Programme

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Netherlands Organisation for Scientific Research
Earth and Life Sciences
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Information on the Research programme:
T: +31 (0)70 344 06 26
E: alwbiodiversiteitwerkt@nwo.nl
W: www.nwo.nl/biodiversiteit
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Managing nature with soil inocula?

Jasper Wubs, and Martijn Bezemer
Netherlands Institute of Ecology (NIOO-KNAW), Dept. Terrestrial Ecology
P.O. Box 50,
6700 AB Wageningen, the Netherlands
T: +31 (0)31 747 36 15
E: j.wubs@nioo.knaw.nl

Nature restoration on former arable fields represent one of the few opportunities to not only protect nature, but strengthen it by providing new habitat and connecting existing nature areas. However, natural succession is a notoriously slow process, which depends in part – as is now becoming clear – on the interactions of plants with their soil communities. Soil biota are the crucial players in many ecosystem processes and the composition of this community is also subject to successional changes. Soil transplantation may provide an effective measure to shortcut natural succession if well-developed soil communities are transplanted to sites that are to be restored.

Using a large-scale soil inoculation experiment on a former arable field on sandy soil (the Reijerscamp, Figure 1) we showed that in combination with top-soil removal – to reduce the high nutrient loads – inoculation with heathland soil resulted in a vegetation far more similar to the target vegetation within six years (Van Noppen et al. 2015). Soil inoculation allows many groups of soil organisms to recover, particularly those on the more basal parts of the food web. The other groups are probably more sensitive to the mechanical forces during the collection of the soil inocula and are also dependent on the successful establishment of their host populations.

Figure 1 | The field experiment at Reijerscamp (near Wolfheze, Veluwe, NL). Left: The boundary between the area treated with heathland inoculum (foreground) and the control (background) where only the top-soil was removed (June 2014). Right: Detail of the area inoculated with heathland soil.
Soil inoculation effects in part driven by soil biota

Our large-scale field experiment demonstrates that large-scale soil inoculations can help to rapidly restore plant and soil communities on former arable fields. In addition, it shows that it is possible to steer the resultant community to some extent (within the confines of the abiotic context). Heathland and grassland inocula led to very distinct plant communities when transplanted into the same background soils. However, since both plant seeds and soil biota were present in the soil inocula, it was unclear whether the soil community also contributed to shaping the plant communities.

We tested this using a greenhouse experiment where we inoculated the background soil used in the field experiment with the same soil inocula (1:9 w:w inoculum:background soil). We then sowed a mixture of thirty plant species evenly covering the range from early- to late-successional species. The seed mixtures were standardised by weighing the seeds of each species separately to make sure that each mesocosm received exactly the same quantity and composition of seeds. Consequently the seed availability was the same across all treatments and only the type of inoculum differed. After thirty weeks of germination, establishment, growth and competition in the greenhouse we recorded the relative abundance of each species in all of the mesocosms. The data showed that both soil inocula had a marked effect on the composition of the vegetation and that both inocula selected for distinct plant communities (Figure 2; MRPP F = 4.1, p = 0.007). This shows that the effect of soil inoculations in the field are at least partly driven by the soil biota introduced. This is in line with earlier greenhouse experiments (Kardol, Bezemer & Van der Putten 2006; Carbajo et al. 2011) and also with our field experiment where we saw that soil transplantations (soil biota + seeds) led to stronger changes in the vegetation than the conventional hay addition (seeds only).

Figure 2 | Effect of soil inoculation with inocula from a grassland and a heathland on plant community composition. An ordination plot (non-metric dimensional scaling) shows the shifts in community composition due to soil inoculation.

Synergistic effects among soil inocula?

Now that we know that the soil community is at least partly responsible for the development of the vegetation in the field, can we take this to the next level? Can we engineer the soil biotic community for our particular purpose? At the moment this is still too early to say and it will be the focus of the recently granted ‘living legacies’ project (NWO Vici to M.B.). However, within the context of the present project we have already conducted a modest greenhouse experiment to test the idea. We were particularly interested in finding combinations of soil inocula that show synergistic effects. The soil is inhabited by a hyperdiverse community of bacteria, fungi (including mycorrhiza) and invertebrates such as nematodes, mites, springtails and enchytraeids. All of these organisms interact in complex ways, e.g. by feeding,
providing shelter and engaging in chemical warfare (e.g. volatile-mediated microbial interactions). By doing this they also affect plant performance. The outcome of these interactions is often highly unexpected when two or more soil communities are mixed, compared to the effects of each of the soil communities on their own (Brandt et al. 2013; Hendriks et al. 2013). This opens up the possibility that particular combinations of soil inocula may outperform the utility of each of the inocula separately with respect to a particularly desired ecosystem state, service or function, i.e. there may be important synergies.

In this greenhouse experiment we mixed soil inocula collected from three different types of fields (heathland, late-successional grassland, and arable fields under active cultivation). We sampled three fields for each type, all on sandy soils in the Veluwe (the Netherlands). We mixed the inocula using a replacement series where the focal inoculum was present in five different proportions (i.e. 100%, 75%, 50%, 25%, 0%), in all possible combinations of inocula. We inoculated (1:9 w:w inoculum: background soil) mesocosms filled with typical ex-arable land top-soil and then compared the effect of the inocula on the growth of six plant species grown in competition. Three of these species are considered to be target species for restoration on ex-arable fields on sandy soils and the three others are typical weeds in these areas. After two months of growth we harvested the plants, measured the biomass of each species in the mesocosms, and calculated the performance of the mixtures relative to what we would expect (i.e. assuming only additive effects) based on the two respective pure inocula. We indeed found synergistic effects among the soil inocula (Figure 3) but they arose in very specific combinations. In many cases the effect of the inoculum mixture was as beneficial or a bit less beneficial for the target species than expected based on the pure inocula. However, we also found that the performance of the target species was markedly improved when heathland inoculum was mixed with a bit of grassland inoculum (75:25 w:w). This shows that combining different soil inocula can lead to unexpected results. This means there could be great scope for the active manipulation of soil communities, which may then have a beneficial impact on the vegetation and potentially cascade up to ecosystem functioning.

Figure 3 | Effect of mixing soil inocula from different field types on the performance of plant species that are targets for nature restoration. The zero line represents the expected effect based on the two respective pure inocula (additive effects only) and the bars show the deviation from this expectation. Error bars represent 95% confidence intervals. Different letters indicate significant differences among treatments ($F_{11, 166} = 2.627; p = 0.004$).
Soil transplantation day

As a crucial part of our project we are organizing a knowledge dissemination day on soil transplantations in collaboration with the Centre for Soil Ecology and Vereniging Natuurmonumenten. This event will be held on 15 October 2015 (Figure 4). This meeting will bring together nature managers, researchers, and other interested parties from a number of Dutch soil transplantation projects. The various projects will be presented and discussed as case studies and we will compare the methods and their success. Based on this we will formulate a research agenda with key questions that need to be addressed so that stakeholders can realise a best practice with respect to soil community manipulations for nature restoration.

Figure 4 | Logo for the knowledge dissemination day on soil transplantations.

References


Understanding the role of plant traits and their plasticity in N:P stoichiometry and competition

Ineke Roeling
Environmental Sciences
Copernicus Institute of Sustainable Development, Utrecht University
Supervisors: Prof. Martin Wassen, Dr Jerry van Dijk, and Dr Maarten Eppinga

For years Dutch nature conservancy organisations have been trying to manage their natural grasslands in such a way that plant species diversity is maintained or restored to its former high species richness. There are several factors that influence plant species diversity, e.g. nutrient availability, soil acidity, soil moisture and seed dispersion. Addressing all of these issues can be a particular challenge when nature reserves are surrounded by agricultural areas.

Management practices have often mainly focussed on reducing the amount of available nutrients without explicit consideration for the three major nutrients: nitrogen, phosphorus and potassium. Nutrient availability is often implicitly regarded as nitrogen availability because many studies have shown a relationship between increased nitrogen availability and decreased species richness (e.g. Stevens et al., 2004; Bobbink et al., 2010). Recent studies have shown that the type of nutrient availability is important for species diversity. The nitrogen:phosphorus ratio is a proxy for the type of nutrient limitation (Koerselman & Meuleman, 1996; Güsewell & Koerselman, 2002; Olde Venterink et al., 2003). It was found that species richness is highest at an intermediate N:P ratio and that endangered species occur more often under P-limited conditions (high N:P ratio; Wassen et al., 2005). Moreover, the effect of N:P ratio on species richness is independent from the total nutrient availability (Fujita et al., 2014). Fujita et al. (2014) found that both endangered and non-endangered plants that grow in P-limited conditions invest less in sexual reproduction; they produced fewer and smaller seeds.

In our study we investigate if plant species are specialised in different nutrient limitation types, i.e. if generalist and specialist species can be distinguished along the N:P axis. We are currently writing an article on this topic, together with Wim Ozinga. Preliminary results are promising. It is an interesting question, also for nature managers. If there are true specialists and generalists, we could infer the nutrient limitation type of a site by looking at the species composition. It would even be possible to indicate what changes in limitation type have to be achieved in order to create favourable conditions for the preservation or return of a target species. We therefore need to test if the N:P ratio inferred from a vegetation recording matches with a chemical N:P ratio measurement of that same site. To test this idea we need vegetation recordings and plant samples.

Last June and July we carried out fieldwork in seven different nature reserves. During the site selection process, we asked advice from Natuurmonumenten (our main stakeholder) as well as Staatsbosbeheer, Landschap Overijssel and several external advisors. We were looking for areas in which nutrients were likely to play a steering role in the species composition and for which the management history was well known. In addition, management had to have been constant over the past five years. The areas were chosen in consultation with stakeholders: they are specifically interested in these areas and potential management measures that influence N:P ratio.

The following sites were selected: ‘de Wieden’ (Photo 1), ‘de Drentse Aa’, ‘Smalbroeken’ (part of the ‘Kampina’ nature reserve, Photo 2), ‘Brecklenkamp veld (Photo 3)’, ‘Stroothuizen’, ‘Punthuizen’ and ‘Lemselermaten’. We gathered plant samples and vegetation recordings from 43 plots. The plant material has been dried and will be chemically analysed for N and P. Measured N:P ratio can then be compared with an N:P ratio estimation that we infer from the species recordings. The latter estimation will be based on the outcomes of our current study on generalist and specialist species along the N:P axis.
We would like to thank all the people who helped us, by giving advice, sharing data, providing fieldwork permission and helping in the field: Bart van Tooren, Rosalie Martens, Arco Lassche, Erwin de Hoop, Niels Vogel and Peter Voorn (Natuurmonumenten); Loekie van Tweel and Evert Dijk (Landschap Overijssel); Jaap Rouwenhorst and colleagues (Staatsbosbeheer); Jan Bakker, Yzaak de Vries and Ab Grootjans (University of Groningen); André Jansen (Coöperatie Unie van Bosgroepen).

**Picture 1** | Normally you walk to your research site, but in nature reserve ‘De Wieden’ you have to take the boat. (Nature reserve ‘De Wieden’, province of Overijssel, Natuurmonumenten.) *Photo: Ineke Roeling*

**Picture 2** | Fieldwork in ‘Smalbroeken’: Martin Wassen and Shuqiong Wang are harvesting plant material, while Jerry van Dijk is trying to identify a species. (Nature reserve ‘Kampina’, province of Brabant, Natuurmonumenten.) *Photo: Ineke Roeling*
Understanding the role of plant traits and their plasticity in N:P stoichiometry and competition

References


*Picture 3* | Martin Wassen trying to find the corners of a permanent quadrat on a rainy day in nature reserve ‘het Brecklenkampse veld’ (province of Overijssel, Overijssels Landschap). Photo: Ineke Roeling
Decision-support systems as a type of science-policy interface: exploring the potential of the QUICKScan software tool for knowledge integration and learning

Romina Rodela¹,², Arnold Bregt¹, Marta Perez-Soba³, Peter Verweij³

¹Laboratory of Geo-Information Science and Remote Sensing, Wageningen University, the Netherlands
²School of Natural Sciences, Technology and Environmental Studies, Södertörn University, Sweden
³Alterra Wageningen UR, the Netherlands

Keywords: Decision-support system, science policy interfaces, QUICKScan software tool, participatory processes, ecosystem services, knowledge integration, learning.

Abstract

As part of the INVALUABLE project¹, funded under BiodivERsA, we have undertaken empirical research meant to evaluate the potential of a novel software tool, the QUICKScan. QUICKScan is meant to be used in a participatory group context and evaluated for aspects of knowledge integration, learning and shared understanding. Results obtained from a pre-test and post-test questionnaire administered to the participants of two different workshops suggest that it performs well on the variables of interest. Here we briefly present the design of our research and direct those interested to see the full data and further details to consult the WP3 report we produced (i.e. Rodela et al., 2015).

1 Introduction

The global decline in biodiversity is a major contemporary challenge. Both policy and science have a major role in contributing to the halt of biodiversity loss. However, communication and exchange between policy and science can at times be slow, awkward and not particularly effective. In view of the importance of the interaction between science and policy this has become a subject of research interest and many scholars are now exploring this interaction. Spatial decision-support systems (SDSS) could help to meet the challenges and opportunities for effective science-policy interfaces (SPI) in the context of biodiversity and ecological systems governance. SDSS are designed to support decision makers in the interpretation of information from data, analyses, and models and in the identification of actions to be taken when knowledge about the nature and effect of environmental problems is uncertain and contested (Van Delden et al. 2001; McIntosh et al., 2007). Recent SDSS tools allow users to try out the weightings, to perform a sensitivity analysis to assess the strength and robustness of decisions, and to reproduce the steps taken during the decision procedure (McIntosh et al., 2011). This last aspect is important in situations where contested issues are at stake, as it allows the logic followed to be tracked. This not only helps to provide a better legitimacy of the decisions taken in the eyes of a larger constituency but also allows for refinement and updates when new information becomes available. From this perspective SDSS can therefore be understood as a tool that can serve at the science-policy interface since it supports policy makers in using scientific knowledge during environmental decision-making processes. When used in a participatory setting by more stakeholders and/or policy makers, SDSS allows disciplinary scientific knowledge about complex environmental issues to be compiled and displayed in ways that are also accessible to non-scientists (McInerny et al., 2014). It can help to capture tacit knowledge, and allow for the integration of traditional knowledge. SDSS integrates spatial data, which allows a visualisation of likely impacts policy options might have in the medium and long term.

for a given territory. Such information can support policy makers in the selection of alternative policy options (Van Delden et al., 2011; McIntosh et al., 2007; Santoro et al., 2013).

Awareness about policy makers needs and recognition of the SDSS soft side led to a collaboration between the European Environmental Agency and Alterra Wageningen UR with the objective of designing and developing a new generation of SDSS that can better accommodate current policy needs. This collaboration resulted in the QUICKScan software tool; a spatial modelling environment meant to be used during participatory decision-making processes, which allows expert knowledge to be combined with spatial and statistical data (for details: Verweij et al., 2010). The QUICKScan software tool integrates a number of novel features and is designed as a "white box" so that users are not confronted with complex operations and can easily follow the logic behind the outcomes produced. It is assumed that this improves transparency of the process, reduces uncertainty of the outputs, and supports learning and the integration of knowledge. The aim of the research reported here was to evaluate the QUICKScan software tool on some of these aspects of interest. More precisely, we addressed the following objectives 1) to evaluate the QUICKScan software tool when used in a participatory group context for aspects of knowledge integration, learning and shared understanding and 2) to reflect on the tool’s potential for mapping ecosystem services and their valuation.

2 QUICKScan: a novel spatial decision support tool

The QUICKScan is a spatial modelling environment that uses spatial and statistical data (visualised in maps, diagrams and tables). When used in a participatory setting the QUICKScan software tool performs as a SDSS and can be used to support group discussions and decision-making. Here we will mention how QUICKScan was developed, provide some technical details and then conclude this section with a few words on the participatory methodology that underpins the QUICKScan workshops.

As mentioned the QUICKScan tool is the product of a collaboration between the European Environmental Agency and Wageningen UR Alterra who joined forces for the development of a novel tool meant to accommodate current policy needs in terms of policy assessments. User / policy maker involvement during tool design and development helped to keep key aspects in focus. Transparency is also strengthened by the possibility to trace the steps made towards a certain outcome and this can also be done at a later stage when, for instance, new information becomes available, or a need emerges to verify the reasoning followed (Verweij et al., 2012). This last aspect is beneficial in terms of improved legitimacy, especially when a policy decision needs to be discussed with stakeholder groups given and possible uncertainties addressed. As already reported by Verweij et al. (2012) the development of the QUICKScan framework was done in collaboration with policy assessors, researchers and software engineers who met throughout the process; during the early period of tool development to identify key ideas and specifying requirements, and later during development and prototyping.

The QUICKScan software was developed to operate as a tool for the exploration of potential policy options and assessment of likely impacts of those options. Given the possibility to use spatial and statistical data to perform assessments the tool can also be applied for the mapping of ecosystem services.

QUICKScan is meant to be used during a facilitated workshop in which participants (policy makers, experts and/or other stakeholders) can contribute with their own knowledge and expertise, combined with available (scientific) data. QUICKScan uses existing datasets. Once the issue to be discussed is defined the activity unfolds as follows. In a first step relevant material such as administrative, statistical and spatial data from satellite imagery, spatial plans and results of scientific models, is gathered and prepared. The tool uses raster GIS maps which are collected together. These maps form the basis on which knowledge rules are applied.

Then, in a second step a workshop is organised. The workshop starts with the assessment of the current state of society and environment to which the participants involved are contributing with their own knowledge and expertise. The moderator(s) capture participants’ expertise and tacit knowledge linking
it with available data through the rule types meant to capture knowledge about the processes of interest. These rule types allows scenarios to be simulated with the “if..then..else structures”, but also multi-criteria analysis and sustainability limits. Each rule type has a specific editor that allows an easy input, or change, of the rules initially inserted into the QUICKScan software (Figure 1).

The possibility to visualise all the steps made during the session on the screen allows for reflection on the causal chain of the rules chosen and about the suitability of the underlying data. The participants can search for patterns and relationships between data and reconsider the steps chosen where necessary. The software allows multiple iterations to be performed in each workshop. Each iteration builds upon the discussion between the participants, and this opens opportunities for learning and facilitates knowledge exchange. An important characteristic of the QUICKScan software is its fast processing time that allows for a rapid comparison of alternatives either by using a different set of rules (including weights and values), or scenarios. Alternatives can be compared by highlighting regional differences, summary graphs and spider diagrams (Figure 2).

Further details about the QUICKScan software tool are given by Verweij et al. (2012) and are also available at http://quickscan.pro.
2.1 Potential for knowledge integration and learning

Knowledge production and its use in policy making is one of the key themes in current literature on the “science policy-interface” which Van den Hove (2007:824) defined as “processes that encompass relations between scientists (researchers in the public and private sector) and actors involved in the policy process (policy makers, bureaucrats) that allow for exchanges, co-evolution, and joint construction of knowledge with the aim of enriching decision-making”. Her analysis is relevant, as Van den Hove (2007) exposes issues surrounding the use of scientific evidence in policy and sees a need for SPI to bring about communication and debate about the assumptions, choices and uncertainties, and about the limits of scientific knowledge. This position rejects the linear model of knowledge production (producer and receiver) and indicates that more information and more knowledge is simply not enough to solve complex environmental issues (Fazey et al. 2013; Raymond et al. 2010). That statement is backed up by research on decision-making where it has been shown that higher quantities of information do not necessarily led to better decisions. Instead this depends on other things such as how conflicts are dealt with, the match between information provided and needs, etc. (Evans, 2006, Van Stigt et al. 2015). Therefore from that view point SPI should allow for the articulation of different types of knowledge in order to construct a more comprehensive understanding of the issue at stake as well as explorations of options. Van den Hove (2007) claims that in SPI space needs to be made for values and for the integration of scientific predictions with considerations of another nature, as is for instance the quality of life we hope to have in the future. Koetz et al. (2012) share this position and see great potential for participatory settings where different claims can be articulated and values underlying problem definition and social choices explored.

Table 1 | The analytical framework

<table>
<thead>
<tr>
<th>Analytical item</th>
<th>Definition/description</th>
<th>Theoretical and source reference</th>
<th>Measures / Operationalisation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge</td>
<td><strong>Use of existing knowledge</strong>: explores how the tool provides support to use current knowledge about the problem domain</td>
<td>Webler et al. 1995</td>
<td>Sharing of knowledge</td>
</tr>
<tr>
<td></td>
<td><strong>Knowledge integration</strong>: explores how the tool provides support for the integration of knowledge from different scientific areas</td>
<td>Raymond et al. 2010</td>
<td>Upgrade of existing knowledge</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fazey et al. 2013</td>
<td>Integration of K into results</td>
</tr>
<tr>
<td>Shared understanding</td>
<td>Convergence towards a shared understanding of the problem domain</td>
<td>Webler et al. 1995</td>
<td>Development of a shared understanding</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Schusler et al. 2003</td>
<td>Change of position</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mathevet et al. 2011</td>
<td></td>
</tr>
<tr>
<td>Learning</td>
<td>Increase in understanding</td>
<td>Inman et al. 2011</td>
<td>Learning process</td>
</tr>
<tr>
<td>Time</td>
<td>Time needed to complete the task</td>
<td>Arciniegas et al. 2013</td>
<td>Perception of time</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Uran and Janssen 2003</td>
<td>Time to complete the task</td>
</tr>
<tr>
<td>Transparency</td>
<td>Transparency of the process and access to information needed to understand the models/ policy options they are working with</td>
<td>Uran and Janssen 2003</td>
<td>Comprehensibility of the modelling process</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Inman et al. 2011</td>
<td></td>
</tr>
</tbody>
</table>

*Knowledge integration is where knowledge from different areas inform a more comprehensive understanding of the complexity of a system that a single perspective might overlook.

3 Methods

To investigate how the QUICKScan software tool performs on selected analytical items (Table 1) we organised participatory workshops where the QUICKScan was used. We collected data with a pre-test and post-test questionnaire, non-obstructive observation and open ended interviews. A pre-test and a post-test questionnaire (self-assessment on a Likert scale) were developed. The pre-test questionnaire
gathered information about demographics, familiarity with GIS and with the topic discussed, if participants knew other participants from before, and confidence in own knowledge. The post-test questionnaire gathered information about participants’ perception about knowledge shared, upgraded and acquired, shared understanding, the visuals, timing, etc. The questionnaires integrated open and closed questions, with questions meant to assess levels of satisfaction on a scale of three negative levels (-3, -2, -1), one neutral level (0) and three positive levels (+1, +2, +3). This scale has been used in previous empirical studies on SDSS tool effectiveness (e.g., Dias, 2007; Inman et al. 2011). For practical reasons we turned this scale into a 1 to 7 Likert scale when transcribing the answers into an Excel spreadsheet and then analysed it with SPSS. So the scale initially used -3,-2,-1, 0,1,2,3 was transformed into 1,2,3,4,5,6,7. Questionnaire data is meant to be triangulated with non-obtrusive observation and interviews. In addition to these, unstructured interviews and non-obtrusive observation were conducted to provide additional qualitative data about group dynamics.

3.1 Two QUICKScan workshops

After we had tested the data collection tools and the workshop lay-out we identified two opportunities to study the QUICKScan tool. In April 2013 a first QUICKScan workshop was organised as part of an Impact Assessment Summer School in Edinburgh, Scotland. The topic of that workshop was Green Infrastructure at a European scale. Thirteen participants (experts in the field of impact assessment who were all PhD students) took part in this activity, which was moderated by one QUICKScan team member while a second team member operated the software. The workshop lasted 1.5 days. In October 2014 a second QUICKScan workshop was organised with a group of local stakeholders participating in the Tomintoul and Glenlivet Landscape Partnership and who are actively collaborating on projects and initiatives for the regeneration of a rural area in Northern Scotland. The topic of that workshop was benefits from nature/ecosystems services in relation to land management options for a selected locality. Out of the 15 stakeholders invited, 13 attended a full day of activities that lasted from 10:00 to 16:00. An expert from a partner institution moderated this workshop, while two QUICKScan team members operated the software and examined the technical aspects involved.

During both workshops participants were asked to complete the pre-test questionnaire before using the QUICKScan software tool and to complete the post-test questionnaire when the session ended. In addition to this we telephone interviewed a few participants from the second workshop to explore some aspects that emerged from the post-test questionnaire.

The analysis of quantitative data collected with the questionnaires was done with the Statistical Package for the Social Sciences (SPSS), while qualitative data collected with open questions and interviews served to identify emerging themes. A presentation of this work and a discussion of the data has already been reported in Rodela et al. (2015)². That information is not repeated here and those interested in knowing more are invited to consult that report.

4 Discussion and conclusion

The research had two main objectives. The first is to evaluate the QUICKScan software tool when it is used in a participatory group context on aspects of knowledge integration, learning and shared understanding. The second is to reflect on the tool’s potential for mapping ecosystem services and their valuation. Based on the results reported in Rodela et al. (2015) we conclude that the QUICKScan software tool seems to perform well on these aspects of knowledge integration, learning and shared understanding when used in a group context underpinned by a participatory approach, as the participants scored high on most of the questions. We acknowledge, however, the limitations that arise from the fact that the two workshops had a demonstration purpose (no real decision-making objective) and brought together a non-representative sample (not policy makers). Yet, while the results might not

² Full version of the report is freely downloadable at: https://www.researchgate.net/publication/280608674_Decision_Support_Systems_as_Type_of_Science-Policy_Interface_Exploring_the_potential_of_the_QUICKScan_software_tool_for_knowledge_integration_and_learning
allow us to draw general conclusions in terms of how and when QUICKScan software can lead to better policy making, based our results we can suggest that the QUICKScan approach can perform well as a type SPI in the context of assessment and mapping of ES. Specifically the QUICKScan approach could contribute to the implementation of Action 5 of the EU 2020 Biodiversity Strategy, which requires that Member States of the European Union map and assess the state of ecosystems and their services within their national territory.

References


A Special Section entitled “Challenges to and opportunities for biodiversity science-policy interfaces”

Romina Rodela\(^1,2\) and Arnold Bregt\(^1\)

\(^1\)Laboratory of Geo-Information Science and Remote Sensing, Wageningen University
\(^2\)School of Natural Sciences, Technology and Environmental Studies, Södertörn University

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In the context of the INVALUABLE project\(^1\), funded under BiodivERsA, we have recently guest edited a Special Section on science-policy interfaces published in volume 54 (December 2015) of the journal Environmental Science & Policy. The Special Section features a selection of five papers reporting on novel ideas and research by scholars from Germany, UK, and Finland.

The Special Section takes stock of the ideas and viewpoints exchanged during an Expert meeting organised in Freiburg (Germany) from 3 to 4 March 2014 as part of the INVALUABLE project. The workshop brought together experts from a diversity of backgrounds who presented current research and addressed selected questions in group discussions over two days (for details: Kilham et al., 2015). Among the key challenges identified in that context was the need to consider the complexity of, and uncertainty in, socio-ecological systems as well as their adaptive and dynamic features (Rodela et al., 2015).

The five contributions selected for the Special Section offer reflective as well as empirical perspectives on contemporary Science Policy Interface (SPI) practices and provide an opportunity for learning and useful insights for policy and current SPI practice (as summarised in Table 1). While each focuses on a specific research objective and different cases, the five papers share the quest for specifying when SPI processes succeed in knowledge integration as a main overarching theme.

Table 1 | Summary of the five contributions in order of their appearance in the Special Section

<table>
<thead>
<tr>
<th>Authors</th>
<th>Research objective</th>
<th>Type of contribution</th>
<th>Main lessons learned</th>
<th>Key message to policy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carmen et al. 2015</td>
<td>Formative evaluation of the European Network of Knowledge</td>
<td>Empirically based</td>
<td>Key attributes of SPIs: inclusiveness, communication, policy usability and capacity building</td>
<td>Address motivation of actors in SPIs by providing tangible opportunities for engagement</td>
</tr>
<tr>
<td>Borie and Hume 2015</td>
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<td>Empirically based</td>
<td>Knowledge integration requires epistemic and ontological plurality and sufficient space for the articulation of critique</td>
<td>When opening up SPIs to include different knowledge systems, allow for a reconciliation of different world views</td>
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<td>Sarkki et al. 2015</td>
<td>Gaining an understanding of when SPI arrangements, objectives, processes and outputs are effective</td>
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<td>Lienhoop et al. 2015</td>
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References


Diversity in ditch networks at multiple scale levels

Sven Teurlincx and Steven Declerck
Netherlands Institute for Ecology (NIOO-KNAW) – Aquatic Ecology
Droevendaalsesteeg 10, 6708 PB Wageningen
T: +31 (0)31 747 35 50
E: s.teurlincx@nioo.knaw.nl

Project goal

The conservation of aquatic biodiversity is a central objective of Dutch nature conservation policy. In the face of ongoing land use changes, this endeavour is especially challenging due to limited availability of space and resources. Management schemes for wetland ecosystems have traditionally focused on the level of individual water bodies (e.g. EU Water Framework Directive). An integrated, landscape-oriented approach, nevertheless, offers much better guarantees for the effective and sustainable conservation of regional aquatic biodiversity. However, scientific knowledge on how such an approach can best be implemented is lacking. It is essential that the limited resources available for nature conservation are allocated to measures that result in maximal effects. Land use changes have a profound effect on biodiversity at different spatial scales. Understanding how biodiversity is structured across spatial scales is an essential piece of knowledge that managers need before embarking on any form of conservation or restoration activity. For example, two water bodies are very different in their species richness, A is rich and B is poor. Intuitively, one would be inclined to manage B in such a way as to make it more like A and increase its species richness. This might be the wrong decision, however, if species in B are very different from A. B in its original state may then indeed contribute more to the regional species pool.

The overall aim of the project is to (1) provide a mechanistic understanding of the factors that determine aquatic biodiversity in Dutch agricultural landscapes, with special attention for rare species, species of conservation concern and functional groups, (2) reveal the pathways through which land use change (agricultural intensification and de-intensification, urbanisation) can affect landscape biodiversity, (3) identify how the response patterns of ecologically contrasting groups of aquatic organisms differ and (4) use this information to develop a strategic framework for the cost-effective management of landscape biodiversity for multiple organism groups. In this newsletter we will focus on understanding the underlying structure of biodiversity across spatial scales and give an outlook at underlying factors driving diversity at a larger spatial scale.

Field study design

We selected the ditch networks in the polders of the Western Peat district as model system for our study. These systems are home to a wide variety of aquatic plants and animals. Based on accessibility and prevailing land use, we selected 21 polders of ±200 hectares each. Within each polder, we sampled 24 ditch reaches, following a stratified random design. For each reach we collected data on community composition and biodiversity of cladocera zooplankton (water fleas) and vegetation in and on the ditch banks (wet bank vegetation, helophytes, hydrophytes) and measured key environmental factors that are generally known to be important in driving the community composition and diversity of these organism groups (e.g., water and soil nutrients, turbidity, ditch morphology and fish presence). Over the course of three field seasons (summer 2012, 2013 and 2014) we sampled 21 different polders, accumulating data on over 500 ditch communities and their local environmental conditions. This design has allowed us to distinguish three scale levels: the local ditch reach (n = 504), the polder system (n = 21) and the regional scale the system of the Western peat district.
Partitioning diversity

By splitting diversity at the regional scale into different components we get a better understanding of its structure and the importance of spatial scale. The local diversity of a reach (α₁) makes up part of the polder level diversity (γ₁). However, the difference between ditch reaches in terms of species composition (β₁) is also a potentially important component. The polder level diversity is part of the regional diversity (γ₂) but again the difference in diversity between regions (β₂) is a relevant component to consider (Figure 1). When partitioning diversity in this manner it is important to understand that the local diversity component is influenced by very different drivers than the β-diversity component. For example, α-diversity may mainly respond to local environmental quality, whereas β-diversity will be influenced by environmental heterogeneity. Both components are relevant in understanding the resulting γ-diversity, and only through adequate knowledge of the importance of all these components in shaping the regional diversity can management on this scale be effective.

Results

When we partition regional diversity of multiple species groups in the ditch networks of the Western peat district (Figure 2) it becomes clear that the α-diversity always only represents a relatively small component of total regional diversity, i.e. about 20%. The β₁ and β₂ components, however, are large, indicating a large difference between communities within a polder, but also a large difference among metacommunities between polders. This clearly illustrates that management focussed on improving local diversity will have relatively little impact on the polder level or regional level diversity.
By further examining landscape characteristics of the polders we get a better understanding of important gradients driving the species richness of the region. For example, we used a gradient forest analysis to identify the important factors associated with polder diversity of helophytes. Surface area of water ($R^2: 0.43$) and the number of hydrological obstructions on the ditch network within polders proved to be two very important variables ($R^2: 0.27$) (Figure 3). Translating these results to a management plan focused on regional diversity suggests that more water (e.g. wider and more ditches) and reduction in the number of hydrological obstructions (dams, weirs, pipes) in the ditch network would be a good start.

![Figure 3](image)

**Figure 3** | Relationship of total helophyte species richness with water surface area and number of hydrological obstructions in polders.

**Outlook**

While quite straightforward at a first glance, our analyses reveal patterns that may have been caused by quite intricate causal pathways. With our current analysis we do not yet have a more mechanistic understanding of the found patterns. In other words, why do hydrological obstructions in the ditch network lead to decreased biodiversity? Is this caused by dispersal limitation of the helophyte species, or does the accumulation of duckweeds near obstructions create unfavourable habitat conditions (anoxia, low light conditions). In-depth analyses at the polder level where we quantify effects of local habitat and spatial patterns in community composition will shed more light on this. By specifically studying dispersal traits of constituent species of the community in relation to these patterns we will be able to gain a deeper understanding of the underlying drivers of the large scale patterns shown here.
Fieldwork in polder Oukoop, Reeuwijk. Photography: Marlies Gräwe
Ecosystem functions of invasive aquatic plants: new insights and outreach

Bart Grutters  
b.grutters@nioo.knaw.nl  
Liesbeth Bakker  
l.bakker@nioo.knaw.nl  

Department of Aquatic Ecology  
Netherlands Institute of Ecology (NIOO-KNAW)  
Droevendaalsesteeg 10  
6708 PB Wageningen  

Research highlights

Invasive plants are spreading rapidly across our planet due to globalisation. In the Netherlands, many waterways contain invaders that are a nuisance for water and nature managers, anglers, rowers and swimmers due to their prolific growth. However, these plants grow in lakes where our native plants were largely extirpated in the past due to contamination and eutrophication. In these cases, invaders might provide some of the ecosystem functions that disappeared along with the native aquatic plants, such as providing food and habitat for macroinvertebrates or preventing algal blooms. Furthermore, native species also exhibit nuisance growth and therefore cause similar problems to non-native plants. This is probably because certain plants enjoy the nutrient-rich Dutch sediments alongside increasing water clarity and light penetration. As the management and eradication of non-native plants is a costly affair, we aim to compare the ecosystem functions provided by native and non-native aquatic plants. Our results should help water managers decide how to manage invaders and how to stimulate biodiversity in aquatic ecosystems.

Figure 1 | Cabomba (Cabomba caroliniana) worries Dutch water managers because its nuisance growth annoys many boat owners. We found in feeding trials that it was inedible to a native insect herbivore (see Figure 2).
Besides the results on habitat provision and edibility to aquatic omnivores that were already discussed in previous editions of the Biodiversity Works newsletter, we have completed additional research. One of the topics is the edibility of native and non-native plants to an aquatic insect herbivore. We tested the biotic resistance hypothesis, where native herbivores restrict invasive plants through consumption. We assessed if *Parapoynx stratiotata* would also consume non-native plants and could thereby provide biotic resistance to invaders. Most plants were eaten regardless of their origin. Although we did not uncover the consumption determinants, likely related to secondary plant chemistry, this shows that native herbivores such as the tested caterpillar can provide biotic resistance to plant invaders (*Hydrobiologia* in press).

**Outreach and the ExotenGame**

Besides the scientific work, we also communicate our results to the general public using the ‘ExotenGame’. This is a game specifically developed to facilitate communication at festivals or exhibitions using interactive learning. Together with media developers (iTZIT), the NIOO-KNAW’s communication department and Aquatic Knowledge Centre Wageningen (AKWA) we devised a concept and turned it into a playable game. So far, the ExotenGame has been played by thousands, after showcasing it at the World Harbour Days 2014 in Rotterdam and at the World Water College 2015 in Leeuwarden (event organised by the Top Sector Water). It helps to educate young and old as they experience that some exotic plants and animals are beneficial and harmful at the same time. Playing the game raises awareness about the multifunctional use of water as ecological, recreational, consumption and economic demands require different, even contradictory, uses. The feedback received at each try-out provides input to develop the game further. Our ultimate aim is to make it available online. Together with others we are spending a lot of time and energy on this outreach project. However, the ExotenGame is very rewarding in its use and a particularly suitable aid for communicating our scientific results on ecosystem functions of invaders to the general public.
Figure 3 | Young and old play the ExotenGame at the World Harbour Days in Rotterdam.

Figure 4 | Dashboard of the ExotenGame showcasing ecological information related to the invasive crayfish.
Figure 5 | Red swamp crawfish (*Procambarus clarkii*) is a notorious invader in European waterways. The species decimates underwater vegetation as it loves shredding plants. It is one of the species present in the ExotenGame to inform the public about the effects of invasive species on ecosystems.

Publications


A love for nature often takes the form of an attachment to specific natural places, ranging from the local city park, to a forest area often visited in the weekends or a spectacular mountain range once visited during holidays. In a recent paper (see Bijker & Sijtsma, submitted) we have shown that, in addition to urban green space, nature areas farther away are also part of urban dwellers’ lives and thus play a major role in their well-being. Urban residents appear to have a ‘portfolio of natural places’. This portfolio consists of favourite places nearby that are rated lower but visited quite often, and natural places that they find highly attractive but are located farther away and visited less often.

The overall aim of the research project ‘Sympathy for the Commons’ is to investigate whether this strong appreciation of individuals for specific nature areas can be used to find new ways of community support and funding for these nature areas. Internet and the development of online tools play an important role in the project, as on the internet physical distance is not a constraint. The internet also offers new possibilities for community building and may help to overcome the “illogic” of collective action (see also Bijker et al., 2014).

The scientific starting point for our research is the Hotspotmonitor (www.hotspotmonitor.eu), an internet-based survey tool in which people mark their favourite natural places on a map, on a local, regional, national and world level. The Hotspotmonitor (HSM) offers a geographically detailed method to investigate cultural ecosystem services. Until now, around 13,000 people have marked their favourite natural places in this way.

In our research project we want to take a next step; not only data gathering to support spatial planning and spatial policy, but also experimenting with improving the governance of nature areas by making it possible to easily reach the fans of these areas. We have therefore developed the software ‘Greenmapper’ (www.greenmapper.nl). Here we would like to discuss the two ‘sides’ of the tool: Greenmapper as an online tool for the nature fan and the ‘backside’, the dashboard side that provides information for nature conservation organisations and researchers.

Greenmapper for the user

The Greenmapper starts with filling in a new (shortened) version of the HSM; a new version that also allows direct sharing of the markers of the respondents on a map, which is required for use within Greenmapper. A screenshot of the newly developed HSM is shown in Figure 1. At the end of the survey people can get access to the next part of the tool by filling in their email address.
Greenmapper has three main functions for the nature fan. First of all, the user remains updated about news and events in the areas saved in ‘My favourite nature’. Since they can be reached as a fan of the area, they can also become involved and be asked about their views on, for instance, the management of the area. The key aspect is that the tool offers the possibility to get in touch with other fans of the same area by sending a message. The second function of the tool is a more individual one. Users can enjoy their favourite nature online by viewing beautiful photos in the tool of different nature areas. The photos can also be rated and saved on a separate page. Figure 2 shows an example of such a personal photo page. The third function is also individual. Users may receive suggestions in different forms to discover or become a fan of new nature areas, based on the personal preferences that were filled in in the HSM.

Figure 1 | A screenshot of the HSM at the moment a marker is placed on the neighbourhood level.

Figure 2 | Page in Greenmapper with ‘My favourite photo’s’.
Just like the HSM, the Greenmapper revolves around favourite natural places. In the tool the users see their own marked favourite natural places; and may endlessly expand these. But the key to the creation of fan communities is that we have created hotspot areas in the tool, based on clusters with a high concentration of markers of HSM participants up until now. These areas that are marked by many people as attractive or valuable could develop into ‘nature communities’. The Greenmapper suggests nature communities to the user that are around or overlap the places the user has marked. Of course the user is free to become a member of other nature communities as well.

**Greenmapper Dashboard**

The ‘backside’ of the tool is the so-called Greenmapper Dashboard. Basic software for this has also been developed during the past year. The information coming from the survey part of the Greenmapper, combined with the online activities in the follow-up part of the tool, may potentially produce a lot of data. The aim of the software is to make these data easily accessible and usable. This is relevant for nature conservation organisations, governments, land owners etc. These organisations can get access to information about the areas they manage and also compare them with other areas. Dashboards are fine-tuned for every individual organisation. Of course the information is also relevant for research. Figure 3 shows an impression of how this dashboard may look for a specific area. The dashboard shows, for instance, the number of fans, recent online activities and the activities most often mentioned for the area. An important element is the two maps, showing in a different way where the fans of the area are coming from. The first map illustrates by means of a spider where the people who have marked the area as their favourite nature spot live. The other map shows the proportion of respondents from each municipality who have marked the area.

![Greenmapper Dashboard](image)

**Figure 3 | An impression of the Greenmapper Dashboard.**

**Relevance for stakeholders**

At present, the Greenmapper tool is being used in two pilots in cooperation with two of our stakeholders, the *Stichting Goois Natuurreservaat* and the *Zeven Bossen van Beetsterzwaag*. The aim is to continue developing and using the tool in cooperation with other nature conservation organisations. The relevance of the Greenmapper tool for nature conservation organisations and other stakeholders in the project is twofold. First of all, it is the large amount of data that is translated into usable, accessible
information in the Dashboard. Using this information, stakeholders learn about the characteristics of the area’s fans and where they are coming from. For instance, are they mainly people coming from the region or are they also coming from elsewhere? Is it possible to distinguish specific target groups within the group of fans? This can be useful for tailored marketing and the provision of facilities. It also becomes clear which specific places within the area are highly valued. Secondly, the dashboard also enables an easy comparison, ‘benchmarking’, with other nature areas.

In addition to providing information, Greenmapper offers the opportunity to explore new forms of online support. The tool offers a new way to reach fans of an area and to involve them in the area’s management, for instance by asking their opinion on management issues. There is also the possibility to experiment with new ways of financing, for instance crowdfunding for a specific project in the area. Finally, because the tool offers the possibility to discover new nature areas, Greenmapper can also be a means for attracting new fans for the area. Several of these potential functions need to be further tested in the coming years.

**Publications**

Bijker, R.A. and Sijtsma, F.J. A portfolio of natural places: Using a participatory GIS tool to compare the appreciation and use of green spaces inside and outside urban areas by urban residents. Submitted to an international journal.

Farm and landscape management for ecosystem services in the Hoeksche Waard

Willemien Geertsema¹, Joana Frazão², Mirjam Pulleman² and Paul van Rijn³

¹Centre for Crop Systems Analysis, Wageningen University
P.O. Box 430, 6700 AK Wageningen

²Department of Soil Quality, Wageningen University
P.O. Box 47, 6700 AA Wageningen

³Institute for Biodiversity and Ecosystem Dynamics (IBED), University of Amsterdam
Science Park 904, 1098 XH Amsterdam

Introduction

Three research projects in the programme Biodiversity Works are being conducted in the agricultural landscape of the Hoeksche Waard. The projects focus on the relation between farm and landscape management and the performance of ecosystem services that support crop production, including natural pest control, pollination, improving soil quality and water regulation. The collaboration with stakeholders of these projects is in many cases a joint action. In this contribution we describe these joint actions, focussing on the way researchers collaborate with stakeholders and the expected output of the projects. First we will start with a short description of how the different approaches of the three projects complement each other and how they are related to farm and landscape management. Next we will describe how the projects collaborate with the stakeholders in the Hoeksche Waard and how knowledge is developed together.

Ecosystem services in the agricultural landscape of the Hoeksche Waard

The Hoeksche Waard is an intensively used agricultural landscape that is characterised by open polders surrounded and crossed by dikes and intertwined with a network of creeks and ditches. Land use is dominated by annual crops, mainly potatoes, sugar beet, cereals and some vegetables. Stakeholders (including individual farmers, farmers’ organisation LTO, agri-environmental collective Rietgors, water board Hollandse Delta, nature and landscape conservation organisation Hoekschewaards Landschap, municipalities, and Province of Zuid Holland) share the ambition to improve natural pest control, pollination, soil quality, water purification, biodiversity and landscape aesthetics. This is a response to concerns regarding the observed negative externalities of agricultural practices such as loss of biodiversity, run-off of pesticides, and loss of soil and water quality. Different measures have been taken to achieve the aims (creating flower strips in field margins, reduced tillage, adjusted management of landscape elements). At the same time, the group of stakeholders is keen to learn about improving the effectiveness of management actions, to scale up from field to landscape level, and to increase understanding of trade-offs and synergies between different ecosystem services. The three projects focus on different aspect of this relation between farms, landscapes and ecosystem services.

The first project is aimed at understanding the interaction between soil properties, arable management and surrounding landscape in their effect on earthworm communities in arable fields and in field margins. This relation is studied with field surveys and experiments (Figure 1). Preliminary results indicate that field margins sustain different earthworm communities than the adjacent arable fields, and that residue management can increase the abundance of the epigeic species *Lumbricus rubellus* (epigeic species live in upper soil layers, are important decomposers). However, increasing the abundance of anecic species (build burrows into mineral soil layers, improve soil structure) with adjusted soil and residue management remains hard. The project aims to advise farmers about which management options improve the diversity of the earthworm community and how this effectively improves soil quality.
The second project studies the relation between landscape composition and natural pest control. The question is how the composition of a landscape (with different annual crops, flower strips, road verges, woodlots, etc.) influences the abundance and persistence of predatory insects (such as hoverflies) and their impact on aphid pests in crops (Figure 2). This question is studied with population dynamics models that are fed with field data (collected in the Hoeksche Waard) on resource availability within different habitats. The results show that for effective pest control hoverflies need different (‘complementary’) habitats to complete their life cycle: e.g. woodlots for shelter and for prey, nectar and pollen in winter and spring, different crops for aphids in early and late summer, and flower strips for nectar and pollen close to these crops. These results are used in the discussion with stakeholders about management and spatial design of crop rotation and non-crop habitats in the Hoeksche Waard.
The third project aims to integrate knowledge about different ecosystem services in the design and management of agricultural landscapes, including the Hoeksche Waard. The project develops knowledge about the seasonal distribution of resources (mainly pollen and nectar) for beneficial insects in the landscape and how that influences the potential for pollination and pest control. The project integrates this kind of knowledge with insights from other projects about the relations between farm and landscape management and the delivery of ecosystem services. These relations will be integrated in the landscape optimisation model ‘Landscape Images’. Understanding trade-offs and synergies between ecosystem services and other landscape functions is an important issue in this project. It takes the different objectives and ambitions of different stakeholders into account.

Collaboration with stakeholders

The three projects collaborate with stakeholders for various purposes. In some activities the projects act together, and in others they operate separately, depending on the phase of the project and the aim of the activity. The separate activities mainly relate to field surveys and experiments. Here we focus on the joint activities.

In the early stage of the projects (2012), two joint workshops were organised. The first one was a kick-off meeting, where a landscape design game was played with project members and stakeholders to exchange ideas about multifunctional landscape design and communicating and discussing the aims of the projects. The second one was organised to discuss with stakeholders their ambitions concerning the future development of the landscape. Not only local stakeholders, but also provincial and national governments were represented. An inventory was made how the objectives of the stakeholders relate to different ecosystem services. The stakeholders were also asked to identify management actions that were needed to realise the different objectives. The results of this workshop already gave an indication of the possible synergies between stakeholders: management actions that support multiple objectives.

In a third joint meeting (spring 2013), the three projects provided more detailed information about the research and expected results. It also informed them about the relation between the different research projects. From this workshop the idea emerged to start an initiative to design and realise a real, ‘ideal landscape’ in two parts of the Hoeksche Waard that could function as pilots for other areas (also outside the Hoeksche Waard).

To elaborate on this idea of the ‘ideal landscape’, stakeholders from the Hoeksche Waard organised different meetings, field visits and a workshop in 2014 with many stakeholders from the area itself, but also representatives from agri-food organisations (‘Sustainable agriculture in a sustainable landscape’) (Figure 3). We participated in these activities by sharing knowledge about the role of semi-natural habitats in the landscape to support ecosystem services and we identified knowledge gaps related to this subject. The original idea for an ideal landscape was modified in the end, and resulted in a plan to identify a number of demonstration farms that each will focus on specific aspects of sustainability and implement measures to realise these specific sustainability goals.

The paragraph above illustrates that participation with stakeholders is not always a predictable process. It requires flexibility within the research plans to respond to requests from the stakeholders. External factors such as the adjustment of European agricultural policies (especially regarding greening measures within the Common Agricultural Policy reform) were modifiers of the process.

Meetings and contact with the stakeholders do not always have to be formally related to the projects. One non-project-based activity is a field practical in May each year as part of the Agrobiodiversity course for students at Wageningen University. These students stay for one week in the Hoeksche Waard, performing a number of experiments at the farms of farmers who also participated in the aforementioned workshops. The students are supervised by the researchers from the three projects and during this week there is ample contact with the farmers, but also with representatives of local government, the Hoeksche Waards Landschap and the agri-environmental collective Rietgors.
In the near future the results from the different projects will be discussed again with the stakeholders, with a focus on the options for management on the farm and landscape scale and the implications for different stakeholder groups.

Figure 3 | Field visit with a number of stakeholders (local organisations and representatives of provincial and national government). Photo: W. Geertsema
Predicting the effect of extreme soil moisture changes on grasslands: a trait-based approach

Astra Ooms, Michiel Blaas, André Dias, Hans Cornelissen, Jacintha Ellers and Matty P. Berg

VU University, Amsterdam, Department of Ecological Science, section Animal Ecology
De Boelelaan 1085, 1081 HV Amsterdam, the Netherlands
E: astra.ooms@vu.nl

Understanding the effect of environmental change on biodiversity and ecosystem processes is a big challenge for nature managers. Besides understanding the effects of management controls it is also important to adapt management to predicted climatic changes to achieve the intended management objectives. One of the most important environmental changes nature managers have to cope with is the increase in frequency, duration and amplitude of extreme climatic events. For terrestrial ecosystems in particular, shifts in precipitation events are important for nature managers due to their strong effect on soil moisture levels. Furthermore, grasslands with a high biodiversity are set aside to store excess water during periods of heavy rainfall. This is often during the seasons that these systems are not adapted to high soil water levels. In many restoration projects with the aim of increasing biodiversity, soil moisture levels are restored in grasslands that were drained during the last century for crop production. For future nature management planning of groundwater levels it is important to understand the effect of these interventions on grassland biodiversity and soil functioning.

One of the difficulties in predicting how ecosystems react to extreme events is the taxonomical perspective of many studies, which often results in strong context dependency. It has been argued that adopting trait-based approaches might overcome this context dependency and provide the necessary generalisation (McGill et al. 2006). In order to understand the effect of (extreme) soil moisture changes on grassland biodiversity and soil functioning we aim to provide a general trait-based framework based on the theoretical framework proposed by Lavorel et al., (2013). This framework is based on correlations between ‘response traits’, which define an organism’s responsiveness to a particular environmental factor, and ‘effect traits’, potential effects of an organism on the next trophic level or an ecosystem function (Lavorel & Garnier, 2002; Suding et al., 2008). The framework might be used to understand the effects of environmental change on ecosystem functions via shifts in community structures. Although a few studies have adopted this framework (Lavorel et al., 2013), hardly any empirical testing of this framework has been conducted. We aim to set up an experiment to test the predictability of the response-and-effect trait framework with known macro-detritivore communities and their traits and a changing soil moisture level.

Figure 1 | Response and effect trait framework is used to predict effects of environmental change on ecosystem processes based on correlations between response traits and effect trait within plant and fauna communities.
We performed a soil moisture manipulation experiment under standardised laboratory conditions to measure the impact of changes in soil moisture levels on soil macrofauna communities and, subsequently, how alterations in community composition affects litter decomposition and nutrient leaching. We used Terrestrial Model Ecosystems (TMEs; polyethylene tubes placed on perforated plates to collect leachates) as described by Knacker et al., (2004). Rain-heads were designed to water the TMEs with artificial rainwater, after which the leached soil solution was collected in a bottle (Figure 2b).

![Figure 2](image)

Figure 2 | (a) Taking soil cores in de Veenkampen near Wageningen; (b) Laboratory setup with rain-heads for watering the TMEs

We added known communities of earthworm species (combinations of *Lumbricus rubellus*, *Aporrectodea caliginosa* and *Alolobophora chlorotica*) to defaunated intact soil cores in the TMEs derived from the Veenkampen near Wageningen (Figure 2a). These cores were exposed to drought or flooding conditions by changing the groundwater table. Drought and inundation resistance of the earthworm species were measured under controlled laboratory conditions, which enabled us to predict community response to soil moisture manipulations. The effect of monocultures of earthworm species on nutrient content in the soil solution was measured during the experiment. The drought and inundation exposure lasted for eight weeks after which earthworm survival and soil mineralisation (ammonium, nitrate and phosphate content in pore water) were measured.

Increasing the water table significantly increased the water content in the cores (55% vs. 45%; $F_1 = 38,174, p < 0.01$; Figure 3a), but this had no effect on earthworm survival (75% vs. 73%; Figure 3b). Soil moisture level had a significant effect on ammonium and nitrate levels in pore water, and were higher in dry soils (resp. $t_{74} = 2.5, p = 0.02$ and $t_{74} = 2.1, p = 0.04$, Figures 3c and 3d). Earthworm treatments had no effect on soil solution nutrient content. Phosphate levels were close to zero in all cores.

![Figure 3](image)

Figure 3 | (a) Mean soil water content ($F_1 = 38,174, p < 0.01$); (b) Mean earthworm survival; (c) Ammonium content in pore water ($t_{74} = 2.5, p = 0.02$); (d) Nitrate content in pore water ($t_{74} = 2.1, p = 0.04$)
Discussion and importance for stakeholders

The increased soil moisture level decreased ammonium and nitrate contents in water leachates. This result is comparable to field studies (e.g. Oomes et al., 1997) and is explained by lower oxygen levels in wet soils. Anoxic conditions negatively affect soil nitrification (Lavelle & Spain, 2003). Earthworms are important bioturbators and often show a positive effect on soil processes due to the mixing of soil and reducing anoxic condition due to tunnelling (Brown, 1995). However, we did not observe any earthworm effects on soil leaching and pore water nutrient content. This result was unexpected, because previous studies show a contribution of earthworms to ammonium and nitrogen level in soils (e.g. de Goede et al., 2003).

An overall survival rate of 75% of the earthworms accounts for approximately 311 individuals/m$^2$. This is comparable to densities found in natural soils, which range from 100 to 500 individuals (Lavelle & Spain, 2003). Earthworm density is therefore not likely to explain the absence of the effect of earthworms on ammonium and nitrogen content in pore water. One explanation might be that the high and low soil moisture levels during this experiment decreased the activity of the earthworms. A second explanation is that earthworms did enhance soil nutrient levels but that plants took up these additionally produced nutrients. We are currently measuring plant productivity to assess if the vegetation reacted positively to earthworm-induced nutrient levels.

The next step is to repeat this experiment with soil moisture regimes that are less extreme and more realistic for nature management (e.g. exposing vegetation in the right developmental stage to spring drought and summer flooding, spring flooding with normal summer conditions and permanent increased (but not flooded) soil moisture level). Understanding the consequences of environmental changes, caused by climate change or land use change, is important for nature managers who can try to adapt their management to these predicted changes. The benefit of the generic framework we are testing is that it can be used to predict potential effects of changes in environmental change on communities and ecosystems of interest. Therefore, this framework might be used as a tool to make predictions and to evaluate outcomes of previous management projects. Trait-based approaches will help us to understand the effects of environmental change on ecosystems and may therefore be of interest to nature managers too.

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