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Development of Environmental Indicators for Monitoring of Genetically Modified Plants

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Summary

In the last decade environmental monitoring is of increasing interest to provide politicians, stakeholders, decision-makers and the general public with information needed to design an adequate environment policy. Some experience is already gained in the field of technical and chemical based surveillance of environmental impacts and levels of pollutants. To observe the current state of the environment and to survey changes in environmental conditions, nowadays also the consideration of biotic aspects is required. A common approach for long-term monitoring is to design sets of indicators, thus various initiatives are preparing indicator based monitoring concepts.

One outstanding achievement in the international environmental debate was the adoption of Agenda 21 during the Earth Summit in Rio in 1992. The Agenda 21 is a comprehensive plan of action to be taken globally, nationally and locally by organisations of the United Nations System, Governments and Major Groups in every area of human impact on the environment. Chapter 40 of the Agenda 21 calls for the development of indicators for sustainable development. In particular, it requests governmental and non-governmental organisations at the national and international level to develop the concept of indicators of sustainable development in order to identify such indicators.
In response to the Agenda 21 the EU adopted the directive on Environmental Indicators and Green National Accounting (COM (94) 670 final) as a framework and a request for a further development of indicators.

Also in the field of biotechnology and genetic engineering an environmental surveillance is requested by the EU. With the adoption of the amended directive 90/220/EEC ‘on the deliberate release into the environment of genetically modified organisms’ (directive 2001/18/EC) in March 2001 a monitoring of the environmental effects of the release of genetically modified plants will be needed from 2002 onwards. Member states are requested to develop appropriate concepts to ensure a general surveillance for unanticipated adverse effects and, if necessary, case-specific monitoring focusing on adverse effects identified already.

Already during the last years the German Federal Environmental Agency initiated some basic research on monitoring of the deliberate release of genetically modified plants. In 1999 two complementary approaches to prepare a monitoring concept were taken:
One research project took adverse effects of transgenic plants as a starting point. Within that project ‘Conceptual development of a long-term monitoring of genetically modified plants’ (FKZ 299 89 406), already identified effects, but also subsequent and potential effects are evaluated. The respective monitoring concept will be based on parameters.
As several environmental indicator sets were launched nationally and internationally in the past, the German Federal Environmental Agency decided to complete the bottom-up approach mentioned above with a top-down approach to assess, if already existing concepts could be adopted for a monitoring of genetically modified organisms. The aim of this study is to evaluate, if indicators of existing sets of indicators could also be used for an environmental monitoring of effects of the agricultural use of transgenic plants. It is to avoid to design a new set of indicators whilst others are available and potentially suitable.

The present study starts with some general considerations on the use of indicators for an environmental monitoring. The potential of indicators is examined as well as expectations in indicators are looked at.
Six international and five German proposals for environmental indicator sets are evaluated regarding their aims, their conceptual background and especially the proposed indicators.
The following indicator sets and concepts are evaluated:

- proposals of environmental indicators by the OECD
- proposals of indicators of sustainable development by the UN Commission on Sustainable Development
- proposals of indicators to assess Biological Diversity in the framework of the Convention on Biological Diversity
- proposals of Environmental Pressure Indicators and Environmental Headline-Indicators by the EU
- indicators used by the European Environmental Agency for the Environmental assessment report in 2000
- a proposal of Environmental Headline-Indicators by the European Environmental Bureau
- proposals of environmental state indicators for an economical and ecological national accounting in Germany (especially suggestions for an Ecological Area Sampling)
- points of the German concept for an integrated environmental monitoring (ökosystemare Umweltbeobachtung)

- a proposal of indicators for the assessment of agricultural impacts on the environment (UFOPLAN 297 81 139)
- a proposal of indicators by the Commission of Inquiry of the German Parliament 'Protection of Humans and the Environment' ('Schutz des Menschen und der Umwelt')
- indicators of sustainable development concerning bt-corn proposed within a risk dialogue by Novartis AG, Foundation Risk Dialogue (Stiftung Risikodialog, St. Gallen, Switzerland), Austrian Ecology Institute (Österreichisches Ökologie-Institut) and the Institute for Applied Ecology (Öko-Institut e. V.).

For the indicators suggested in these proposals and concepts it is assessed if they could serve as well as indicators for a monitoring of genetically modified plants. They are analysed regarding their potential suitability to reflect effects of the deliberate release of transgenic plants in agriculture. Besides the direct application it is evaluated if modifications or additions would be needed.

For some of the selected indicators a more detailed assessment is done. Taking 'pesticide use' as an example, the possible use and the capacity of the indicator are evaluated. Some additional suggestions for a practical adjustment are made. Further indicators are proposed.

To discuss this approach and the preliminary list of selected indicators with experts involved in the national and international indicator discussion a workshop was held in January 2001 in Berlin. The possible practical value of indicators already proposed was discussed as well as their expressiveness. To evaluate the actual possibilities to use indicators from other sets for a monitoring of transgenic plants or to integrate additional relevant indicators in existing systems an overview on international and national environmental indicator concepts was given.
This led to a discussion on the indicator approach as such and especially to a discussion on an indicator approach to monitor effects of genetically modified plants.

Results:
International suggestions for a monitoring have to work on themes with a world-wide relevance. Consequently international sets of environmental indicators have to be suitable to reflect effects in a broad range of various ecosystems and of very different agricultural systems and practice. Therefore they can not be adopted to every possible special issue but have to provide a general overview.

For several years a process of identification and implementation of environmental action targets is ongoing. For the abiotic sector agreements on targets are partly found and some action targets are implemented even legally. Based on clear and agreed environmental action targets the development of specific indicators is possible.
For several abiotic environmental phenomena a clear indication is feasible by few indicators, based on data, comparatively easy to sample.
On the other hand there is incomplete knowledge and data to establish trends for some other areas. Especially concerning biodiversity, habitats and landscape, the knowledge and measurement of impacts is still at a preliminary stage of research. International standards and agreed action targets are still under preparation. Besides others this is due to a very controversial, partly ethical debate on values and baselines.

To assess biotic aspects and trends within the biotic compound of the environment a broad set of indicators is needed to reflect the complex set of interactions and interdependence within biological systems.
The capacity of indicators to monitor trends in biodiversity was questioned during the workshop.

Presumably as a result of the uncertainties in designing a sound monitoring on biotic aspects, very often international sets of indicators are incomplete or claim problems to assess biotic aspects. Whilst for several years chemical and technical data are already sampled continuously for an environmental long-term monitoring, such an approach is still missing for a large-scale biological monitoring.
Just two of the German proposals under consideration, the Ecological Area Sampling (Ökologische Flächenstichprobe) and the concept for an integrated environmental monitoring (ökosystemare Umweltbeobachtung), suggest reporting systems to provide regular and reliable information on trends and states in the natural environment.

Sets of environmental indicators developed in the international context refer to issues already identified and accepted as problematic.
Biotechnology and genetic engineering are rather new technologies. There are several data and hints both from laboratory and field trials, that unintended effects could occur by the agricultural use of transgenic plants. But there is no exact and complete knowledge or documented experience on effects to expect by a large-scale release of genetically modified plants. Besides this lack in knowledge there is a deficiency in data, to be the basis for a development of relevant indicators. This situation may be one reason why all of the evaluated international sets of (environmental) indicators were drawn up regardless of possible effects by the agricultural use of transgenic plants.
As long as there is no particular development of indicators and as there are no suggestions for indicators reflecting possible effects of genetically modified plants, such information could possibly be provided by other indicators. Probably indicators drawn up in another context could be adopted for this additional purpose.

Is such a transfer an adequate means?
It should be held in mind that an ideal indicator is an indicator with a clear relation to a question to answer. It would be perfect, if an indicator could be integrated in an evident and certain relation between trigger and effect. For an adoption of an indicator for an additional purpose this ideal criteria remains the same.

Looking at indicators proposed for an environmental monitoring it is striking, that rarely aims, assessments done to select the indicators, the significance of a single indicator in a set of indicators or reference values are given. Given selection criteria are mainly pragmatic aspects. However, normally indicators are chosen following several criteria and aims – although they are not always presented in a transparent way.
For indicators, accompanied by selection criteria or even reference values, the question of transferability would be easy to assess.

If a limited set of indicators should represent several themes, a certain degree of aggregation cannot be avoided. Main purpose of such aggregations is to communicate detailed information to an audience that requires condensed,

“simplified” information. During the process of aggregation some links or precise information may be lost. As a consequence indicators (and especially biological indicators) can not always be related to a specific cause. For such a clear relation between cause and effects there is often a need for additional information, especially as biological phenomena often can have diverse causes.

One aim of an indicator approach is an aggregation on the national level. Phenomena will be reflected as soon as they show a large-scale occurrence or a regional but massive appearance. The evidence of local or regional effects will be statistically ‘diluted’ if data are aggregated over vast areas. Simultaneously the number of possible reasons for the tracked effects is raising.

Indicators have to meet pragmatic criteria to be accepted. Indicators have to be simple, unambiguous, easy to assess and affordable with (very) limited means. Sets of indicators should be as small as possible which leads to high levels of aggregation. Indicators have to simplify complex circumstances and facts, as they aim at the description of general tendencies. This reduction to a simplified indicator is made regarding the specific needs the indicator originally is developed for. To adopt indicators to a new context it is necessary for each indicator to evaluate, if the reduction of a complex system to a single indicator is appropriate to the new context too.
Looking at ecosystems with their diverse interactions and interdependencies an aggregated indicator can hardly provide clear and unambiguous messages. Only a set of indicators may have the potential to reflect such complex systems in an adequate way. As a consequence each indicator has to have its exact and meaningful place and function in such a set. Thus sets of indicators can not be an accidental collection of indicators available.

The detailed examination of the sets of indicators mentioned above revealed 130 indicators possibly relevant to monitor effects of transgenic plants within agricultural systems. Several of the proposed indicators are very similar.
None of them has the potential to serve immediately as an indicator for a monitoring of transgenic plants. For such a monitoring a modification or specification of the indicators would be needed.
There are few indicators right to show direct effects of the use of transgenic plants. Mostly the indicators are suitable for a general assessment of impacts and trends. Partly they could provide essential background information to explain phenomena. Some indicators (especially agri-environmental indicators, e.g. ‘pesticide use’) are more likely to contribute to an evaluation of some frequently promised positive impacts of the agricultural use of transgenic plants (e.g. reduction of pesticide use).

By using the indicators suggested up to now, no complete reflection of the ecological and environmental impact of the commercial use of transgenic plants in agriculture would be possible. Partly this is due to the lack of knowledge and subsequently the lack of indicators regarding biodiversity and biological phenomena. Most of the effects expected to be likely by the use of transgenic plants in agriculture are in the biological area. Consequently the very preliminary stage of the indicator discussion concerning biotic aspects has a remarkable impact on the process of developing indicators for monitoring effects of biotechnology and genetic engineering.

In addition a much broader set of indicators is required for the field of biodiversity than for others, which hampers the finding of an appropriate set of indicators and the building of a consensus on these indicators.

Up to now there are no proposed indicators suitable to monitor effects of transgenic plants in general but only to monitor effects of some species or of specific changes. None of the indicators allows to associate beyond doubt an effect reflected by an indicator with a transgenic plant as the single possible cause. Thus there is always the need for additional information to try to assess if changes or variations in the indicator values are related to the release of genetically modified plants or to some other reasons.

Looking for implemented or at least widely accepted and agreed concepts of sets of environmental indicators it turns out that there are no such sets yet. As a consequence actually no already ongoing survey by indicators is available to be used for monitoring effects of genetically modified plants.
There are still several sets of (environmental) indicators under development and discussion, e.g. the environmental indicators of the OECD, indicators of sustainable development of the UN Commission on Sustainable Development, indicators to assess Biological Diversity in the framework of the Convention on Biological Diversity or environmental pressure indicators within the EU. As the development of these sets is ongoing, there may be the chance to integrate some additional aspects into this process. This may be one starting point for a monitoring of effects of the release of genetically modified organisms into the environment.

In addition, this open situation offers the opportunity to define the expectations towards a long-term monitoring of genetically modified plants, which also meets the requirements of a general surveillance as included in the new directive 2001/18/EC. It is to consider which of the expectations towards the monitoring should be met by an indicator approach.
Thereby it is to bear in mind, that indicators are a means to provide ‘easy’ information by the condensation of information, which implies a loss of detail.

For a development of new indicators it is to determine the case in question, the aim and the target group. Normally the starting point are effects. On the basis of a selection of data on these effects, indicators are derived, considering general action targets. As soon as indicators are defined, specific target values can be discussed. The basic criteria used for the selection during the whole process of developing indicators should be documented.
Sets or even systems of indicators help to describe general tendencies and should allow an (early) warning. However the possibilities for drawing conclusions on basic causes are limited. To provide information on complex interactions and situations it may be worthwhile to design a monitoring based on hypothesis and anticipated effects. It would be very welcome if these could be linked to indicators. But as indicators aims on a description of general tendencies and can not provide detailed information or even an analysis, an indicator approach can probably be only one part of a monitoring which should include aspects of a general and a case-specific surveillance (see other conceptual approaches mentioned above).

In the course of the workshop it occupied a large part of the discussion, which scale of a survey would be suitable.

There were many voices emphasising to start a monitoring by a regional, farm-scale census of data and to build indicators by data of representative farms. But a wide-ranging, detailed survey could probably only be put into practice for a test phase. It was named to be impossible to implement such a system on the long run in terms of limited means. On the other hand the idea was mentioned to impose the duty of data collection whenever a farmer cultivates transgenic plants.
Already now farmers are obliged to keep a record of their pesticide use for instance. But in accordance with the legislation in force (data protection) there are no possibilities to utilise those data for an analysis. To use these data, they have to be anonymisated. This hinders finding relations between agronomic and environmental data.
As up to now farm-scale census approaches were limited to regional and temporary test projects and not part of nation-wide or international proposals for indicators no such proposals were evaluated within this study. But to develop a concept for monitoring impacts of the release of genetically modified plants in agriculture the consideration of those projects sounds useful.

Looking at farm-scale approaches during the workshop it was emphasised, that a monitoring of the use of transgenic plants in agriculture could not been done without considering the cultivation practice as a whole. The idea came up to implement a large-scale agricultural monitoring, covering all farmland area and not just to implement a specific monitoring of transgenic plants.
Regarding this suggestion it is to consider that by a ‘traditional agricultural monitoring’ not all possible effects of all transgenic plants could be covered. On the one hand there are plants with transgenic modifications leading to changes in agricultural practice (e.g. herbicide resistance). Those changes in agricultural practice could be reflected by an agricultural monitoring whilst ecological side effects can still stay undetected. On the other hand there are transgenic plants with an alteration of metabolic pathways or the capacity of producing new compounds. For such transgenic plants impacts on other organisms or the food-webs are expected. Those would not be reflected by a purely agricultural monitoring. A monitoring of ecological and biotic aspects would be needed in addition.
It is not to expect, that environmental effects of transgenic plants will be restricted to the area under cultivation. Consequently a corresponding ecological monitoring should cover a wider area.

The study reveals potential capacities and limits of an indicator approach for a monitoring of impacts of genetically modified plants used in agriculture.
At present none of those indicators included to the evaluated national and international proposals of sets of (environmental) indicators could be suggested for a direct adoption to monitor effects of transgenic plants.
For a future development of indicators as well as concerning the co-ordination with those bodies already involved in the development of environmental indicators, several starting points and clues are shown.