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Developing policy-relevant biodiversity indicators: lessons learnt from case studies in Africa

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Abstract

There is an increasing need for monitoring schemes that help understand the evolution of the global biodiversity crisis and propose solutions for the future. Indicators, including temporal baselines, are crucial to measure the change in biodiversity over time, to evaluate progress towards its conservation and sustainable use and to set conservation priorities. They help design and monitor national and regional policies on biodiversity; they also feed into national reporting on international agreements such as the Convention on Biological Diversity and the Sustainable Development Goals. We analyse the methodological approach of five small African projects resulting from a call to promote indicator development, improve monitoring capacity and strengthen the science-policy interface in the field of biodiversity. We compared their approach to existing guidance provided by the international community, specifically the Biodiversity Indicators Partnership. To this end, we assess whether internationally recommended steps are effectively applied to national/local biodiversity monitoring in selected developing countries. We also present lessons learnt from workshop interactions between partners involved in these projects. Through our pilot projects we identified data availability and data accessibility, together with the involvement of stakeholders, as critical steps in indicator development. Moreover, there is a need for a better awareness and a wider application of the indicator concept itself. Hence, training of key actors both in the policy and science spheres is needed to operationalize indicators and ensure their continuity and sustainability. We hope that these case studies and lessons learnt can stimulate and support countries in the Global South to formulate policy-relevant biodiversity indicators.

Introduction

Earth is experiencing a mass extinction event (Ceballos *et al* 2017, Tilman *et al* 2017). To address the current biodiversity crisis, understand its evolution and propose solutions, monitoring schemes are needed. Baselines are crucial to understand temporal changes in biodiversity, to evaluate progress towards its conservation and sustainable use and to set conservation priorities (Mihoub *et al* 2017). They help design and monitor regional and national biodiversity policies, feed into national reporting on international agreements such as the Convention on Biological Diversity (CBD) and the Sustainable Development Goals (Bubb *et al* 2010, Joppa *et al* 2016), and provide input for global reports such as WWF's Living Planet Report, IPBES assessments or CBD's Global Biodiversity Outlook. Jones *et al* (2011) define monitoring as a process that includes collection of primary biodiversity data, feeding of data into indicators, and public dissemination of their spatial and temporal trends. Indicators can be defined as a 'measure based on verifiable data that conveys information about more than just itself', hence they are purpose-dependent (Biodiversity Indicators Partnership (BIP) 2011). Global efforts—e.g. by the Group of Earth Observations Biodiversity Observation Network (GEO BON), the Biodiversity Indicators Partnership (BIP) and the ad hoc Technical Expert Group on Indicators for the Strategic Plan for Biodiversity 2011–2020—identify and develop indicators for assessing progress towards the CBD Strategic Plan and its Aichi Targets, intended to guide the efforts of the international community to address the biodiversity crisis. Although these indicators could be used both at the global level and by parties and international organisations, recent studies show that the disaggregation of global indicators for use at the national level is rare, one of the reasons being that they are often intended for different types of users and purposes (Bubb 2013, Convention on Biological Diversity (CBD) 2017, Geijzendorffer *et al* 2017, Han *et al* 2017). Bubb (2013) strongly argues for aggregating national-level indicators to create a global index, instead of disaggregating global indicators to the national level: indicators should primarily be designed for national needs and be tailored to nationally adopted targets.

Despite significant efforts to develop biodiversity indicators, global indicators still fall short of an accurate and comprehensive picture of biodiversity, and are often underused in decision-making. Biodiversity data richness is skewed towards the poles, while species richness and conservation relevance is greatest in the tropics (Collen *et al* 2008, Wilson *et al* 2016). Biodiversity data are lacking in the tropics because (1) data is either scarce or of poor quality due to poor research efforts and (2) available data may not be accessible for lack of collaboration between institutes or because data are not adequately presented, published or centralized. Unfortunately, there is a lack of collaboration and communication at the science-policy interface between the data holders and the policymakers who need to use the information. The lack of cross-sectoral or inter-ministerial collaboration is a major barrier for using and mainstreaming biodiversity information (overview: Stephenson *et al* 2017). Moreover, a lot of technical barriers prevent efficient use of data, e.g. with regard to data-sharing platforms or availability of software or internet for e.g. remote sensing applications (de Klerk and Buchanan 2017). Despite efforts to disaggregate global indicators for use at national level (Biodiversity Indicators Partnership (BIP) 2011), major gaps persist in the Global South, beyond just data quality and availability: relevance to national context, capacity, funding, infrastructure, technologies, and governance (Han *et al* 2014). Also, the willingness to generate indicator data varies between countries (Bubb 2013, Han *et al* 2014). Finally, awareness of indicators is insufficient, limiting their use (Vanhove *et al* 2017). This results in biodiversity not being adequately taken into account in decision-making and national planning and reporting and hinders countries in monitoring their biodiversity for their National Biodiversity Strategies and Action Plans (NBSAPs) (Collen *et al* 2008). This can then lead to a negative feedback loop: a lack of policy-relevant scientific research leads to inappropriate policies because these are not sufficiently science-based and vice versa.

To improve capacity for indicator-based monitoring and stimulate collaboration between scientists and policymakers, the CEBioS programme, funded by the Belgian Development Cooperation, developed a competitive call for projects in line with the Measuring, Reporting and Verification (MRV) approach mostly known from carbon management and forestry (Vanhove *et al* 2017, CEBioS (Capacities for Biodiversity and Sustainable Development) 2018). As with MRV within the typically multilevel framework of carbon management, we expect the integration of information to be key to success but also a challenge for MRV of biodiversity and biodiversity policy (see Korhonen-Kurki *et al* 2013).

The five African case studies resulting from this call aimed to develop biodiversity indicators to support reporting on their NBSAPs. While the countries in question do conduct monitoring of biodiversity, biodiversity policies or ecosystem services, it is generally focused on specific services or indicator taxa and does not routinely feed into national policy-relevant indicators. Examples include a study on the conservation importance of sacred forests in Central Benin (Ceperley *et al* 2010), and a recent project on monitoring anthropogenic impact in the littoral zone of Burundian Lake Tanganyika (VLIR-UOS 2018).

We discuss lessons learnt from project workshops. Moreover, the quality of the indicators and the methodological approach of these projects are analysed. We compared it with guidance provided by the international community, specifically the BIP (Bubb *et al* 2010), to assess whether recommended steps are effectively applied to national/local biodiversity monitoring in developing countries. We hope that these case studies and lessons learnt, and the comparison between countries, can encourage and support other African countries to develop policy-relevant biodiversity indicators.

Methods

The case studies

A competitive call was launched for year-long projects aiming to improve monitoring capacity and strengthen the science-policy interface in the field of biodiversity in selected partner countries of the Belgian development cooperation (Vanhove *et al* 2017, CEBioS (Capacities for Biodiversity and Sustainable Development) 2018). In line with the abovementioned recommendation of Bubb (2013) to focus on indicator development at the national level, it aimed to develop and test an approach, for national or sub-national monitoring and reporting (Measuring, Reporting, Verification) of biodiversity and biodiversity policy, that is better tailored to countries in the Global South, specifically Africa. The call required submission of detailed proposals, ensuring genuine demand from partners in the South, and supporting local institutions to stimulate local development of capacity needed for long-term monitoring (see also Collen *et al* 2008).

The call asked applicants to develop, apply or improve one or more biodiversity indicators that should serve to set a baseline for one or several NBSAP objectives and/or to measure the status of such objectives. While national-level indicators were preferred, projects at a sub-national level were also eligible. The steps promoted under this call to convert policy-relevant biodiversity data into trends that are communicable to decision makers are described in figure 1 and table 3.

A jury of in-house and external experts selected four out of nine projects submitted. A fifth selected project was terminated halfway for administrative reasons, but its results are included here. Table 1 and Vanhove *et al* (2017) give an overview of topics and the type of partners involved.

All four selected countries—Benin, Burundi, Democratic Republic of the Congo and Morocco—recently updated their NBSAP and intend to develop

Figure 1. Approach promoted in the call for projects: the case studies are commonly developed by scientists and decision-makers to fill the gap between biodiversity data and their use for policies, strategies and action plans.

indicators for reporting. To bridge the gap between data collection by academics and data use by decision-makers, a 'tandem' approach was chosen, in which a scientific institution (university, government research centre) collaborates with a National Focal Point for the CBD or for the Clearing House Mechanism.

Training, collective restitution and exchange of best practices in workshops

Two representatives from the CEBioS programme and two from each project—one scientist and one decision-maker—met twice to share best practices and methodological concerns. An opening workshop in Brussels, Belgium (September 2015), provided opportunities to discuss and address expectations, priorities, methodological concerns and requests from the partner countries. Participants received training on elements of MRV and on subjects relevant to the topics of their projects. Sessions addressed the Global Biodiversity Information Facility (GBIF), indicator development, Geographic Information Systems, economic valuation of ecosystem services, and ethnobiology. During the closing workshop organized in October 2016 in Cotonou, Benin, participants discussed best practices, lessons learnt, conclusions and perspectives after the projects ended. One session also focussed on communicating with decision-makers, and co-produced policy briefs (Akouehou *et al* 2016, Akpona *et al* 2016, Mayundo *et al* 2016, Nzigidahera and Habonimana 2016), which were disseminated through follow-up awareness projects in 2018. The Beninese teams hosting this workshop offered sessions on additional topics relevant to MRV in general and the participants' specific projects, including species distribution modelling and community-based conservation. The capacity building components of the call are summarized in table 2, together with the main challenges they aim to address. Lessons learnt from the projects, on the basis of workshop interactions with project participants are summarized in the Discussion.

Comparison between projects' methodologies and international guidelines

The five projects represent different stages of biodiversity indicator development (figure 2). They differ in choice and prioritization of indicators, scale,

Table 1. Overview of the selected projects on measuring, reporting and verification of biodiversity and biodiversity policy (adapted from Vanhove *et al* 2017).

	Country	Topic	Type of project partners	Indicators identified prior to project implementation	Scale
A	Benin	Installing a follow-up system for biodiversity in Benin	• Environmental agency • University laboratory	Not identified prior to project	National
B	Benin	Value chain and traditional knowledge regarding selected medicinal plants in the major urban centres of Benin	• Environmental ministry • Forestry research institute	Not identified prior to project	Sub-national
C	Burundi	Indicators for the follow-up of biodiversity trends in Burundi	• Environmental agency • University laboratory	– the size, state and vulnerability of ecosystems and natural habitats – trends in the influence of unsustainable agricultural practices on species typical to a natural forest habitat – trends in distribution, state and sustainability of ecosystem services regarding human well-being	National
D	DR Congo	Floristic and ethnobotanical investigations on the plants utilized in an area near the capital	• Environmental ministry • University laboratory	Not identified prior to project	Sub-national
E	Morocco	Design and implementation of biodiversity indicators as part of the revised National Strategy for Biodiversity	• Environmental ministry • University laboratory	– the size, state and vulnerability of ecosystems; – trends in the coverage, state, representativeness and efficiency of approaches linked to protected areas, as well as other local policy interventions.	National

Table 2. Correspondence between the MRV approach used in the climate change field, the Biodiversity Indicator Development Framework and the MRV approach used in the present call for projects. Capacity building components of the call are also summarized, together with the main issues for MRV for biodiversity they aim to address.

		MRV and capacity building approach for biodiversity (Vanhove *et al* 2017)		
MRV in the context of climate change (from Dagnet *et al* 2014, Singh *et al* 2016)	Steps of the BIDF framework (see figure 2, Biodiversity Indicators Partnership (BIP) 2011)	Description (see figure 1)	Main issues for MRV for biodiversity in Africa addressed by the call	Capacity building component in the call
'Measure or monitor (M) data and information on emissions, mitigation actions, and support related to climate change.'	• Steps 1–5 to determine policy-relevant data • 6-gather and review data	Collect policy-relevant data about biodiversity drivers, pressures, states, impacts and responses.	• Lack of biodiversity data in the tropics • Lack of evidence-based reporting • No sufficient research capacities/poor quality of data • No valorization of existing data.	• `Tandem' approach (scientists-decision-makers) enabling decision makers to express their needs for policy-relevant data • Training about field methodologies and the use of online data sets
'Report (R) by compiling this information in inventories and other standardized formats to make it accessible to a range of users and facilitate public disclosure of information.'	• 7-calculate indicators • 8-communicate and interpret indicators • 9-developing monitoring and reporting systems	Turning data into databases, indicators, trends and communicate them to decision-makers	• Lack of capacity in database management • Poor understanding of the indicators concept • Low to no communication towards decision-making	Training about database management, indicator development and communication towards policy-makers, followed-up by funded awareness projects to disseminate key results and policy briefs.
'Verify (V) by periodically subjecting the reported information to some form of review or analysis or independent assessment to establish completeness and reliability.'	• 10-test and refine indicators • Steps 1–5 can also be seen as verification when they follow step 10	Review the developed indicators, and adapt them if appropriate	• No permanence and quality review of developed indicators	Call for indicator follow-up projects in 2019

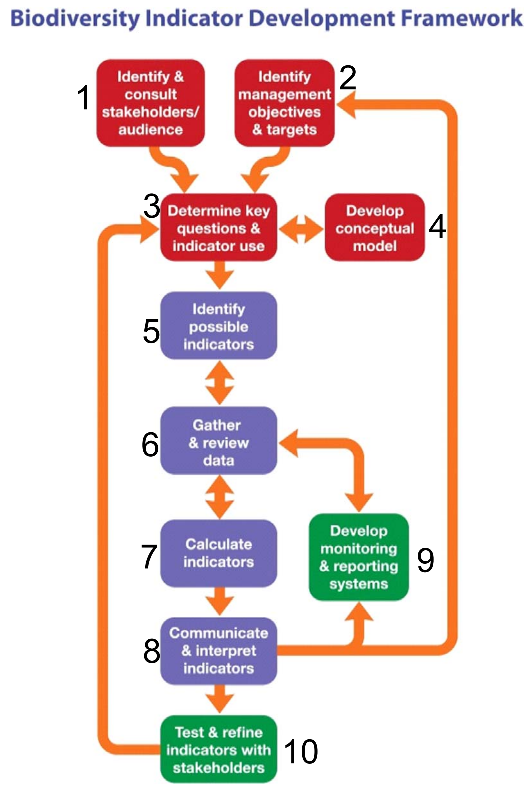

Figure 2 The biodiversity indicator development framework (adapted from Biodiversity Indicators Partnership BIP 2011). It is divided into three themes: purpose (1–4, in red), production (5–8, in purple) and permanence (9–10, in green).

development and use of indicators, and level at which data is collected (local or national).

The quality of the indicators is assessed using criteria identified by the BIP for 'successful' indicators, which are key factors in determining whether an identified indicator is taken up and produced over time (Biodiversity Indicators Partnership BIP 2011). The methodological diversity between projects is analysed using the Biodiversity Indicator Development Framework (BIDF) developed by the BIP (figure 2), whose mandate is derived primarily from the CBD and decisions taken by its Parties. As shown in table 2, indicators are at the heart of the MRV approach used in the climate change field, in the call for projects addressed in this paper, and the BIDF and strong similarities exist between these three approaches, which oriented our choice of using this internationally recognized framework for our analysis.

The BIDF is promoted globally as methodology to develop successful biodiversity indicators and is 'intended to be used as a guide to better understand what is involved in producing biodiversity indicators and to help plan the most appropriate development process for each situation' (Biodiversity Indicators Partnership BIP 2017). It describes ten key steps divided into three themes to support indicator development.

The first four steps under the 'purpose' section refer to actions needed for selecting successful indicators. The next four steps are essential to generate the indicators and fall under the 'production' section. The last theme—'permanence'—comprises two steps for ensuring indicator continuity and sustainability (Biodiversity Indicators Partnership BIP 2011). Although most project partners had heard of this framework, most of them only implemented it partly. We analyse whether and how each step was taken into account in each project.

Results

Between two and four indicators were developed per project, sometimes associated to a set of sub-indicators (see supplementary material, available online at stacks.iop.org/ERL/14/035002/mmedia), that address different NBSAP objectives and the corresponding Aichi targets (table 3). The most common themes are traditional knowledge, habitat loss reduction, protected area expansion and the conservation of ecosystems and ecosystem services. The involvement of different people at each step reflects the level of stakeholder engagement in the project.

The analysis of the quality of the developed indicators against the BIP criteria for successful indicators, shows that indicators are rarely 'based on available data', 'championed' and 'used' (table 4) (see supplementary material for the analysis of each indicator).

Examples of indicators that were fully developed are provided, along with their interpretation, in figure 3. The interpretation refers to the relevant national target or the key-messages for decision making.

An overview of the flow of each of the five projects compared against each step of the BIDF is provided in table 5, as well as the contribution of the CEBioS capacity building to the process. Not all steps are applied by each project, and the order in which they are implemented differ among projects.

Discussion

Developing indicators: a plea for more awareness of the indicator concept and for stakeholder involvement

The case studies demonstrate that, even to professional scientists and policymakers working on biodiversity monitoring, the concept of 'indicator' is insufficiently understood and applied in a standardized or operational way. While the small number of funded projects, and thus the modest number of indicators in this study, is a limitation, the focus was on the process of piloting an indicator-based MRV approach rather than on the resulting indicators. For example, in view of the above-mentioned challenge of integrating information across different levels, our participants found it instructive to bring together teams collecting data locally with those focusing on country-wide

Table 3. Indicators developed in each project, their links with the Aichi biodiversity targets and the objectives of the National Biodiversity Strategies and Action Plans, and number and profiles of persons involved in the key steps of the Biodiversity Indicator Development Framework (A–E corresponds with the projects as listed in table 1).

Project	Developed indicators	Aichi targets addressed	NBSAP objectives addressed	Number and profiles of persons involved in the key steps of the BIDF
A	– Percentage of forest land converted annually to other categories of land use – Area reforested annually per municipality – Scores of Knowledge, Attitudes and Practices – Coverage of protected areas in percentage of the country area	– 1 (Awareness increased) – 5 (Habitat loss halved or reduced) – 7 (Sustainable agriculture, aquaculture and forestry) – 11 (Protected areas increased and improved)	– 1 (Awareness) – 4 (Degradation of natural habitats) – 6 (Biodiversity in areas for agriculture, fisheries, forestry) – 16 (Restore and safeguard ecosystems)	– Steps 1–5: 27 representatives from sectoral ministries related to biodiversity issues, universities, NGOs and foresters to select the priority objectives and the relevant indicators
B	Diversity and vulnerability of medicinal plants and associated traditional uses	– 14 (Ecosystems and essential services safeguarded) – 18 (Traditional knowledge respected)	– 14 (Traditional knowledge) – 16 (Restore and safeguard ecosystems providing essential services)	– Five people for implementing the project – eight people for collecting data – 43 people interviewed – 43 people present at the presentation of the results: researchers, herbalists, sellers of medicinal plants, forest officers
C	A set of indicators to report on– the size, state and vulnerability of ecosystems and natural habitats – trends in the influence of unsustainable agricultural practices on selected species typical to a natural forest habitat – trends in distribution, state and sustainability of ecosystem services regarding human well-being – (see supplementary material for all indicators)	– 5 (Habitat loss halved or reduced) – 14 (Ecosystems and essential services safeguarded)	– 5 (Degradation of natural habitats reduced) – 7 (Forest ecosystems known and sustainably used) – 13 (National biodiversity monitoring system in place) – 15 (Restore and safeguard ecosystems providing essential services)	– Ten representatives from the University of Burundi, Ministry of Agriculture and Ministry of Environment were involved in the opening workshop and the closing workshop to validate outcomes of the project.

Table 3. (Continued.)

Project	Developed indicators	Aichi targets addressed	NBSAP objectives addressed	Number and profiles of persons involved in the key steps of the BIDF
D	The number of non-timber forest products (NTFPs) identified and their use by local and indigenous communities	– 14 (Ecosystems and essential services safeguarded) – 18 (Traditional knowledge respected)	– 2.1 (Depletion of ecosystems reduced) – 9.1 (Traditional knowledge)	– Eight representatives from the University, the Ministry of Environment, and the quarter office involved in steps 5, 6, 8, together with farmers' associations – 248 informants interviewed for ethnobotanical surveys (data collection, step 6)
E	A set of indicators to report on– the efforts made in the development of the network of protected areas – the effectiveness of the creation and management of protected areas (see supplementary material for all indicators)	– 5 (Habitat loss halved or reduced) – 11 (Protected areas increased and improved)	– A3 (Protected areas increased and representative)	– Two people involved in the project coordination and implementation

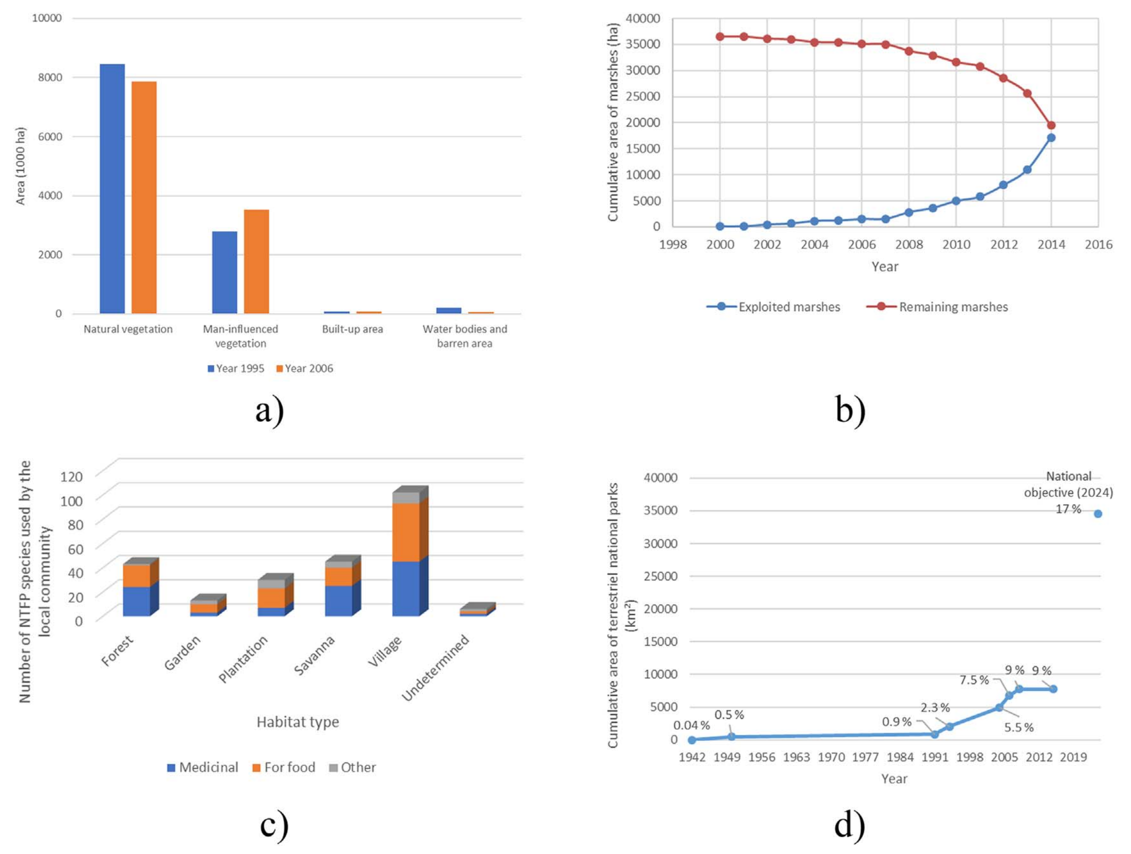

Figure 3. Selected indicators developed in the projects and their interpretation. (a) Project A (Benin): change in land use between 1995–2006. Overall, natural vegetation areas are reduced and converted to other land use categories. This information enables calculating the indicator 'Percentage of forestland annually converted to other categories of land use' related to the objective of reducing the degradation of natural habitats (data source: Sinsin and Kampann 2010). (b) Project C (Burundi): trend of the marsh area of Burundi from 2000–2014. Considering the government's forecast to exploit 8000 ha of marshes per year, it was projected that in two years all the marshes will be put into cultivation. The policy brief calls for action to take strict measures to protectall remaining marshes and wetlands. (c) Project D (DR Congo): repartition of non-timber forest products (NTFPs) by habitat type and use in Nguma quarter, Maluku, Kinshasa. Most of them are collected in villages. (d) Project E (Morocco): cumulative area of terrestrial national parks (km²) in Morocco and percentage of natural ecosystems covered. The national objective is to reach 17% in 2024, which is planned to be achieved by designating 25 new sites of biological and ecological interest.

Table 4. Assessment of each project based on the key factors determined by the BIP for 'successful indicators'. Each indicator developed by the projects is analysed in the supplementary material; the data here shows the majority obtained per project for each criterion (++: fulfils the criterion; +: moderately fulfils the criterion, =: neutral, -: does not fulfil the criterion).

Project	Scientifically valid	Based on available data	Responsive to change in the issue of interest	Easily understandable	Relevant to user's needs	Championed by an institution respon-sible for the indicator	Used
A	++	+	+	++	+	=	+
B	=	-	+=	+	+=	-	-
C	++	=	++	+	+	-	+
D	=	-	=	+	=	-	-
E	+	=	+	+	+	-	+=

indicator development. Also, the needs expressed even in these small projects already aptly illustrate that the working conditions and availability of skilled people limit the ability to uptake capacity building and take advantage of funding for biodiversity monitoring in developing countries (Danielsen *et al* 2005). We cannot agree more with Jones *et al* (2011) that the 'constant reinvention of indicators is costly in terms of time, cost, and public engagement'. To strengthen capacity for indicator use, indicator development initiatives and South–South cooperation should be better promoted (Convention on Biological Diversity (CBD) 2010). Exchanging good practices between countries with similar ecosystems or similar contextual challenges (such as governance or the lack of funding and capacity) enabled the workshop participants to acquire and use more interoperable and relevant methodologies.

Steps 5–9 of the BIDF, referring to the 'Production' and 'Permanence' sections, are implemented by

Table 5. Summary of the inclusion of the BIDF key steps in each project and the contribution of the CEBioS capacity building to the process. The framework is separated into three themes (see figure 2): purpose (actions needed for selecting successful indicators), production (essential stages for indicator development), permanence (mechanisms for ensuring indicator continuity and sustainability) (Biodiversity Indicators Partnership BIP 2011).

Theme	Key step of the BIDF	**A-Benin** Installing a follow-up system for biodiversity in Benin	**B**-Benin Value chain and traditional knowledge regarding selected medicinal plants in the major urban centres of Benin	**C-Burundi** Indicators for the follow-up of biodiversity trends in Burundi	**D-DR Congo** Floristic and ethnobotanical investigations on the plants utilized in an area near the capital	**E-Morocco** Design and implementation of biodiversity indicators as part of the revised National Strategy for Biodiversity
Purpose	1. Identify and consult stakeholders/audience	Three day workshop with 27 representatives from sectoral ministries related to biodiversity issues, universities, NGOs and foresters to select the priority objectives and the relevant indicators (steps 1–5) (key results, see supplementary material).	Around 40 stakeholders present at the presentation of the results: researchers, herbalists, sellers of medicinal plants, forest officers. They did not directly contribute to the other steps of indicator development.	Workshop with key informants to analyse the main ecosystems for which the trends are important for the country (after step 2).	Identification but no consultation of stakeholders interested in traditional knowledge (local communities as knowledge holders) and users of data (scientists and competent authorities).	Identification of the stakeholders that could be interested by the indicator, after steps 2 and 5 were implemented. However, they were not consulted due to a lack of financial resources.
	2. Identify management objectives and targets	Selection of 5 priority NBSAP objectives.	—	Objectives selected before the other steps, while writing the project.	Choice of the national objectives that address traditional knowledge (because of expertise of the researcher in this field) and for which data are available or can be collected.	The selection of the objective was a first step to answer the following criteria: focus of the call, available data and expertise of the implementing research institute.
	3. Determine key questions and indicator use	For each priority objective, key questions were stated.	—	Key questions determined during the workshop.	Three key questions unilaterally developed by the researchers to address the selected objective.	—
	4. Develop conceptual model	For each priority objective, a conceptual model was sketched by the participants	—	—	—	—
	Capacity building contribution: The opening workshop organized by CEBioS gathered all projects representatives and included training sessions about indicators production, especially finetuning the identified possible indicators (step 5), and collecting, processing and organizing data in suitable databases (step 6) for indicator calculation (step 7).					
Production	5. Identify possible indicators	For each priority objective, three indicators were selected. A scoring of the 15 indicators ended with the four most relevant indicators (criteria: cost,	The indicators were identified in parallel to step 6 and based on collected data.	Indicators collectively selected during the workshop. For each indicator, a set of sub-indicators was selected (see supplementary material).	Unilaterally developed by the researchers based on research subject and data to be collected. Five indicators were proposed to address key	Selection of a set of indicators based on available data, and to respond to the selected national objective A3.

Table 5. (Continued.)

Theme	Key step of the BIDF	**A-Benin** Installing a follow-up system for biodiversity in Benin	**B**-Benin Value chain and traditional knowledge regarding selected medicinal plants in the major urban centres of Benin	**C-Burundi** Indicators for the follow-up of biodiversity trends in Burundi	**D-DR Congo** Floristic and ethnobotanical investigations on the plants utilized in an area near the capital	**E-Morocco** Design and implementation of biodiversity indicators as part of the revised National Strategy for Biodiversity
		budget availability, availability of data over time, data reliability, availability of expertise)			questions. The most feasible indicator was selected for the project (availability of data, feasible methodology).	
	6. Gather and review data	Land use mapping with satellite imagery, statistics from the National Office for Wood, data from a national survey and consultation of official documents.	Surveys in main markets of the country about plant species used, medicinal applications, plant organs used.	Identification of the nature and sources of existing data during the workshop. Gathering of existing data into time series (maps, satellite imagery, protected areas coverage, list of species delivering ecosystem services).	Field sampling and ethnobotanical surveys	Data gathered from ministries, Biodiversity Reports, bibliographic research, surveys with key informants, international online databases.
	7. Calculate indicators	Calculation methodology developed in the reference sheet of each indicator (see step 9 and supplementary material).	Vulnerability index calculation, diversity of used species, mapping of rare medicinal plants.	A set of indicators to report on (1) size, state and vulnerability of ecosystems and natural habitats; (2) trends in the influence of unsustainable agricultural practices on species typical to a natural forest habitat;(3) trends in distribution, state and sustainability of ecosystem services (see supplementary material for all indicators).	The number of NTFPs identified and their use by local and indigenous communities.	Trends in coverage, condition, representativeness and effectiveness of protected areas and other local actions, represented by a set of indicators (see supplementary material).
	Capacity building contribution: The closing workshop organized by CEBioS and gathering all project representatives included training and brainstorming sessions about the best way to communicate indicators, leading to the co-production of policy briefs and the development of their dissemination strategies. Follow-up awareness projects were supported by CEBioS to disseminate key-results and produced policy briefs.					
	8. Communicate and interpret indicators	Information detailed in the reference sheet of each indicator (see step 9) about: (1) representation type suggested, (2) possible significance of the trends, (3) publishing	Value chain of the two most frequently sold species considering origin, spatial distribution of rare species, collection methods, and conservation strategies. Two workshops were organized,	Graphs showing the trends in species and ecosystems, distribution maps. Communicated through accessible leaflets and policy briefs with the key message 'Worrying trend of	Policy brief showing the results of the study.	Each sub-indicator is presented in a graph, map or table.

Table 5. (Continued.)

Theme	Key step of the BIDF	**A-Benin** Installing a follow-up system for biodiversity in Benin	**B**-Benin Value chain and traditional knowledge regarding selected medicinal plants in the major urban centres of Benin	**C-Burundi** Indicators for the follow-up of biodiversity trends in Burundi	**D-DR Congo** Floristic and ethnobotanical investigations on the plants utilized in an area near the capital	**E-Morocco** Design and implementation of biodiversity indicators as part of the revised National Strategy for Biodiversity
		frequency, (4) users of monitoring results. The indicators were communicated through a policy brief.	at the beginning and end of the project, to communicate its objectives and results. A policy brief presents the results of the study.	biodiversity degradation. Call to decision-makers to reverse the situation', illustrated with graphs and numbers, and giving policy recommendations.		
	Capacity building contribution: The closing workshop organized by CEBioS and gathering all project representatives included a general reflexion about the best way to develop monitoring and reporting systems for the projects in particular, and for biodiversity indicators in general. The main outcomes of the discussions are summarized in this paper.					
	9. Develop monitoring and reporting systems	Operationalization of the selected indicators through indicator reference sheets to guide and support indicator development and their ongoing production (see supplementary material for an example). Training of key actors for collecting data. A policy brief summarizes the selected indicators and the content of the reference sheets, and recommends their inclusion in existing monitoring processes.	A policy brief gives recommendations for the creation of a national structure for future reporting about traditional knowledge, for the follow-up of the value chains and the inclusion of all concerned actors.	A database was created for the continuous updating of data. It contains all figures gathered in the form of time series and graphs for three categories: species, ecosystems, protected areas. Maps are also centralized. The activity of continuously updating the database was integrated in existing national biodiversity monitoring. The indicators will be included in future biodiversity reports.	A reference sheet for the indicator was developed using the BIP fact sheet model.	An information sheet for the indicator was developed using the BIP fact sheet model.
	10. Test and refine indicators with stakeholders	Application of the methodology in the indicator reference sheets to collect data on indicators	—	Validation workshop with stakeholders.	—	—

all projects, which can be related to the fact that they correspond to the 'M' (measure or monitor) and 'R' (report) aspects of the capacity building process (see table 2). Through these steps, indicators are produced and communicated, but do not necessarily fulfil the requirements for a 'successful' indicator. Most projects failed to meet the criteria 'based on available data', 'championed' and 'used' (table 4); possible reasons are further investigated in the discussion.

Indicators should also be purpose-dependent; hence their development or selection should start with identifying the issue or policy need concerned (Biodiversity Indicators Partnership (BIP) 2011, figure 2). Therefore, the first BIDF steps, corresponding to the 'Purpose' area, increase stakeholder involvement—and consequently ownership—and sustainability of the indicators. In Benin, the existing framework for stakeholder dialogue on biodiversity issues was an asset for project A to prioritize objectives and indicators in a participatory, multidisciplinary approach. It enabled the development of a strategy for gathering available and new data. These stakeholders must be involved throughout the process as they are crucial for data mobilisation, including localizing and accessing existing information, and assessing data reliability. They are key in prioritizing indicators, as the lack of data, funds and capacity may mean a limited number of indicators can actually be used in NBSAP reporting, as illustrated in the prioritization methodology of project A. As a result, three of the developed indicators under project A were included in the Beninese NBSAP and will be used in national reporting. Likewise, it is the only project to have developed indicators that are positively assessed for the 'championed' criterion (see supplementary material). Conversely, in projects C and E, stakeholders were involved at a point when the indicators were already defined, thereby limiting their effective use for reporting. This again illustrates the importance of the order of steps and the involvement of stakeholders from different sectors and backgrounds. This approach reflects field reality, data availability and policy needs and promotes cost-efficiency, investment in positive outcomes, and validity of indicators (e.g. Gemmill and Bamidele-Izu 2002, Danielsen *et al* 2007, Soberon and Sarukhan 2009, Torres and Skutsch 2015, McCall *et al* 2016).

Creative solutions for data availability and accessibility

When asked about the key steps identified in their MRV approach, responses vary between the project teams. The above-mentioned emphasis on prioritization of targets and indicators was echoed by projects A, D and E. Conversely, project C underlined the importance of gathering quantitative, reliable and comprehensive data, while project B also stressed that the development of a methodology for data processing is crucial. This reflects the weight that many projects give to acquiring new data. It also reflects substantial gaps in (existing) data availability and accessibility in the South (Chambers *et al* 2017), as demonstrated by the poor results for the 'based on available data' BIP criterium for most developed indicators (table 4). Moreover, data may be of insufficient quality (weak sampling design and methodology), badly processed or interpreted, presented in a user-unfriendly format or insufficiently harmonized, rendering replication and comparison difficult and time-consuming (Costello *et al* 2013, Stephenson *et al* 2017). Therefore, scientific capacity—resources or skills—for data collection and processing is essential and should be continuously supported, as under this CEBioS programme.

The lack of data for certain indicators forced some projects towards indicators for which data exist. For example, for the indicators aiming at measuring the effectiveness of protected areas management of project E, many parameters were required to ensure a scientifically sound indicator that is responsive to the issue of interest—two main BIP criteria for 'successful' indicators. However, data on total species richness, habitat cover or total vegetation cover were missing (see supplementary material), although they are crucial to assess the ecological performance of these areas, in terms of representation and maintenance of key biodiversity features and hence ecosystem services (Gaston *et al* 2008). Indicators had to be built using parameters for which quantitative data are available: trends in the coverage of protected areas and some selected conservation actions. The same happened for project C, where the focus on marshes and wetlands was driven by the availability of data; savannahs and Lake Tanganyika and surroundings were excluded because of data scarcity. It is hence clear that, often, feasible indicators will not align with the (often top-down) priority needs identified by authorities or other stakeholders.

Considerable information gaps may already be resolved through existing data collection efforts (Geijzendorffer *et al* 2016) and sources of biodiversity data, such as herbaria or other collections (Greve *et al* 2016), grey literature or environmental impact assessments (Hugé *et al* 2017), and tapping into currently underused information providers. Citizen scientists (including indigenous communities), observations by tourists (Pimm *et al* 2015), and paraecologists can greatly improve the flow of biodiversity information to all users, from local stakeholders to the academic realm (Schmiedel *et al* 2016, Schmeller *et al* 2017). Establishing a baseline based on historical data allows to detect subsequent trends, as was the case in projects A, C and E. Therefore, for the subsequent MRV call, which focused on the DR Congo only, we decided to capitalize on existing data, rather than collect new information (Vanhove *et al* 2017).

There are a number of global initiatives to provide access to data (e.g. World Database on Protected

Areas, Integrated Biodiversity Assessment Tool or the GBIF) but these resources are often poorly known and not easily discoverable or available in the global South (in particular where English is not widely used). Apart from language, capacity for database management, software availability and internet connection quality are barriers for the use of such databases or tools at the national level. Despite being promoted during the opening capacity building workshop, only one project (project E) used such databases. Efforts should be made to harmonize these existing databases and communicate about them and their relevance/applicability for national monitoring and to lower access thresholds by promoting technology transfer through easy and user-friendly tools accessible to a wide range of users.

The BON (Biodiversity Observation Networks) concept developed by the GEO BON network promotes networks which may be regional, thematic or national; they engage in harmonized and interoperable biodiversity monitoring and in making biodiversity data and data products publicly available (Group on Earth Observation (GEO BON) 2017a). Such networks should be developed keeping in mind the policy priorities of the countries and international bodies involved, so that their observations contribute to management, conservation and sustainable use of biodiversity and ecosystem services (see Walters and Scholes 2017). There are no such BONs in Africa so far and we would strongly recommend their creation.

Opportunities at the science-policy interface and the challenge of permanence

Unequivocally, all project participants stressed the need to repeat monitoring over time, becoming a permanent process. Assessments of biodiversity and ecosystem services are often too costly to be sustained once project funding ends in developing countries (Danielsen *et al* 2003; Schmeller *et al* 2017) and elsewhere (Watson and Novelly 2004). Hence, they do not become established monitoring, nor do they inform on policy-relevant trends. This may be a challenge for our projects funded for a single year. However, the influence of local research funding should not be underestimated, nor should the importance of funding for data mobilization over funding for research leading to peer-reviewed output (Meyer *et al* 2015). A solution may be locally-based monitoring. This has been demonstrated to be sustainable in developing countries after foreign funding ceases, although external input for capacity building or data analysis remains beneficial (Danielsen *et al* 2005). Several recommendations that also emerged from our MRV workshops, such as institutionalization across different levels of governance, and involvement of local communities, are known to contribute to the sustainability of monitoring schemes (Danielsen *et al* 2005).

Producing indicator reference sheets following the BIP model, as most projects did, is an important tool to guide and support the development and use of indicators. However, to ensure permanence, monitoring should be included in governance and management structures, (national) plans and strategies. Monitoring results need to be integrated and centralized in a harmonized database to encourage continuous collection and processing of data, and its development should involve both researchers collecting and aggregating data, and policymakers. The lack of an efficient and well-established national coordinating structure that is responsible for coordinating national biodiversity indicators (Bubb 2013) was emphasized by all participants (see table 4: 'Championed by an institution responsible for the indicator' and consequently the 'used' BIP criterion). Most indicator development projects in these countries are sporadically supported by international donors for short periods and no local institution is responsible for the indicator's continued production and communication. For example, the indicator 'Percentage of forest land annually converted to other categories of land use' developed by project A (figure 3(a)) was selected during the indicator prioritisation process but was not integrated into annual monitoring and evaluation systems of the Beninese forestry department. During the last 12 years, this department was 'housed' within four different ministries. Consequently, the indicator was not standardized and data collection was neither systematic nor mandatory, which led to a data gap from 2006 to 2016. More awareness and lobbying to integrate this indicator systematically into the monitoring and evaluation system of the ministry responsible for forests should improve data availability in the future. Similarly, whereas the quality of technical capacities seemed less of a problem, administrative capacity and good governance and management related to MRV was shown to be more problematic for most REDD+ countries, requiring capacity building for a wide range of actors (Ochieng *et al* 2016).

Continuously updating biodiversity indicators obviously presents a financial challenge that poses a threat to the permanence of these monitoring initiatives. However, networking and gap-filling between existing initiatives is much more cost-efficient than setting up new structures. Agreements between government agencies, NGOs, academic institutions and even the private sector can fulfil many roles related to the collection of data, calculation of indicators, and their communication to users (Scholes *et al* 2008, Bubb 2013). Whether new entities are created or not, scattered, unharmonized data and lack of collaboration across governance levels have been identified as major obstacles to national MRV systems in a carbon context, where information flow across levels is crucial (Korhonen-Kurki *et al* 2013).

The capacity development model elaborated by CEBioS stimulates and facilitates collaboration between scientists and policymakers (Vanhove *et al* 2017), hence between entities that often evolve and work independently. It can be seen as an action research component: 'a learning process between stakeholders to understand the problems at stake, each other's roles, the policies and mandates and the access to information' (Janssens de Bisthoven 2015). This contributes to 'decompartmentalisation' of different types of actors and of different levels (Ubels *et al* 2010), which is essential for mainstreaming biodiversity information into decision-making (Stephenson *et al* 2017). Participants positively evaluated their interactions, and the better understanding of each other's expectations and role in the process. They also identified additional positive outcomes, such as the joint exploration of available data: their potential, where to find them and who can work with them. The involvement of scientific institutes ensured the use of quantitative data, collected in a scientifically sound way. Therefore, participants felt that the chosen priorities and the ensuing co-produced policy briefs calling policymakers to action had received scientific legitimacy.

Policy briefs may serve as knowledge-brokering tools or 'digests' to address issues of biodiversity and other topics related to sustainable development. Ideally, key results and recommendations should be presented orally, accompanied by the policy brief. Designing policy briefs requires an understanding of the audience's needs, and a personal engagement between policymakers and scientists (Balian *et al* 2016). Policy briefs are indeed a co-produced output of joint prioritization exercises of scientists and policymakers (Sutherland *et al* 2011). Such a joint project may reconcile academic and policy motivations (Young *et al* 2014), ensure shared ownership, and make the application of results in the policy realm more likely (Sutherland *et al* 2011). It is therefore unsurprising that the 'tandem' approach of our capacity development concept proved particularly rewarding to participants, as it provides a basis for long-term dialogue at the science-policy interface. In this way, our capacity building contributes to two of the 'core capabilities' that, according to the European Centre for Development Policy Management, come with effective capacity: the capability to relate, and to achieve coherence (Ubels *et al* 2010). Therefore, it would be commendable for funding agencies to stimulate this (Neßhöver *et al* 2013) by specifically and systematically allocating funds to the identification and formulation of monitoring projects together with stakeholders from the policy-side. Project E is an example that seems very relevant to NBSAP reporting and monitoring but that could not apply any of the 'purpose' steps due to the lack of funding, hence it could not involve stakeholders in the process, risking that Moroccan national reporting on protected areas will not consider its results.

Participants stressed that indicators should not be the only focus of messages to policymakers. Other useful communication tools that they identified are the economic valuation of ecosystem services or the use of scenarios, projections and models to simulate the impact of future policies (e.g. Visconti *et al* 2016, Kubiszewski *et al* 2017). For example, regarding the use of scenarios related to biodiversity and ecosystem services in policy planning in Africa, there is a clear lack of capacity and of inter-African knowledge transfer (Biggs *et al* 2018). Another reason to not only focus on indicators is the notion that progress towards certain Aichi Targets is not purely hampered by a lack of quantifiable data, but rather by institutional challenges, namely the mismatch with existing commitments. This is the case e.g. for targets related to access and benefit sharing (Hagerman and Pelai 2016). In this respect, projects B and D explicitly focused on traditional knowledge, and hence bridged the local level of data acquisition in this field with national indicator development. Such subnational projects have indeed been proposed, for MRV in a REDD+ context, to serve as case studies for a more participatory approach that also considers social impact (Korhonen-Kurki *et al* 2013). The poor coverage of the BIP criteria (table 4) by the indicators developed under project B and C also reflects that indicators are not always the best suited tools to address specific questions. The weak 'scientific validity' of the indicators indeed refers to the lack of widely accepted scientific knowledge and understanding of traditional knowledge (see also Hernández-Morcillo *et al* 2013, for an overview of the difficulties surrounding indicators for cultural ecosystem services and the importance of involving stakeholders). These projects call for authorities to set up structures to access scientifically sound information on the sustainable exploitation of plants and to play a role in training in and conservation of related traditional knowledge. This illustrates the importance of better communication between scientists and policymakers in this field. The approach taken by Burundi, where a formal agreement between the scientific community and traditional practitioners was reached regarding access and benefit sharing, may serve as a pioneering example of best practice (Janssens de Bisthoven *et al* 2017).

Conclusions and perspectives

Within the methodology for indicator development in the South, through our pilot projects we identified data availability and, probably even more important, data accessibility, together with the involvement of stakeholders, as critical steps. Indeed, while we agree with Wilson *et al* (2016) that certain countries in the South, and even more their researchers, are underrepresented in research and policy, our case studies demonstrate that numerous and diverse scientific (monitoring) activities exist, but are unfortunately poorly accessible, visible or harmonized. Moreover, at a more basic level, there is a need for a better understanding and a wider application of the indicator concept itself.

Various recent capacity development initiatives are being developed to assist governments in developing more effective and timely biodiversity monitoring and policy responses, e.g. 'BON in a Box' (Proença *et al* 2017, Group on Earth Observation (GEO BON) 2017b). Our MRV pilot programme demonstrated the need to step up capacity development, to initiate an indicator-based approach and to sustain long-term monitoring. This fits into the trend of focusing on policy-relevant biodiversity monitoring when setting up new capacity building programmes in the Global South. Of the main existing schemes of biodiversity data collection *sensu* Proença *et al* (2017), our MRV projects seem closest to the 'intensive monitoring programmes', with capacity building focusing on professional development. In this scheme, Schmeller *et al* (2017) highlight the importance of transferring technical expertise and strengthening institutions. It was clear from the onset that our participants valued training, especially in ground-truthing, economic valuation of ecosystem services, the indicator concept in itself, and a variety of information technologies to collect, access and share data (Vanhove *et al* 2017). Given limited resources to initiate capacity building in biodiversity monitoring, identifying local and topical priorities relevant to biodiversity policy instruments together with national governments, is a way to increase impact and sustainability (Henle *et al* 2013, Schmeller *et al* 2017). With our MRV approach, we subscribe to this approach. We recommend that in future capacity development efforts, the perspectives that we identified from an African viewpoint, in particular the demonstrated potential of collaboration between scientists and policymakers, and the South–South collaboration and South ownership, be promoted. Adopting this approach would necessitate changes in information flow, incentives and structures across multiple scales at the institutional level and including policy and funding agencies. Therefore, we propose that setting up a biodiversity MRV system could foster wider transformational changes in biodiversity governance, as has been suggested in a REDD + context (Korhonen-Kurki *et al* 2013).

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