

1 Ecosystem Services in Global Sustainability Policies

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30

31 Abstract

32 Global sustainability policies, such as the Sustainable Development Goals (SDGs) or the Aichi Targets, aim
33 to ensure sustainable development, including improved human well-being and the conservation of
34 nature. Although not yet explicitly used to evaluate the progress towards sustainable development, the
35 ecosystem service concept implies a direct link between biodiversity and human well-being. This study
36 explores how and which ecosystem services are currently considered in the SDGs and the Aichi Targets.
37 We also identify which information might be already available for monitoring the progress towards their
38 goals by reviewing national ecosystem assessments. This allows the identification of the main knowledge
39 gaps for monitoring progress towards these global sustainability targets.

40 There is a wealth of information on all major ecosystem services categories which is directly relevant for
41 the Aichi Targets and the SDGs. The top 25% most cited ecosystem services across both policy
42 documents are: Natural heritage and diversity, Capture fisheries, Aquaculture, Water purification, Crops,
43 Cultural heritage & diversity and Livestock. Most monitoring information recommended for the global
44 sustainability goals, as well as in the information available from national assessments, is biased towards
45 supply related aspects of ecosystem services flows. In contrast, there is much less information on social
46 behaviour, use, demand and governance measures. Indicators are rarely available for all aspects of a
47 specific ecosystem service.

48 The national statistical bureaus currently in charge of providing observations for reporting on SDGs,
49 could be well placed to address this bias, by integrating ecological observations with socio-economic
50 statistics into socio-ecological indicators for ecosystem services flows. IPBES can potentially address the
51 gaps identified in this paper by improving coverage of the different dimensions of ecosystem services
52 flows.

53
54 **Keywords:** Aichi Targets, human well-being, indicators, monitoring, reporting, Sustainable Development
55 Goals.

56 57 Highlights

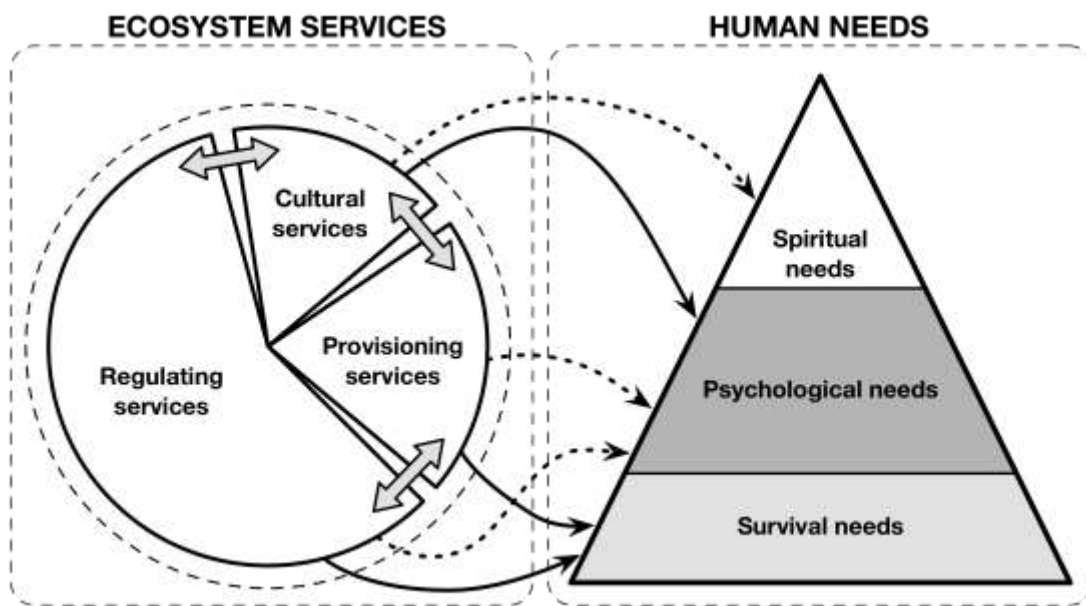
- 58 • All ecosystem services categories are relevant for the Aichi Targets and the SDGs
- 59 • There is an information bias towards the supply side of ecosystem services
- 60 • Information on social behaviour and governance is lacking for ecosystem services flows
- 61 • Trade-offs caused by unsustainable development will likely remain undetected
- 62 • IPBES and national statistical bureaus offer an opportunity to improve ecosystem services
- 63 assessments

64

65 1. Introduction

66 Multiple international policy objectives aim to ensure human well-being and the sustainability of the
67 planet, whether via sustainable development of society or via biodiversity conservation, e.g. the
68 Sustainable Development Goals (SDGs) and the Conventional of Biological Diversity (CBD) Aichi Targets.
69 To evaluate progress made towards these objectives and to obtain information on the efficiency of
70 implemented measures, effective monitoring schemes and trend assessments are required (Hicks et al.
71 2016). Whereas the CBD has been reporting on progress towards objectives in Global Outlooks since
72 2001¹, a first list of indicators has recently been launched.

73 There is broad consensus that pathways to sustainability require a secure supply of those ecosystem
74 services that contribute to human well-being (Fig. 1; Griggs et al., 2013; Wu, 2013). The ecosystem
75 service concept is an important integrated framework in sustainability science (Liu et al., 2015), even if
76 the term ecosystem services is not often explicitly mentioned in policy objectives. Nevertheless, a
77 number of specific ecosystem services are mentioned in documents relating to the different objectives
78 stated in the SDGs and Aichi Targets. For example, there is an explicit mentioning of regulation of natural
79 hazards in SDG 13 and of carbon sequestration in Aichi Target 15. Especially for the poorest people, who
80 most directly depend on access to ecosystems and their services (Daw et al., 2011; Sunderlin et al.,
81 2005), information on ecosystem services state and trends should be highly relevant (Wood and
82 DeClerck, 2015).



83
84 **Figure 1. Contribution of ecosystem services to human well-being**, with direct contributions being
85 indicated with black arrows and indirect contributions by dotted arrows. Figure adapted from Wu (2013).
86

¹ (<https://www.cbd.int/gbo/>) last consulted on the 22nd of April 2017

87 Trends in biodiversity, ecosystem services and their impact on human well-being as well as sustainability
88 must be studied using an integrated approach (Bennett et al., 2015; Liu et al., 2015). The SDG ambitions
89 could potentially offer key elements for this integration. Most assessments use a pragmatic approach to
90 select indicators for ecosystem services, often only focusing on those indicators and ecosystem services,
91 for which data are readily available. Although this helps to advance the knowledge on ecosystem
92 services on many aspects, it may not cover the knowledge required to monitor progress towards
93 sustainability (Hicks et al., 2016). Regions characterized by high vulnerability of ecosystem services
94 supply and human well-being, such as the Mediterranean Basin (Schröter et al., 2005), require
95 information on the trends in on all aspects ecosystem services flows including the impact of governance
96 interventions and pressures on social-ecological systems.

97 Considerable progress has been made in developing integrative frameworks and definitions for
98 ecosystem services and the quantification of indicators (e.g. Kandziora et al., 2013; Maes et al., 2016),
99 but it is unclear to which extent the current state of the art in ecosystem services assessments is able to
100 provide the information required for monitoring the SDGs and the Aichi Targets. Since the publication of
101 the Millennium Ecosystem Assessment in 2005, multiple national ecosystem services assessments have
102 been undertaken, such as the United Kingdom National Ecosystem Assessment (UK National Ecosystem
103 Assessment, 2011), the Spanish NEA (Santos-Martín et al., 2013) or the New Zealand assessment
104 (Dymond, 2013). Furthermore, in the context of the Intergovernmental Platform on Biodiversity and
105 Ecosystem Services (IPBES), regional and global assessments are planned for 2018 and 2019,
106 respectively. The ecosystem services indicators used in these national, regional and global assessments
107 could also provide relevant information for monitoring the progress towards these global sustainability
108 objectives.

109 The main goal of the present study is to explore to what extent the ecosystem services concept has been
110 incorporated in global sustainability policies, particularly the SDGs and the Aichi Targets. For this
111 objective, we i) assessed the information on ecosystem services currently recommended to monitor the
112 progress on both policy documents and ii) identified which information on ecosystem services can
113 already be provided on the basis of the indicators reported in national ecosystem assessments. Based on
114 these two outputs, we iii) identified knowledge gaps regarding ecosystem services for monitoring the
115 progress on global policy objectives for sustainability.

116

117 **2. Material and methods**

118 Numerous frameworks exist to describe ecosystem services (e.g., Kandziora et al., 2013; Maes et al.,
119 2016), but there is general agreement that a combination of biophysical, ecological and societal
120 components is required to estimate the flow of actual benefits arriving to the beneficiary. In line with the
121 ongoing development of an Essential Ecosystem Services Variable Framework in the scope of the Global
122 Earth Observation Biodiversity Observation Network (GEO BON), we used a framework that distinguishes
123 variables of ecosystem services flows (Tab. 1): the ecological potential for ecosystem services supply
124 (Potential supply), and the societal co-production (Supply), Use of the service, Demand for the service as
125 well as Interests and governance measures for the service (Tab. 1, adapted from Geijzendorffer et al.,
126 2015). We hereafter refer to these variables with capitals to increase the readability of the text. Using
127 this framework, we i) identified and ranked the frequency at which specific ecosystem services are

128 mentioned, within and across the selected policy documents (CBD, 2013; United Nations, 2015a); ii)
129 reviewed indicators currently used for reporting on the Aichi Targets (Global Outlook) and iii) reviewed
130 the 277 indicators currently being used in national ecosystem assessments, to identify any existing
131 information gaps.

132 Only monitoring data that feed all the variables of this framework allows detecting trends and
133 interpreting changes in ecosystem services flow. One example relevant for the SDGs is a food deficit
134 indicator (e.g. insufficient calories intake per capita). An increase in calorie intake in a specific country
135 would indicate the need for additional interventions. However, depending on the cause of this increased
136 deficit, some interventions are more likely to be effective than others. For example, the food deficit
137 could be caused by a change in demand (e.g. increased population numbers), in the service supply (e.g.
138 agricultural land abandonment), or in the ecological potential to supply services (e.g. degradation of
139 soils).

140 We structured our analysis of indicators by distinguishing between indirect and direct indicators (Tab. 1).
141 While direct indicators assess an aspect of an ecosystem service flow (e.g. tons of wheat produced),
142 indirect indicators provide proxies or only partial information (e.g. hectares of wheat fields under organic
143 management) necessary to compute the respective indicator. Our review does not judge the
144 appropriateness or robustness of the respective indicator (as proposed by Hák et al., 2016), nor did we
145 aim to assess whether the underlying data source was reliable or could provide repeated measures of
146 indicators over time. We only looked at the type of information that was described for each of the
147 ecosystem services mentioned in the policy objectives and the type of indicators proposed for reporting
148 on these policies.

149 The data for reporting on the SDGs is currently provided by national statistical bureaus and we therefore
150 wanted to identify which ecosystem services indicators might be available at this level. To get a first
151 impression, we reviewed the indicators used in 9 national ecosystem assessments and the European
152 ecosystem assessment.

153 A network analysis was used to determine the associations between i) ecosystem services within the
154 SDGs and the CBD Aichi Targets, ii) the variables of ecosystem services flows and proposed indicators for
155 both policies and iii) the categories of ecosystem services and the components of the ecosystem service
156 flow, in the indicators used in national and the European ecosystem assessments. The network analysis
157 was performed using Gephi (Bastian et al., 2009) and their visualization was subsequently produced
158 using NodeXL (<https://nodexl.codeplex.com/>, last consulted January 13th 2017).

159

160 **Table 1: Evaluation framework for the indicators on ecosystem service flows** (adapted from Geijzendorffer et al., 2015). While direct indicators
 161 can be used to immediately assess the needed information, indirect indicators provide proxies or only partial information necessary to compute
 162 the respective indicator.

Information component	Definition	Related terms used in other papers	Examples of direct indicators	Examples of indirect indicators
Potential Supply	Estimated supply of ecosystem services based on ecological and geophysical characteristics of ecosystems, taking into account the ecosystem's integrity, under the influence of external drivers (e.g., climate change or pollution).	Ecosystem functions (de Groot et al., 2002); ecosystem properties that support ecosystem functions (van Oudenhoven et al., 2012)	Modelled estimates of harvestable biomass under natural conditions; potential pressures that an ecosystem can absorb; landscape aesthetic quality.	Qualitative estimates of land cover type contributions to biomass growth; species traits (e.g. root growth patterns); landscape heterogeneity of land cover types.
Managed Supply	Type and quantity of services supplied by the combination of the Potential supply and the impact of interventions (e.g., management) by people in a particular area and over a specific time period.	Capacity (Schröter et al., 2005), supply (Crossman et al., 2013), service capacity (Villamagna et al., 2013); supply capacity of an area (Burkhard et al., 2012); actual ecosystem service provision (Guerra et al., 2014); ecosystem functions under the impact of "land management" (van Oudenhoven et al., 2012); Service Providing Unit-Ecosystem Service Provider Continuum (Harrington et al., 2010).	Harvested biomass; potential pressures that a managed landscape can absorb; extent of landscape made accessible for recreation.	Modelled estimates of harvestable biomass under managed conditions; soil cover vegetation management; financial investments in infrastructure.
Use	Quantity and type of services used by society.	Flow (Schröter, 2005; Schröter et al., 2014); service flow (Villamagna et al., 2013); "demand" (<i>match</i> and <i>demand</i> aggregated into one term) (Burkhard et al., 2012; Crossman et al., 2013).	Biomass sold or otherwise used; amount of soil erosion avoided while exposed to eroding pressures; number of people actually visiting a landscape.	Estimations of biomass use for energy by households; reduction of soil erosion damage; distance estimates from nearby urban areas.

Demand	Expression of demands by people in terms of actual allocation of scarce resources (e.g. money or travel time) to fulfil their demand for services, in a particular area and over a specific time period.	Stakeholder prioritisation of ecosystem services (Martín-López et al., 2014), service demand (Villamagna et al., 2013), demand (Burkhard et al., 2012).	Prices that people are willing to pay for biomass; amount of capital directly threatened by soil erosion; time investment, travel distances and prices people are willing to pay to visit a landscape.	Computation of average household needs; remaining soil erosion rates; survey results on landscape appreciation.
Interests	An expression of people's interests for certain services, in a particular area and over a specific time period. These tend to be longer wish-lists of services without prioritisation.	Identification of those important ecosystem services for stakeholders' well-being (Martín-López et al., 2014); beneficiaries with assumed demands (Bastian et al., 2013).	Subsidies for bio-energy; endorsement of guidelines for best practices for soil management; publicity for outdoor recreation.	Number of people interested in green energy; number of farmers aware of soil erosion; average distance of inhabitants to green areas.

163 **2.1 Identification of ecosystem services in the SDGs and Aichi Targets**

164 Two international policy documents were selected for review: the SDGs (United Nations, 2015a) and the
165 CBD Aichi Targets (CBD, 2013). Both documents have global coverage and contain objectives on
166 sustainable development, related to maintaining or improving human well-being and nature. The
167 classification of ecosystem services used in this paper is based on Kandziora et al. (2013), which matched
168 best with the terminology of policy documents and the national assessments.

169 For each policy document, we determined the absolute and relative frequency at which an ecosystem
170 service was mentioned. This frequency was also used to produce a relative ranking of ecosystem
171 services, within and across these policy documents. Although the SDGs and the Aichi Targets include
172 several statements on specific ecosystem services (e.g. food production, protection from risks), the term
173 “ecosystem services” is not often mentioned. In the SDGs, for instance, ecosystem services explicitly
174 occur only once (Goal 15.1). In contrast, “sustainable development or management” and “sustainable
175 use of natural resources” are mentioned several times, although not further specified. While the latter
176 could be interpreted to mean that the use of nature for provisioning purposes should not negatively
177 affect regulating services, we preferred to remain cautious and not make this assumption, when
178 reviewing the policy documents. We are therefore certain that we underestimate the importance of
179 knowledge on ecosystem services regarding the different policy objectives.

180

181 **2.2 Proposed ecosystem services indicators for the SDGs and Aichi Targets**

182 In addition to the ecosystem services directly mentioned in the policy objectives, we also reviewed the
183 type of information on ecosystem services proposed to monitor the progress towards the policy
184 objectives. To this end, we used the 2015 UN report (United Nations, 2015b) for the SDGs. For the Aichi
185 Targets, we focused on the recently proposed (but still under development) indicator list (CBD, 2015)
186 and on the indicators recently used in the Global Biodiversity Outlook 4 (CBD, 2014).

187

188 **2.3 Review of national ecosystem services assessments**

189 Although many authors propose indicators for ecosystem services (e.g. Böhnke-Hendrichs et al., 2013;
190 Kandziora et al., 2013), not all indicators can be used for monitoring, due to lack of available data at the
191 relevant scale or because current inventories do not provide sufficient time series for trend assessment.
192 For the CBD reporting, continuous efforts are made to provide monitoring information at global level, for
193 instance via the use of Essential Biodiversity Variables (e.g. O’Connor et al., 2015). Reporting for the
194 SDGs, however, will heavily rely on the capacity of national statistical bureaus to provide the required
195 data (ICSU, ISSC, 2015).

196 To estimate the type of ecosystem services indicators that might be available at national level, we
197 selected national ecosystem assessment reports, which were openly available and written in one of the
198 seven languages mastered by the co-authors (i.e. English, Spanish, Portuguese, Hebrew, French, German
199 and Dutch). Nine assessments fulfilled these criteria (see Tab. 2). We complemented them with the
200 European report (Maes et al., 2015), which is considered to be a baseline reference for upcoming
201 national assessments in European member states. The selection criteria resulted in the inclusions of

202 national assessments from three continents, but there is a bias towards European and developed
203 countries.

204 **Table 2: Ecosystem service assessments considered in the analysis**

Included countries	Reference
Belgium	(Stevens, 2014)
Europe	(Maes et al., 2015)
Finland	http://www.biodiversity.fi/ecosystemservices/home , last consulted January 13 th 2017
New Zealand	(Dymond, 2013)
South Africa	(Reyers et al., 2014)
South Africa, Tanzania and Zambia	(Willemen et al., 2015)
Spain	(Santos-Martín et al., 2013)
United Kingdom	(UK National Ecosystem Assessment, 2011)

205

206 **3. Results and discussion**

207 **3.1 Ecosystem services mentioned in policy objectives**

208 The need for information on ecosystem services from all three categories (i.e. provisioning, regulating
209 and cultural) is mentioned in both policies, and reflects earlier suggestions on the integrative nature of
210 the policy objectives on sustainable development, especially for the SDGs (Le Blanc, 2015). Among the 17
211 SDGs and the 20 Aichi Targets, 12 goals and 13 targets respectively, relate to ecosystem services. Across
212 both policy documents, all ecosystem service categories are well covered, the top 25% of the most cited
213 ecosystem services being: Natural heritage and diversity, Capture fisheries, Aquaculture, Water
214 purification, Crops, Livestock and Cultural heritage & diversity (Table 3). In the SDGs, provisioning
215 services are explicitly mentioned 29 times, regulating services 33 times and cultural services 23 times. In
216 the Aichi Targets, provisioning services are explicitly mentioned 29 times, regulating services 21 times
217 and cultural services 13 times.

218 When considering the different ecosystem service categories, SDG 2 (*end hunger, achieve food security*
219 *and improved nutrition, and promote sustainable agriculture*) and Aichi Goal B (*reduce the direct*
220 *pressures on biodiversity and promote sustainable use*) heavily rely on provisioning services, with the
221 latter also relying on regulating services (Fig. 2). Cultural services are more equally demanded over a
222 range of policy objectives, with the service Natural heritage & diversity being the most demanded
223 ecosystem service (see Tab. A.1).

224 Recent reviews of scientific ecosystem services assessments (e.g. Geijendorffer et al., 2015; Lee and
225 Hautenbach, 2016) demonstrate that easily measurable ecosystem services (i.e. most of the provisioning
226 services) or ecosystem services that can be quantified through modelling (i.e. many of the regulating
227 services) are most often studied, whereas cultural ecosystem services are much less represented,
228 despite their importance for global sustainability policies. The reason for this knowledge gap is partly
229 theoretical (e.g. lack of agreement on for monitoring and measuring, and partly because the assessment
230 of cultural services in particular requires a multi-disciplinary approach (e.g. landscape ecologists,

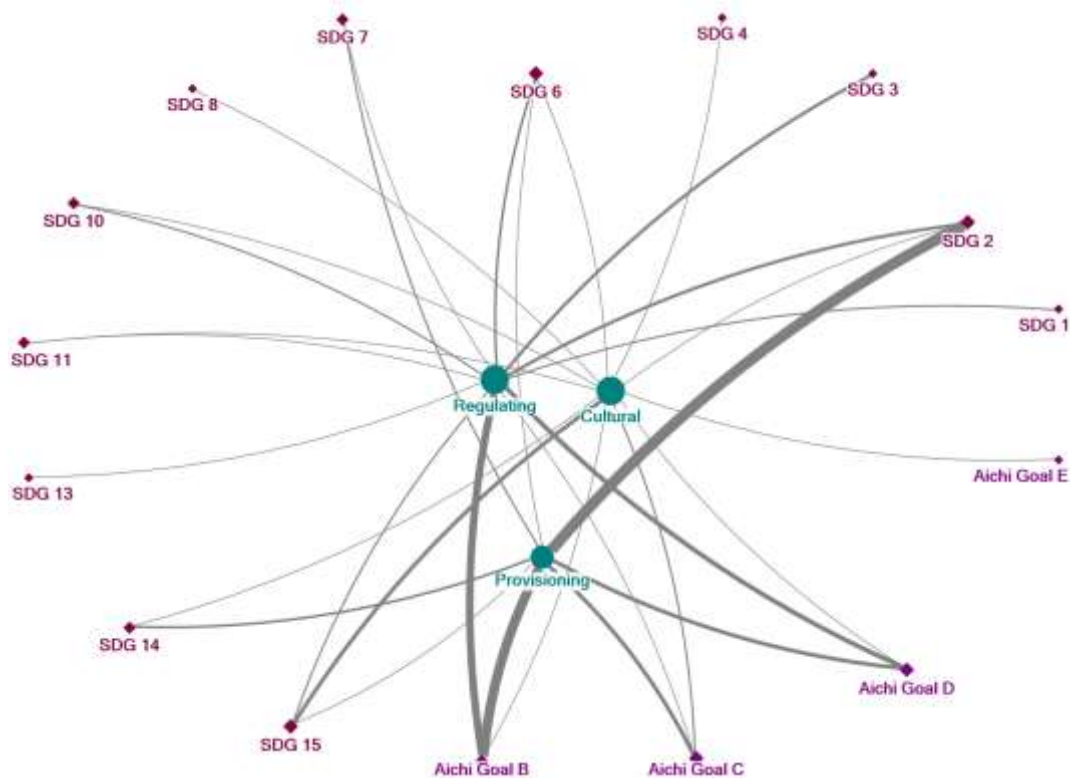
231 environmental anthropologists, or environmental planners) which is difficult to achieve (Hernández-
 232 Morcillo et al. 2013; Milcu et al. 2013). The development of cultural services indicators would benefit
 233 from a truly interdisciplinary dialogue which should take place at both national level and international
 234 level to capture cultural differences and spatial heterogeneity. The capacity building objectives of IPBES
 235 could provide an important global incentive to come to a structured, multi-disciplinary and coherent
 236 concept of cultural services.

237 **Table 3. Frequency at which the different ecosystem services were mentioned in both policy**
 238 **documents.** Presented ecosystem services frequency scores are for the SDGs per target (n=126) and for
 239 the Aichi Targets per target (n=20).

Ecosystem services	SDGs	Aichi Targets
Provisioning services (total)	29	29
Crops	4	3
Energy (biomass)	2	1
Fodder	0	1
Livestock	4	3
Fibre	0	2
Timber	0	3
Wood for fuel	2	1
Capture fisheries	8	3
Aquaculture	5	3
Wild foods	2	3
Biochemicals/medicine	0	3
Freshwater	2	3
Regulating services (total)	33	21
Global climate regulation	0	2
Local climate regulation	3	1
Air quality regulation	2	0
Water flow regulation	5	2
Water purification	5	3
Nutrient regulation	0	3
Erosion regulation	3	3
Natural hazard protection	6	1
Pollination	1	2
Pest and disease control	2	2
Regulation of waste	6	2
Cultural services (total)	23	13
Recreation	4	0
Landscape aesthetics	0	0
Knowledge systems	2	3
Religious and spiritual experiences	0	1
Cultural heritage & cultural diversity	4	3
Natural Heritage & natural diversity	13	6

240

241



243

244 **Fig 2. Relative importance of ecosystem service categories for the different policy objectives.** The line
 245 width indicates the frequency at which a certain ecosystem service category was mentioned in relation
 246 to a specific goal of the SDGs or Aichi Targets (goals for which no relation to ecosystem services was
 247 found are not shown). The size of the nodes is proportional to the number of ties that a node has.

248

249 3.2 Proposed ecosystem services indicators

250 The analysis of the proposed indicators for reporting on both policy objectives (n=119) demonstrated
 251 that in total 43 indicators represented information on Potential supply with the other variables being
 252 represented by indicators in the 15-24 range (Fig. 3A). This bias towards supply variables is remarkable
 253 for the Aichi Targets (Fig. 3A). Another observed pattern is that the variables Demand and Interest are
 254 more often represented by proposed indicators for the SDGs than for the Aichi Targets (i.e. demand 11
 255 versus 5 and interest 13 versus 4, respectively). The results therefore provide support for the claim that
 256 the SDGs aim to be an integrative policy framework (Le Blanc, 2015), at least in the sense that the
 257 proposed indicators for SDGs demonstrate a more balanced inclusion of ecological and socio-economic
 258 information.

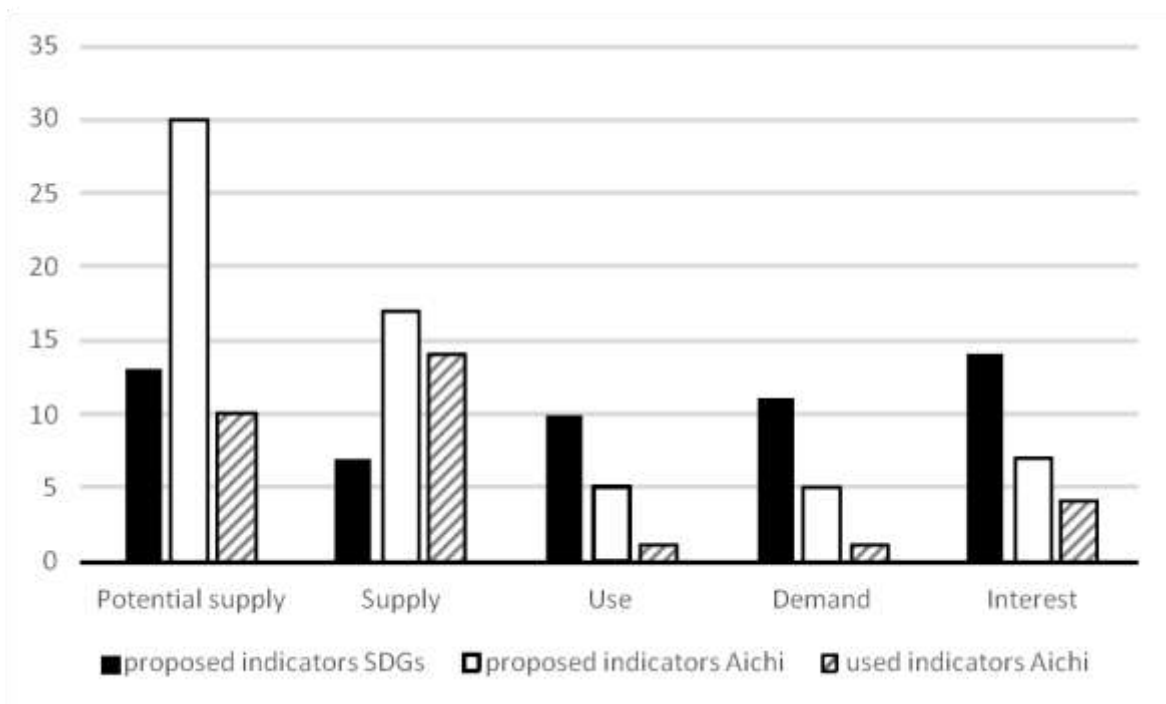
259 A comparison of the number of ecosystem services that are relevant for the SDGs with the total number of
 260 indicators proposed for monitoring, however, reveals that balanced information from the indicators is
 261 unlikely to concern all ecosystem services (Figure 3). The proposed indicators never cover all five
 262 variables for a single SDG target except for one SDGs target (i.e. SDG 15: "Protect, restore and promote
 263 sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt

264 and reverse land degradation and halt biodiversity loss”). Among the Aichi Targets, none of the Strategic
265 Goals was covered by indicators representing all five variables.

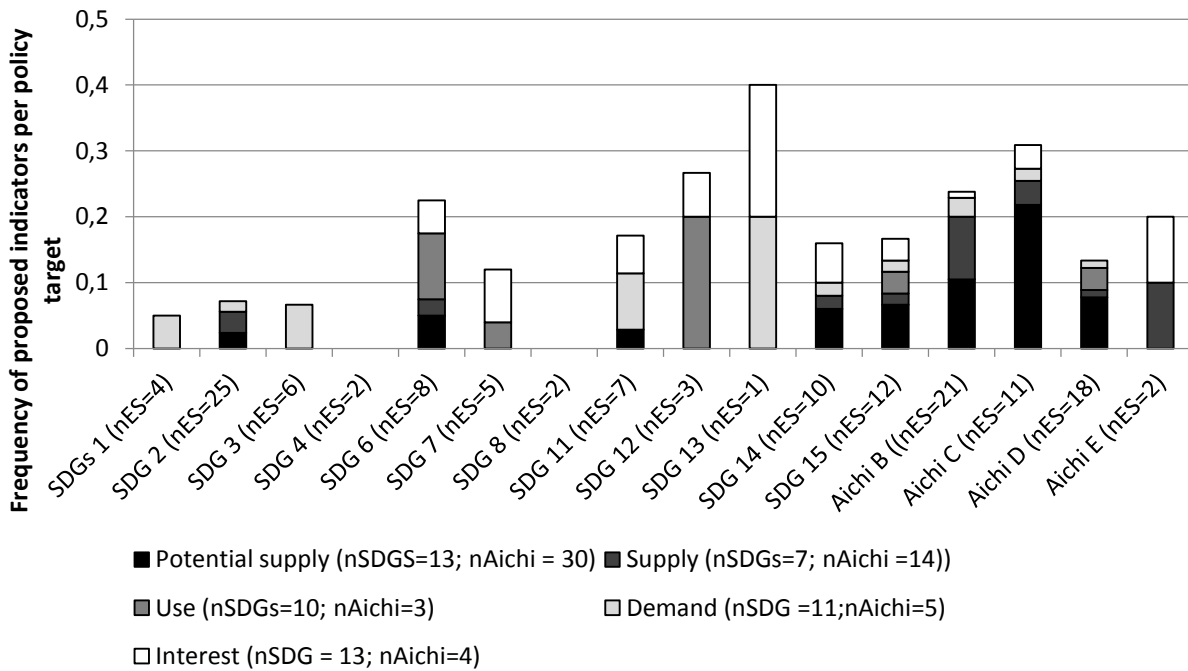
266 The frequencies at which ecosystem services are presented for the policy reports are surprisingly low
267 (Figure 3B). In an ideal situation, each of the ecosystem services would have been covered by indicators
268 representing the five variables (i.e. frequency value of 1). Our results demonstrate a highest frequency
269 value of 0.4 for SDG target 13 (“Take urgent action to combat climate change and its impacts”), caused
270 by several indicators representing only two variables (i.e. demand and interest). The SDG list of
271 indicators is kept short on purpose to keep reporting feasible, but if the indicators and data were
272 available through national or global platforms (e.g. IPBES, World Bank), a longer list of readily updated
273 indicators might not be so problematic.

274 For the Aichi Targets, we can additionally compare between proposed indicators in the policy document
275 and used indicators in the most recent reporting, i.e. the Global Biodiversity Outlook 4 (CBD, 2014)(Fig.
276 3A). Due to data gaps, the total number of used indicators is lower than the number of proposed
277 indicators, but it is interesting to note what happens to the bias in the representation of the ecosystem
278 service variables: although the indicators proposed by the policy documents showed a strong bias
279 towards the Potential supply and the Supply variable, the indicators actually used in the reporting
280 significantly reduce this bias. Especially for Potential supply, much less indicators are being used.
281 Nonetheless for the already underrepresented variables, i.e. Use and Demand, even less indicators are
282 actually included in the reporting (Fig. 3A).

283



284 3A



286

287 **Figure 3. Relative importance of each of the ecosystem services variables (Potential supply, Supply,**
 288 **Use, Demand and Interest) recommended for the monitoring of the global sustainability objectives. (A)**
 289 **The number of proposed and used indicators for the reporting on the progress of the sustainability**
 290 **goal in policy documents per ecosystem service variable. (B) Relative frequencies (0-1) at which**
 291 **information from variables are represented by indicators per policy target.** Frequency values are
 292 standardized for the total number of services linked to individual policy target (nES) and the legend
 293 indicates nSDG and nAichi for the total number of proposed indicators for each ES variable per policy
 294 programme respectively. Policy targets which did not mention ecosystem services were not included in
 295 the figure.

296 Despite the identified value of information on ecosystem services as presented in section 3.1, it seems
 297 that entire ecosystem service flows (from Potential supply to Interest) are poorly captured by the
 298 proposed and (potentially) used indicators. The information recommended for Aichi Targets shows a
 299 strong bias on the supply side of ecosystem services flow (i.e. Potential supply and Supply), whereas this
 300 seems more balanced for SDGs. However, the overall information demanded is very low, given the
 301 number of services that are relevant for the policies (Fig. 3). Variables linked to social behaviour and
 302 ecosystem services consumption (i.e. Demand and Use) and Governance (i.e. Interest) are much less
 303 represented in Aichi targets and this bias is enforced when looking at the actually used indicators. As the
 304 SDGs reporting is based on information from national statistical bureaus, we can wonder whether their
 305 data will demonstrate a similar bias or not, as the used data sources can be of a different nature (e.g.
 306 some indicators may come from national censuses). Results from section 3.3 make it clear that if SDGs
 307 reports rely only on national ecosystem reports for their information, it will likely demonstrate the same
 308 bias as found in the Aichi Target reports. To obtain more balanced information for the SDGs, national
 309 statistical bureaus would be ideally placed to add complementary social and economic data on other
 310 variables.

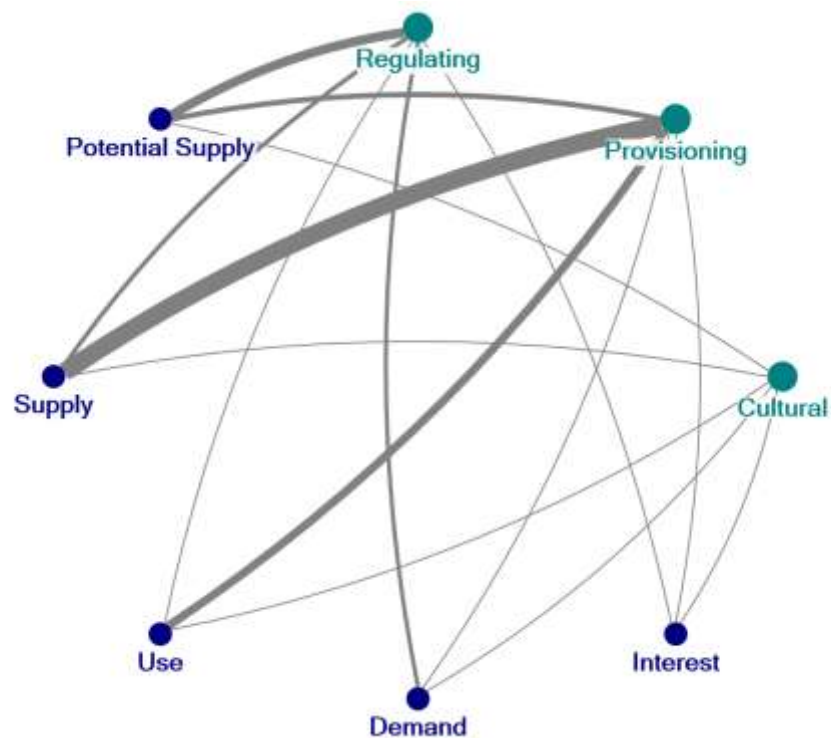
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312 3.3 Ecosystem service information in national assessments

313 The national ecosystem assessments analysis demonstrates the availability of a significant amount of
314 information on ecosystem services flows at national level (*Appendix A*, Tab. A.4). It has to be noted that
315 as the analysed national ecosystem assessments under represent developing countries and non-
316 European countries, the available information at a global level might be significantly lower. However,
317 some national reports may not have been detected or included in our review, for instance because we
318 did not find them on the internet or because they were not written in any of the languages mastered by
319 the authors.

320 The available knowledge in the selected ecosystem assessments on ecosystem services flows shows,
321 however, a considerable bias towards Supply information on provisioning services and Potential supply
322 information for regulating services. Cultural ecosystem services as well as Use, Demand and Interest
323 variables are not well covered in national assessments. In addition, only for some ecosystem services
324 (e.g., Timber, Erosion Regulation, Recreation) information is available for all relevant ecosystem services
325 variables (Fig. A.2).

326 In total, we identified 277 ecosystem services indicators in the ten selected ecosystem services
327 assessments (Tab. A.2). Within these 277 indicators, most provide information on provisioning services
328 (126, 45%), whereas 121 indicators provide information on regulating services (44%). The remaining 30
329 indicators (11%) provide information on cultural services. Based on the network analysis, we can clearly
330 see that indicators used for provisioning services mostly represent information on the Supply variable,
331 whereas indicators used for regulating services mostly represent the Potential supply variable (Fig. 4).
332



333

334 **Figure 4. Relative representation of the indicators used in analysed National Ecosystem Assessments,**
335 **according to ecosystem services category** (provisioning, regulating or cultural services) **and the**
336 **ecosystem service variables** (Potential supply, Supply, Use, Demand or Interest). The line width indicates
337 the frequency at which indicators of a certain ecosystem service category were used to monitor any of
338 the components of the ecosystem services flow. The size of the nodes is proportional to the number of
339 ties that a node has.

340
341 Among the 277 indicators, 39 did not provide a measure of service flow, but rather of the pressure (e.g.
342 amount of ammonia emission) or of the status quo (e.g. current air quality). None of these measures
343 provide information on the actual ecosystem service flow; they rather reflect the response to a pressure.
344 The status quo can be considered to result from the interplay between exerted pressure and triggered
345 ecosystem services flow. Among the 39 indicators, 38 were used to quantify regulating services, leaving a
346 total number of 83 indicators to quantify variables of regulating ecosystem services flows.

347 The 238 indicators of ecosystem service flows are almost equally divided between direct and indirect
348 indicators, namely 124 versus 114, respectively (Tab. A.2). The distribution of the indicators within the
349 different ecosystem service categories differs. Among the different variables, Interest is least
350 represented by the different indicators. The pattern is most pronounced for provisioning services, where
351 there is relatively little information available on Demand and Interest (Fig. 4). For regulating services,
352 most information seems available on the Potential supply side of the ecosystem services flow (Fig. 4).
353 The cultural ecosystem services category has the lowest number of indicators used for monitoring the
354 ecosystem service flow (Tab. A.2). Regardless of general patterns, indicators are available only for very
355 few services, for all five variables (Fig. A.2). For the top 25% services most frequently mentioned in the
356 policies, there is a similar bias towards indicators on Supply (Tab. A.3), mainly stemming from the
357 provisioning services crop and livestock (Tab. A.4), whereas no indicators were included for the
358 ecosystem service Natural heritage and natural diversity.

359 As already acknowledged by IPBES, capacity building is needed to increase the number of readily
360 available indicators for ecosystems services at national and global levels. The capacity to monitor
361 spatially-explicit dynamics of ecosystem services, including multiple variables of the ecosystem services
362 flow simultaneously, could benefit from the application of process-oriented models (e.g. Bagstad et al.,
363 2013; Guerra et al., 2016), the use of remote sensing for specific variables (e.g. Cord et al., 2015), or by
364 aligning with census social and economic data (e.g. Hermans-Neumann et al., 2016).

365

366 **3.4 Recommendations for improvement towards the future**

367 The biased information on ecosystem service flows hampers an evaluation of progress on sustainable
368 development. If policy reports are not able to identify whether trends in supply, consumption and
369 demand of ecosystem services align, it will be difficult to identify if no one is left behind (Geijzendorffer
370 et al., 2015). Apart from the results of the structured analysis, three other issues emerged from the
371 review, which we want to mention here to raise awareness and stimulate inclusion of these issues in
372 further scientific studies.

373 First, trade-offs play a crucial role in the interpretation of the sustainability of developments related to
374 human well-being (Liu et al., 2015; Wu, 2013) and often include regulating services (Lee and Lautenbach,

2016). Interestingly, in the case of the SDGs, where the objective of sustainable development is a key concept, no indicators are proposed to monitor whether the impacts of progress on some objectives (e.g. industry development mentioned in Target 16) might negatively affect progress towards another objective (e.g. water availability and water quality mentioned in Target 6). Without monitoring of trade-offs between objectives and underlying ecosystem services, it will be difficult to determine whether any progress made can be considered sustainable for improving human well-being (Costanza et al., 2016; Nilsson et al., 2016). Reporting on global sustainability policies would greatly benefit from the development and standardisation of methods to detect trends in trade-offs between ecosystem services, and between ecosystem services and other pressures. The ongoing IPBES regional and global assessments could offer excellent opportunities to develop comprehensive narratives that include the interactions between multiple ecosystem services and between them and drivers of change. Global working groups on ecosystem services from GEO BON² and the Ecosystem Services Partnership³ can render ecosystem services data and variables usable in a wide set of monitoring and reporting contexts by developing frameworks connecting data to indicators and monitoring schemes.

Second, the applied framework of variables of ecosystem service flows did not allow for an evaluation of the most relevant spatial and temporal scales, or for indicators' units. Most ecosystem services are spatially explicit and show spatial and temporal heterogeneity that requires information on both ecological and social aspects of ecosystem services flows (e.g. Guerra et al., 2016, 2014). To monitor progress towards the Aichi Targets, the tendency to date has been to develop indicators and variables that could be quantified at global level, with the framework of Essential Biodiversity Variables being a leading concept (O'Connor et al., 2015; Pereira et al., 2013; Pettorelli et al., 2016). Although indicators with global coverage can be very effective in communicating and convincing the audience on the existence of specific trends (e.g. the Living Planet Index⁴), they are not likely to provide sufficient information to inform management or policy decisions, at local or national scales. For the SDGs, which are at a much earlier stage of development than the Aichi Targets, data will be provided at national level by national statistical bureaus (ICSU, ISSC, 2015), which may better suit national decision makers deciding on implementation of interventions. The current approach of reporting on SDGs progress at national level may also allow easier integration of information on ecosystem services available from national assessments. Although the number of available national ecosystem assessments is still rising, developing countries are currently underrepresented. Developing national assessments in these countries is therefore an important for the credible reporting on Aichi targets and SDGs.

Third, national ecosystem assessments would ideally provide information at the spatio-temporal scale and unit most relevant for the ecosystem services at hand (Costanza, 2008; Geijzendorffer and Roche, 2014). This would allow for the identification of people who do not have enough access to particular ecosystem services (e.g. gender related, income related) at a sub-national level. The assessment of progress in human well-being for different social actors within the same country, requires alternative units of measurement than national averages for the whole population in order to appraise equity aspects (Daw et al., 2011; Geijzendorffer et al., 2015). Further, although the setting of the SDGs was done by national governments, achieving sustainable development requires the engagement of multiple

² <http://geobon.org/working-groups/>, last consulted 22th of April 2017

³ <http://es-partnership.org/community/workings-groups/>, last consulted 22th of April 2017

⁴ www.livingplanetindex.org/home/index, last consulted 22th of April 2017

414 social actors operating at local level. Some of these local actors (e.g. rural or indigenous communities,
415 low-income neighbourhoods, migrants or women) play a relevant role in achieving the SDGs, because
416 they are more vulnerable to the impact of unequal access to and distribution of ecosystem services.
417 Although some of the indicators and objectives of SDGs mention particular actor groups (e.g. women),
418 the representation of vulnerable groups will require special attention throughout the different targets
419 and ecosystem services.

420 **4. Conclusion**

421 This study demonstrates that information from all ecosystem services categories is relevant for the
422 monitoring of the Aichi Targets and the SDGs. It identifies a bias in the information demand as well as in
423 the information available from indicators at national level towards supply related aspects of ecosystem
424 services flows, whereas information on social behaviour, use, demand and governance implementation
425 is much less developed.

426 The National statistical bureaus currently in charge of providing the data for reporting on the SDGs could
427 be well placed to address this bias, by integrating ecological and socio-economic data. In addition, IPBES
428 could potentially address gaps between national and global scales, as well as improve coverage of
429 ecosystem services flows. As its first assessments of biodiversity and ecosystem services are ongoing,
430 IPBES is still adapting its concepts. To live up to its potential role, IPBES needs to continue to adapt
431 concepts based on scientific conceptual arguments and not based on current day practical constraints,
432 such as a lack of data, or political sensitivities. This manuscript demonstrates the importance of data and
433 indicators for global sustainability policies and which biases we need to start readdressing, now.

434

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443

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612

Appendix A: The frequency at which ecosystem services are mentioned per target, in the policy documents.

Table A.1. Overall ranking of the frequency that ecosystem services were mentioned across both the SDGs and the Aichi Targets. The top 25% most frequently mentioned ecosystem services are highlighted in bold. Ecosystem services categories are Provisioning (P), Regulating (R) and Cultural (C).

Ecosystem service category	Ecosystem services	SDGs Ranking	Aichi Targets Ranking	Combined ranking
C	Natural heritage & natural diversity	1	1	1
P	Capture fisheries	2	8	2
P	Aquaculture	6	8	3.5
R	Water purification	6	8	3.5
P	Crops	9,5	8	6
P	Livestock	9,5	8	6
C	Cultural heritage & cultural diversity	9,5	8	6
R	Erosion regulation	12,5	8	8,5
R	Regulation of waste	3,5	17,5	8,5
R	Water flow regulation	6	17,5	10
P	Wild foods	17	8	12
P	Freshwater	17	8	12
C	Knowledge systems	17	8	12
R	Natural hazard protection	3,5	23,5	14
P	Timber	25,5	8	16
P	Biochemicals/medicine	25,5	8	16
R	Nutrient regulation	25,5	8	16
R	Pest and disease control	17	17,5	18
R	Local climate regulation	12,5	23,5	19
C	Recreation	9,5	28	20
R	Pollination	21	17,5	21
P	Energy (biomass)	17	23,5	22,5
P	Wood for fuel	17	23,5	22,5
P	Fibre	25,5	17,5	24
R	Global climate regulation	25,5	17,5	25
R	Air quality regulation	17	28	26
P	Fodder	25,5	23,5	27,5
C	Religious and spiritual experiences	25,5	23,5	27,5
C	Landscape aesthetics	25,5	28	29

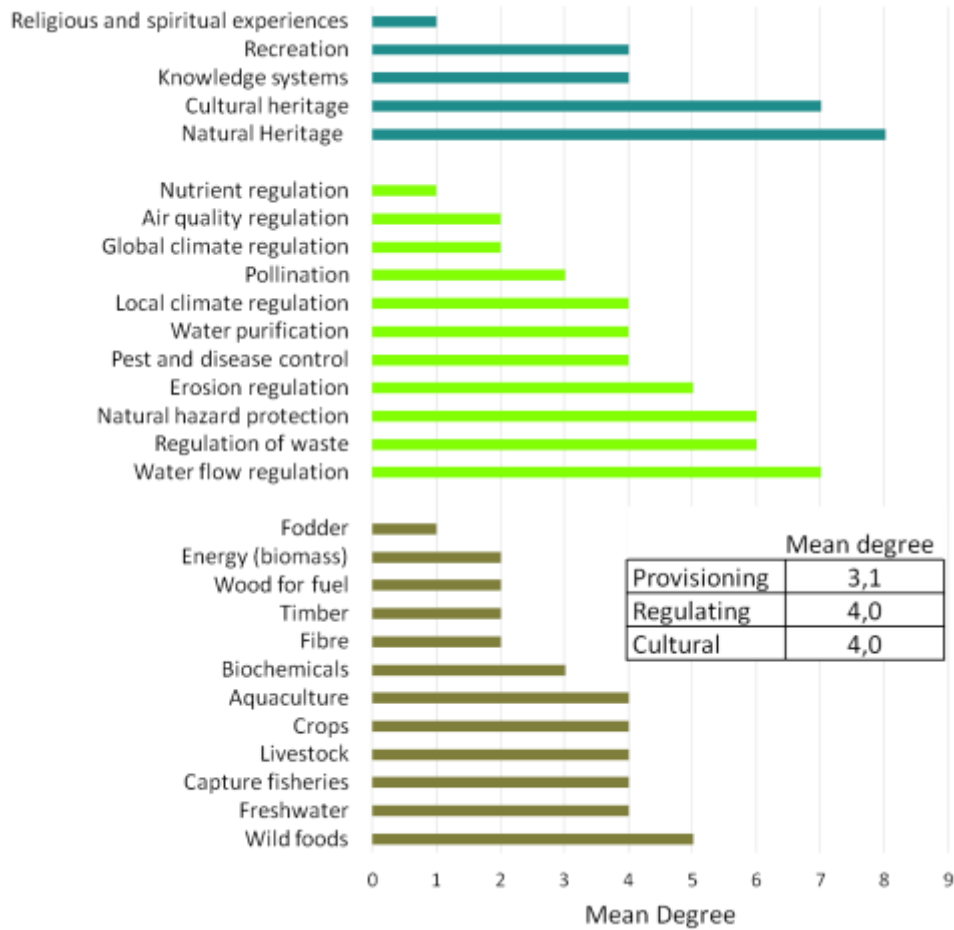


Figure A.1: Degree (the number of connections) per ecosystem service across both policy documents

Assessment of the representation of the indicators used in the ten selected national assessments of the ecosystem services, ecosystem service categories and ecosystem service variables.

Table A.2. Number of indicators identified from national ecosystem assessments, presented per ecosystem service category (provisioning, regulating or cultural services), ecosystem service variable (Potential Supply, Supply, Use, Demand or Interest) or indicator type (direct or indirect). For regulating services, 39 additional indicators describing pressures and states were identified.

	Direct	Indirect	Potential				
			Supply	Supply	Use	Demand	Interest
Total	124	114	59	89	46	31	13
Provisioning	82	43	22	61	31	8	3
Regulating	26	57	34	19	5	18	7
Cultural	16	14	3	9	10	5	3
Potential Supply	19	40					
Supply	45	44					
Use	40	6					
Demand	17	14					
Interest	3	10					

Table A.3. Number of indicators identified from ecosystem services assessments for the top 25% of ecosystem services recommended by the reviewed policies, presented per ecosystem service variable (Potential Supply, Supply, Use, Demand or Interest) or indicator type (direct or indirect).

	Potential supply		Supply		Use		Demand		Interest	
	direct	indirect	direct	indirect	direct	indirect	direct	indirect	direct	indirect
Natural Heritage & natural diversity	-	-	-	-	-	-	-	-	-	-
Capture fisheries	0	0	1	0	0	1	0	0	0	0
Aquaculture	0	0	2	0	0	0	0	0	0	0
Water purification	2	1	3	3	0	0	2	2	0	0
Crops	0	0	5	8	1	0	0	0	0	0
Cultural heritage & cultural diversity	0	0	2	0	1	0	1	0	1	0
Livestock	2	0	1	4	5	0	0	0	0	0
Total number of Direct or Indirect indicators per Variable type	4	1	14	15	7	1	3	2	1	0
Total number of indicators per Variable type	5		29		8		5		1	

The review of the national assessment reports showed no indicators explicitly linked to the Natural heritage and natural diversity service (Table S3). We might consider that some aspects of this service may be captured by other cultural services, such as the appreciation by tourists or knowledge systems.

However, the interpretation of this specific service is generally considered to be very difficult. Many consider that the intrinsic value of biodiversity, although very important, cannot be considered an ecosystem service as the direct benefit for human well-being is not evident, but rather as an ecological characteristic (Balvanera et al., 2006; Kandziora et al., 2013). To include to the Natural heritage and natural diversity service in our review, we considered that only information on biodiversity aspects for which human appreciation was explicitly used as criteria, should be included in this particular ecosystem service. This means that general patterns in species abundance (e.g. Living Planet Index), habitat extent or the presence of red list of species, were considered as important variables for biodiversity, only if they supported specific ecological functions (e.g. mangrove extent for life cycle maintenance by providing nurseries for fish), but not as an indicator for the supply of the natural heritage service in general.

Table A.4. Overview of the distribution of 277 indicators from ten selected national ecosystem assessment over the different ecosystem services and ecosystem service variables.

Ecosystem services and categories*	Total number of indicators	Ecosystem service variables										Indicators on pressures or current state
		Potential supply		Supply		Use		Demand		Interest		
		Direct	Indirect	Direct	Indirect	Direct	Indirect	Direct	Indirect	Direct	Indirect	
Provisioning services	125	11	11	35	26	28	3	8	0	0	3	1
Crops	14	0	0	5	8	1	0	0	0	0	0	0
Fodder	5	0	0	1	2	0	0	2	0	0	0	0
Products from domestic animals*	12	2	0	1	4	5	0	0	0	0	0	0
Fish	2	0	0	1	0	0	1	0	0	0	0	0
Aquaculture	2	0	0	2	0	0	0	0	0	0	0	0
Fibre	4	0	0	3	0	1	0	0	0	0	0	0
Timber	22	6	0	5	6	1	1	1	0	0	2	0
Wild foods	18	0	6	3	0	8	0	1	0	0	0	0
Wood fuel and biomass for energy	22	1	1	8	4	4	1	2	0	0	1	0
Fresh water	24	2	4	6	2	8	0	2	0	0	0	1
Regulating services	83	7	27	8	11	4	1	5	13	2	5	38
Pollination	5	0	3	0	1	0	0	0	1	0	0	1
Pest and disease control	0	0	0	0	0	0	0	0	0	0	0	1
Nutrient regulation	6	2	1	0	1	0	1	0	1	0	0	3
Air quality regulation	5	1	1	0	1	1	0	1	0	0	0	4
Noise reduction*	6	2	0	0	1	0	0	0	2	0	1	0
Erosion regulation	14	0	3	2	0	2	0	1	4	2	0	5
Flood risk regulation*	10	0	3	0	2	0	0	1	0	0	4	7
Coastal protection*	5	0	2	1	1	0	0	0	1	0	0	0
Global climate regulation	12	0	7	2	1	1	0	0	1	0	0	2
Water purification	13	2	1	3	3	0	0	2	2	0	0	10

Water flow regulation	7	0	6	0	0	0	0	0	1	0	0	1
Soil quality regulation*	0	0	0	0	0	0	0	0	0	0	0	2
Lifecycle maintenance*	0	0	0	0	0	0	0	0	0	0	0	2
Cultural services	30	1	2	2	7	8	2	4	1	1	2	0
Recreation*	13	1	0	0	4	3	2	0	1	0	2	0
Tourism*	11	0	2	0	2	4	0	3	0	0	0	0
Knowledge systems and education	1	0	0	0	1	0	0	0	0	0	0	0
Cultural heritage and cultural diversity	5	0	0	2	0	1	0	1	0	1	0	0
<p>* In the paper we used the ecosystem services definitions from Kandziora et al. (Kandziora et al., 2013), but based on the indicators found in the selected ecosystem services assessments, we made small adjustments: 1) for livestock the definition remained the same, but we changed the name for clarity in the table; 2) noise reduction, soil quality regulation and lifecycle maintenance were absent from Kandziora et al., (Kandziora et al., 2013) and were added; 3) we split natural hazard regulation in two: flood risk regulation and coastal protection; and 4) we separated recreation and tourism.</p>												

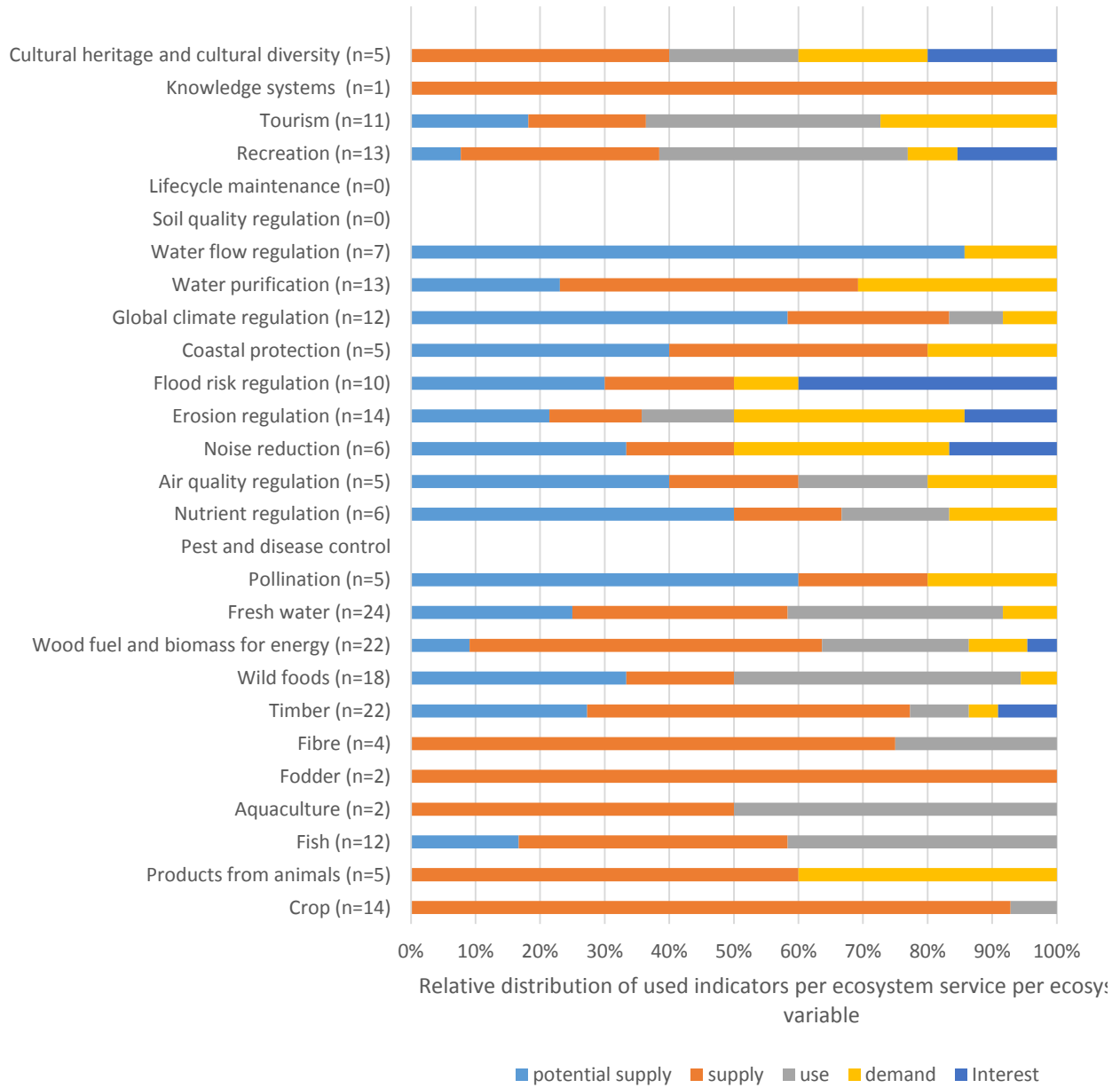


Figure A.2. Relative distribution of indicators used in national assessments per ecosystem service per ecosystem service variable. For the services Lifecycle maintenance, soil quality regulation and Biological control, the national assessments only presented indicators describing pressures or current status quo, but not on the ecosystem service variables.