Exploring the Future of Ecological Genomics

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Abstract

Interactive approaches to technology development provide opportunities for the development of innovative technologies which clearly connect with social practices and address the positive and negative effects as perceived by relevant actors. The challenge for the development of new technologies is to start an interactive approach already in an early phase. At that point, many options are still open for exploration and there are good possibilities for steering. Early involvement of societal actors is, however, challenged by the absence of concrete applications on which they can develop their own visions from the perspective of their own needs, interests, norms and values. Interactive vision assessment is proposed as an approach to overcome this dilemma in the field of ecological genomics and bridge the knowledge gap between parties involved with ecogenomics research and other relevant actors. We present and discuss the process of identifying guiding visions of the technology developers as a first step in this approach and end with some suggestions on how desirable futures for ecogenomics can subsequently be assessed from the perspectives of different actors.

1. Introduction

Ecological genomics, the application of genomics techniques in the field of (soil) ecology (hereafter called ecogenomics), is now emerging as one of the latest branches on the genomics tree. In the field of ecogenomics, a genomics-based approach is used to enhance our understanding of the functioning of ecosystems, in order to unlock their full genetic potential for sustainable use of ecosystems for agricultural and other anthropogenic purposes[1]. The Ecogenomics Consortium that has been established in the Netherlands in 2003 pursues these goals with respect to soil ecology. Besides scientific activities in the fields of ecology, microbiology, soil sciences, biotechnology and bioinformatics, the Consortium also comprises research projects on the societal aspects of ecogenomics. The research we describe in this paper is conducted as part of this latter sub programme. Since modern science and technology is known to have both positive and negative societal effects (e.g. in the case of modern biotechnology and genomics), the challenge for a new scientific field, such as ecogenomics, is to realize its societal promise in a generally accepted way – i.e. seizing opportunities by means of active reflection upon societal aspects. The question for the scientific field however is how to actually realize these aims. How

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could scientists interact with relevant actors in order to identify future opportunities and threats?

Empirical research has indicated that interactive approaches to science and technology development provide a promising alternative in realizing a better societal embedding (Gibbons, Limonges et al. 1994; Rip and Misa 1995; Grin, van de Graaf et al. 1996; Schot and Rip 1997; Fuller 2000; Nowotny, Scott et al. 2001). Central to interactive approaches is the recognition that technologies and their effects are produced by various interested groups in society. Bringing in a broader range of actors into the innovation process will, therefore, most probably change the outcome of decisions and, thus, influence the process of variation and selection. This supposedly leads to the development of better, more widely acceptable, innovations.

Involving relevant actors in an early phase of innovation processes appears to have the greatest advantages for developing technologies that clearly connect with social practices and address the positive and negative effects as perceived by the actors involved. In an early phase of technology development many options are still open for exploration and there are good possibilities for steering. There are however uncertainties about the positive and negative societal effects the technology will bring about in the future and social attention is rather weak. This has been described as the Collingridge dilemma of control (Collingridge 1981).

Seventeen exploratory semi-structured interviews with actors outside the Ecogenomics Consortium, including industry, policy makers, advisory councils and NGOs, illustrated the early phase ecogenomics is currently in. The interviews with societal actors pointed out that they are hardly acquainted with ecogenomics. Some never heard of the term, while others vaguely heard of the Consortium, but had no idea about its work and goals. The role soils play in the different practices of the actors (e.g. policy making on soil use, environmental issues, nature development, traditional and organic agriculture and soil remediation), and the preliminary ideas about what ecogenomics could contribute in the future differ greatly. The interviews illustrate the early phase ecogenomics is currently in. There are some ideas about ecogenomics and its implications among societal actors, although they had (almost) never heard of the term ‘ecogenomics’ before. The ecogenomics approach triggered a lot of perspectives and actors clearly showed an interest in the topic. Interviewees also specifically expressed the need for more concrete visions of the technology to reflect upon. This indicates that more input about what the future possibilities of the technology are, will probably bring the discussion about societal aspects of ecogenomics and desirable directions a step further.

Rip (2001; 2002) states that when technology assessment addresses technologies in their early phases of development, visions of the future are necessary in order to stimulate learning about possible impacts and to orient future actions. However, the use of technology foresight methods as a component of technology assessment in an early stage of innovation is currently underdeveloped. In our research we chose to combine the interactive approach to the innovation processes in the field of ecogenomics with the approach of vision assessment. In the next section we will elaborate upon the methodological aspects of interactive vision assessment. Subsequently we will describe the first step in this process, in which guiding visions of the technology developers were constructed. We will end with some suggestions on how to further apply an interactive approach to scientific developments in the field of ecogenomics.

2. Interactive vision assessment

With applying an interactive approach in the case of ecogenomics we aim at reflective analysis and deliberation among actors already in an early phase of science and technology development. Focusing on future ecogenomics applications implies that the interactive approach aims at the orientation of future actions. In the past, different approaches to exploring the future have been developed. These approaches relate to what kind of future is explored. The first approaches to investigating the future focused on extrapolating current trends into the future and aimed at predicting *probable* future developments. The analysis of *possible* futures is central in most scenario approaches, which aim at broadening the scope of expectations. A third way of investigating the future is to think about *desirable* futures from the perspective of different actors. These approaches have their origin in the German 'leitbilder' tradition. In the research described in this paper we focus at assessing desirable futures for ecogenomics from a wide variety of perspectives.

Departing from the 'leitbilder' tradition, Grin and Grunwald (2000; 2004) proposed vision assessment as a way to achieve reflective analysis, contribute to societal learning processes and to provide orientation for future acting. Visions can be described as mental images of attainable futures that are considered desirable and shared by a collection of actors. These images guide the actions of, and the interactions between, those actors. The guiding function of visions implies that actively shaping these visions with the different actors might guide us towards desirable futures. Creating shared visions among actors requires learning about the assumptions underlying ones own and others' visions. Uncovering these assumptions is a prerequisite for constructively assessing visions and orient future actions.

Interactive approaches aim at assessing technologies from the perspectives of relevant actors in a learning process (Grin, van de Graaf et al. 1996). In interactive approaches, knowledge is perceived as embedded in (communicative) practices, activities and uses (Regeer and Bunders 2003). The focus on contextual analysis within vision assessment does justice to a wide variety in perspectives. It implies a process in which knowledge is co-created, and seems to offer a promising approach for the design of an interactive approach which can be implemented in an early phase of technology development.

Up till now, the experiences with vision assessment have been mainly with approaches in which the analyst has a central role in constructing visions out of discourses (Grin, Grunwald et al. 2000). Through combining an interactive approach with vision assessment, a contribution can be made that is in line with the interactive nature of these discourses and the development of visions. Furthermore, experimenting with this approach will increase our understanding of how visions of the future can contribute to the interactive assessment of emerging technologies. The question now is how this process of interactive vision assessment should be shaped in the case of ecogenomics.

3. Constructing the visions of technology developers as a first step

In the case of ecogenomics, the technology developers' visions about the future of ecogenomics are expected to be the most developed ones existing. At the moment, no other social groups are developing their own visions so far, and public awareness

is rather low. It has been argued that these visions of the technology developers could be taken as a basis for technology assessment when emerging technologies are addressed (Decker 2000). Within the research described in this paper, there are four objectives for constructing the guiding visions of the technology developers as a first step:

1. These visions are needed to identify fields of application and identify relevant actors[2].
2. Constructing these visions is important to gain insight in the ideas of the technology developers of the future and their perspectives on ways in which the technology will be used.
3. These visions are needed as input for future phases in the technology assessment in which other other actors are involved. These actors can develop their perspectives on the technology developers' visions and subsequently the different visions can be discussed and combined into one more complete and balanced vision in which a shared perspective on the technology is uncovered or constructed.
4. Constructing these visions in an interactive process aims at learning processes among the technology developers. They have a central place in the process of interactive vision assessment because they have to be committed to the process right from the beginning. After all, broadening the design of new technologies implies that technology developers need to take other perspectives into account when designing the technology.

In figure 1, the subsequent steps in which different actors are involved are visualized. Experts are the first ones with visions of the future, and therefore the starting point for constructing future visions. As a next step, users of the technology can reflect on these visions and the effectiveness of the technologies from their own perspectives and subsequently develop their own visions. Involving citizens aims at reflection upon broader acceptability of the technologies.

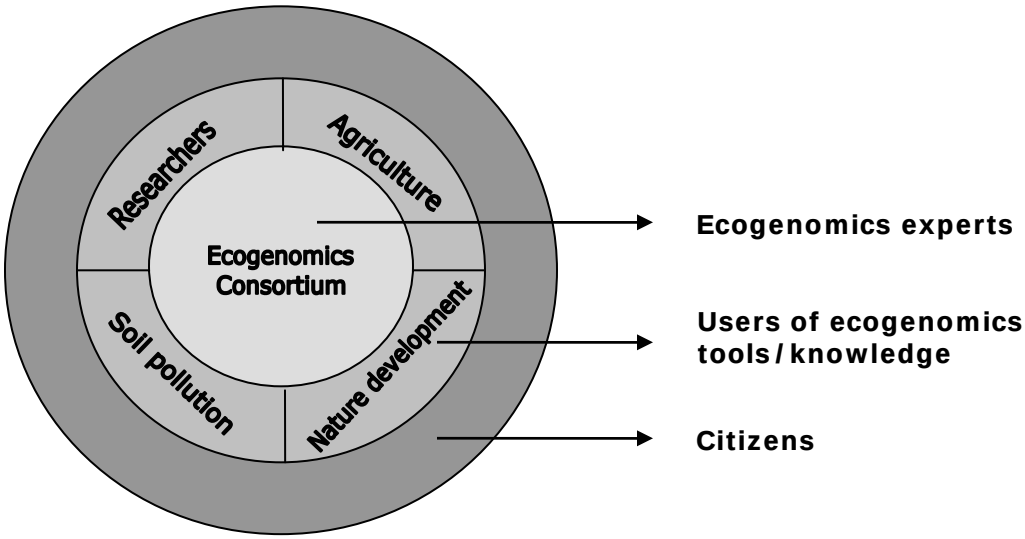

Figure 1 – The exploration of future ecogenomics developments moves in a widening societal circle.

[2]These are the actors that are considered relevant by the technology developers. This does not imply that these actors are the *only* relevant actors.

In order for the guiding visions to meet the abovementioned aims, we address the assumptions underlying the guiding visions by focussing on four central elements (Grin and Grunwald 2000):

1. The current state of knowledge
2. Purposes to be reached
3. Interpretation of the relevant contextual aspects
4. Normative premises

The current state of knowledge and purposes to be reached address ideas about solutions. The interpretation of relevant contextual aspects refers to perceptions of problems or challenges and to what is perceived as a desirable future situation. Normative premises include world views and value systems.

4. The process of constructing guiding visions

As subsequent steps in the construction of the guiding visions of the technology developers a literature study, semi-structured interviews and focus groups were conducted. Furthermore, the results of these steps were analyzed according to the elements mentioned above. Below we will elaborate on these methodological steps more in depth and illustrate them with some results.

4.1. Step 1: literature survey

As a first step, we conducted a *literature survey* of (review) articles dealing with developments related to ecogenomics (e.g. eco-toxicogenomics, soil sciences, ecology) to identify ideas about future applications of ecogenomics. Since professional literature is the medium through which scientists communicate their ideas and research results, reviewing this literature was thought to be an important first step in the construction of guiding visions of ecogenomics scientists.

The literature survey revealed information about the genomics tools used and the current state of the art, but only gave a few hints about possible applications in the future. The main goals of ecogenomics research seem to be contributing to more sustainable soil use and identifying new microbial secondary metabolites. Exactly how this is going to be achieved, with what kind of applications and by whom these will be used is not clear. This can probably be understood by the early phase of development ecogenomics is in. In current research most emphasis is put on understanding what the opportunities of genomics tools for ecology are and how data derived from these tools should be interpreted. In this rather basic stage of the research, actual applications are not yet addressed. The literature survey mainly illustrates the current state of knowledge, but does not give information about the other three elements of the guiding visions. Therefore we needed additional sources to construct the guiding visions in ecogenomics in more detail.

4.2. Step 2: semi-structured interviews

As a next step, 21 *semi-structured interviews* were conducted with members of the Ecogenomics Consortium. They were questioned about their research within the Consortium in order to gain insight in the genomic approaches they use and their

relation to the different approaches that are discussed in the literature. The interviewees were also questioned about their motives for participating in the Consortium. This was considered relevant since their reasons for participating are expected to be related to their visions of the future. Furthermore they were questioned about their expectations of scientific developments of ecogenomics in the future (nationally as well as internationally). Particularly they were asked to reflect upon applications they thought ecogenomics would eventually result in and what possible positive and negative implications these developments would bring about for society (and specifically for whom in society). The interviews were recorded and transcribed for further analysis. The interview reports were sent back to the interviewees and they were asked to reflect and give comments on it.

In general, the interviewees found it difficult to reflect upon societal aspects of future ecogenomics developments and applications. Therefore, the relevant contextual aspects and normative premises underlying their visions were hardly articulated during the interviews. The results of the interviews focus for a large part on the current state of knowledge since interviewees explained their research within the consortium and mentioned possible future applications. Several interviewees indicated that ecogenomics research would eventually result in the development of tools which can be used to measure 'soil health' or the 'soil condition'. These applications were especially mentioned in relation to agriculture:

> 'A gene chip that gives information about soil health would be a valuable tool to test soils.'

They also had some ideas about the purposes to be reached with these applications:

> 'You could get an image of the disease suppressiveness of the soil and the necessity of the use of insecticides.'

It became clear that, during the interviews, Consortium members put some important elements of the guiding visions into words. However, for the construction of more detailed guiding visions, additional research was necessary.

4.3. Step 3: Focus groups

Since guiding visions also serve the function of a collective projection (Mambrey and Tepper 2000), focus groups were thought to be an effective tool to stimulate the experts in the field of ecogenomics in articulating the guiding visions in more detail. Focus groups are a form of group interviews in which the emphasis is on the production of data and insights through group interaction rather than on a group interview with a question – response format (Morgan 1997). Focus groups can be used to gain a deeper understanding of participants' attitudes and opinions. The partners of the Ecogenomics Consortium were brought together in focus group settings to discuss the future of ecogenomics from their perspectives. By doing this in a structured way, they could challenge each other in expressing their ideas about ecogenomics in the future.

In June 2005, two focus groups were organized in which fourteen Consortium members participated[3]. These Consortium members were invited because of their specific expertise (in relation to the research themes of the Consortium) and their position within the Consortium (coordinator of a research theme or leader of one or more workpackages within these themes). Since Consortium members have different

[3] Except for one, al these Consortium members had also been interviewed in the previous step of the research.

disciplinary backgrounds (ranging from bioinformatics and molecular biology to environmental sciences and ecology), and come from different professional backgrounds (universities, research institutes and companies), the focus groups were also intended to bring these different research areas together. Together they were expected to give a more complete view on the guiding visions from the Consortium perspective.

The focus groups lasted four hours. The interviews already gave an indication of four fields related to ecogenomics applications (agriculture, nature conservation/development, soil pollution and environmental quality). One group, consisting of six Consortium members, focused on ecogenomics in the areas of agriculture and nature conservation, the other group of eight Consortium members focused on the areas of soil pollution and environmental quality. Each group was led by an experienced moderator, who guided the discussion, and notes were recorded by an assistant. The discussions were audio taped and transcribed for further analysis.

Since guiding visions are clearly normative in nature (they include ideas about what the future should look like, according to a person or a group), the focus was on the desirable developments in ecogenomics. Participants were stimulated to think about what the future of ecogenomics should look like, instead of thinking about what the future would probably look like. This approach is also important for creating a setting in which creativity is an important element instead of the truth-ness or validity of the visions (Van der Meulen, Wilt et al. 2003). We achieved this by taking a future situation as a starting point for the discussion. Participants were asked to imagine being in a future, something like forty or fifty years from now, in which ecogenomics has succeeded and in which the future of ecogenomics they consider as desirable is realized. Applications are easy to handle and there are no technical or societal obstacles.

The focus groups were designed to construct guiding visions in which the four elements of guiding visions are articulated. By starting with the assessment of solutions (what applications will be used in a desirable future for ecogenomics?) and the technical aspects and subsequently focusing on the context and asking questions about why a certain future situation is prefered, we tried to gain insight in the assumptions underlying the visions of the participants.

After the participants were asked to imagine their desirable future for ecogenomics, the following six steps were taken in both groups:

1. Participants were asked what applications they think will be used in this imaginable future and for what purpose. Participants were asked to write down one application for each area under discussion and for other areas (spin-offs) on a post-it. All the applications were listed in a scheme (figure 1).
2. During the first step, the moderator questioned the participants about what exactly is measured with the applications they mentioned. This was also written on post-it's and placed in the scheme.
3. When all the applications were listed, the moderator – together with the participants – clustered the applications and asked the participants to think about who the end-users of the applications will be (who will have the benefits?).
4. Subsequently, the participants were asked what parties will lose (e.g. their job) by the introduction of the ecogenomics applications.

5. Next, the participants were asked to think about if and how other technologies or approaches could have the same results as the ecogenomics applications (e.g. what are competing technologies?).
6. In the last step of the group discussions, the moderator asked the participants to point out which applications they felt were technically more attainable than others and why.

The subsequent steps were visualized during the focus groups in a scheme (figure 1). The left three columns of the scheme visualized the current state of knowledge and the purposes to be reached. The two columns on the right visualized the interpretation of the relevant context. Normative premises are implicitly present throughout the scheme, underlying many statements about technology, competing technologies, applications, and contextual aspects.

5	**2**	**1**	**3**	**4**
Alternatives	**What is measured?**	**Applications**	**End users/ End benefits**	**Losers**
		Detection agriculture		
		Detection nature		
		Spin-offs		

Technical elements ⟷ Contextual elements

Figure 2 – Example of scheme used to list participants' ideas in one of the focus groups

The focus group closed with a plenary session in which the two moderators gave a short summary of the group discussions on the basis of the produced schemes. The participants were asked to reflect on the results of both groups.

Two weeks after the focus groups, participants received a detailed report and an evaluation form. They were asked about their experiences with the focus groups, if they felt they had been able to give a constructive contribution, if they had any suggestions for improvement and how they felt about future participation. They were also asked to reflect and give comments on the focus group report. In order to ensure that all key aspects were addressed, *feedback interviews* were held with two Consortium members and one scientific advisor of the Consortium who had not been able to attend the focus groups, but whose input was considered important for the process of constructing guiding visions. The feedback interviews gave them a chance to reflect upon the visions as constructed during the focus groups and at the same time express and reflect upon their own visions.

One of the aims of the focus group design was the articulation of both technical and contextual aspects. A considerable amount of time was spent on discussing these aspects and, as a result, they were clearly articulated by the participants. Compared to the interview results, participants mentioned more, and more specified, applications and purposes to be reached with these applications. Where contextual aspects were hardly mentioned during the interviews, the focus group participants discussed these aspects and expressed them in more detail. Normative premises were articulated throughout the workshop when participants talked about, and articulated their motives for, desirable futures for ecogenomics.

Through the literature survey, interviews and focus groups, much data on the guiding visions was created. The next challenge was to structure this data in order to provide insight into the guiding visions and the relevant underlying assumptions.

4.4. Step 4: Towards concrete images of the future

The results of the literature survey, the interview reports and focus group reports were analyzed according to the four elements of guiding visions. *The current state of knowledge* refers to the technical knowledge that currently exists. This can for instance be illustrated with the results from the literature survey, but also the technical applications mentioned in the interviews and focus groups illustrate this element. The *purposes to be reached* refer to the actual objective the technical application is aiming at. The *interpretation of the relevant contextual aspects* refers to the interviewees' and focus group participants' ideas about the context in which the applications will be used. This comprises the actors that will use the applications and the actual advantages it will have for them, but also the ideas about actors that will not necessarily benefit from the developments in ecogenomics. We distinguished between direct and indirect contextual aspects. Direct contextual aspects show a direct relation between the use of a technological artefact and its effects (e.g. an increase in production and a decrease in costs for farmers as a result of ecogenomics tools). Indirect contextual aspects relate to the more indirect effects or consequences of the use of the technology (e.g. necessary changes on a policy level in order to make optimal use of the technology). The *normative premises* refer to the basic assumptions that are disseminated through the vision. It comprises ideas about what the world should look like and defines preferred states of affairs.

Analysing the guiding visions according to the abovementioned elements reveals some interesting aspects. For example in the field of agriculture we can see that the discussion about who will or will not use the ecogenomics applications results in interesting insights about what are considered to be relevant contextual aspects. Some technology developers see the organic agricultural sector as an important user, while at the same time focussing the applications on precision agriculture, which is not directly of interest to organic farmers. Another result of the analysis is the difference in normative premises that seem to underlie the visions in different areas of application (agriculture, soil pollution, environmental quality, nature conservation/development). As an overall goal sustainability is often mentioned. Sustainability in agriculture is defined as using as less polluting substances as possible. For the field of soil pollution sustainability is formulated as the absence of harmful effects of pollutants. For nature conservation/development interviewees and participants talked about understanding the ecological basis of nature in order to

develop ‘better’ or more ‘enjoyable’ nature. For environmental quality sustainability was more broadly defined as preserving the soil ecosystem for future generations.

After these four steps in the construction of the technology developers’ guiding visions were conducted, the process was presented at the annual meeting of the Ecogenomics Consortium with the aim to introduce the research to consortium members that had not yet participated.

5. Discussion

In this paper we argued that combining an interactive approach with the approach of vision assessment seems promising for technology assessment endeavours in which technologies are assessed in their early phases of development. The interviews with societal actors and the literature survey on developments in ecogenomics clearly illustrated the early phase technology developments in ecogenomics are currently in. Societal actors are hardly acquainted with ecogenomics at the moment, but expressed their interest in the topic.

The interviews and focus groups played a constructive role in identifying the guiding visions held by the Consortium members. Where articles on ecogenomics only revealed technical aspects about the genomics tools used to investigate the soil ecosystem, the interviews and focus groups brought up valuable information about what applications end-users might expect from ecogenomics. With respect to the aims of constructing the guiding visions of technology developers as a first step, some remarks can be made.

Fields of application were already articulated by the interviewees. They also identified relevant actors, however, in discussing contextual aspects in the focus groups they came up with more ideas about who might (or might not) benefit from ecogenomics developments. These two steps in the research also contributed considerably to the insight that was gained in the perspectives of the technology developers about ecogenomics in the future. The results of the focus groups illustrate and highlight the different approaches to the technology in terms of main fields of application and purposes to be reached. Some participants indicated that the method used during the focus groups gave them a feeling of structured and in depth discussion, and that they were all stimulated to give active input. The guiding visions, however, are not very detailed, i.e. the contextual aspects could be further elaborated upon, which will be a central point of attention in future phases of the research. Also the applications are not described in great detail (including for instance technical specifications and a marketing plan). This was also brought up by one of the focus group participants:

> ‘The discussion about future applications stayed on a more general level, but I think that in this early stage you can not expect much more yet.

Another important aim of the research was to create visions in an interactive process in order to initiate a learning process among the technology developers. Already in the interviews, Consortium members were asked to reflect on societal aspects, but particularly the interactive setting of the focus groups proofed to be useful for challenging each others thinking. Participants experienced the interaction between different groups within the Consortium (companies, research institutes and universities) as an effective way of sharing knowledge and keeping each other informed about the research. One participant from a research institute observed a difference between researchers from different institutions:

> ‘I have the impression that my vision as a researcher at an institute with connections to environmental policy is somewhat different than the vision of researchers at ‘real’ research institutions’.

Interaction between the participants (with different scientific backgrounds and from different professional institutions) stimulated creativity, broadened the perspectives and created awareness among ecogenomics researchers of their positions within the social context. Furthermore, the meeting also triggered their ideas about how they could benefit from interaction with other relevant actors. Some participants explicitly expressed their interest in attending meetings together with other actors:

> ‘It would be nice to have societal groups, potential users or developers [companies] present at these kind of meetings as well.’

Presenting the approach and goals of this research at the Ecogenomics Consortium 2006 annual meeting triggered a lot of thoughts. Some Consortium members expressed the need of discussing the visions of the consortium. The interest in talking to future users about these visions was clearly expressed by a question of one of the attendants:

> ‘During this [interactive] process, do we actually get to talk to users about ecogenomics ourselves?’

These reactions are important with respect to the following steps in the process in which the perspectives of other actors will be involved. Commitment of the technology developers to the process is a crucial element with respect to constructive and reflexive discussion of visions for ecogenomics from multiple perspectives.

With regard to the research design, some remarks can be made concerning the group composition and the visions that are expressed. During the process it became clear that the technology developers separate strictly between genomics and genetic modification. Participants in the Ecogenomics Consortium emphasized repeatedly that genetic modification is not an objective within the Consortium. This line is also explicitly drawn in other genomics areas like food and health in the Netherlands (Zwart 2005). However, the interviews with societal actors showed that they immediately link ecogenomics to biotechnology and genetic modification. Distinguishing between genomics and genetic modification seems to result from the notion that the public perception of GMOs is negative and the expectation that this trend will extrapolate into the future. Several interviewees indicated that, though genetic modification is not an explicit aim within the Consortium, data derived from the research has the potential to make genetic modification more directed and informed. We asked the technology developers to think about a desirable future for ecogenomics and, as a result, the guiding visions that were constructed in this process do not include future applications that involve genetically modified organisms. The input from the experts has clearly been framed within the context of the Ecogenomics Consortium. This indicates that not only users in the fields of application that are expressed by the experts should reflect on these visions. Reflection of experts from other fields (e.g. biotechnology and nanotechnology) on these guiding visions might provide us with additional interesting perspectives on desirable future developments in ecogenomics.

The construction of guiding visions as presented in this paper is the starting point for the interactive assessment of ecogenomics. The guiding visions serve as essential input for future phases. On the basis of these guiding visions, relevant actors in the fields of agriculture, soil pollution and nature development can develop their visions

on the technology and define their desirable futures for ecogenomics. However, having framed our research approach from a vision assessment perspective, contextual analysis has a central place in these future phases. By focusing on actors' needs, interests, norms and values, we aim at identifying not only perspectives on the guiding visions, but also additional opportunities for ecogenomics that are currently not addressed within the Consortium. Constructing desirable future visions in an interactive process eventually aims to influence decision making on ecogenomics research towards desirable directions. Integrating the visions on desirable futures in a dialogue between relevant actors and experts is expected to lead to the construction of a shared vision on the technology. On the basis of this shared vision, concrete opportunities and threats for realizing desirable directions for ecogenomics could subsequently be identified.

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