

## **ECOGEN Final Report**



# ECOGEN Final report

## Introduction and Summary

By

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# Introduction to the ECOGEN project

The soil environment is a recipient and a resource subject to agricultural activities including conventional farming practise elements such as pesticides, tillage practices and crop types. The introduction of genetically modified (GM) crops calls for an ecological and economic assessment in particular as the consequences of this technology cannot be predicted from conventional technologies. The soil biodiversity cover a broad range of taxonomic groups each requiring specific expertise and experience and soil organisms perform a multitude of functions that all together creates a complex ecosystem. The ECOGEN project included main taxonomic groups and decomposition of organic matter as its main focus for the ecological investigations of GM cropping systems.

An ecological risk assessment of the GM cropping systems and the non-GM conventional cropping system for the soil ecosystem was based on single species tests, multispecies tests and long-term (4 years) field investigations. Existing first tier ecotoxicity protocols for testing of chemicals were modified to the exposure to GM plant material and validated in a tiered risk assessment system.

When performing ecological risk assessment (ERA) it has become an established practise to analyse the hazard in successive steps or tiers, where a lower tier of low complexity and realism will lead to a higher tier of high complexity and high realism. ECOGEN has approached the risk assessment similarly, but without using a low tier test result to trigger a higher tier. Instead three tiers were employed as a full package for scientific reasons, to support a mechanistic interpretation of the highest tier field level observations by the lower tier observations. Furthermore, a lower tier allows for asking more questions, i.e. inclusion of many more factors, than higher tier levels due to lower costs.

The objective of assessing the ecological and economical impact of GM cropping systems was achieved by establishing a field experimental infrastructure at three locations including GM and non-GM farming systems. They were located in the three geographical European zones corresponding to the zones in force for authorisation of plant protection products: Zone A - North (Denmark), Zone B - Centre (approximated by a Northern France location), Zone C - South (Mediterranean South France). Soil biodiversity responses were detected mainly from tillage practices, soil types, crop type and history, pesticides and the maize variety.

The economic approach taken for evaluation of the costs and benefits of introducing GM crops in Europe was to distinguish between cost and benefits that would be temporary (reversible) and of a long-term nature (irreversible), i.e. a *real options* approach. The real option makes it possible to consider long-term effects of GM crops in an economic analysis. In the context of transgenic crops where people are more concerned about the uncertain irreversible costs of the technology, threshold values that indicate the maximum incremental social irreversible costs (MISTICs) that an individual or society in general is willing to tolerate for the sake of the benefits of the technology can provide useful information. It was then investigated when incremental irreversible costs would exceed the MISTICs at national, farmers and *per capita* EU level.

Facing the problem of reaching a decision based on knowledge originating from disparate scientific domains a multi-attribute decision support model comes in handy, as it inherently

has no restrictions on the nature of the knowledge being build into the model, as long as the knowledge about the system can be broken down into attributes and the attributes can be given qualitative symbolic values that influence aggregate system properties. The evaluation of cropping systems is suitable for multi-attribute modelling, because it deals with scenarios, which need to be evaluated, analyzed and compared with each other. And a cropping system can be decomposed into smaller, less complex elements, for which relationships between factors can affect the evaluation of the scenarios. The ecological knowledge from single species tests, multispecies tests, field investigations and economic information from farming practices was conveyed via the domain experts to the computer scientists building the rule based model to be used for predictions of economic decision-making processes and ecosystem behaviour.

The ECOGEN project organisation proved to be successful probably because the elements in the organisation: the Work packages reflected well the main goals as broken down into the WP's and because these goals were very clear from the beginning. The conceptual model of the project combined economics, agronomics and ecotoxicological risk assessment approaches with a modelling enterprise using data mining and decision support. The underlying field studies were conceived as a real world base and infrastructure upon which the scientific analyses and interpretations were building.

# Summary

The ECOGEN project addressed soil ecological and economic questions concerning the introduction of GM crops to European agriculture. It consisted of:

- soil ecological evaluations of GM maize productions systems at three levels of biological organisations: single species, model communities and field ecosystems,
- socioeconomic evaluation of the benefits and costs of *Bt*-maize and HT-maize at farm level and national level for selected EU member states,
- decision support to aid in concomitant economic and ecological factor valuation by employing a qualitative multi-attribute decision support tool.

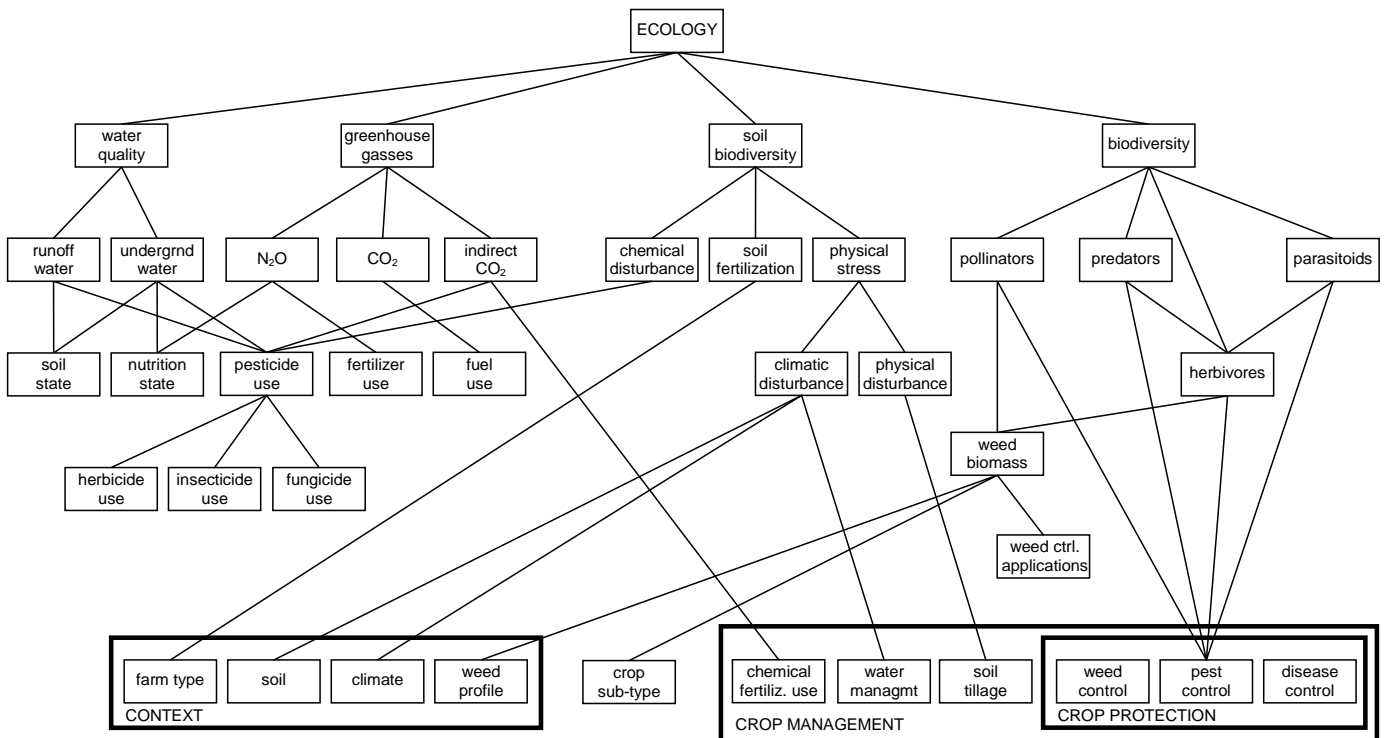
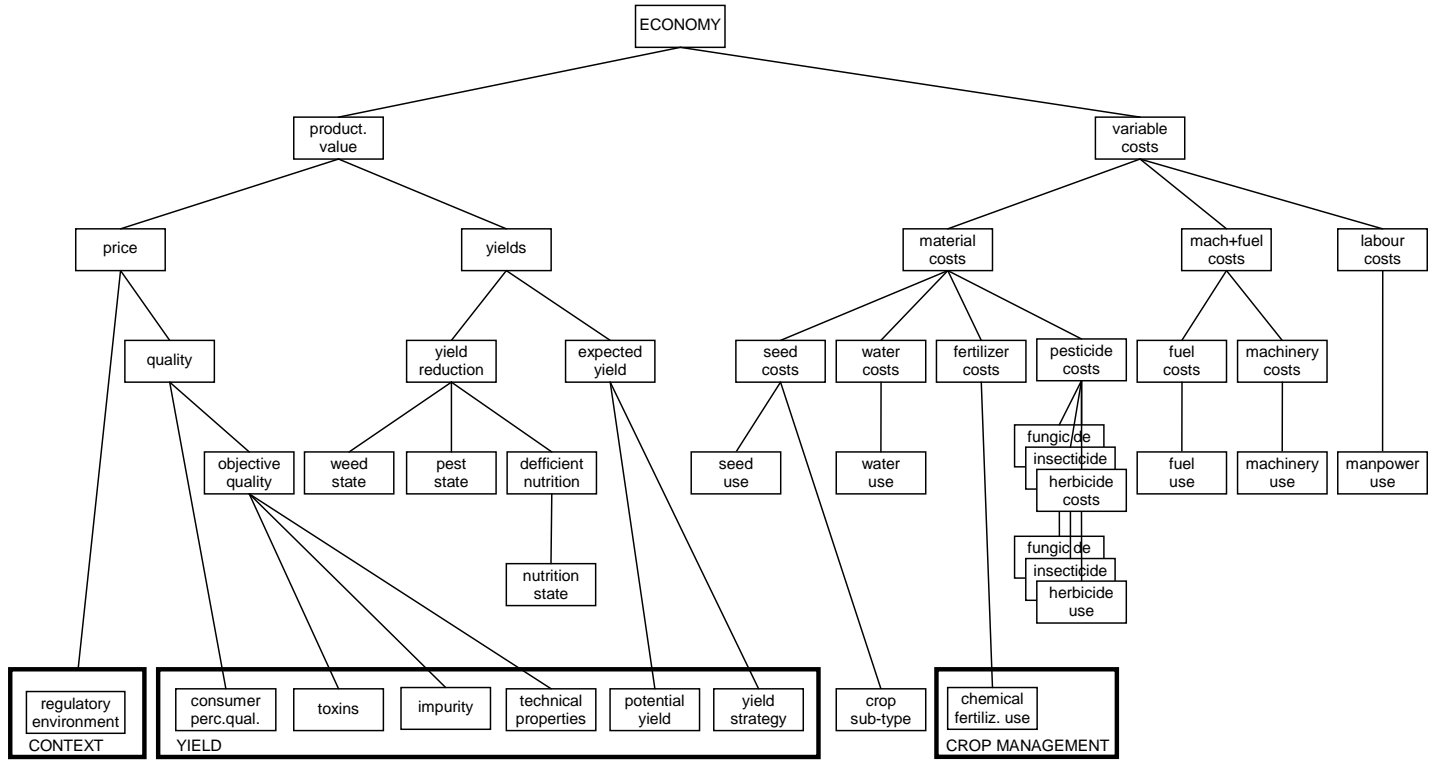
A field experimental infrastructure was established to provide the project participants with agricultural management data, experimentally designed comparisons of farming systems and economic data. The field studies were situated in each of the three geographical European zones as used for the authorisation of plant protection products: Zone A - North (Denmark), Zone B - Centre (approximated by a Northern France location), Zone C - South (Mediterranean South France).

The existing first tier ecotoxicity protocols used for testing of chemicals were modified to fit the exposure to GM plant material. A wide range of taxonomic groups covering Acari, Oligochaeta, Collembola, Protozoa, Nematoda and Mollusca were investigated for direct sensitivity to *Bt*-toxin both in pure chemical form and in the plant biomass of maize in first tier lab screening tests. These tests did not reveal effects of *Bt*-toxin and *Bt*-maize, while insecticides selected from the pesticides used in ECOGEN field study sites, would have effects on soil invertebrates. The microfauna was not affected by the pesticides at levels around field application rates. The tier one overall conclusion is to expect higher impact from insecticides than from *Bt*-maize on soil invertebrates.

Mesocosm model systems were employed as a middle tier approach with the benefits of including soil ecological complexity and green-house control of experimental condition. Field relevant factors such as soil type, pesticides and a range of *Bt*-maize varieties compared with their near isogenic non-*Bt* were studied. The largest effects observed were from the soil type and plant growth stage. The GM variety tested had effects on soil populations and processes that were less pronounced than pesticide effects. Comparison between *Bt*-maize and near-isogenic *Bt*-maize did not reveal general trends pointing to adverse or beneficial effects of *Bt*-maize to soil organisms. In particular when comparing a range of varieties of *Bt*-maize and near-isogenic *Bt*-maize it was demonstrated that there were no detectable differences in the concentration of *Bt*-toxin in plant or soil with any of the *Bt*-expressing varieties. Although soil nematodes and microbial community structure differed between maize varieties, these could not be related to the *Bt*-trait.

An extensive soil ecological field sampling programme was running throughout the project life for soil microorganisms (Bacteria), microfauna (Protozoa and nematodes), mesofauna (Collembola, mites, enchytraeids) and macrofauna (earthworms). For all major groups of soil organisms we observed no differences of *Bt*-maize that were greater than differences caused by season, soil type, tillage practice or cultivar. Effects observed in the glufosinate-ammonium herbicide tolerant maize is interpreted as stemming from the application of the Basta herbicide, which was observed for Collembola and earthworms. Concerning the de-

Figure 1. The hierarchical structure of the comprehensive economy and ecology multi-attribute decision support model for evaluation of cropping systems. The model included economic, agronomic and ecological knowledge as conveyed via domain expertise of ECOGEN experts.



composition of organic matter as studied using a straw-litterbag methodology *Bt*-maize had no negative effect on the decomposition on any of the three locations.

With herbicide tolerant (HT) crops reduced tillage is made agronomically more acceptable because the efficiency of broad spectrum herbicides does not require the assistance of tillage for weed-control. We found higher faunal abundances in reduced tillage both in *Bt*-maize and in HT-maize; however this outcome depends on the actual reduced tillage system, so we found dramatic reductions in earthworms when the system consisted of omitting the autumn ploughing, while retaining vigorous superficial soil cultivation in spring.

The soil ecological evaluations at three levels of biological organisations: single species, mesocosm model communities and field ecosystems produced specific conclusion at each level of complexity:

- Soil organisms held singly in lab cultures did not respond negatively to neither pure *Bt*-toxin or maize plant material containing *Bt*-toxin.
- Mesocosm experimental test systems responded mainly to properties of maize varieties other than the *Bt*-toxin and to pesticides.
- Soil biodiversity field responses were detected mainly from tillage practices, soil types, crop type and history, pesticides and the maize variety.

The two upper tier levels did not correspond well with the first tier level, so a triple strategy is suggested when assessing the impact of GM plants befitting from the strength of each level in understanding and predicting field level effects.

Socioeconomic evaluation of the benefits and costs of *Bt*-maize and HT-maize at the farm level and national level for selected EU-15 member states generated crucial conclusions important for EU agricultural policy:

- The economic analyses indicated that the EU corn growing farmers would forego direct economic benefits in the area of 150 million Euro per year by the postponement of a full introduction of *Bt*-maize. Based on the ECOGEN analysis of impacts of *Bt*-maize and HT maize on soil biodiversity, we conclude that the direct economic benefits are likely to be high enough to compensate for possible irreversible costs of full introduction. Further delay is, therefore, not warranted.
- The decision by the European Commission to postpone further approvals of GM crops until labelling and tracking systems for GMOs were in place and coexistence rules established can be considered a wise decision albeit this decision came at high economic costs.
- From a purely economic perspective there might have been a social gain in waiting to adopt *Bt*-corn until more information was gathered to reduce the uncertainty associated with reversible net-benefits of private consumers.
- The introduction of *Bt*-corn and HT-corn does only generate small economic benefits on a per capita level. This can explain why many consumers in the EU do not favour GM crops.

The complex of economics and ecological factors involved in assessment of cropping systems including new technologies such as GM crops were handled and integrated by a qualitative multi-attribute decision support model (Figure 1). The model was based on domain specific knowledge from ECOGEN experts and used for assessment at the farm-level of GM and non-GM maize crops. Cropping systems were defined by four groups of features: (1) crop sub-type, (2) regional and farm-level context, (3) crop protection and crop management strategies, and (4) expected characteristics of the harvest. The impact assessment of cropping systems was based on four groups of ecological and two groups of economic indicators: biodiversity, soil biodiversity, water quality, greenhouse gasses, variable costs and production value. The

evaluation of cropping systems was governed by rules defined by domain experts and used by modellers to build a rule based model aiding the economic decision-making processes and predicting ecosystem behaviour. When the ecological knowledge from single species tests, multispecies tests and field investigations from maize cropping systems was conveyed via the domain experts to the computer scientists, it was obvious that chemical disturbance, soil fertilization and physical stress was paramount in determining soil biodiversity. In an overall practical assessment of the ecological and economic outcomes the model ranked cropping systems in the order: organically managed > GM systems including Bt and HT traits > conventionally managed maize.

The ECOGEN results were communicated to stakeholders from industry, governmental advisors, national and international competent authorities, agricultural institutions and the scientific community. The organisations receiving information created by the ECOGEN project included: EFSA, Monsanto Europe S.A., Bayer Cropscience, Arvalis France, CETIOM France, Austrian UBA (Umwelt Bundes Amt), Danish Forest and Nature Agency (competent authority), SCIMAC UK (The Supply Chain Initiative on Modified Agricultural Crops), IOBC/WPRS, The VERDI project, Switzerland (supported by European Science Foundation and Swiss National Science Foundation), the BEETLE project, BVL Germany (supported by EU Commission, DG Environment).

## **Acknowledgements**

The ECOGEN project was supported by the EU RTD Quality of Life Programme; contract QLRT-2001-01666. We thank Monsanto Europe for supplying maize seeds. We acknowledge the following entities for their collaboration and support: SIGMEA (EU contract no: 501986), Bayer Cropscience, Arvalis (France), CETIOM ( France), Austrian UBA (Umwelt Bundes Amt), Danish Forest and Nature Agency (competent authority), SCIMAC UK (The Supply Chain Initiative on Modified Agricultural Crops), Bernard Lacroix, Association Générale des Producteurs de Maïs (AGPM). The late Nicole Poinot-Balguer and Christian Kampichler (UJAT, Tabasco) is thanked for participating in the initiation of the project beginning in year 2000. Members of the ECOGEN Steering Committee: Helmuth Gaugitsch, The Federal Environment Agency, Austria; Daniel Pearsall, Supply Chain Initiative on Modified Agricultural Crops (SCIMAC); Per Henriksson and Judith Rylott, Bayer Cropscience; Yelto Zimmer, KWS AG plant breeding company; Gösta Kjellson, GMO Risk Assessment Unit of the National Environmental Research Institute, Denmark, Francesca Tencalla and Silvia Fernandez, Monsanto Europe. SCRI received grant-in-aid from the Scottish Executive Environment and Rural Affairs Department. IJS received support from the Slovenian Research Agency programme Knowledge Technologies (2004–2008).