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Research Article

Germany's Ecosystem Services - State of the Indicator Development for a Nationwide Assessment and Monitoring

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Abstract

The obligations of the EU Biodiversity Strategy 2020 are generating a need to create national maps and monitoring systems for the state of biodiversity and ecosystem services (ES) on the basis of indicators. The paper gives an overview of the ecosystem services indicators being developed for Germany in the context of ongoing research projects. Additionally, it provides the indicator specifications, which are aligned with the EU MAES framework concepts (initiative on Mapping and Assessment of Ecosystems and their Services).

We illustrate aspects of data selection, calculation and negotiation procedures, results and target values in general and by way of examples. The German indicator-based approach presents measures and sums up ES in their spatial expression and temporal change and compares them with objectives. As far as possible, this is carried out according to the demand-supply concept. A prioritization of ES classes to be processed was carried out in the framework of an expert-based assessment. The results indicated that 21 of the 48

CICES classes (Common International Classification of Ecosystem Services) were most relevant for Germany in recent years. We proposed a total of 51 indicators, of which 14 indicators for 4 ES classes were accepted, implemented and published by the end of 2016. The development of ES maps and the indicator-based assessment on a national scale is a process. Consequently, the necessary further steps are shown.

Keywords

Biodiversity; CICES-classification; ecosystem condition; flood protection; MAES-framework; soil erosion; urban green space; wood accrual

Introduction

Ecosystems contribute to human well-being in many ways (MEA 2005). The European Union has therefore obliged its member states to record and assess the state of ecosystems and their services in national reports (EC 2011; Target 2, Action 5). In 2013, an EU initiative on Mapping and Assessment of Ecosystems and their Services (MAES) was launched, and a dedicated working group was established with member states, scientific experts and relevant stakeholders. ES maps are mandatory instruments for landscape planning, environmental resource management and land use optimization (Burkhard and Maes 2017).

The nationwide mapping and assessment of ES can be seen as part of a National Ecosystem Assessment (NEA) and is essential to understanding how ecosystems contribute to human well-being and to supporting decisions on policies which have an impact on natural resources (Burkhard and Maes 2017). The manner in which the EU member states implement the national surveys of ecosystem services (ES) can differ considerably, because the starting points and priorities are different (Schröter et al. 2016).

In Germany, the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (Environment Ministry, BMUB) and the Federal Agency for Nature Conservation (BfN) commissioned several research projects to address the requests made in the MAES context (Albert et al. 2015a, Grunewald et al. 2016). The implementation of MAES in Germany (in the following MAES-DE) is an ongoing process and forms the basis for a comprehensive assessment in terms of a German National Ecosystem Assessment (NEA-DE, Albert et al. 2017).

In parallel, the project “Natural Capital Germany – TEEB-DE” (www.naturkapitalteeb.de), supported by a broad community, was realized and completed in 2017. It was intended to make the services and values of nature more visible to German population and to develop proposals for how natural capital can be better integrated into private and public decision-making processes. However, a systematic analysis and mapping of ES at the national level (quantitative, reproducible) was not planned in this project.

Scientifically credible, practically relevant, and politically legitimate indicators are seen as key for a nationwide assessment of ecosystems and their services. In order to operationalize and present such indicators cartographically, they must be formalized and derived in terms of a basic spatial unit. In general, these are 1 km² grid fields (see CICES- and SEEA-Systems, Hein et al., 2016). The geo-spatial interpretation of indicators necessarily involves the simultaneous analysis of related aspects of spatial structure or processes with a spatial impact (e.g., www.IOER-monitor.de). This applies to basic data (land use, soil, population, etc.), administrative units (municipality, district, federal state) as well as figuring the results in maps. National ES indicators are indices which have a high level of aggregation and are mainly used for the strategy level. Furthermore, the indicators should have the following profile (Grunewald et al. 2016):

- The indicators should be relevant to environmental and nature-protection policies and further sectoral policies, i.e. maps and assessments should be generated to make the significance of the services of nature for humans visible.
- The ES indicators should be analytically clean, i.e. secured according to the current theoretical, scientific-technical knowledge and international standards, but also simple, repeatedly measurable and reproducible, practical, easy to interpret and spatially resolved for Germany, and should indicate trends over time.
- They should form a basis for international comparisons and enable an implementation of the ES approach with reference to the EU Biodiversity Strategy.

A national inventory of ecosystems and their services for Germany in the sense of a NEA-DE (Albert et al. 2017) is new. Against this background, the aim of the paper is to outline the conception of the development of nationwide indicators for ES, to discuss the state of implementation and to present further work. Starting point is the conceptual-methodological approach. Based on preliminary work (Marzelli et al. 2014, Albert et al. 2015a) and in regard with the specific data situation we show how the EU-MAES requirements can be implemented in Germany.

Such cross-media environmental assessment on ecosystem and landscape level presents a new part of the environmental reporting system. MAES-DE indicators are planned to inform different policies, e.g. agriculture, forestry, tourism, traffic planning, spatial planning, climate change mitigation and adaption, flood control, water quality, fresh water supply, air quality, etc. Additionally, MAES-indicators can become a nationwide data base for enhanced landscape planning. Landscape planning in Germany is a sectoral environmental planning with the aim to conserve and develop ecosystems to provide healthy living conditions, recreation opportunities and habitats for flora and fauna (Haaren 2004). Landscape planning is also responsible for looking at the capacity of ecosystems for long-term provisioning of services (e.g. natural soil fertility, filtering services, water retention, urban climate). By way of integration into different landscape planning procedures, national indicators for ecosystem services can become relevant also for Environmental Impact Assessment or Strategic Impact Assessment either as an additional piece of information or as an additional basis for evaluation in our opinion.

In the second step we explain for the three categories of final ES (provisioning, regulating, cultural ES) the processed ES classes with proposed national indicators. To become part of other existing official environmental indicator systems, the MAES indicators will have to go through additional negotiation processes with other ministries in the follow-up. Here 'relevance' and 'acceptance' are important criteria. Practical implementation is briefly illustrated on the basis of concrete examples. This includes particularly the template of indicator description, calculation steps and interpretation of results. In the latter, the focus is placed on the relationship between ES indicators and biodiversity, as the indicator development takes place within the scope of the EU Biodiversity Strategy 2020. Finally, we summarize first results and show the monitoring concept as well as the steps ahead.

Methodological framework and target category ES indicators

A scoping study proposed first national ES indicators and provided example maps based on existing data (Albert et al. 2015a). On this basis, the MAES-DE approach follows the recommendations of the European MAES working group (Maes et al. 2014, Maes et al. 2013Maes et al. 2014, Maes et al. 2013) as well as internationally and nationally accepted approaches (Brouwer et al. 2013, econcept/WSL 2013, Burkhard et al. 2014, Grunewald and Bastian 2015, Grunewald et al. 2016, Staub et al. 2011 and others). For assessing ecosystems and their services, the MAES conceptual framework includes the modules of (1) mapping the ecosystems, (2) assessing the ecosystem conditions, (3) assessing the ecosystem services and (4) integrated ecosystem assessment with connection to natural capital accounting. From the outset, the primary focus was placed on ES mapping and assessment (module 3). The principal system in Germany is based on ES classes of the international classification CICES (Common International Classification of Ecosystem Services, Haines-Young and Potschin 2013) and not on main ecosystem types (as in other countries such as UK, Spain or Portugal, cf. Schröter et al. 2016). Only selected ES indicators of relevance are implemented and monitored in Germany. This also differs from other countries, for example Finland, where an initial assessment of four indicators (structure and function of ecosystems, benefit and values of ES) for 28 ES classes were provided completely (so-called TEEB-Finland report, Jäppinen and Heliölä 2015).

Today, perhaps surprisingly, no comprehensive 'Ecosystem Type Map' for Germany is available, which should be provided for module (1). The development is only at the methodological stage now. The current situation regarding MEAS-DE data in Germany is as follows:

It is recommended that EU member states use CORINE Land Cover data (CLC, EEA 2007) to classify ecosystems at the national level (MAES module 1, Maes et al. 2014). CLC provides a concept and system across countries for acquiring and assessing this information and changes in it. In case land-use data should be regionally available with better spatial resolution or additional information, these should be used if suitable.

The Official Topographic-Cartographic Information System ATKIS is the base information system of the Federal Republic of Germany for digital topographical geodata. It consists of digital landscape models (Basic-DLM), digital terrain models (DGM), digital topographic maps (DTK) as well as digital ortho-photos (DOP). The scope of information of the basic landscape model is oriented according to the contents of topographic maps 1:25,000. There is an object-type catalogue with the categories: settlement, transportation, vegetation, water, relief and terrain. Generalized object types of Basic-DLM are shown in Fig. 1 (for further information see Federal Agency for Cartography and Geodesy 2011).

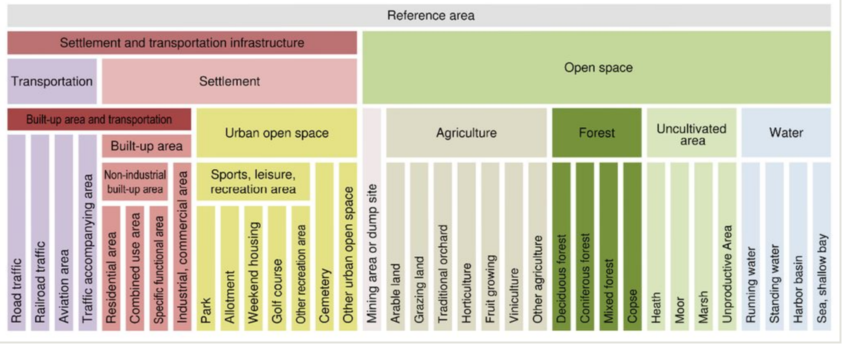

Figure 1.

Generalized object types of Basic-DLM (Source: www.ioer-monitor.de)

In order to produce a data set with the CORINE classification and a higher spatial resolution than CORINE (1:100.000), the Federal Agency for Cartography and Geodesy *(Bundesamt für Kartographie und Geodäsie*, BKG) has developed the digital land cover model for Germany (*Landbedeckungsmodell Deutschland*, LBM-DE) in cooperation with the Federal Environmental Agency (*Umweltbundesamt*, UBA) (EEA 2007, Hovenbitzer et al. 2014). For this purpose, the objects modeled as areas in the ATKIS Basis-DLM were reclassified into the CORINE categories and updated based on satellite images. The final scale of LBM-DE is 1:50.000.

Besides the ATKIS information further nationwide data sets (selection), which were used for ES-mapping and assessment:

- Additional spatial data sets are soil maps (particularly the topsoils map 1:1,000,000 of the Federal Institute for Geosciences and Natural Resources, BGR 2016), mapping of inundation areas, nitrate exposure modeling, elevation models, erosion modeling, ground waterbodies, groundwater infiltration rates, groundwater quality (Nitrate Directive monitoring points), number of inhabitants per 100m^2, suitability of land-use mix for recreation.
- Additional statistical data per city and county (German: „kreisfreie Stadt" and „Kreis"; Germany consists of 401 counties – "Kreise" and independent cities – "kreisfreie Städte") on nitrate surplus, freshwater extraction from groundwater and running water, water use.

- Additional point sources that provide a representative picture for Germany and each of the 16 federal states (Bundesländer): farmland ecosystems with high nature value, national forest inventory.
- Reporting data for WFD (Water Framework Directive) and Natura 2000 with rather low spatial resolutions.
- Additional national indicators from the national biodiversity strategies, e.g. bird population index.

Meanwhile, the European Environment Agency has presented a concept for capturing the condition of ecosystems (module 2) that should be the basis for analyzing the relationships between ecosystem condition and ES, since a Europe-wide harmonized approach is desired (EEA 2015). This concept provides for capturing the condition in a differentiated manner using several individual indicators that – just like the indicators for ES – are to be captured and represented comprehensively. Adopting this approach makes it necessary to provide corresponding indicators for Germany, too. On behalf of the Federal Agency for Nature Conservation (*Bundesamt für Naturschutz*, BfN), the Leibniz Institute of Ecological Urban and Regional Development (IOER) is currently developing the following nationwide indicators and maps for the condition of ecosystems: open space area with vegetation; nitrogen load; carbon stocks in soil and vegetation; amenities of landscapes with near-natural biotopes.

Indicators for assessing ES (module 3) can be directed at different quantities: e.g. the current flow of ES, nature's potential to provide ES or the demand or need for ES. The basis of the service is material and thus basically measurable. An exception is the group of intangible values for cultural ES. Usually, several service providers can be identified for a final ES (Hein et al. 2016, Syrbe et al. 2017b). It is to be noted that the indicators include a more technical part (such as measurability, data processing/quality, survey methods) and on the other hand socio-cultural aspects (Who values what and how?, problem recognition, deliberations, communication, etc.).

In the context of past research projects (e.g. TEEB-DE; Albert et al. 2015a), foundations were developed for module (4). But a complex integrated presentation, e.g. of the connections between ecosystem conditions and ES, has not been provided yet, among other because modules 2 and 3 were not yet available.

In order to adapt the German economy and society to a sustainable development path in keeping with the ecosystems' capacities, the ES must be integrated into economic accountings. The implementation of the EU Biodiversity Strategy requires this by 2020 (EC 2011). The concrete implementation of such an ecosystem accounting will be a challenge in the coming years (Hein et al. 2016). National Capital Accounting needs a database that is at least partially provided by the ongoing ecosystem service and condition assessment. In Germany this is not planned as a one-off campaign but as a permanent procedure to measure trends. In this way it could constantly (e.g. every five years) feed into Capital Accounting.

Developing indicators for ecosystem services at the federal level

In the framework of the BfN research project "TEEB Germany Overview Study" ("TEEB Deutschland Übersichtsstudie") completed in 2014, the possibilities of capturing ES in Germany at the federal level were examined (Marzelli et al. 2014). Building on this, "Recommendations for developing a first national indicator set for capturing ecosystem services" were prepared as a basis for further discussion (Albert et al. 2015a). A considerable need for further methodological development became apparent for actually generating new information that can be relevant to and useful for EU reports and strategic decisions in Germany and that is suitable for future accounting (Grunewald et al. 2016).

The BfN/BMUB research project "Implementation of Action 5 of the EU Biodiversity Strategy - Development and implementation of a methodology for capturing and assessing ecosystem services at the federal level in the context of the implementation of Target 2 and Action 5 of the EU Biodiversity Strategy for 2020" (2014-2016, research participants: IOER Dresden/ifuplan Munich) was initiated for this purpose. In addition to the further development of the concept and the implementation, some initial selected ES indicators were to be integrated into the "Monitor of Settlement and Open Space Development (IOER Monitor)", for which the IOER provides basic funding. The research work was in consultation BfN/IOER focused on 21 priority ES classes, and principles for describing indicandum (ES) and indicator were developed (Grunewald et al. 2016).

Overview of the state of implementation

Of the indicators with particularly high priority by the contracting authority (BfN), prototypes have been developed for four ES classes so far, which are largely harmonized and accepted (Table 1). The description of the ES, the justification of the indicator proposal, the methodology and data selection and the interpreted results are represented in detailed specification sheets (a comprehensive publication is planned for the end of 2017, for pre-releases on individual indicators see references). Result maps of the main indicators are illustrated in Fig. 2 (Grunewald et al. 2017, Grunewald et al. 2016, Syrbe et al. 2017a, Walz et al. 2017). Further map data and results can be viewed and evaluated in the indicator category Ecosystem Services in the IOER-Monitor (www.ioer-monitor.de).

The remaining indicators are still being developed (Table 2). The crucial reason lies in the fact that the coordination processes with client and external experts turned out to be more time-consuming and difficult than expected. At the request of BMUB and BfN, the indicators developed so far had to be adapted several times during the concept phase as well as in the later project.

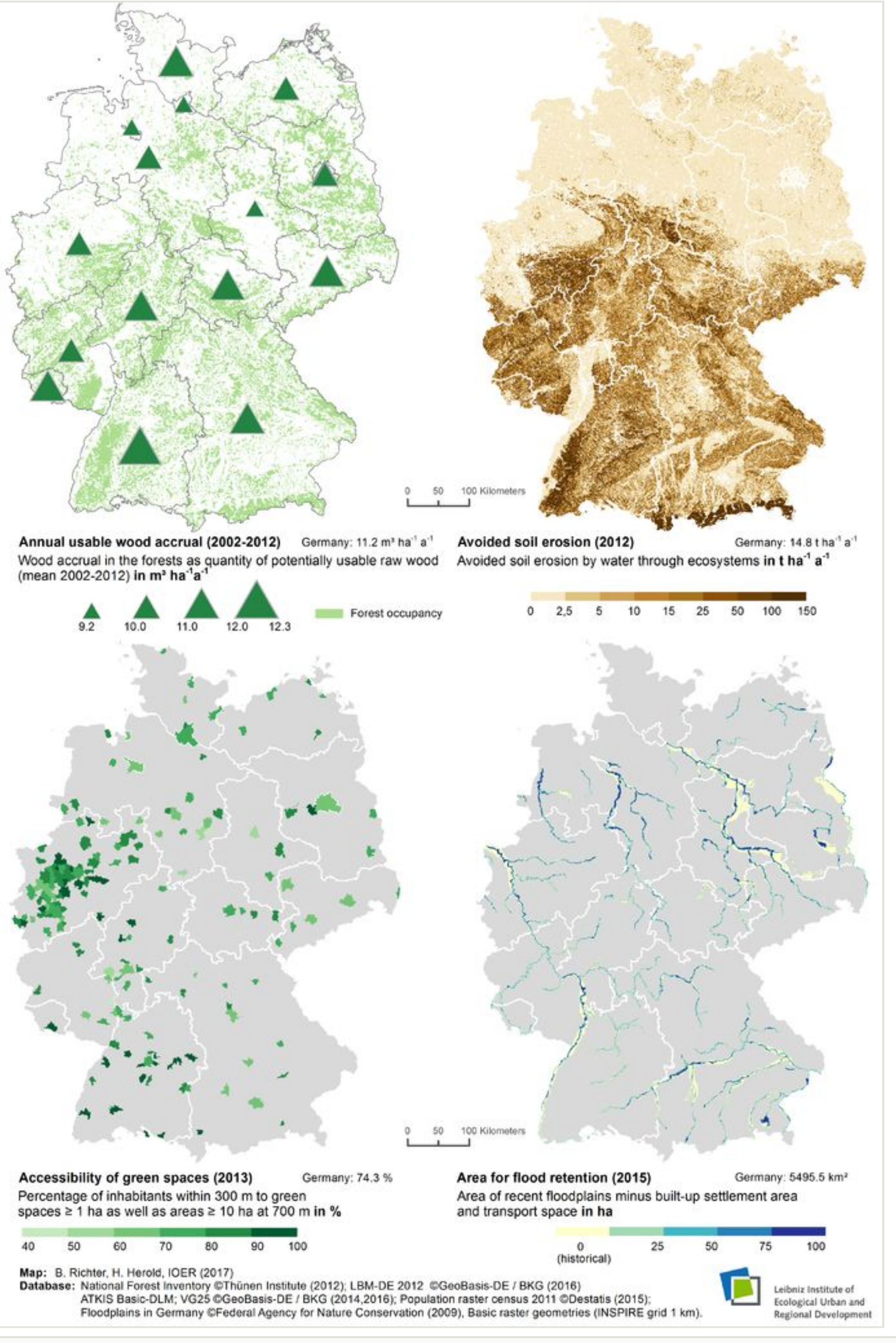

Figure 2.

Maps of the implemented main ES indicators

Table 1.

Selected ecosystem services for which nationwide indicators were implemented in Germany (as of December 13, 2016)

ES class according to CICES (modifications or further divisions in brackets)	Indicators* with average value of an ES for all of Germany (year)
Fibres and other materials from plants, algae and animals for direct use or processing (forest wood material)	M Annual usable wood accrual: 11.2 m^3 ha^{-1} a^{-1} (mean value 2002-2012) S1 Forest area: 11,419,124 ha (2015) S2 Wood stock 2012 referred to the forest area: 336 m^3 ha^{-1} S3 Development of the annual logging and wood utilization: 40.2 million tons (2013) S4 Change in wood stock as balance of growth and extraction: increase of 106.6% (2002-2012) S5 Proportion of near-natural forest areas 15% natural; 22% near-natural (2012) S6 Proportion of unfragmented forests > 50 km^2 in reference area: 3.5% (2014)
Flood protection	M Area for flood retention: 547,550 ha (2015) S Proportion of built-up areas in the current floodplain: 3.9 % (22,076 ha) in 2015
Mass stabilization and control of erosion rates	M Avoided water erosion: 14.8 t ha^{-1} a^{-1} (2012) S1 Actual water erosion: 1.4 t ha^{-1} a^{-1} (2012) S2 Water erosion avoided by small landscape structures: 0.5 t ha^{-1} a^{-1} (2012) S3 Proportion of organic farming: 1.9% of arable land (2012)
Experiential use of plants, animals and land-/ seascapes and physical use of land-/seascapes in different environmental settings (in this case we combined two CICES-classes)	M Accessibility of green spaces: 74.3% of city dwellers (2013), calculated for all cities ≥ 50,000 inhabitants S Green-space provision per inhabitant related to total amount of green space: 250 m^2 (2013)

* M – Main indicator, S – Supplementary indicator

Table 2.

Proposed nationwide ES indicators, which are still under development and negotiation (selection of ES-classes: cf. Albert et al. 2015a, Grunewald et al. 2016)

ES class (according to CICES)	Indicators (first pre-proposal)
Groundwater for drinking	M proportion of drinking water extracted (from groundwater) with respect to newly formed groundwater
Cultivated crops	M Change in yield potential S1 Harvest statistics grain units S2 Proportion of agricultural area S3 Proportion of organic farming
Reared animals and their outputs	M Stocking density (administrative area) S1 Stocking density (agricultural area) S2 Animal nitrogen fertilizer

Materials from plants, algae and animals for agricultural use	M Grassland area S Grassland area (agricultural area)
Plant-based resources	M Area for cultivating non-wood energy crops
Filtration/sequestration/storage/accumulation by ecosystems	M Protection potential of the groundwater cover (zone of aeration) S1 Nitrate pollution of groundwater S2 Extraction of drinking water from groundwater S3 Superposition of demand from GW aquifers of different levels of protection potential
Dilution by atmosphere, freshwater and marine ecosystems	M Proportion of waterbodies with good hydromorphological state S1 Biological water quality S2 Demand through use of drinking water S3 Demand by residents for recreational use S4 Chemical state of the surface waters
Pollination and seed dispersal	M Pollination potential S1 Bee colonies in Germany S2 Yield of tree fruits
Global climate regulation by reduction of greenhouse gas concentrations	M Annual net effect of ecosystems S1 Absolute value of the CO_2 stock S2 Index of the change in CO_2 stock
Ventilation and transpiration; Micro and regional climate regulation (we combined these two CICES-classes for practical reasons)	M Specific green volume S Population density / degree of sealing
Chemical condition of freshwaters	M1 Denitrification in the waterbody M2 Phosphorus retention in the waterbody
Pest control	M Density of small-scale structures in farmland or in specialty crops
Maintaining nursery populations and habitats	M Main areas of distribution with cultured species of related wild plants
Experiential use of plants, animals and land-/seascapes in different environmental settings	M Agricultural potential for leisure-time, daily and weekend recreation
Aesthetics	M Aesthetic value of the landscapes
Existence value	M Landscape diversity

Exemplary indicator specification for provisioning ES (forest wood material)

Provisioning services such as food, wood and drinking water rightly rank first among the ES, as human existence is impossible without them. However, since the end of the hunter-gatherer period the main quantity of food, for example, has not come from near-natural ecosystems, but from agriculture (agroecosystems). Increasingly, “non-natural” production systems for plants and animals have been created, which have been ethically justified with reference to the increase in population and competition for land and have continuously been perfected (Haber and Bückmann 2013). In this context it is contested whether ES merely refer to the natural foundations (e.g. soil fertility, groundwater supply) for the development of a beneficial good or a beneficial service (e.g. food or wood) or whether human production inputs (e.g. cultivation, fertilization and irrigation) are also included. The CICES classification indicates the latter (Haines-Young and Potschin 2013).

From the category of the supply ES, the class "Fibres and other materials from plants, algae and animals for direct use or processin" with the main indicator "annual usable wood accrual" and six secondary indicators was realized (Table 2) and interpreted (Grunewald et al. 2016). Using this ES class, it could be shown that data can sometimes be taken directly from governmental records (in this case: from the National Forest Inventory). In this case, however, they are only collected every 10 years and are only available for the state level. However, the secondary indicator "forest area" can be made available from ATKIS data with a higher spatial and temporal resolution (Table 1 and Table 3).

Table 3.

Synthesis of the main indicators implemented so far

Indicator	Spatial approach *						Time periods (to date and prospective next period in brackets)	First trend GER**	Assessment of the service provision
	IN	GER	FS	DISTR	MUN	GR			
Annual usable wood accrual	x	x	x				2002-2012 (2022)	3	
Area for flood retention	x	x	x	x	x	x	2010-2015 (2020)	2-3	
Avoided water erosion		x	x	x	x	x	2009-2012 (2015)	2	
Accessibility of urban green spaces		x	x		x	x	2008-2013-2015 (2018)	2-3	

* IN-international, GER-Germany, FS-federal state, DISTR-district, MUN-municipality, GR-grid
** Assessment scale: 0-cannot be assessed, 1-falling, 2-slightly decreasing, 3-constant, 4-slightly increasing, 5-strongly increasing

In principle, it should be noted that the provision of ES does not occur individually and independently but often entire bundles of ES are affected by decisions on use (keyword multifunctionality; e.g. forest as a provider of building materials or fuel, but also as an important carbon and water storage or recreation area) and that the quantification of provisioning ES is not about an increase in the quantity of goods or services from the ecosystems but about sustainable approaches for use.

The assessment of a provisioning service usually does not provide any information on the ecosystem condition or the biodiversity. For the main indicator "annual usable wood accrual", values between 9 and 12 m^3 ha^{-1} a^{-1} were determined for the federal states (mean for Germany 11.2 m^3 ha^{-1} a^{-1}, Table 1). The discussion with nature conservation experts showed among other things that in the framework of the biodiversity strategy the main indicator should not be communicated by itself, as a causal relationship with the naturalness of forests cannot be established. The secondary indicators S5 and S6 (Table 1), but also, for example, the parameters "Nature-related tree species composition", which are compiled within the framework of the National Forest Inventory, support the indicators on "provisioning" with selected information on biodiversity (Grunewald et al. 2016).

Exemplary indicator specification for regulating ES (erosion, flood protection)

Regulating ES are closely coupled to the state of the environment and usually positively correlated with greater biodiversity, e.g. flood control in floodplains and renaturalization of floodplains or mitigation of CO_2 emissions through peatland renaturalization and each lead to a better state of biodiversity. The clean distinction between indicators of the ecosystem condition and service indicators as well as the representation of dependencies and interactions are particular challenges in this area. In this respect, too, the CICES classification is not always sufficiently clear (e.g., ES class “Chemical condition of freshwaters”).

Out of this category, the classes “flood protection” and “mass stabilization and control of erosion rates” have been implemented so far (Table 1) in the context of the nationwide development of ES indicators.

In addition to the area size, flood retention is particularly dependent on the volume of the retention areas and the (distribution of the) flow velocity (valley floor gradient, damming “obstacles”, among others). Reliable statements on the actual flood retention of floodplains can only be made using modeling technology, which is currently not feasible with reasonable effort on a federal level. The BfN has therefore so far eschewed a nationwide determination of the flood retention capacity. Consequently, two simplified indicators for measuring the potential flood retention at the federal level were proposed, coordinated and implemented (Table 1). The indicators provide illustrative results on the reduction or on the positive development of regulative services of floodplains (Walz et al. 2017). This allows to indicate tendencies, successes and needs for action, which can be pointed out to the public and decision-makers with a view to the Biodiversity Strategy.

Although the actual service consists in the protective effect against soil loss, the amount of average soil loss can also be an indicator for erosion regulation service as the areas with high amount represent low erosion regulation supply. But this is not applicable vice versa since a low amount is also calculated for paved surfaces without a real service. In order to determine this protective effect, a reference value as stable as possible must be known (i.e. a maximum or mean erosion), which can be used for measuring the (positive) service. The hypothetical erosion in the case of open soil and a standard surface area size can be considered as a reference value; the protective service of the ecosystem then consists of the difference between possible and current erosion (Syrbe et al. 2017a).

Exemplary indicator specification for cultural ES (green-space access in cities)

Cultural and socio-cultural ES are the immaterial values and the use that people attribute to or derive from ecosystems. These hardly measurable features lead to the cultural ES being the least operationalized so far. However, qualitative assessments of landscape qualities are useful (e.g., Frank et al. 2012, Paracchini et al. 2014, Tratalos et al. 2016). Environmental psychology also provides many results on the interactions between ecosystems / nature / landscape and human well-being (for example, Abraham et al. 2010).

According to the CICES classification (Haines-Young and Potschin 2013), a distinction is made between the two divisions 'Physical and intellectual interactions with biota, ecosystems, and landscapes' and 'Spiritual, symbolic interaction with biota, ecosystems, and landscapes'. A one-to-one assignment of individual ES to the groups and divisions is usually not possible due to various interferences. For instance, the recreation service is to be assigned to both the use and the experience of landscapes.

The BfN has been defined to focus the work within the framework of Action 5 of the EU Biodiversity Strategy 2020 in Germany on the functions of the landscape for nature experience, recreational activities and aesthetics (Albert et al. 2015a). The indicators for the ES 'recreation in the city' (Table 1) were proposed, coordinated, implemented and published (e.g., Grunewald et al. 2017) in close coordination with the BfN/BMUB (partly also with the Federal Institute for Research on Building, Urban Affairs and Spatial Development, BBSR). Further indicators of this category (Table 2) are being developed through the research project 'Assessment of cultural ecosystem services in Germany' and are soon to be finalized (Albert et al. 2015b).

The assessment of the ecosystem service "recreation in the city" showed that for 74.3% of the inhabitants from the 182 cities studied (all cities ≥ 50,000 inhabitants), green spaces and water areas (≥ 1ha) were reachable at a linear distance of 300 m (≈ 500 m walking distance) as well as green spaces and water areas (≥10 ha) at a linear distance of 700 m (≈ 1,000 m walking distance). The individual cities can make comparisons among themselves and learn about their deviation from the mean or target value – the BfN proposes a target value of 95% by 2020. Not only this indicator shows that the results depend on the methods chosen, the data used, the stipulations made and the connections drawn, and that any interpretation should thus be cautious (Grunewald et al. 2017).

The ES indicator "Accessibility of green spaces" is also proposed for the German National Strategy on Biological Diversity (*Nationale Strategie zur Biologischen Vielfalt*, NBS). The ES indicator can underpin this NBS target as a measurement and monitoring quantity. The indicator is selected to address the aims of increasing the percentage of green areas and structures, linking them and pursuing a qualified brownfield development of settlements as well as reducing land use (BMU 2010). By 2020, the greening of the near-residential open spaces is to be increased significantly, and publicly accessible green spaces with varying qualities and functions are to be available within walking distance. This is not only important for human health reasons but also because a good accessibility and interconnection of green spaces is critical to their usability and enhances the attractiveness of inner cities. It helps to stop the land-intensive migration into the surroundings and contributes to reducing the volume of traffic (Grunewald et al. 2017).

First Synthesis

The German MAES process is still ongoing. A draft with a first nationwide trend analysis of ecosystem services combined with an assessment will be available at the end of 2017. MAES indicators in Germany are planned to become part of sets of other national environmental indicators that are monitored regularly. The ES indicators developed and implemented so far were mostly represented spatially in maps as well temporarily in their development trend (Table 3). However, the representation of relevant temporal changes / trends remains vague (methodological adjustments in ATKIS Basis-DLM until 2013; partly long survey periods), i.e. the trend of changes is partly not yet clear, comprehensible and assessable (Grunewald et al. 2016). Table 3 provides a first insight into what a future synthesis could look like. Every indicator and every ES class can stand on its own, but a general overview or insights according to categories are also possible. The "smiley" as an expression of positive development for the indicator wood is among other things due to the increase of the forest area, the nitrogen fertilization from the air and the increase in CO_2.

The indicators provide insights into the values and resilience of nature in Germany with respect to individual aspects, in different dimensions and with spatiotemporal specificity. In the desired aggregate (more complete set of ES indicators) also a more comprehensively and systematically assessment is aspired. In the best case, not only trends and priority areas but also requirements, consequences of action and load limits become apparent. This explicitly occurs against the background of functioning ecosystems and for the purpose of conserving biodiversity. Whether we can point to a “safe scope of action” for using natural resources in which growth is possible and change/limitation is necessary, requires further in-depth work and discussions.

The work so far allows the following further assessments and qualifications:

- The assignment of indicators and CICES classes is not always one-to-one (several indicators are possible for one ES class, and on the other hand one indicator can sometimes be assigned to different ES classes).
- The demand side (for example, the need for green areas in the city, woodcutting, flood protection) is considered a characteristic for the relationship between social needs and ecosystem change (responsiveness to changing needs) – but the relationship is difficult to represent. So far we have been trying to capture the intensity of the demand for ES.
- ES indicators are always a simplification of reality / complexity and there is no sure formula as to whether many indicators should be developed in order to represent the complexity or only few indicators (indexing) in order to focus practice and policy-making on the “essentials”. Accordingly, they cannot be taken alone as a guideline for political or practical decisions.
- It is a considerable challenge to simultaneously fulfil the indicator requirements from an environmental policy view (intuitive and comprehensible, coherent, cross-media, polluter-specific, adjustable, long-term), an economic policy view (in particular, they should allow scope for design and action, indicate solution ranges)

and a specialist view (see above). Accordingly, it is necessary to strike compromises.
- It must always be critically reflected what the indicators "indicate" for whom and what societal goals are associated with an indicator. Not the indicator but the indicandum is of real interest, i.e. the indicated, not directly measurable and often complex issue or condition/service and its changes.

Conclusion

In accordance with the requirements of the EU Biodiversity Strategy 2020, a system of national initial capture of ES for Germany was developed and coordinated. The representation of selected ES using indicators allows an overview and guarantees reporting (e.g. to the EU) and the use of first results for different purposes (e.g. via the IOER Monitor). However, this does not yet fulfil the intention of the ES concept to serve as an operative instrument for a sustainable development. The establishment and legitimation of the ES indicators is still at an early stage in Germany. In the long and medium term we therefore recommend from a scientific perspective:

- Continuing the work, started especially with regard to a NEA-DE and as a prerequisite for successful IPBES work (see section 1): development, implementation and coordination of a more complete ES indicator set;
- Maintenance: keeping indicators current, updating them (regular data analyses, interpretations) and recalculating them (time series, monitoring); including further development and reporting with regard to target deviation (validation of normative specifications, negotiation of societally desired conditions and developments). Competences, legal aspects, standards, GIS routines etc. for keeping and maintaining data and reimbursements need to be clarified.
- Complementary contributions: Supplementary surveys on selected indicators of the ecosystem condition are required, *inter alia* pointing out the connections/ interactions between conditions, services and biodiversity features of the most important ecosystem types including steering possibilities for policy-makers and nature conservation experts.
- Communication: communicating the results to the EU (via MAES working group) and policy fields (provision/communication of strategy-supporting visions and emotions), decision-makers and the public (e.g., costs of damage prevention, health potentials); further cooperation with affected/relevant ministries, in particular at the federal level. Coordination of these interdisciplinary tasks at the intersection of science and policy-making (institutional framework required).

Aiming at implementation: It would be desirable to use the coordinated ES indicators as a measurement and steering instrument for sustainable development at the national level e.g. with a view to concrete planning cases or integration of ES into the national resource policies. This need, however, a balancing of opportunities and risks.

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