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Editorial

Use of ecological indicators in models

The use of ecological indicators in models has been a highly relevant topic in science and practice for several decades. Ecological indicators is a broad and diverse topic (Müller et al., 2013): for ecosystem and landscape organisation depiction (Müller, 2005), ecosystem health assessments (Müller et al., 2012), theoretical foundations of ecosystem dynamics (Fath and Müller, 2010; Müller and Leupelt, 1998), ecosystem service analyses (Müller and Burkhard, 2012), applications in environmental management (Müller and Lenz, 2006), or human-environmental system analysis (Burkhard and Müller, 2008; Müller and Li, 2004; see also Boxes 1–4). The use of models is not less manifold, including not only computer-based simulation models (Müller et al., 2011b) but also conceptual models (Müller et al., 2011a), data models (Müller et al., 2000), landscape models (Müller and Steinhardt, 2003), hierarchy models (Li and Müller, 1995; Müller, 1992), gradient models (Müller, 1998), theoretical and network models (Jørgensen and Müller, 2000; Müller, 1997) as well as economic and societal models (Kroll and Müller, 2011).

This Special Issue of Ecological Modelling is dedicated to our highly appreciated colleague Prof. Felix Müller from Kiel, Germany, celebrating his 60th birthday in November 2014. We brought together a diverse and very international group of colleagues which accompanied Felix during the last decades and produced this collection of high quality scientific articles in a Special Issue. The topics of the 21 articles in the Special Issue are related to Felix' life and work, full of ecosystem indication, ecosystem theory, systems analysis, ecological modelling, ecosystem services, holistic indicator

Box 1
Felix Müller by Sven Erik Jørgensen.
I met Felix 30 years when shortly after the *Projektzentrum Ökosystemforschung* Kiel has been founded. We have had since a fruitful and frictionless cooperation in ecological modeling, systems ecology, and later ecological indicators. We have both participated in many rewarding brainstorming meetings in Denmark, Germany, and Italy, which have given new insight in ecological theory. The use of ecological indicators started about 25 years ago and the first conference on ecological indicators was held in Fort Lauderdale, Florida in 1991, with Eric Hyatt as chairman. During the 1990s, Kiel University started a series workshops at the Salzau castle focusing on goal functions, orientors, and indicators. The journal *Ecological Indicators* started in the year 2000. *Elsevier* wanted to start a journal called *Biodiversity* and asked me about it and I proposed that they should rather give it the name *Ecological Indicators*, because biodiversity was just one of many ecological indicators and it was very much discussed in ecology at that time. It could, however, change their opinion and therefore it was better to use a name for the journal that would encompass all indicators. Eric Hyatt was the first editor in chief of *Ecological Indicators*, but he could not find the time needed for promoting a new scientific journal. *Elsevier* asked me if I could recommend a new editor in chief and I did not hesitate a second to propose Felix. The time has shown that it was a splendid recommendation, because today, *Ecological Indicators* is a very successful international scientific journal in applied ecology due to Felix's eminent leadership. In spite of it is publishing more than 2000 pages per year it receives many more good papers than it can publish. Congratulations, Felix.

Box 2
Felix Müller by Brian D. Fath
I want to extend my warmest wishes to Felix on this occasion and in particular note his outstanding contributions to science as an scholar, author, philosopher, teacher, editor, and colleague. I had the pleasure to first meet Felix during the first EcoSummit in Copenhagen in 1996. I was a Ph.D. student at the time, excited and overwhelmed by my first international conference. In fact, I can directly thank Felix for my participation in the EcoSummit because I travelled there on funds supplied from his own workshop on Goal Functions which immediately followed the EcoSummit. This smaller workshop held at the castle in Salzau, Germany was my first taste of true intellectual brainstorming and exchange. Of course a big part of the success of that workshop was the extensive and thorough preparation that Felix and his team had done. I was also drawn in by Felix's patience and humanity. Here, I was as a graduate student, and he was already a name in the field, yet he treated me with respect and collegiality, which later grew to friendship. This successful introduction to international science left an impression that I knew that I wanted to continue such activities. I had the opportunity to return to Salzau for several more workshops Felix organized, several of these tied to a course in the European Masters in Applied Ecology Program in which I was included as a lecturer at the University of Kiel. In addition there were brainstorming meetings in Denmark, Italy, and, Austria, as well as conference overlaps around the world. In each case, science advanced, and we had fun doing it. Felix, it has been a pleasure working with you and I look forward to continued collaborations.

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Box 3
Felix Müller by B. Larry Li
Someone ever said that "Friendship is not something that is written on paper, because paper can be torn. It is neither something that can be written on a rock, for even a rock can break. But it is written on the heart of a person, and it stays there forever." As you celebrate your 60th birthday, Felix, I celebrate the beautiful friendship we share! I met Felix back to late 1993 when I was invited to give the keynote address to an international workshop on fuzzy logic applications in ecology hosted by his German Ecology Center at Kiel, Germany. Since then we have enjoyed more than 20 year's academic and personal life together – as coauthors, collaborators, co-organizers, co-PhD student advisors, co-editors, and many more, and more importantly as several of my U.S. colleagues called us – brothers! On this occasion I would also like to congratulate Felix for his significant contributions and achievements to ecosystems science and ecological indicators. Shortly after I found Ecological Complexity journal with Elsevier, they discussed with me about the replacement of chief editor for Ecological Indicators. I recommended Felix to them; he has been excellent editor for the journal and made it very successful. Well, I have so many nice things I can say about him, but at this moment, again from the bottom of my heart, Happy Birthday, my dearest friend, Felix!!!

sets, and gradients on various spatial, temporal and interpersonal scales. The contributions refer to the use of (mainly ecological but also other) indicators in models and are organised in three key sections:

(A) New concepts and reviews of indicator-model linkages;
(B) Applications of ecological indicators in models; and
(C) Case study applications for ecosystem-based management.

The contributions include original research papers, review articles, and short communications.

Box 4
Felix Müller by Benjamin Burkhard
Since 13.5 years I have had the pleasure now to work in Felix' group in Kiel. And if I say pleasure, I really mean it – from a business point of view but particularly also from a personal one. Where would we be without our daily 9:30 and 12:30 coffee breaks with highly inspiring and often amusing discussions and talks?! Nobody knows; but what I know is that since I came to the Ecology Centre at Kiel University as a PhD student in 2001 to work in the EU project RENMAN about systems analysis of reindeer husbandry in northern Finland, Felix has always been an excellent supervisor, scientific and personal mentor and one of the most patient, relaxed and convincingly competent persons I have ever met. Truly as firm as a rock! Also in the follow-up projects in which we were involved, the numerous conference and workshop trips, taking us as far as Salzau, Butterworth, Columbus, Näkkälä and many other places all over the world, it has always been highly enjoyable to be in company with Felix and to enjoy his coffee's and/or cigarillo's fragrance. Felix' devotion to science, teaching and people in general have always been a constant source of inspiration, motivation and energy for me and many other persons who also had the pleasure to experience him. I am very grateful to have met you, Felix, and I am looking forward to future times together. I hope you enjoy reading this Special Issue dedicated to you and I wish you all the best - may you live long and prosper!

A: New concepts and reviews of indicator-model linkages

Approaches for data analysis in environmental research and related open source tools were reviewed by Lausch et al. (2015a). They suggest data mining and Linked Open Data (LOD) as new concepts to extract knowledge from complex and large interdisciplinary data sets and to avoid 'information overload'. Jørgensen (2015) presents a new method to calculate work energy of information using Boltzmann's equation for the free energy of information. He reveals how an organism's work energy is covered by eco-exergy calculations, including derivation and application of the new method. Jacobs et al. (2015) present pros and cons of the 'ecosystem service matrix' approach, where ecosystem service supply and demand are modelled against land use or land cover types. They reviewed relevant literature about expert elicitations and discuss the urgency-uncertainty dilemma of ecosystem service-based decision making.

Lausch et al. (2015b) compared and critically reviewed the application of the patch matrix model and the gradient model in landscape ecological process-pattern analysis. They found out, that depending on a landscape's hemeroby, either of the two should be implemented. Wiggering and Steinhardt (2015) elaborated on a conceptual model for future site-specific agricultural land-use. They argue for a systemic approach including landscape laboratories, new monitoring approaches, site-specific land use scenarios and modelling tools as alternatives to existing agricultural land use practices.

B: Applications of ecological indicators in models

Patten (2015) developed 'link tracking' as a methodology and applied it to an ecological stock-and-flow model. His results show that networks depict wholeness and that they can be used as models for holism for human systems as well as for ecological systems. Jørgensen and Nielsen (2015) argue for stronger consideration of vertical connections in network analyses. They analysed four competing ecosystems as a 'network within a network' in a model landscape.

Real-time-multi-purpose data applications for data assembling, evaluation, real-time modelling and visualisation are presented by Klug and Kmoch (2015). Hydrological indicators referring to flooding or water scarcity were used to exemplify the utility of publicly available and standardised ecological data for example for early warning purposes. Stoll et al. (2015) used the 'ecosystem service matrix' approach and harnessed knowledge from ecological, social, and economic science in the European Long Term Ecological Research (LTER) network to model ecosystem integrity and ecosystem services. Their results show ecosystem gradients across Europe and indicate differences between natural systems and anthropogenically determined systems.

Indicators for biodiversity and landscape diversity, derived for natural and cultural diversity as well as for anthropogenic impacts in Germany and Europe, were reviewed, selected, applied and mapped by Walz (2015). He used mainly publicly available data and the indicators will be integrated into an open access web platform. Different methods for pre-selecting sets of landscape metrics to model the richness of six organism groups as well as overall species richness in a Mediterranean forest landscape were tested by Schindler et al. (2015). They conclude that landscape metrics can be applied as indicators for species richness, but the appropriate method has to be selected carefully.

Flora species richness was applied as an ecological indicator for biodiversity in order to model agricultural field habitat values in the study of Bredemeier et al. (2015). They assessed impacts of Agri-Environmental Measures by comparing conventional

farming, organic farming, and nature conservation management in a case study in Germany. Lausch et al. (2015c) used different vegetation indices as indicators for a model that predicts different phenological stages of barley. They recommend the use of hyperspectral remote sensing data as a cost-efficient source of input data for ecological modelling.

C: Case study applications for ecosystem-based management

The Swiss Landscape Monitoring Program LABES includes a comprehensive indicator set for landscape assessments at the national scale (Kienast et al., 2015). The indicator framework refers to four pillars based on the DPSIR model. It includes physical landscape aspects such as ecosystem integrity and services as well as their perception by local people. Kienast et al. (2015) present the framework, tested the indicator set for geographical representativeness, and give recommendations on how to progress. Grunewald and Bastian (2015) describe the human-environmental system dynamics in the German 'Erzgebirge' (Ore Mountains) and related impacts on ecosystem integrity and ecosystem services. They furthermore give suggestions for sustainable landscape management, ecosystem research, indicators, and modelling.

A GIS-based Decision Support System with an integrated conceptual linear model of vulnerability for protected areas was developed and applied in Mediterranean maquis and dunes by Aretano et al. (2015). Their approach aims at dealing with complex systems by looking at inherent multiple causal chains and to guarantee a system's long-term functionality. Cadastral division of landscapes in relation to ecosystem service supply were analysed in three landscapes of western Denmark by Vejre et al. (2015). They found that cadastral units determine ecological modelling attempts and that a large number of land owners has effects on ecosystem service management. Spangenberg et al. (2015) applied the DPSIR model in a conceptual case study about rice production systems in Asia in relation to pest infestations. They suggest a modified 'double belly' DPSIR model in order to better take into account feedback mechanisms in ecosystem management.

Hainz-Renetzeder et al. (2015) provide recommendations for restoration projects based on comparisons of potential landscape service supply and actually used services in an Austrian case study. The potential service supply was modelled based on a constructed land cover map derived from potential vegetation types. Harmackova and Vackar (2015) assessed the outcomes of regulating ecosystem service trade-offs from alternative scenarios in a Czech Wetlands Biosphere Reserve. They found out that regulating ecosystem service values were highest under a nature conservation scenario whereas an exploitation scenario would lead to net carbon losses.

Wetland ecosystem services were also the topic of Sun et al.'s (2015) study, who evaluated system performance after different restoration measures in a Chinese case study based on an originally developed indicator system. They found that one-half of the wetland restoration projects would profit after the measures' implementation.

The articles included in this Special Issue, as well as Felix Müller's numerous contributions to ecological science and education, show that there is an amazingly diverse use of ecological indicators in models. Furthermore, the high quality of the individual contributions illustrates the progress that has been made in related research fields and practical applications of models and indicators. Future steps could include an exchange and streamlining of methods (where appropriate and useful), better use of data, e.g. by further employment of open data access strategies, improved engagement of end-users of ecological indicator and model data, and improved implementation of scientific findings for sustainable policy and decision making.

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