fig. 1).

One of the nine farmers consented to undertake the role of potential GMO producer, and the other eight were selected as neighbours to this 'GMO producer'. Due to the fragmented character of property (and leased land) of the GMO producer, the area under investigation comprises two coherent areas. All nine farmers were experienced sugar beet producers, with sugar beet accounting for between 14% and 27% of their area under agriculture (Table 1).

Based on qualitative interviews with the farmers and experts related to the production, processing and control within the sugar beet trade, the listing of important control measures for managing crop purity below a certain level of GM content established by the Working Group has been developed further. It resulted in a manual serving as practical rules for cultivation of GM sugar beet in respect of the EU Directive 2001/18/EC adducing the precautionary principle to guarantee that the way of handling GMOs is carried out so as to minimize the spreading of organisms (see Table 2).

Table 2 is rather comprehensive. There are a lot of practices to remember and a lot of precautions to take, which makes GM growing much more complicated than conventional sugar beet.

To ensure a systematic coverage of the human aspects of cultivation practice under GM conditions, special emphasis was put on the elucidation

Table 1. Characteristics of the nine agricultural holdings in the investigation area. Roman numerals indicate the eight neighbours of the 'GMO producer'. A neighbour of a holding is another agricultural holding, having production areas within 50 metres from the production areas of the holding.

Holding	GMO-producer	I	II	III	IV	V	VI	VII	VIII
Land under rotation, ha	101	450	110	140	50	270	320	225	500
Acreage of sugar beets, ha	28	100	23	22	10	52	46	50	100
Percentage area with sugar beets related to the total land under rotation	27	22	21	15	19	19	14	22	20
Number of years as a sugar beet producer	35	6	20	27	23	13	20	17	15
Number of additional employees	A harvester assistant	4	None	A harvester assistant	None	2	2	1	3
Number of neighbours	8	17	7	10	5	10	23	9	20

of rules, where the land users had to change or add some new practices to their current practices of growing sugar beet, or expand some of their current practices.

This is illustrated and explained in Table 3, which shows that seven new practices are added to the present five and, on top of this, some of the current practices are being further extended.

The simulations

To relate the recommended rules to a realistic cultivation and management practice, simulations of co-existence in the investigation area have been carried out. Since the dominant crop rotation in the area is a three-year rotation of barley, wheat and sugar beet, the actual rotation of crops during 2000, 2001 and 2002 has been used as a starting point for a simulation of land use in 2003, 2004 and 2005. The purpose has been to achieve as realistic a picture as possible of what is going to happen when the requirements for co-existence are implemented. It is a precondition for the simulations that the recommended guidelines established for growing GM sugar beet (shown in Table 2) are met by the farmers.

When making simulations, it is very important to keep some parametres constant, since it would otherwise complicate the separation of the effect of the parametres in the subsequent analysis.

The following parametres were chosen as constants:

- The 'GM farmer' grows only GM sugar beet and the neighbours grow only conventional sugar beet.
- The spatial delineation of the holdings, including land in tenure and excluding farming out land, are unchanged, which means that the geographical location of the production areas of a holding is not changed during the three years. It means that the property will neither extend during the simulation – nor will the internal rounding off of the single fields be changed.
- The 'GM farmer' has to hold neighbour hearings each year in order to adjust the location of his crops in relation to the neighbouring farmers' conventional crops.
- The 'GM farmer' keeps his existing sugar beet contract with the sugar production company.
- The 'GM farmer' keeps to a three-year crop rotation.
- It is not possible for the 'GM farmer' to have sugar-beet seed production (which the farmer in the case study in fact has) because of the distance requirement of 2000 metres.

The following parametres were chosen as variables: The 'GM farmer' can choose between the following types of practice:

- If a neighbour is growing conventional sugar beet in an adjacent field, the 'GM farmer' must establish a 50-metres border zone on his own field without GM beet.
- He can move crops to other fields to avoid growing GM beet within 50 metres of neighbours' conventional sugar beet fields.
- He can make agreements with the neighbours to place their conventional sugar beet fields at least 50 metres from a GM field.

Table 2. Recommended rules for the cultivation of GM sugar beet – based on practical- and expert knowledge.

Practical rules to be followed by land users growing GM sugar beet:

1. *The right to choose first*: The conventional and the organic sugar beet growers have the right to choose where to place the crops. This means that the GMO grower has a responsibility to make a request to the neighbours.
2. *Neighbours*: GM growers have a duty to inform their neighbour farms in writing on 1 August – 1.5 years before sowing GM sugar beets. In this way, other sugar beet growers have a chance to make their field plan for crops in time. If the GM grower keeps his GM fields within the permitted distance (see demand 5) the neighbours cannot object. In addition, the registration can be done via the Internet as soon as the grower knows where to place the crops.
3. *Placing*: The GM sugar beets must be registered giving their exact position in the field plan or in coordinates via GPS (global positioning system). The field plan must be sent to the Directorate for Food, Fisheries and Agribusiness. There must be a very clear physical separation between the GM and the conventional fields growing the same crop.
4. *Keeping the field plans for 20 years*: The reason for this is that the sugar beet seed can remain in the soil for up to 20 years and still possibly germinate.
5. *Demand of distance*[1]: Between growing of:
   - GM sugar beet and conventional sugar beet: 50 metres
   - GM sugar beet and organic sugar beet: 100 metres.
   - GM sugar beet and the sea beet (Beta vulgaris ssp. Maritima): Sugar beet growers have to make enquiries at the office of Nature and Planning (Natur- og Plankontoret) to get information as to whether sea beet are grown in the area of growing GM sugar beets and if there is any distance requirement. We suggest that the required distance should be 100 metres.
6. *Spraying plan*: One has to follow a specific spraying plan, which cannot be changed due to the importance of the pesticide and the time of spraying that is crucial for flora and fauna (spraying must take place later than current procedure, and the GM sugar beets may not be sprayed in rainy weather).
7. *Information* on precautions for hunters, who go hunting in GM areas. The hunters must be informed of the risk of spreading seeds, and, therefore be informed about the distance requirements. The reason for this kind of information is the possibility of spreading GM seed via the hunters' boots when they walk from a GM field into a conventional or organic field.
8. *Manure*: If livestock receives the top of the sugar beet as feed, its manure may only be used on GM fields.
9. *To make sure that agricultural machinery and other means of transport are cleaned* of GM seeds (sowing machines, beet lifters, beet cleaners) when going from and to the field of GM sugar beets. It is also important to pay special attention to machines which have been borrowed, particularly where GM and non-GM growers share machinery. At delivery to Danisco (when going back and forth to the sugar factory) the means of transportation must be cleaned. Beyond this the means of transportation must be secured in a way that prevents the beets from falling off the truck during transport. If the beets fall off the truck there is a possibility they will sprout the coming year and grow a stalk, which might spread pollen to other fields with beets and sea beet.
10. *Separate GM seeds from conventional seeds*: A clear specification of what GM seeds are and are not. The filling of different sorts of seeds into the sowing machine is not allowed before the machine is empty and cleaned to ensure that there are no remaining GM seeds. This rule has been passed by the EC for labelling and tracing of GM products.
11. *To cut down and destroy bolters* from GM sugar beet to avoid seed and pollen spread (the land users will be told when to do so by Danisco, which informs the growers via the Internet). The bolters must also be removed from the field the following year in the field growing GM sugar beet.
12. *To separate GM sugar beet* from other beet by, for example, marking the clamp and the loads going to the factory. If the GM sugar beet are mixed with non-GM beet, they are characterized as GM beet. To avoid loss of sugar beet during transport from the field to the factory, the truck must be covered with, for example, tarpaulin. The trucks also have to be completely emptied before being loaded again. The growers are responsible for carrying out these rules.

Source: Tolstrup *et al.*, (2003) and interviews with land users (2003).
Note
1. Since the formulation of the rules, the Danish bill for co-existence has been published. Its requirements for distance are identical with the given assumptions.

Only these three types of practice were included in the scenarios. Many other types of practice are possible, but in general they are not relevant in relation to the simulations. The division of parametres into constants and variables is theoretical, and in real life most parametres will be variable, even within a three-year period: some farmers use two- and four-year crop rotations. More farmers may want to grow GM beet if the profit proves higher than currently assumed. Farmers will continuously buy, sell and rent new areas. Some farmers will change the placement of sugar beet fields later than agreed upon. Regulations could possibly be changed as a result of new knowledge.

Within the given constant and variable parametres, the following simulations were made:

- A *dependence simulation,* referring to a situation where the 'GM farmer' decides to depend on agreements with his neighbours about the placement of his crops.
- An *independence simulation* referring to a situation where the 'GM farmer' avoids agreements

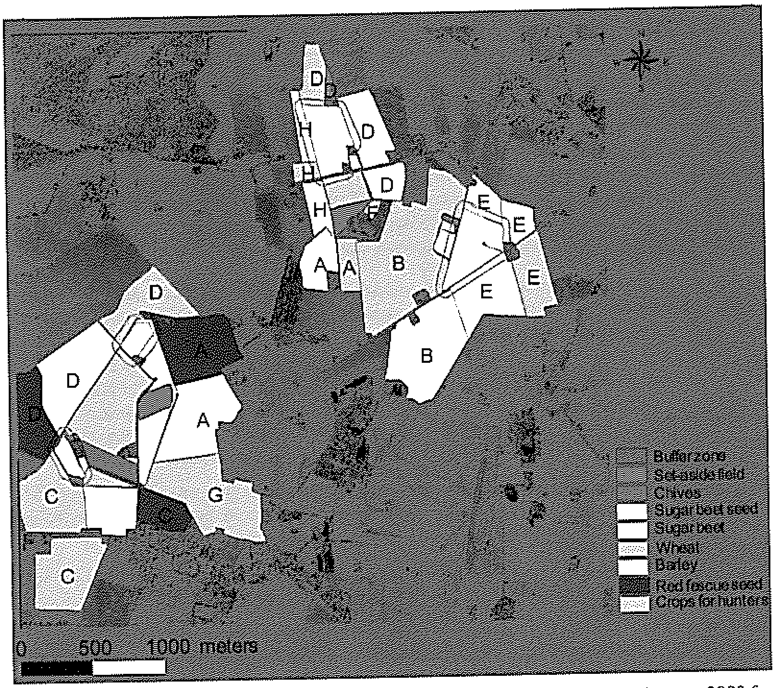
Table 3. Changes in cultivation practices by conversion from conventional to GM-based production of sugar beet.

Proposal for rules of growing GM sugar beets			
Rule no	Present practice	New practice	Comments
1 (The right to choose first)	X	X	At present, the grower discusses seed growing with neighbours, but there are no rules regarding the first right to choose where to place the crop. In some cases, the seed company handles the planning of placing. If the land users do not grow seeds, they are not familiar with this practice.
2 (Neighbour information)		X	The duty to inform the conventional or the organic growers 1.5 years before growing GM sugar beet is a new practice and means that the GMO grower has to communicate with the neighbours
3 (Placing)	X	X	At present, the grower sends field plans to the Directorate for Food, Fisheries and Agribusiness in order to get EU support (www.dffe.dk A – d. 20 February 2004). In this sense, the growers already give an account of the placing of the crops, but the rules for growing GM sugar beet are to be even more accurate.
4 (Keeping field plans)	X	X	At present, the field plans must be kept for five years. The rules for growing GM sugar-beet suggest expanding this period to 20 years, as the seed may survive in the soil for that long.
5 Distance requirement		X	The distance requirement between GM sugar beet and non GM beet and the sea beet is a new practice, which might complicate the three year crop rotation and the hectare planted with GM sugar beet.
6 (Spraying plan)	X	X	Some land users had a set spraying plan – others did not. Thus the practice is both current and new.
7 (Info to hunters)		X	To inform hurters who walk and hunt on GMO areas is not a current practice.
8 (Manure)		X	Livestock may only be given the tops of the GM sugar beet if the manure is sprayed on fields growing GM crops.
9 (Cleaned machines)		X	The land users know the problems regarding soil diseases and how they spread (e.g. via agricultural machinery). But they do not take action to stop the spread of the diseases – they accept it. When growing GM sugar beet the machines must be cleaned when leaving GMO areas.
10 (Separation of seeds)		X	At present, there is no separation of seeds of different kinds; when growing GM sugar beet the seeds must be separated.
11 (Bolters)	X	X	The bolters are torn up by the roots and left on the fields. The new practice is that these must also be destroyed.
12 (Separating GM beets)		X	If a land user grows both GM sugar beet and conventional beet, they must be separated. On top of this, they must make sure that no beets fall of the trucks on the way to the factory by, for example, covering the trucks.

Source: Interviews with land users (2003).

with the neighbours through his placement of GM fields.

The *dependence simulation* involves agreements with the neighbours for all three years (in this article we only discuss one year, 2003; for the simulations of the years 2004 and 2005, see Quist and Lundsgaard, 2004). The first land-use simulation map of the 'GM farmer' and his eight neighbours (Map 1) shows the simulated placement of crops for the year 2003. The map indicates which neighbours the 'GM farmer' has to make agreements with concerning the placements of crops to ensure that the neighbours grow other crops than sugar beet on the adjacent fields. In this simulation, the 'GM farmer' keeps the placements of his crops. This means that his rotation of crops in the three previous years (2000, 2001 and 2002) is replicated in the following three years (2003, 2004 and 2005). This can only be achieved if the neighbours are willing to move their sugar beet fields to other locations which are at least 50 metres from the field boundary to the 'GM farm-



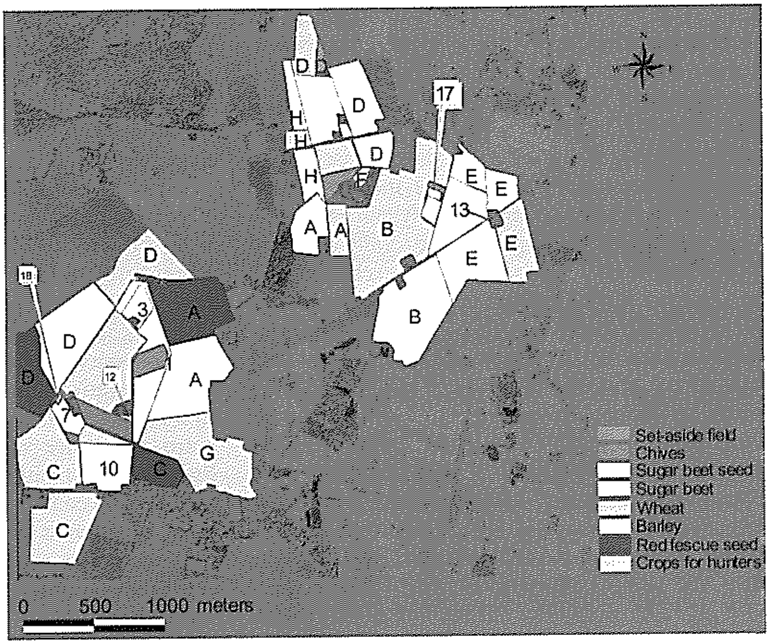
Map 1. Dependence simulation for 2003. The rotation of crops may be seen for the year 2003 for the 'GM farmer' (framed fields without letters) and his eight neighbours (framed fields with capital letters). To keep the information in Table 1 anonymous, the Capital letters A to H do not correspond to the Roman numerals in Table 1. The curved lines around the GM sugar beet fields are marked to show the distance of 50 metres to the adjacent fields. Via the line on the map it is possible to see which neighbours the 'GM farmer' has to contact for enquiring whether they are going to grow conventional beets on the adjacent field of an intended GM sugar beet field. It may be concluded that the 'GM farmer' should try to reach agreement with neighbours B, D and E. *Source*: Background orthophoto, COWI 2002.

er'. This simulation diverges from our guidelines, which give non-GM farmers the prerogative to decide the placement of their crops, but this may be considered to be a 'best case situation', simulating which neighbours that have to and are willing to adapt their own allocation of sugar beet fields to the rotation needs of the GMO grower.

The *independence simulation* involves border zones and field rotations. Map 2 shows the simulated placement of crops for the year 2003, where the sugar beet fields of the 'GM farmer' have been placed in order to avoid having to make agreements with his neighbours. Thus the simulation assumes that the 'GM farmer' wants to avoid depending on his neighbours' good will. It may also be considered a 'worst case situation', where no neighbours are willing to change their field rotation to accommodate the rotation needs of the GMO producer. This is obtained through a combination of using border zones where sugar beet fields are located adjacent to neighbours' sugar beet fields, and moving sugar beet fields so that they are not adjacent to the neighbours' sugar beet fields. To fulfil these conditions the 'GM farmer' sometimes has to make a compromise with his wish to find a field with the same area or with the condition of a three-year crop rotation, which means that for two years he would have to grow the same crop (sugar beet) in a field.

The consequences of the dependence simulation 2003

In this article, we only discuss the consequences o dependence agreements with neighbours for th first year. The 'GM farmer' has to contact farmer B, D and E in 2003 to try to make agreements no to grow sugar beet within 50 metres of his GM fields. If they agree, the distance would often b more than 50 metres, and consequently the contam ination risk might be reduced.



Map 2. Independence simulation for 2003. In this simulation, the 'GM farmer' is independent of agreements with the neighbours. The placement of crops may be seen for the year 2003. For explanation of the scenario, see the text. For further explanation of the signatures, see Map 1.
Source: Background orthophoto: COWI 2002.

However, there is still a risk that the farmers will not be able to agree on the placement of their crops. One reason may be that they do not want to grow the same crop in the same field for two years running. Another is that the neighbour may have limited freedom in selecting fields for growing beet due to soil quality, water regime or a disease in the ground such as nematodes. In addition, some farmers may want to grow the same crop in a field for two successive years and would consider their own interests first. Finally, it does not seem likely that a conventional farmer would want to move his crops because of the GM neighbour's wish, unless they a have very good social relationship.

The consequences of the independence simulation 2003

To ease the comprehension of the consequences, the independence simulation 2003 is described in comparison with the simulation shown in Map. 1. For 2004 and 2005, see Quist and Lundsgaard, (2004).

Field no. 13 has been moved to field no. 10 to avoid the GM sugar beet fields lying side by side with the conventional fields of farmers B and E. This has reduced the sugar beet area by 1.1 ha. In 2002 (the year before the simulation start) there were sugar beets on field no. 10, so the risk of sugar beet diseases has increased. Sugar beet diseases reduce the yield. To compensate for the reduced field no. 17 has been involved. This field is only 0.9 ha, and is therefore not as profitable as the bigger field no. 13. Thus the GM farmer has got two small fields rather than one big field, which is obviously more inconvenient. In addition, the move to field no. 10 places it in contact with several gardens outside of agricultural control.

Field no. 3 has been moved 50 metres from the farmer D's sugar beet field. This is problematic, since the machines have to drive through relatively narrow areas. Sugar beet field no. 7 has been extended with a previous sugar beet seed field (which anyhow has to be abolished due to the GM fields). Finally, a border zone, no. 18, has been added (where wheat is grown), but this adjustment is also suboptimal from a field production economy point of view. It is most likely that field no. 7 could be extended south at the expense of the little set-aside fallow area.

It was not the purpose of the simulations to confront the farmers with the results and the concrete conflicts related to the simulations. Rather, the simulations served as a stimulating basis for qualitative interviews concerning a hypo-sized situation, where the context in general would be very well known to all involved partners. The purpose of the interviews was to obtain a realistic picture of the farmers' attitudes and practices in relation to rules of co-existence which are forthcoming.

All nine farmers were asked to comment on the recommended rules for growing GM sugar beet. Table 4 summarizes the results by dividing all comments on the basis of whether the land users agreed or disagreed. The ones who did not agree commented on why they disagreed about the proposed rules. These comments are summed up in the last column and they have been edited as lightly and as little as possible. Only two of the rules are totally accepted by the land users; rule no 1 (the right to choose first) and rule no. 8 (separation of seeds). There are objections to the rest of the rules – and very strong objections to rule no. 7 (information to hunters) and rule no. 9 (clean machines). No. 7 is unpopular because the farmers think it is out of proportion and they would feel silly informing the hunters. They mention that it is possible to inform the hunters but not the wild animals, which will also be moving around in GM sugar beet areas. This means that this rule is theoretical and difficult to manage in practice. The same kind of complexity characterizes rule no. 9. Cleaning the agricultural machinery is not something the farmers see as a realistic practice. They consider it too time consuming and inconvenient. The Working Group emphasizes this rule in order to prevent a spread of GM crops into conventional and organic crops. Practices similar to rules nos 9, 10 and 12 have already been implemented on organic farms: here, machinery and containers also used on conventional farms have to be cleaned before use. A critical examination of this practice on organic farms, including an estimate of the care and extent of working time involved, would have been useful, but seems to absent from the investigation of the Working Group.

Conclusion

The accomplishment of a Danish bill concerning co-existence between GM crops and non-GM crops may be considered in tightening up the EU rules with the purpose of making sure that both producers and consumers have a free choice between different crops. In the case of GM sugar beet, however, the assumptions behind the bill have not been tested sufficiently under the dominant, prevailing, structural geographical conditions and seem not to be in accordance with actual or realistic cultivation practices. Efficient control of flowering beet as well as cleaning of sawing machinery is among the most important measures for managing purity of sugar beet crops mentioned in the Danish expert report on co-existence (Tolstrup *et al.*, 2003). However, even if the authorities involved should accept the tightened proposals for guidelines set up for the simulations of co-existence used in this investigation, it must be considered undocumented both that the control of flowering beets and the sufficient cleaning of sawing machines will be an embedded part of the production practice under future co-existence conditions. The territorial competence of the farmers seems to relate to a practice which cannot ensure that a separation between GM sugar beet and non-GM sugar beet within the main sugar beet production region in Denmark will be sustained. Practical experience of farmers concerning the cleaning of machinery, control of flowering beets and dissemination risk related to wildlife and hunters should however also be evaluated in the risk assessments made by scientists. Such an investigation should also evaluate spatial variations in control and workload, especially in relation to different distances and neighbourhoods.

In particular, the assumption of 'Good farming practices' ensuring strict observance of the rules for co-existence cannot be expected to work in practice. The farmers will have to change and extend their cultivation practices considerably if they choose to grow GM sugar beet. Beet harvesters need to be cleaned when driving from a GM field to a non-GM field. Seed stalks need to be removed completely. These guidelines will not all be observed in practice when the wide variety of rules are confronted with the limitations of time, space and material nature. These will determine the limits of the potential choice space of the actor (Hägerstrand, 1995b, p. 2). In the responses from the interviews most of the farmers wanted to grow GM sugar beet, but after reading the proposed guidelines they were hesitant about it, and it seems plausible that the farmers will accept only to a very limited degree the additional workload of extra control procedures to prevent dissemination of GM seed. In addition, it is only partly possible to control 'natural' dissemination.

The principle of general spatial contact in the process landscape as a unity seems not to be considered in the rules limited to the agricultural zone. Thus, it is unclear who will control dissemination from bolters through gardens or other non-rural areas in close contact with production areas.

Outlook

This investigation has been based on qualitative methods and the analysis at the landscape level in a typical Danish agricultural area dominated by

Table 4. Land users comments on proposal for rules of growing GM sugar beet

	Comments from land users on the proposal for rules of growing GM beets		
Rule no	Agree	Disagree	Comments of those who disagree
1 (The right to choose first)	9	0	
2 (Neighbour information)	7	2	The land users do not agree upon how long in advance the GM grower must ask the conventional neighbours where they place their sugar-beets. One thinks a year in advance must be enough, while another want to know 1.5 year before sowing the beet.
3 (Placing)	6	3	Some of the land users think that the present procedure, where they send in field plans to Directorate for Food, Fisheries and Agribusiness must be enough to prove, where the GM sugar-beet are placed.
4 (Keeping field plans)	6	3	The practice to keep the field plan for five years is enough. To keep them 20 years is too long a period of time.
5 (Demand of distance)	8	1	A land user did not agree, but he did not make any comments.
6 (Spraying plan)	6	3	It can be difficult to change the spraying behaviour from spraying when they feel it is necessary – to a behaviour where it is planned exactly when to do so. The land users cannot spray in rainy weather or when the wind is too strong. A land user said that it was problematic to have a spraying plan, because he felt it would be restricting him in his choice of crops. And one said that no one could control if they followed the spraying plan or not.
7 (Info to hunters)	5	4	The comment to this demand is that it is totally out of proportion if the land users have to inform the hunters before they enter GM area. One says that it is hysterical that the hunter must wash their boots, when it is allowed to have 0.5% of GM crops in non GM crops. One land user noted that one might be able to tell the hunters how to behave in GM areas, but the same kind of control was not possible to have on the wild animals (birds and deer etc.)– their movement cannot be limited.
8 (Manure)	9	0	
8 (Cleaned machines)	3	6	This demand was the one to which most of the land users had objections. Some said it was totally unrealistic – others found it hysterical that there was a demand to clean the agricultural machinery. Some said it was not possible to clean a machine entirely and some said they didn't want to spend the time doing it. A land user made the comment that cleaning the machines actually was 'Good Farming Practice', because of the spread of diseases, which commonly happened via the machines, but as we can see most of the growers do not do it anyway. One land user said he thought this demand would be the one, which stopped the growing GM sugar-beets.
9 (Separation of seeds)	8	1	The land user felt it was inconvenient to separate the seeds.
10 (Bolters)	6	3	The growers felt this demand was inconvenient and time consuming. They would have to bring a wagon to put the bolters on, and transport these away from the fields to destroy them elsewhere. Another land user did not take the demand seriously and said he would just leave the bolters on the field – as he used to do.
11 (Separating GM beets)	7	2	It is very inconvenient to separate the GM sugar beet frrom the non GM beet. A land user said that it should not be possible to grow both GM and conventional beets at the same holding – you have to choose.

Source: Based on comments from land us ers on the proposal of the rules for growing GM-sugar beets 2004 middle-sized holdings specializing in sugar beet production, and with a certain fragmentation due to ongoing adjustment of an increased size of holdings within the existing property conditions but without any structural revisions, (e.g. in the form of reallotments). It is concluded that within this agricultural structure implementation of the precautionary principle in the form of a durable co-existence of GM and non-GM sugar beet in Denmark cannot realistically be based only on rules for co-existence to be implemented within a framework of 'good farming practice'. A more detailed control of GM producers and/or a clear economic responsibility of GM producers for the eventual contamination of non-GM sugar beet seems necessary. However, one of the problems of such a detailed control will be the discrepancy in the view of the farmers between the control measures of the farmer's care and the risk of contamination due to uncontrollable natural factors. Thus, although dissemination of GM seeds from the boots of hunters in principle can be prevented, meticulousness in this respect is not realistic when confronted with the fact that it will never be the case with cloven-footed animals.

Additional studies on the fragmentation of agricultural holdings in Denmark seem to be an important part of further studies of co-existence, since the degree of fragmentation strongly influences the amount of borderlines between the holdings, the number of involved neighbours and the agricultural area involved in the planning of co-existence.

In addition, changes in the structure and management of agricultural biotopes will influence the risk of uncontrollable dissemination of GM crops, and may be a way to alleviate the contradiction between the degree of uncontrollable contamination risk and the claim on rigorous implementation of co-existence within 'good farming practice'. The dissemination at the landscape level is, however, a complicated matter that will need much systematic landscape ecological research to investigate. Thus, in the Danish debate on experience with co-existence, the cutting of field divides and road edges has been emphasized to prevent dissemination of certain GM plants, such as GM-grass and rape (Boelt, 2004). However, an increased plantation of hedgerows and to a minor degree the use of demarcations crops will also reduce the level of pollen dissemination, including dissemination from eventually overlooked sugar seed stalks. This has, for example, been a major issue in the Austrian debate on ecological research related to co-existence (Müller, 2004).

Alternatively, the establishment of GM sugar beet zones outside or in the periphery of the major sugar beet production regions in Denmark could be proposed referring to the precautionary principle as an argument in relation to the European Union.

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