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CO-GENERATING KNOWLEDGE ON ECOSYSTEM SERVICES AND THE ROLE OF NEW TECHNOLOGIES

Wouter Buytaert, Boris F Ochoa-Tocachi, David M Hannah, Julian Clark and Art Dewulf

Introduction: evidence-based governance of ecosystem services

Much of the global research on the interface between ecosystem services and sustainable development is driven by the need for a better scientific evidence base to support decision making and policy (e.g. Balian et al., 2016). In many developing regions in particular, the natural processes that determine the magnitude and spatiotemporal dynamics of ecosystem services are still poorly characterised (e.g. Wohl et al., 2012). Perhaps even less is known about the way people interact with these services, and how this determines their livelihoods and poverty status (e.g. Doswald et al., 2014). This makes it pertinent to reflect on the process of generating data, evidence and knowledge on ecosystem services, and on how this process can be improved to maximise the potential for poverty alleviation.

This is particularly relevant because of the transformative potential of new technologies to this process, and the accelerating adoption of such new technologies by the poor. In particular, information and communication technology (ICT), such as mobile phones and computer-based social networks can be instrumental in the collection, analysis and sharing of information. At the same time, an exponentially increasing amount of information is becoming available online. A significant amount of this information relates to ecosystem services: witness for instance the boom in satellite-based earth observation, which provides great opportunities to create relevant scientific knowledge to support management of ecosystem services.

However, technological development also has a more fundamental impact on the way that ecosystem service-relevant knowledge is created, how it flows between different actors, how it influences power relations and negotiation strategies, and thus how it influences decisions and policy-making. This is particularly the case for technologies and approaches, such as collaborative governance, participatory action research and citizen science, that disrupt conventional knowledge generation processes.

In this chapter we reflect on the current state of science and the gaps in understanding of processes of knowledge creation on ecosystem services and their relation to poverty. We then outline a conceptual framework to discuss future opportunities to support and improve the process by which knowledge is generated, how it influences decision making and how it can be used in poverty-alleviation contexts.

Opportunities for poverty alleviation

Poverty is a multi-dimensional phenomenon, impeding groups of people from undertaking the actions and activities that they want to engage in, and being who they want to be, thereby realising the kind of life they have 'reason to value' (Sen, 1999: 87; see also Coulthard et al., this volume). The required capabilities to take these actions relate to different concrete dimensions of quality of life, such as avoiding hunger, being educated, escaping premature death or being an accepted and respected member of society.

In many regions in the world and developing countries in particular, these dimensions depend on a variety of ecosystem services, including provisioning (e.g. drinking water), regulating (e.g. biocontrol of pests), supporting (e.g. habitat provision) and cultural services (e.g. religious heritage sites). Based on their access to and use of these services, people can take individual decisions on how to manage ecosystems to improve their quality of life. By making more efficient use of ecosystem services, individual benefits can be increased. By considering impacts on the long-term availability of these services, individual decisions can also contribute to more sustainable management of these services. Access to relevant information and knowledge about ecosystem services is therefore a key element in supporting individual decisions that relate to the alleviation of an individual's poverty.

However, people's capabilities to escape poverty also relate to the opportunities they have to actively participate in shaping their livelihoods beyond their individual decisions and in the struggle over the conditions that allow or impede them to do so. Because there are many interdependencies in social-ecological systems, and because many ecosystem services have common pool resource characteristics (Ostrom et al., 1999), collective decision-making arrangements on ecosystem services can have an important impact on livelihoods. For instance, trade-offs often have to be made within and between different ecosystem services, whereby prioritising one service compromises the production of others (for example, carbon uptake versus water use by forests; water use upstream and downstream in a watershed). Ecosystem services that have common pool resource characteristics (e.g. water, communal land) also run a risk of overexploitation or unsustainable use, which has to be addressed through some form of collective knowledge generation and monitoring arrangement. Environmental information can support collective choice and monitoring arrangements between ecosystem service users and/or public authorities. The usefulness of this information increases when these actors are involved in generating this knowledge (Dewulf et al., 2005), for example, to use it legitimately to assess different management scenarios.

The dynamics of both individual and collective decision making on ecosystem services depend on people's entitlements. These are alternative sets of utilities derived from environmental goods and services over which social actors have legitimate effective command, and which are instrumental in achieving wellbeing (Leach et al., 1999). People's entitlements are related to their identity and position in social networks (e.g. gender, age, ethnicity and social class), and to the nature of local institutional rules and norms. They determine the conditions of access to natural resources as well as opportunities for their use, exchange and valorisation.

Marginalised and excluded members of communities may have their access to, and their possibility to, valorise ecosystem services restricted, while other community members may benefit at their expense. These entitlements and their impact on poverty and wellbeing are therefore critical processes to understand in any attempt at leveraging ecosystem services for poverty alleviation. They are intrinsically related to institutional processes, because this is where stakeholders mutually learn and struggle over issues of access to, legitimacy of use, and conditions for valorisation of natural resources.

It is also key in poverty alleviation to improve the voice and participation of poor groups in these learning processes and struggles, and to support them in finding more effective strategies, to change the rules of entitlement in their favour. The access of people in poverty to the relevant knowledge can give them advantage when negotiating individual access to ecosystem services, and increase their voice in collective decision making about ecosystem services. It can also support them in negotiating the monitoring of institutional arrangements that give them access to ecosystem services. This can help to reduce exploitation or abuse of ecosystem services by those that are better off or have more power in the negotiation process. Lastly, continuous access to relevant knowledge and information about the current state of ecosystem services and potential changes (e.g. induced by environmental degradation and climate change) also supports the poor to adapt to changing conditions, and more generally to support adaptive governance of ecosystem services.

Knowledge co-generation in polycentric governance systems

Given the importance of information and knowledge generation on ecosystem services in the poverty-alleviation process, it is crucial to understand the processes of such knowledge generation in the social-ecological system in which people interact with ecosystem services. The work of Nobel Laureate Elinor Ostrom on the governance of natural resources triggered an increasing recognition that social-ecological systems, especially in developing contexts, are often characterised by multiple centres of decision making across different scales, thereby relying on a distribution of responsibilities, multiple sources of information, and co-generation of knowledge (e.g. Buytaert et al., 2016; Folke et al., 2005). As a result, a highly structured, hierarchical and top-down paradigm of governing (e.g. integrated river basin management, Lankford and Hepworth, 2010), may not be an optimal model for such systems.

Instead, a polycentric approach to natural resources management has been proposed as a potential alternative to tightly integrated (e.g. state-centralised) management systems (Lankford and Hepworth, 2010). Even if they are less streamlined than centralised systems, polycentric approaches to governance tend to 'enhance innovation, learning, adaptation, trustworthiness, levels of cooperation of participants, and the achievement of more effective, equitable, and sustainable outcomes at multiple scales' (Ostrom, 2010: 552).

Polycentric governance also recognises much more explicitly the existence of different types of knowledge within the social-ecological system in addition to scientific knowledge, i.e. local (indigenous) knowledge and hybridised knowledge forms. As a result, this stresses the concept of knowledge co-generation and its benefits, such as a stronger emphasis on the indigenous knowledge of marginalised groups, and explicit recognition of concepts such as access, participation and negotiating power within the process of knowledge generation.

The role of technology in knowledge co-generation

Technology can play a potentially transformative role in the process of knowledge co-generation. Perhaps the most conspicuous adoption of ICT among the poor is the rapid uptake of mobile phones (Lu et al., 2016a,b). Mobile phones enable a plethora of new direct information flows, including calls, text messages and informative apps. Indirectly they also foster interaction and knowledge exchange by enabling the use of social media and other peer-to-peer interactions. Increasingly, these channels are used by actors with a specific agenda or purpose within the context of ecosystem services, for instance to support farming practices, or to implement early warning systems. However, these technologies may also be used to influence decision making less directly, for example, through publicity and commercial applications.

The advent of social networks and other 'interactive' ICT applications also enables a more structural form of knowledge co-generation. The development of computerised decision support systems in natural resources management dates back several decades. However, such systems have often been criticised for being strongly supply-driven, and rigidly oriented towards a very specific problem or use (Karpouzoglou et al., 2016; Zulkafli et al., 2017). Recent ICTs have a potential to change this, and to break open the traditional unidirectional flow of information from the system to an end-user into a multidirectional flow of information between various actors, by integrating social networking technologies and similar application over networks such as the internet. Such 'second generation' decision-support systems are sometimes referred to as 'environmental virtual observatories', because they provide an opportunity to enhance conventional information about the environment with virtual technologies (Buytaert et al., 2012).

Lastly, a broader range of technologies supports new methods for data collection. These can range from easily accessible datasets in the public domain, such as satellite imagery and governmental monitoring records, to low-cost and robust sensors connected to the Internet. These technologies enable data collection and processing by stakeholders that are not traditional analysts or scientists. This promotes new and 'alternative' approaches to information collection and knowledge generation, such as participatory monitoring and modelling, participatory action research and citizen science.

Much of this evolution is occurring in the broader environmental realm. For instance, one of the most active areas of citizen science is biodiversity assessments, while it also underpins grassroots action on water quality (Buytaert et al., 2014) and some of the biggest online environmental datasets, such as the Open Street Map. As such, it is a force to be reckoned with in the context of ecosystem services assessment, and increasingly in the context of sustainable development and poverty alleviation.

A conceptual framework to analyse knowledge co-generation

As argued above, knowledge generation in the context of managing ecosystem services for poverty alleviation is often a complex, multi-directional and iterative process of interactions between different stakeholders. Here, we provide a simple conceptual framework to guide our discussion on the dynamics of knowledge co-generation and the role of new technologies in this process.

We identify three major steps in the process of creating actionable knowledge in which new technologies can be instrumental: the collection of new observations; the processing of these observations and extraction of knowledge; and the interaction between different actors ('communication') on the newly created knowledge. Such interaction may raise new questions and identify needs for further knowledge, resulting in an iterative process of knowledge generation conceptualised in Figure 11.1. Especially in polycentric systems, it is likely that the knowledge generation process is not linear, but consists of many iterations, feedback loops and shortcuts between individual actors. This would result in secondary and parallel loops of knowledge generation in addition to the main loop represented in Figure 11.1. The existence of such secondary loops is probably a major characteristic of the knowledge co-generation process.

In the following sections, we apply our conceptual framework to the portfolio of literature emanating from the Ecosystem Services for Poverty Alleviation (ESPA) programme, and discuss how ESPA activities have created new insights into the co-generation of knowledge relating to ecosystem services.

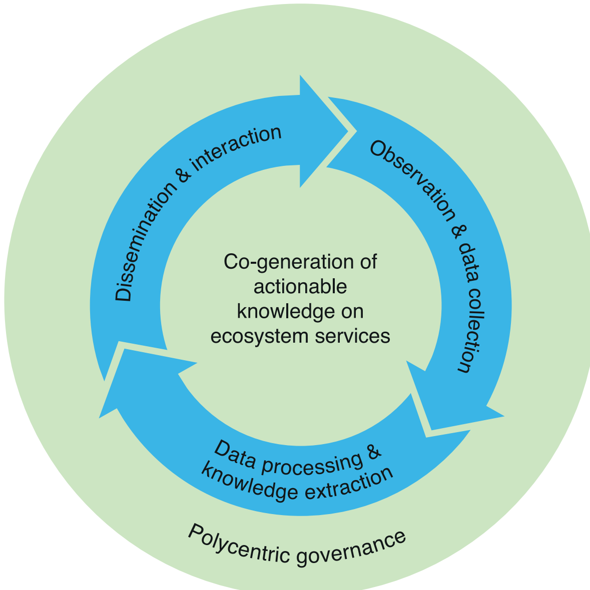

FIGURE 11.1 Conceptual overview of the knowledge co-generation process in a polycentric system.

Observations and data collection

Several ESPA projects have experimented with, and developed, new methods to enhance the observation of ecosystem processes, and to alleviate the issue of data scarcity that is endemic in many development contexts.

One set of projects is mostly concerned with exploring new data sources. Satellite imagery, in particular, is a promising new source of information on ecosystem processes as diverse as mangrove forest extent and disappearance (Kirui et al., 2013), soil salinisation of river deltas (Amoako Johnson et al., 2016) and spatiotemporal patterns of precipitation (Futter et al., 2015). The spatiotemporal coverage of satellite imagery is particularly relevant to identifying spatial and temporal patterns of change and variability, especially in regions where local observations are difficult to make (e.g. conflict areas, mountain regions), and where institutional capacity for data collection is low. However, major problems remain with regard to coarse resolutions and uncertainties, especially for processes such as precipitation that rely on proxy measurements – for example, cloud top temperature and related variables, with imperfect correlations to the variable of interest (Futter et al., 2015). Nevertheless, these studies and, in particular, methods and approaches that are specifically tailored for data-scarce regions (Pandeya et al., 2016), provide a direct contribution to the globally recognised need for better quantitative data about natural processes (e.g. Wohl et al., 2012).

Novel methods for data collection leverage new technologies in unexpected and unintended ways – for instance, using data from the mobile phone network to track migration patterns in the context of floods in Bangladesh (Lu et al., 2016a,b; and Box 11.1). The increasing adoption of mobile phones and ICT also facilitates the collection of natural and social science information, both from the scientist's perspective (e.g. online storage and processing) and from the participant's perspective (e.g. online surveys, email questionnaires). An example of the latter is the deployment of a participatory video process to facilitate the understanding of local wellbeing in four villages in rural Tanzania in the context of community-based forest management (Gross-Camp, 2017).

A more radical form of data collection in a co-creation context is that of citizen science (Haklay, 2013). Because of its strong reliance on technology, citizen science is often associated with data collection in developed regions (e.g. bird counting). However, the possibility to leverage citizen science in a developing country context is receiving increasing attention as a method to support participatory action research and to promote inclusion (Buytaert et al., 2014). One promising example is a participatory hydrological monitoring network in the Andes (iMHEA by its Spanish abbreviation), which generates data on water resources to evaluate the impacts of land use change and other human interventions. By bringing together community members, users of soil and water, policy makers and scientists, this new generation of hydrological information has the potential to extrapolate results and inform actions in a regional data-scarce context (Ochoa-Tocachi et al., 2016). This case also exemplifies the use of new technologies such as robust, low-cost sensors, automatic data transmission and interactive mobile phone applications (Buytaert et al., 2014). This increasing access to environmental data collection techniques, which is driven by low-cost sensors and similar technology, has important consequences for the knowledge-generation process. For example, it can influence (and potentially reduce) monopolies on data access, and in negotiating access to natural resources (Buytaert et al., 2016).

At the same time, these technological developments can also incur risks. The disruptive nature of technology can result in a realignment of social structures and practices because of the availability of information and new connections between actors. For instance, the availability of online models can reduce land value or impact existing social practices. It is therefore paramount that researchers and implementers are aware of these pitfalls and, in particular, the risk of increasing imbalances in information access (Buytaert et al., 2014).

Data processing and knowledge extraction

Raw observational evidence often needs to be processed to convert it into relevant and actionable knowledge for decision makers. The type and level of processing is very diverse, and may range from direct visualisation to complex analysis and processing using computational models, such as in weather forecasts (Grainger

BOX 11.1 DETECTING MIGRATION PATTERNS AS CLIMATE ADAPTATION STRATEGIES WITH MOBILE PHONE NETWORK DATA

The low elevation and highly climate-stressed south coast of Bangladesh is likely to suffer from climate-related migration trajectories, with unprecedented complexity and dynamism resulting from both extreme weather events and slow-onset climatic stressors (Martin et al., 2014). Conventional survey-based research may be insufficient to track such migration patterns, the study of which could benefit from more rapid, cost-effective and accurate tools processing detailed mobility data over a larger range of temporal and spatial scales (Lu et al., 2016b). Lu et al. (2016a) report on a collaboration between the International Centre for Climate Change and Development (ICCCAD), Flowminder, Grameenphone, Telenor Research, United Nations University and the Bangladeshi Ministry of Disaster Management and Relief, to understand climate-induced migration and displacement in Bangladesh. They accessed mobile network operator call detail records, which contain for each subscriber the location of the closest mobile phone tower at the time of each call, text message or data download. By using two de-identified datasets, one covering a period of three months and the other a period of two years, they analysed the directionality and seasonality of migration patterns on both local and national scales, and investigated behavioural responses in the population exposed to cyclone Mahasen. Because of the large sample size and detailed spatiotemporal resolution, mobile phone data allow for characterisation of locally and contextualised mobility patterns as well as identification of anomalies before and after climate shocks. Although the use of such data has limitations – for example, uncertainty in the representation of vulnerable groups such as women, children and the poorest – they provide a novel tool to complement other information sources (Wesolowski et al., 2012). For instance, they have potential to indicate when and where impacts of disasters have occurred, support audits of the effectiveness of early-warning programmes and overcome potential biases in the selection of post-disaster damage sites for humanitarian interventions (Lu et al., 2016b).

et al., 2016). Although data processing and algorithm development are most typically associated with the realm of scientists, new and increasingly participatory methods for doing so are emerging.

Among these, participatory modelling has emerged as a way to incorporate views and insights from local, non-scientist experts into a conceptual model. This is particularly relevant in an ecosystem services context. Local experts tend to have an in-depth understanding of the natural processes occurring in an ecosystem, albeit often in a qualitative manner. A joint approach to conceptualising a social–ecological system may be instrumental to incorporate such indigenous knowledge in evidence generation (e.g. Dewulf et al., 2005). However, methods and tools to do so are still scarce and often strongly context dependent and idiosyncratic. Within the context of the ESPA programme, Daw et al. (2015) and Galafassi et al. (2017) used participatory modelling with stakeholders to understand and build a conceptual model of the trade–offs that are inherently present in the balancing of different ecosystem services. They used a 'toy model' to support discussions and to construct

BOX 11.2 A PARTICIPATORY SOCIAL-ECOLOGICAL MODELLING APPROACH TO ASSESS TABOO TRADE-OFFS

The small-scale tropical fishery at Nyali, Mombasa, Kenya is a social-ecological system that includes different primary stakeholders that use and impact on the natural ecosystem. McClanahan (2010) identified that a reduction in fishing intensity could result in a win-win scenario between profitability and conservation. However, this solution at the aggregate scale overlooked trade-offs with food production, employment and wellbeing of marginalised women who have limited visibility and voice in governance (Matsue et al., 2014). Daw et al. (2015) applied a participatory framework to identify and consider some of these 'taboo' trade-offs in ecosystem services and human wellbeing hidden within apparent win-win situations. First, focus group discussions with five primary stakeholder groups (fishery users) explored their perceptions of wellbeing and their dependence on the system (Abunge et al., 2013; Galafassi et al., 2017). Second, 15 years of biological and fisheries data collected from ecological monitoring, landing site surveys and online databases were assimilated through an ecological model to provide expected ecosystem responses to diverse fishing effort scenarios. Third, participatory conceptual modelling with secondary stakeholders (staff from local government and non-governmental organisations, and representatives of fishery and tourism interests) regarded as local experts, identified social and ecological linkages, feedbacks and drivers of the system. These data sources were integrated into a simplified social-ecological 'toy model' and a set of narrative scenarios of possible futures. Local learning assessment, through entry and exit questionnaires, observation and follow-up qualitative interviews, evidenced an expansion in local systemic understanding of the nature and dynamics of trade-offs. An explicit consideration of trade-offs, values and possible taboos can ultimately support socially equitable and sustainable decision making. Such a combination of participatory modelling and scenario development has the potential to enhance transparency, accountability, relevance and trustworthiness in the management of social-ecological systems (Daw et al., 2015).

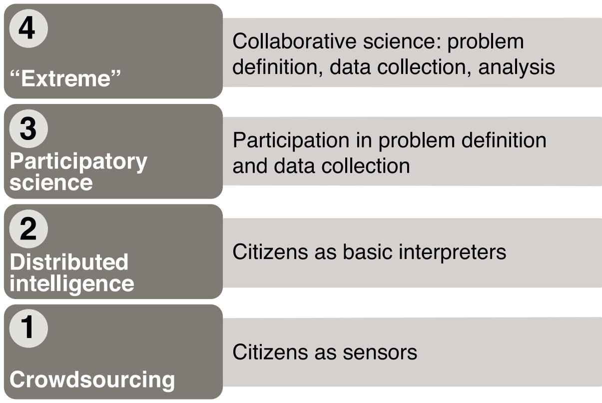

FIGURE 11.2 Levels of participation in citizen science as identified by Haklay (2013) and explored in a poverty alleviation context by Buytaert et al. (2014).

and evaluate future scenarios (see also Box 11.2). Applications of participatory modelling in the context of improving models of infectious diseases can be found in Grant et al. (2016).

New technologies can also be instrumental in facilitating participatory approaches to data processing, and need further exploration. For instance, Ramirez-Gomez et al. (2015) developed techniques based on participatory Geographic Information Systems (PGIS), combining mapping and focus group discussions, to involve indigenous peoples in the lower Caquetá River basin in Colombia in the analysis of changes in the location and stocks of provisioning ecosystem services. They recommend using PGIS in data-scarce scenarios and for building common mapping information.

Related to such participatory approaches, citizen science is also promoted as a powerful tool for interactive data processing and knowledge extraction. Although the concept is more commonly associated with data collection, citizen science can promote the involvement of stakeholders at all stages of the knowledge-generation process, including during the problem identification and analysis phases. This more inclusive form of knowledge generation has been referred to as 'extreme' citizen science (Haklay, 2013; and Figure 11.2), and is particularly appropriate in a context of sustainable development (Buytaert et al., 2014).

A potential issue with citizen science, and related participatory approaches developed within a scientific context, is their reliance on the traditional scientific method, which is not necessarily compatible with forms of indigenous knowledge that are common in a poverty context. Overcoming these issues may require more holistic approaches of inclusive knowledge generation. Collins et al. (2009) and Wei et al. (2012) pursued the building of 'learning systems' to create an incipient social learning platform to address the pitfalls of classic paradigms in water resources management, which fail to address the 'wicked' nature of policy making in regions that are characterised by large institutional complexity and informality. Such platforms tend to be less centralised and aim for a more organic and 'messy' form of learning and knowledge creation. From that perspective, such learning systems are closely aligned to the recognition of polycentricity in natural resources management systems (Buytaert et al., 2016; Lankford and Hepworth, 2010).

Knowledge dissemination and interaction

The scientific community increasingly recognises the need to improve the way in which potentially complex information is being conveyed to stakeholders (Grainger et al., 2016). This is particularly relevant in a poverty-alleviation context, in which the background and educational level of actors tend to be highly variable and insufficiently tailored information may disadvantage the poor. Knowledge dissemination activities that rely on technology or present a learning curve, such as computer-based decision-support systems and mobile phones, can run the risk of being hijacked by elites with better access and an educational advantage. In such contexts, it is paramount to co-design knowledge dissemination systems, and to evaluate the usefulness, usability and accessibility of such systems.

Zulkafli et al. (2017) implemented a comprehensive study of user-centred design of a computer-based interface to convey hydro-meteorological information in a farmer community in the Peruvian Andes (Box 11.3). Other authors have studied the evaluation of environmental information and interaction between scientists and stakeholders. For instance, Willcock et al. (2016) evaluated the relevance of ecosystem service maps and models to meet stakeholders' needs in the context of ecosystem services in sub-Saharan Africa, identifying significant deficiencies in the currently available information.

More complex issues arise when data contain large uncertainties or are more difficult for non-scientists to grasp (e.g. highly dimensional datasets such as precipitation, or abstract concepts such as biodiversity). New technologies such as interactive visualisations, infographics and social media hold promise to enhance the flow of information between actors in a complex, multi-layered social-ecological system; however, exploring their potential within the context of ecosystem service management for poverty alleviation is still in its infancy (Grainger et al., 2016). The same holds for more complex and intangible aspects of knowledge dissemination, such as trustworthiness, credibility, reliability and their impact on power relations, and poverty-alleviation efforts in general. The dynamics of social media interaction, for example, involve personalisation, amplification, polarisation and dispersion of information through networks, which is likely to create hypes and to reinforce convictions among like-minded people (Stevens et al., 2016). While some studies investigating ICT for development show a positive correlation between ICT and social capital (including boosting trust and credibility) (e.g. Thapa et al., 2012), others are much more cautionary (e.g. Ahmed, 2018).

BOX 11.3 USER-DRIVEN DESIGN OF A DECISION-SUPPORT SYSTEM FOR POLYCENTRIC ECOSYSTEM MANAGEMENT

Upstream/downstream water users in Lima, Peru, are adapting to water scarcity at various levels, from communities to regional decision makers. The diverse interests and interactions of decision makers result in local water and pastoral land management decisions being influenced by larger, more formal, decision-making structures beyond the community scale (Buytaert et al., 2016). Some institutions have reflected on the importance of scientific evidence to support and balance policy design, but environmental decision support systems (EDSS) are commonly single actor-oriented and science-driven (Karpouzoglou et al., 2016). Zulkafli et al. (2017) developed and applied a framework for an iterative research and collaborative design process of EDSS based on a more complete understanding of the contextual decision-making structures and practices. First, an immersive field-based discovery phase identified up to 23 different entities existing in a polycentric governance arrangement where data, information and knowledge on water resources have been generated, owned and shared separately. Second, an iterative participatory design phase leveraged the interdisciplinary nature of the involved actors and research team (for instance, visualisation for non-technical audiences, Grainger et al., 2016) for rapid conceptual design, parallel prototyping and user testing. The different users were formalised in a set of profile personas with connected interests, agendas, roles, decision-making processes and goals, and requirement criteria for useful (relevant), usable (intuitive) and unobstructed (exchangeable) information. These requirements were clustered in data-driven (e.g. mapping and monitoring), model-driven (e.g. indices) and communication- and knowledge-driven (e.g. uncodified knowledge exchange) EDSS solutions and translated into web-tools. The integration of collaborative design, user-tailoring and regional and international interests in the data and knowledge generated and owned locally could potentially shift power balances in support of polycentric ecosystem management, particularly for marginalised actors. This contrasts with top-down approaches that might have required a forced change in how decision makers access and use information (Zulkafli et al., 2017).

Conclusions

The presented evidence and insights highlight the strong potential for new technologies to support an inclusive process of knowledge co-generation on ecosystem services that benefits poverty alleviation. Here we created a framework to analyse the knowledge generation process in three stages, i.e. data collection, data processing and knowledge extraction, and knowledge communication and dissemination. The portfolio of ESPA projects has generated new approaches and evidence in each of these stages. New approaches to participatory monitoring and the development of low-cost and robust sensors can enhance participation in the data collection stage. These activities bear a strong resemblance to the concept of 'citizen science', and only recently is its potential in a context of poverty alleviation being explored.

Participatory modelling and the valorisation of indigenous knowledge are examples of approaches that promote inclusiveness in the stage of data processing and knowledge extraction from raw observations. Lastly, the increasing adoption of ICTs by the poor creates significant potential to improve the access to relevant information and its sharing between actors, thus supporting a more decentralised and participatory process. An important factor here is the need for tailored visualisation of environmental data, including the role of infographics.

Reflecting on these processes, we perceive a strong parallel between the potential for technology to support decentralised forms of evidence generation on the one hand, and the existence of polycentric governance processes in many social–ecological processes related to ecosystem services on the other. These parallels can be leveraged for poverty alleviation. Knowledge generation in social-ecological processes is a continuous and strongly iterative process, which is further enhanced by the increasingly real-time nature of observations and predictions. This can stimulate participation in knowledge generation and reduce the knowledge gap. Inevitably, such development also incurs risks that need to be evaluated and addressed, such as the re-alignment of social structures and practices because of newly introduced information and new connections between actors.

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