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MAPPING AND ASSESSMENT OF ECOSYSTEMS AND THEIR SERVICES (MAES): HIGHLIGHTS AND UNCERTAINTIES OF A SCIENCE-POLICY INTERFACE ON BIODIVERSITY AND ECOSYSTEM SERVICES

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ROZPOZNANIE I OCENA EKOSYSTEMÓW I ICH ŚWIADCZEŃ (MAES): WYBRANE ZAGADNIENIA I NIEPEWNOŚCI WSPÓŁDZIAŁANIA NAUKI I POLITYKI W ZAKRESIE BIORÓŻNORODNOŚCI I ŚWIADCZEŃ EKOSYSTEMÓW

STRESZCZENIE: Działanie 5 sformułowane w Unijnej Strategii Bioróżnorodności do 2020 r. zobowiązuje kraje członkowskie do rozpoznania i oceny ekosystemów oraz dostarczanych przez nie świadczeń (MAES). Ostatnie analizy wskazują, że działanie to zostało zainicjowane przez prawie wszystkie kraje członkowskie Unii Europejskiej. Oceny na poziomie krajowym są wspierane wytycznymi przygotowanymi przez Grupę Roboczą MAES (raporty techniczne MAES). Podejście MAES jest oparte na modelu "wspólnota praktyk", zgodnie z którym naukowcy i politycy wypracowują wspólnie wskazania dla państw członkowskich, oparte na ich wiedzy oraz ekspertyzach dotyczących ekosystemów i ich świadczeń. Ocena w skali europejskiej jest prowadzona w oparciu o czteroetapowe postępowanie: rozpoznanie ekosystemów, ocenę stanu ekosystemów, kwantyfikację świadczeń ekosystemów oraz integrację wyników uzyskanych na powyższych etapach w celu wsparcia procesu tworzenia i wdrażania polityk. W artykule zaproponowano trzy podejścia dla rozwiązania wątpliwości, które pojawiają się podczas rozpoznania i oceny ekosystemów oraz w trakcie wykorzystywania tej wiedzy na potrzeby polityki: lepsze rozpoznanie publikowanych dowodów naukowych, porównanie rezultatów procesu MAES w różnych skalach przestrzennych, a także jednoczesne współtworzenie wiedzy przez naukowców i polityków.

SŁOWA KLUCZOWE: MAES, ocena ekosystemów, świadczenia ekosystemów, mapowanie, Unia Europejska, niepewność

Introduction

Target 2 of the EU Biodiversity Strategy to 2020 aims to maintain and enhance ecosystem services by developing green infrastructure and by restoring 15% of Europe's degraded ecosystems by 2020. A similar target exists at global level. Aichi target 15 aims to enhance ecosystem resilience and the contribution of biodiversity to carbon stocks through conservation and restoration, including restoration of at least 15% of degraded ecosystems, thereby contributing to climate change mitigation and adaptation and to combating desertification.

To meet these targets, the European Commission and the EU Member States have made the commitment to develop a strategic framework to set priorities for the development of green infrastructure and for restoration activities at sub-national, national and EU level: which degraded ecosystems need to be restored in priority? Clearly, such planning needs to be well informed, which requires spatially explicit information on ecosystem condition and delivery of ecosystem services.

This knowledge base is currently developed under the MAES initiative on Mapping and Assessment of Ecosystems and their Services. MAES is the implementation of the first part of Action 5 of the EU Biodiversity Strategy which encourages the EU Member States, with the assistance of the Commission, to map and assess the state of ecosystems and their services in their national territory.

This paper presents a review of the work that has been developed so far under Action 5. It firstly describes the MAES approach to ecosystem assessment. Next the implementation of the MAES process is evaluated at national and EU levels. Finally the paper briefs on how scientific uncertainty and gaps between science and policy related to mapping and assessment can be addressed.

The MAES approach

Ecosystem assessments form an essential knowledge base to provide information for decision making in policy and practise. In this context, an assessment refers to the analysis and review of information derived from research for the purpose of helping someone in a position of responsibility to evaluate possible actions or think about a problem. In Europe, several approaches for ecosystem assessment are used, which have been recently

reviewed[1]. The Millennium Ecosystem Assessment (MA)[2], completed in 2005, spurred several national ecosystem assessments including assessments in Portugal, Spain and the United Kingdom. They are founded on the MA conceptual model which links biodiversity and ecosystems to human well-being (MA 2005). Other countries, including Germany[3], The Netherlands and Finland, adopted the TEEB (The Economics of Ecosystems and Biodiversity) approach, which puts focus on making visible the values ecosystems and ecosystem services for the economy, often using case studies. The MAES approach, which is under development since 2012, differs from the MA and TEEB approaches in that, besides assessment, it also focuses on mapping. This focus originates from the conviction that spatially-explicit information is needed to guide decisions on restoration and the development of green infrastructure in urban and rural settings. Ecosystems are inherently spatial and so, too, is their condition and their capacity to deliver services.

The working group MAES is mandated to coordinate and oversee Action 5. The working group consists of different actors: staff members of different services of the European Commission and the European Environment Agency, official representatives of the member states with a mandate of the ministry which implements the biodiversity strategy, and independent scientific experts. The working group MAES carries out its activities as a community of practise with two main areas of attention: guidance to member states based on ecosystem pilots, and EU wide assessments of ecosystems and ecosystem services. Specific guidance for member states on how to map and assess ecosystems and their services is given in a series of MAES reports. A first report[4] proposes a conceptual framework linking biodiversity, ecosystem condition and ecosystem services to human well-being. Furthermore, it develops a typology for ecosystems in Europe and adopted the CICES classification as a typology for ecosystem services (Common International Classification for Ecosystem Services). The second MAES[5] report describes a common assessment framework for measuring ecosystem condition and ecosystem services for forests, cropland, grassland, wetlands, lakes and rivers, groundwater sys-

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1 M. Schröter et al., *National Ecosystem Assessments in Europe: A Review,* "BioScience" 2016 (in press).

2 *Millennium Ecosystem Assessment, Ecosystems and Human Well-being: Biodiversity Synthesis*, Washington 2005.

3 B. Hedden-Dunkhorst, L. Braat, H. Wittmer, *TEEB emerging at the country level: Challenges and opportunities*, "Ecosystem Services" 2015 no. 14(37).

4 J. Maes et al., *Mapping and Assessment of Ecosystems and their Services. An analytical framework for ecosystem assessments under action 5 of the EU biodiversity strategy to 2020*, Publications office of the European Union, Luxembourg 2013.

5 J. Maes et al., *Mapping and Assessment of Ecosystems and their Services: Indicators for ecosystem assessments under Action 5 of the EU Biodiversity Strategy to 2020*, Publications office of the European Union, Luxembourg 2014.

tems and four marine ecosystem types. The third report[6] describes the state of the art in mapping and assessment of ecosystem condition at European scale while the fourth report[7] presents guidance for mapping and assessment of urban ecosystems.

The community-of-practise model which is adopted by the working group MAES ensures that the guidance is scientifically sound while at the same time relevant for policy and decision making. The different ecosystem pilots have been set up as working groups which include scientists and civil servants employed a public administration responsible for biodiversity. The MAES urban ecosystem pilot for instance formulated guidance on mapping assessment using the support of local planners and administrators from 10 European cities.

Current implementation of MAES at EU and member state level

The EU biodiversity strategy was adopted on 3 May 2011 and subsequently endorsed by the Council of Ministers and the European Parliament. The working group MAES started its activities on 13 March 2012 with a first working group meeting. Four years later, substantial progress on mapping and assessment has been achieved. While much of the focus went to biophysical mapping and assessment of ecosystems and ecosystem services, current attention will increasingly shift to develop methods and indicators to quantify ecosystem condition and to assess the economic value of ecosystems in Action 5.

Progress made by the EU Member States

The progress made by the EU member states has been evaluated by the Esmeralda project, a coordination action funded under the Horizon 2020 programme with the specific aim to support the implementation of Action 5. Kopperoinen and co-workers[8] have analysed the progress of each country based on country fact sheets which contain information on the policy process, the relevant actors and the executive agencies involved in Action 5, the problems encountered, the data needs, the research capacity, and the actual

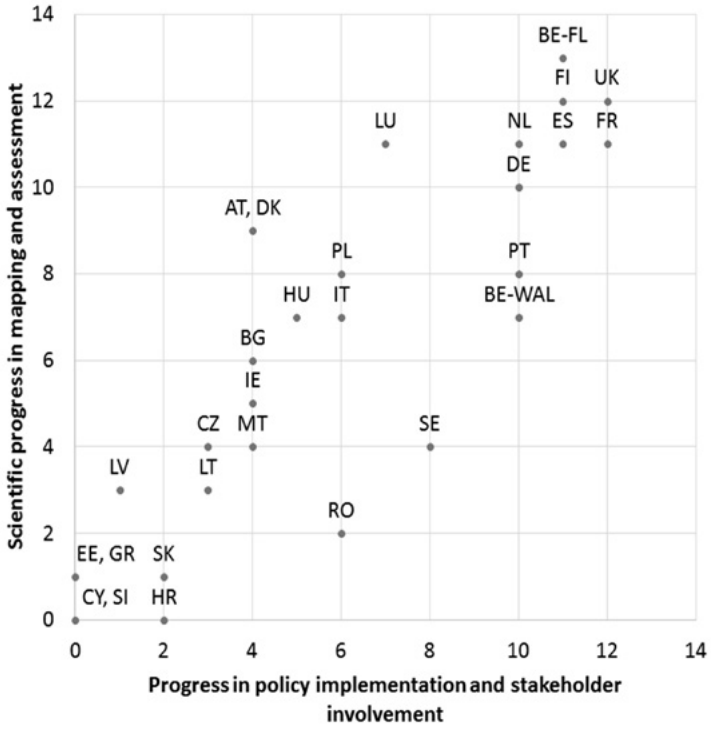
6 M. Erhard et al., *Mapping and Assessment of Ecosystems and their Services: Mapping and assessing the condition of Europe's ecosystems – Progress and challenges*, Publications office of the European Union, Luxembourg 2016.

7 J. Maes et al., *Mapping and Assessment of Ecosystems and their Services: Urban ecosystems*, Publications office of the European Union, Luxembourg 2016.

8 L. Kopperoinen et al., *Ecosystem service mapping and assessment gaps in EU member states and recommendations to overcome them. Deliverable 2.2*, EU Horizon 2020 ESMERALDA Project, Grant agreement No. 642007, 2016.

results and outcomes. These fact sheets are made available on BISE, the biodiversity information system for Europe[9].

Most EU member states are now actively involved in mapping and assessing the state of ecosystems and their services on their national territory. However, differences in policy response to the ambitions set forward in the Biodiversity Strategy, lack of sufficient resources and research capacity, different levels of stakeholder engagement and problems related to data availability have resulted in different implementation levels of Action 5 across the EU member states.



Country codes according to the international two digit codes. A separate assessment was made for two Belgian regions (BE-WAL stands for Wallonia, BE-FL for Flanders).

Figure 1. Implementation of Action 5 of the EU Biodiversity Strategy to 2020 in the EU Member States. Assessment from the Esmeralda project

Source: L. Kopperoinen et al., *Ecosystem service mapping and assessment gaps in EU member states and recommendations to overcome them. Deliverable 2.2,* EU Horizon 2020 ESMERALDA Project, Grant agreement No. 642007, 2016.

9 www.biodiversity.europa.eu/maes [29–10–2016].

Figure 1 shows the progress made by the different countries along two main working streams which are deemed necessary to successfully implement Action 5: progress made in policy activities and stakeholder consultation and progress made in the scientific activities (mapping and assessment). Each axis measures progress by summing the number of positive answers (yes) to a set of questions (see also Annex 1 in Kopperoinen et al.). The maximum score on the policy and stakeholder axis of figure 1 is 12; the maximum score on the research axis of figure 1 is 15. The analysis is based on data collected before December 2015. Consider for instance the position of Poland (PL) on the biplot. Questions for Poland about the policy implementation and stakeholder involvement of the MAES initiative resulted six times in a positive answer (yes) and six times in a negative or unknown answer. As for research (status of mapping and assessment) Poland received eight positive answers (see also Annex 2 in Kopperoinen et al.). This puts Poland exactly in the middle of the implementation process.

Two main findings emerge when inspecting figure 1. First, there is a high variability in progress made across the EU and second, progress in policy and stakeholder involvement is positively correlated to scientific progress.

Countries in the upper right corner have implemented MAES or have made substantial progress over the last two years. These include for instance the UK, Spain and Portugal which already carried out a national MA type ecosystem assessment. Countries in the lower left corner including the Baltic countries and several Balkan countries have yet to implement MAES. Often a lack of sufficient resources is at the basis of slow implementation. Countries in the middle of the cloud such as Austria, Malta or Ireland are in the process of implementation and several of these countries have started MAES-type projects and assessments.

Figure 1 clearly shows that Action 5 has resulted in a functional science-policy interface across the EU. Both processes, policy and research, go hand in hand and are probably reinforcing each other. There are no countries in the upper left corner or the lower right corner of the biplot which would suggest that either policy or research are disproportionally developed.

Figure 1 represents a snapshot of the situation how it is assessed at the end of 2015 but it is a useful baseline to measure progress of the MAES process in the next years.

Progress at EU level

Whereas Action 5 requires implementation at national level, progress has also been made at EU level where the work is mainly guided by the MAES

common assessment framework (figure 2). The MAES conceptual model[10] builds on the premise that the delivery of certain ecosystem services upon which we rely for our socio-economic development and long-term human well-being is strongly dependent on both the spatial accessibility of ecosystems as well as on ecosystem condition. This working hypothesis has been translated into a working structure which follows a four step approach to pan-European ecosystem assessment:

- Mapping ecosystems;
- Assessment of ecosystem condition;
- Quantification of the services provided by the ecosystem;
- Compilation of these into an integrated ecosystem assessment (figure 2).

The process of mapping and assessment of ecosystems and their services starts with mapping ecosystems themselves. A full map of European ecosystems has now been completed by the European Environment Agency. The dataset combines the Corine based MAES ecosystem types (figure 2) with the EUNIS habitat classification[11].

The second step is to assess ecosystem condition, which is defined as the physical, chemical and biological condition of an ecosystem at a particular point in time which can also be referred to as its quality. Different EU environmental directives already require the collection of data which can be used to assess the condition of ecosystems. Under Article 17 of the Habitats Directive the conservation status of vulnerable habitats and species is assessed every six years (Art. 17 assessment, figure 2). The Water Framework Directive (WFD) and the Marine Strategy Framework Directive (MSFD) also foresee in regular EU wide assessments of ecological status and environmental status, respectively. These data are of prior importance to assess the condition of ecosystems under Action 5. In addition other data can be used to approximate ecosystem condition including drivers and pressures on ecosystems such as nitrogen loadings, habitat fragmentation or pollution. A recent assessment of the condition of the different MAES ecosystem types[6] reveals similarities and differences, but also strong linkages between many ecosystems. Most striking is the level of threat to European ecosystems: well over half of all the habitats and species covered by the Habitats Directive are assessed as being in 'unfavourable' condition and their status is generally declining or stable, with only a small proportion 'improving'.

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10 J. Maes et al., *An indicator framework for assessing ecosystem services in support of the EU Biodiversity Strategy to 2020*, "Ecosystem Services" 2016 no. 17, p. 14–23.

11 www.eea.europa.eu [20–10–2016].

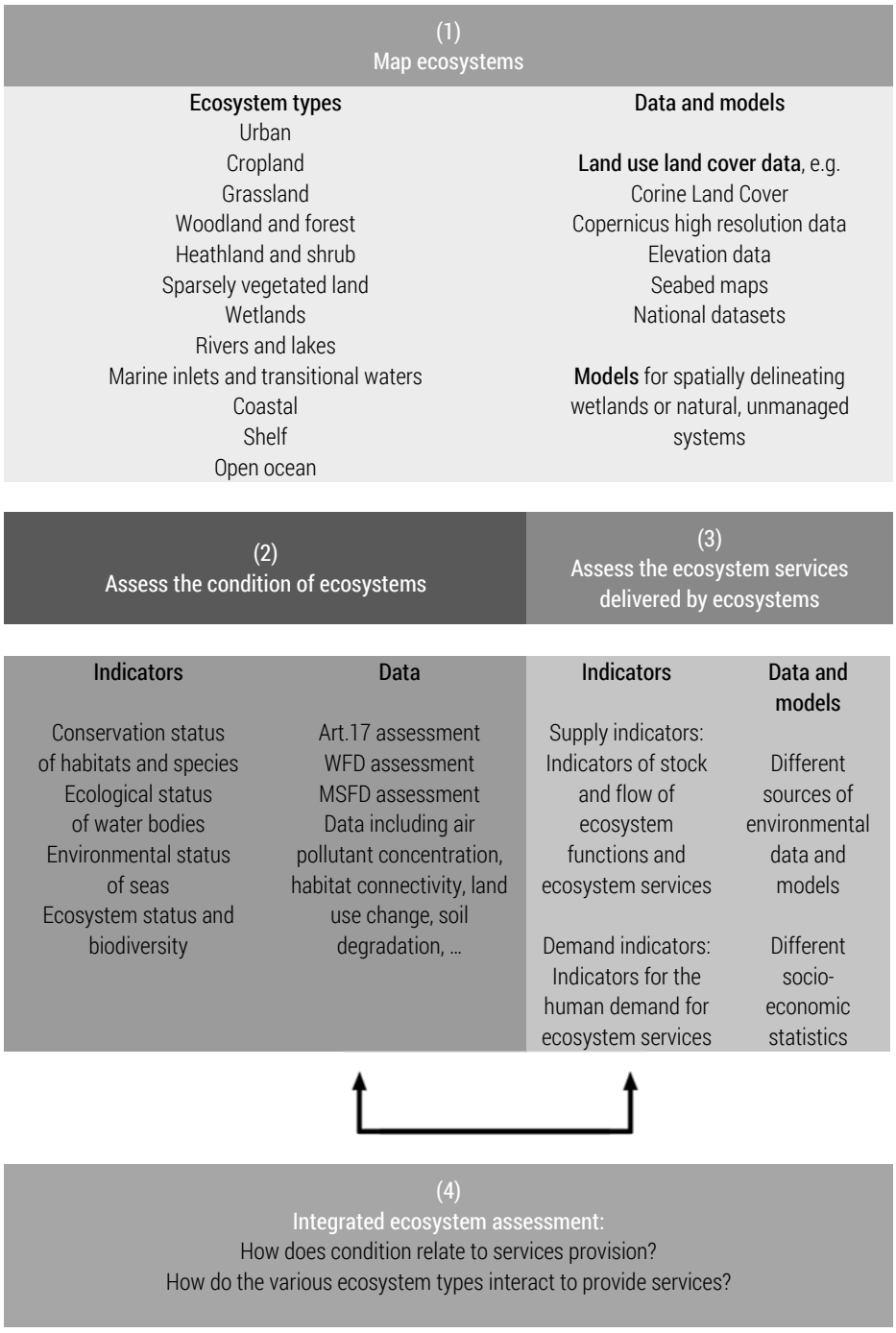

Figure 2. The MAES common assessment framework for mapping and assessment of ecosystems and their services

The third step is to assess ecosystem services based on an assessment of supply and demand for ecosystem services (figure 2). Maes et al.[12] assessed the trends of ecosystem services at the European scale between 2000 and 2010 based on a set of 30 indicators. Most provisioning services showed increasing trends. More crops were produced on less arable land. Organic farming gained importance. More timber was removed from forests with increasing timber stocks. The increasing extent of forests resulted in positive influences on erosion control, carbon storage, water retention, air quality regulation and recreation. Indicators for these services remained stable or showed upward trends. More nature was protected in 2010 than in 2000 but in contrast, the trends of two ecosystem services indicators which are directly related to biodiversity, pollination and habitat quality, were worsening.

The fourth step is integrated assessment which is currently under development. The capacity of an ecosystem to deliver different ecosystem services is related to the condition of this ecosystem. In a "healthy state", an ecosystem may provide a sustained flow of a variety of services compared to an ecosystem, which is managed to provide only a maximum amount of one specific service, e.g. fish, crops or timber. As a result, the overall capacity of such a system to provide services will be higher. Ecosystems in a "healthy state" are considered resilient systems, which are able to recover after disturbance and they are generally characterized by higher species diversity and a balanced trophic community. Every ecosystem delivers multiple services. The mapping work is therefore not targeted to identify the maximum potential of one service but to understand the spatial delivery of multiple services by interconnected ecosystems.

Addressing uncertainties of a science-policy interface

The conceptual model which was developed to support MAES-type ecosystem assessments links biodiversity and ecosystems to the socio-economic system via the flow of ecosystem services, and through the drivers of change that affect ecosystems either as consequence of using the services or as indirect impacts due to human activities in general. Uncertainty emerges at several points in the model. How certain are we that biodiversity underpins the delivery of ecosystem services as suggested by the MAES conceptual model? What is the uncertainty associated to mapping or quantifying ecosystem services? How to communicate scientific uncertainty when designing or imple-

12 J. Maes et al., *Mapping and Assessment of Ecosystems and their Services: Trends in ecosystems and ecosystem services in the European Union between 2000 and 2010*, Publications office of the European Union, Luxembourg 2015.

menting biodiversity policy? It is essential to address these uncertainties and finding ways to reduce them if we want to mainstream biodiversity and ecosystem services into policy and decision making processes.

One obvious but often overlooked way of addressing uncertainty is to map the evidence[13]. The digital revolution has not only resulted in an increase of scientific articles and reports but has also increased the accessibility to scientific results. This has greatly improved the capacity to synthesise what is known, develop an evidence base and to map uncertainties, gaps and unknowns. Mapping the evidence is particularly useful in the debate on the nature of the relation between biodiversity and ecosystem services. Sound and correct evidence in support of this relation is crucial to the development of biodiversity policy and for the conservation and management of natural resources. An illustration of an evidence map on the linkages between biodiversity and ecosystem services is provided by Harrison et al.[14] as part of the BESAFE project. These authors reviewed 530 studies and mapped the relation between biodiversity attributes and 11 ecosystem services. They found that most reported relationships between biodiversity attributes and ecosystem services were positive. The OpenNESS project, also funded under the 7th framework program for research and innovation of the European Commission, has further elaborated the analysis by Harrison et al (2016) including more studies and more ecosystem services[15].

The MAES initiative has undoubtedly triggered many studies in Europe which map ecosystem services. However, the lack of data for many ecosystem services and the consequent reliance on models to approximate them may result in considerable error. Seppelt et al.[16] reviewed 153 studies of ecosystem services and found that less than 40% of the studies derived their results on primary data from observations or measurements whereas about two-thirds based their results on mainly unvalidated, secondary data. They concluded that less than one-third of all studies provided a sound basis for their conclusions. Clearly, more efforts are needed to collect primary data of ecosystem service flows, to validate model-based proxies for ecosystem services and to compare outcomes among different models within and across geographic scales. Examples of such comparison are already available. Schulp et

13 M.C. McKinnon et al., *Sustainability: Map the evidence*, "Nature" 2015 vol. 528, no. 7581.

14 P.A. Harrison et al., *Linkages between biodiversity attributes and ecosystem services: A systematic review,* "Ecosystem Services" 2014 no. 9, p. 191–203.

15 M. Pérez Soba et al., *Database and operational classification system of ecosystem service – natural capital relationships*, European Commission FP7, 2015.

16 R. Seppelt et al., *A quantitative review of ecosystem service studies: Approaches, shortcomings and the road ahead*, "Journal of Applied Ecology" 2011 no. 48, p. 630–636.

al.[17] compared four different approaches to map the same ecosystem services at European scale. Differences among the maps were caused by differences in indicator definition, level of process understanding, mapping aim, data sources and methodology. Yet, comparing the maps revealed that they broadly agree (between 50% and 80% agreement) on the location of hotspots and coldspots for ecosystem services in Europe. Dick et al.[18] downscaled a set of ecosystem service maps developed at the European scale to quantify ecosystem service delivery of 11 long-term ecological monitoring sites and compared the results with locally collected data and measurements of ecosystem services. Then they used multivariate and regression statistics to compare the results of the two separate methods. The data collected at EU level captured between 20% and 40% of the variance present in the locally collected data. So despite differences emerging across methods and scales, these sorts of collaborative mapping have provided encouraging results and can contribute to delivering a coherent message on the condition of ecosystems and the services and benefits they provide to society.

Even if scientific uncertainty is reduced, there remains a science-policy gap on how citizens, policy makers or practitioners can use new information of ecosystem condition and services which is collected in the MAES process. Science typically produces cognitive dissonance, uncomfortable levels of uncertainty, and resistance in policy and practise[19]. Knowledge co-production is potentially a powerful approach to increase the acceptance of new data and information and thus to increase its potential use in policy-making processes. In the framework of the MAES initiative the European Commission has organised several so-called hands-on mapping workshops20. The Member states were invited to these workshops in order to engage in a joint mapping effort. Every member states was asked to send a mixed team consisting of the mandated MAES representative (or someone from the ministry or an agency involved in the national implementation of Action 5), a scientist working on the biodiversity and ecosystem services science-policy interface and a specialist in digital mapping and geographical information systems. Based on policy questions, these teams started mapping ecosystem services such as timber, pollination, carbon sequestration and recreation using a vari-

17 C.J.E. Schulp et al., *Uncertainties in ecosystem service maps: A comparison on the European scale*, "PLOS ONE" 2014 nr 9.

18 J. Dick et al., *Cross-scale analysis of ecosystem services identified and assessed at local and European level*, "Ecological Indicators" 2014 no. 38, p. 20–30.

19 G.A. Bradshaw, J.G. Borchers, *Uncertainty as information: narrowing the science-policy gap*, "Conservation Ecology" 2000 no. 4(7).

20 M. Pérez-Soba et al., *Training member states on ecosystem services mapping through hands on workshops*, Final report to DG Environment, Alterra Wageningen University and Research centre and ETEH Zurich 2015.

ety of tools and methods while going through a process of several iterations to improve the maps and to reduce their uncertainty. In the context of MAES it is expected that knowledge co-production (i.e. the joint mapping of ecosystem condition and ecosystem services) enhances uptake of the scientific outcomes in policy.

Conclusions

Halfway through the MAES initiative on Mapping and Assessment of Ecosystems and their Services to ecosystem assessment delivered varying outcomes ranging from almost full implementation by some countries to a relatively poor uptake by others. At EU level substantial efforts have been made to map ecosystems, to assess their condition and to quantify the provision of ecosystem services but an integrated approach which links good ecosystem condition to the delivery of multiple services is still lacking. Such information and related case studies are essential to support the future development and implementation of policies such as agriculture, fisheries, climate change, and disaster risk reduction and management. The next steps will increasingly focus on the integrated valuation of ecosystem services and the translation of the knowledge base on ecosystem condition and services to reporting and accounting systems.

The successful experiments of knowledge co-production using training and mapping workshops where policy-makers and scientists work hand in hand to deliver useful products based on reliable data and scientific expertise may also serve as an example for the IPBES (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services) regional assessments. The European and Central Asian assessment of biodiversity and ecosystem services will be delivered in 2018. MAES can provide a crucial source of data and information for this assessment but also provide inspirational examples of how to set-up a science-policy interface at continental scale.

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