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Identifying governance challenges in ecosystem services management – Conceptual considerations and comparison of global forest cases

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ABSTRACT

Ecosystems around the world generate a wide range of services. Often, there are trade-offs in ecosystem service provision. Managing such trade-offs requires governance of interdependent action situations. We distinguished between (1) enhancing action situations where beneficiaries create, maintain, or improve an ESS and (2) appropriation action situations where actors subtract from a flow of ESS. We classified ESSs in order to identify focal action situations and link them to ESS governance types which are likely to strengthen sustainable ecosystem management. The classification is applied to six forest cases in Asia, Africa and Latin America.

Our results confirm that ecosystem management, which more strongly supports the provision of public goods and common pool resources, is often under strong pressure to be transformed into systems that mainly provide private goods. This can be partly explained by incentive constellations in the action situations of public goods and common pool resources. Therefore, governance has to be adapted to specific ESSs. ESS governance needs to identify institutions which best fit to different ESSs and to harmonize them for all the ESSs provided by the system. Our approach helps to understand why institutions fail or succeed in maintaining ESSs.

1. Introduction

Beneficiaries at local, regional and global scales enjoy provisioning, cultural, regulating, and supporting ecosystem services (ESSs) as aspects of ecosystems that are utilized to produce human well-being (MEA, 2005, Fisher et al., 2009, Raudsepp-Hearne et al., 2010). In particular, poor, rural households depend on provisioning ESSs such as food, fuel, grazing biomass, timber, and medicine. In addition, the poor are the most vulnerable to ecosystem disservices such as pest infestation or flooding and to ecosystem losses such as diminishing forest resources. The social-ecological interactions relevant to the governance of ESSs are, however, not yet sufficiently understood (Reyers et al., 2013, Ban et al., 2015, Cook et al., 2016). Finding ways of managing ecosystems that strike a balance between enhancing the provisioning of ESSs while limiting losses is still an unresolved challenge.

Alternative management and governance choices at various scales lead to different combinations of actual and potential ESSs. Often, there are trade-offs where optimizing one ESS results in gains and losses of other ESSs (Tallis et al., 2008, Howe et al., 2014, Ban et al., 2015). Decisions favouring the provision of bundles of ESSs with lower societal welfare value at the expense of bundles of ESSs with higher value result from (i) insufficient knowledge about ESS values and interactions (Rodríguez et al., 2006, Costanza et al., 2017) and/or (ii) diverging interests, with some people not having full control over the costs they

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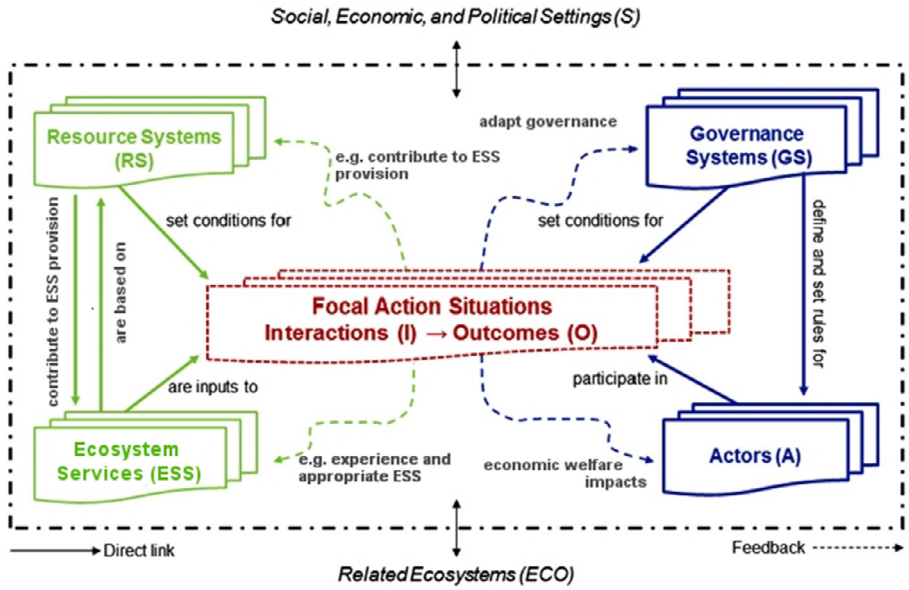

Fig. 1. SES framework with ESS link. Based on McGinnis & Ostrom (2014).

experience from other people's actions or of people enjoying benefits but not contributing to their creation (Ostrom, 1990). The latter challenge creates incentives for short-sighted individual actions at the expense of society's welfare. Avoiding such suboptimal actions requires appropriate governance responses. Whether and which problematic incentive situations occur depends on features of the ESS. Equally, which governance responses are most promising to improve decisions also depends on features of the ESS. Our first contribution to the ESS governance discussion is the classification of ESSs in order to link them to ESS governance types which are likely to strengthen their sustainable management.

Natural resource governance studies often focus on a single resource used by rather homogeneous groups of people (Howe et al., 2014). ESS research teaches us, however, that ecosystems provide multiple opportunities for generating a broad range of benefits to people (e.g., OECD, 2003, MEA, 2005, Maynard et al., 2015, IPBES, 2015, Barnaud et al., 2018). There are both competing and complementary ESS bundles, which affect different stakeholder interests (Raudsepp-Hearne et al., 2010, Maynard et al., 2015). Our second contribution to the ESS governance discussion is to create awareness about the fact that ecosystem governance must simultaneously address different types of ESSs which require different governance responses. As a result, ecosystem governance is typically a mixture of different types of interacting institutions.

Our analyses contribute to a better understanding of why institutions fail or succeed in maintaining ESSs (Carpenter et al., 2009). It enriches the ESS discourse by illustrating the linkages of ESSs with human agency and governance and contributes to the understanding of making the ESS concept operational for policy makers and the sustainability science community (Ruckelshaus et al., 2015, Costanza et al., 2017, Barnaud et al., 2018). This paper is driven by the motivation to guide policy makers and the sustainability science community in the process of identifying sustainable ecosystem governance frameworks. Our study addresses, however, issues of stakeholders beyond this target group. Stakeholders are defined as all those that affect or are affected by the ESS governance and management. They encompass individuals, groups, and organizations.

We will first present the conceptual background of our approach before applying it to cases in Asia, Africa and Latin America, with forests as the example land-use type. This will demonstrate the potential for the approach to support comparative studies.

2. Analytical framework and its justification

To disentangle the governance challenges related to ESSs, we distinguish action situations (AS) related to ecosystem management understood as social spaces where people and organisations interact with each other in relation to ecosystems and ESSs (Ostrom, 2009). Natural resource governance research distinguishes between provisioning and appropriation ASs (Hinkel et al., 2015, Costanza et al., 2017). In the ESS context, we slightly refine them and differentiate between (1) enhancing ASs, where people support the creation, maintenance, improvement, or degradation of ESSs through investments, management or restoration, and (2) appropriation ASs, where people subtract from available ESSs. Each ESS has its own ASs and the interplay of enhancing and appropriating ASs of all ESSs in the system needs to be governed. We understand ecosystem governance as the combined societal processes organising the appropriation and enhancing ASs of all ESSs in a specific social-ecological system (inspired by Ostrom, 2009, Woodhill, 2010, Loft et al., 2015). Governance concretizes in institutions understood as formal and informal norms, rules, and laws (Loft et al., 2015, McGinnis and Ostrom, 2014).

ESS governance is effective when the interplay of its institutions understood as norms, rules, and laws successfully organises the societal processes to support the production of desired outcomes (Cole et al., 2014, Barnaud et al., 2018). To be effective, governance needs to be adapted to the social-ecological system (SES) context (Ostrom, 2007, Mann et al., 2015). No governance regime is intrinsically superior to the other (Williamson, 2000, Ostrom, 2007, Woodhill, 2010). Instead, institutions need to fit to the context (Fisher et al., 2009). For ESS governance this means that the characteristics of ESS affect the likelihood of different types of institutions to produce outcomes. We call the combination of ESS and institution which most likely produces desired management outcomes the institutional fit of the ESS (Cox, 2012, Loft et al., 2015). The ESS-specific institutions organising the enhancing and appropriating ASs of all co-produced ESSs in a specific social-ecological system build an interconnected bundle of norms, rules and laws.

We refer to the SES framework (Ostrom, 2007, 2009, McGinnis & Ostrom, 2014, Fig. 1) as an attempt to capture the complexity of social-ecological systems. We believe that a focal link between the ESS and SES thinking are the Resource Units in the SES framework. To highlight this link, we replaced in Fig. 1 McGinnis' and Ostrom's (2014) Resource Units by Ecosystem Services. Making this adaption requires to

Table 1
Characteristics of ecosystem services, related focal action situations, and implications on ecosystem governance; (typology of goods based on Ostrom 2009).

			Subtractability	
			Low competition	High competition
Excludability	Difficult	*Type of ESS*	*Public good ecosystem service (PG ESS)*	*Common pool resource ecosystem service (CPR ESS)*
		Focal ASs	Enhancing ASs	Enhancing and appropriation ASs
		Frequent governance challenges	Large number of widely distributed beneficiaries, value difficult to estimate	Insecure property rights, freeriding on enhancing actions and overexploitation
		Typical governance responses	State regulation, taxes, subsidies, hybrid conditional payment schemes	Cooperation, community-based management, community tenure, state regulation
	Easy	*Type of ESS*	*Toll good ecosystem service (TG ESS)*	*Private good ecosystem service (PRG ESS)*
		Focal ASs	Enhancing ASs	Appropriation ASs
		Frequent governance challenges	Insecure property rights, value not acknowledged	Insecure property rights, hidden costs of appropriation e.g. due to trade-offs with incompatible PG or CPR ESSs
		Typical governance responses	Market mechanisms	Market mechanisms, state regulation

conceptualise Resource Units/ESS as flows being based on the stocks and processes of the resource/ecosystem rather than being part of it. As in the original SES framework, the layers of the boxes indicate that multiple ESSs are inputs to multiple layers of action situations with multiple people being involved and multiple governance systems organising the interactions.

We acknowledge that appropriation ASs can be understood as a transformative process from ecosystem functions to actual benefits for people (Spangenberg et al., 2014a). The cascade model of ESS generation and valuation as originally presented by Haines-Young and Potschin (2010) describes steps that eventually link biophysical aspects with human well-being. Spangenberg et al. (2014b) modified the cascade by including societal processes and the role of stakeholders. This modification allowed the linking of the ESS transformation processes to enhancing ASs (Spangenberg et al., 2015). We emphasise people's efforts to change resource systems to affect its contribution to ESS enhancement by adding respective links between ASs, resource systems and ESSs to Fig. 1.

We classify ESSs according to their excludability and subtractability (Table 1) as these features strongly determine which ASs require special attention and which institutions fit to an ESS. Excludability refers to the costs of preventing a beneficiary from enjoying an ESS. Subtractability describes to which degree one beneficiary's enjoyment of an ESS affects the possibility of other beneficiaries to enjoy the same ESS (Ostrom, 2009). For instance, private good ESSs (PRG ESSs) can usually be handled well within markets as one can easily exclude somebody from their appropriation. This creates strong incentives to enhance the PRG ESS's provision and avoid unsustainable appropriation even though they are strongly subtractable. This is different for public good ESSs (PG ESSs) and common pool resource ESSs (CPR ESSs). The difficulty of excluding people from PG ESSs offers incentives in the enhancing AS to free-ride on the investment of others. Economic theory suggests that this situation leads to insufficient enhancement of the ESS. Individual benefits are spread amongst many beneficiaries for many PG ESSs. Transaction costs prevent markets from providing efficient incentives ensuring maintained continued provision of PG ESSs (Barnaud et al., 2018). State-based institutions are often considered to be an appropriate response to this situation. In the case of CPR ESSs, this enhancing challenge is combined with the risk that even if the ESS is provided it is prone to overuse - due to strong subtractability. Groups benefiting from the resource must find rules on how to appropriate ESSs. Table 1 summarizes links between characteristics of ESSs, focal ASs and ESS governance.

3. Research approach

For this paper, case experts categorized ESSs using forest cases in Asia, Africa and Latin America. The case data were collected between 2010 and 2017 by collaborative research projects implemented under the Sustainable Land Management Program (Eppink et al., 2012) of the German Ministry of Education and Research (BMBF). All projects participated in the effort to improve the understanding of selected socio-ecological systems and to support sustainable land management with transdisciplinary scientific approaches. Cases studied in the following projects from the following countries are compared: INNOVATE/Brazil (www.innovate.tu-berlin.de), SuMaRiO/China (www.SuMaRiO.de), LEGATO/Philippines (www.legato-project.net), SuLaMa/Madagascar (www.sulama.de), The Future Okavango (TFO)/Namibia (www.future-okavango.org) and SASSCAL/Zambia (www.sasscal.org). The initial case selection happened during network meetings of the aforementioned BMBF program. The lead author shared the idea with colleagues of other projects and six out of ten non-European projects confirmed interest in developing a shared analysis.

The primary data sources are scientists of each project who were typically part of the respective coordination teams. The experts consulted members from their project teams and partners to gain feedback on their assessments and adjust the ratings. This loop happened in an unstructured way. Depending on the intensity of the experts' inputs they became co-authors of this paper. Co-authorship was granted if an expert was not only an informant but also contributed to the conception, analysis, and discussion of results.

Data were collected in 2016 using an openly accessible online diagnostic procedure (cmap.icrisat.ac.in/ges). The procedure is basically a questionnaire but follows a tree logic where (only) items listed in a previous step appear in the next step. It contains a series of questions that help clarify the steps in the ESS transformation process, the classification of ESSs as well as additional information regarding ASs.

The experts first listed ESSs relevant to their case. They further described management scenarios and their impacts on ESSs provision (the tool proposes a time horizon for impact estimates of approximately 20 years). This allowed us to assess how resource management changes would affect different types of ESSs. The scenarios were formulated by the case experts based on their judgements on plausible development pathways.

For the classification of ESSs, the experts rated the excludability and subtractability of each ESS they had mentioned. Substractability was rated on a three point scale (no competition in use, moderate competition, strong competition). Excludability was rated on a four point scale (very easy to exclude others from use, easy to exclude, difficult to exclude, very difficult to exclude). We analysed the classification in a descriptive way and visualise them in Figs. 2–7. For better readability of these figures we placed the markers of ESSs around the ordinal value. This should not give the impression that the two variables were measured on a metric scale. All ESSs falling in one of the twelve figure fields marked by grid lines actually have the same value.

The emerging cases descriptions and ESSs classifications reflect

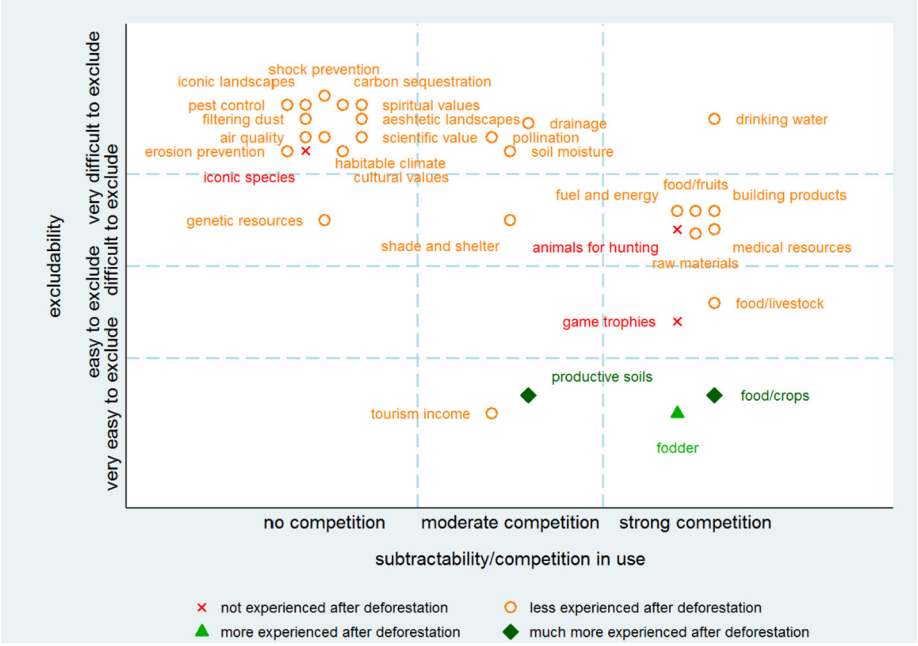

Fig. 2. Mapping types of and changes in the provision of ESSs in the TFO deforestation scenario.

rather subjective impressions based on longstanding transdisciplinary work in the regions. Our results condense findings of assessments with much more methodological depth, reported in published material to which we refer in the case descriptions.

4. Results

4.1. The future Okavango case

This case refers to the Namibian Kavango regions characterized by a semi-arid climate with an annual precipitation of approximately 600 mm (Weber, 2013). Although a significant proportion of the Okavango basin is still covered with primary forest of different types (Revermann & Finckh, 2013) more than 70 percent of the riverine vegetation has been lost over the past few decades (RoN, 2004). The expansion of agricultural fields is the main driver of deforestation (Pröpper et al., 2010). The sandy, porous soil texture in most of the Kavango holds few nutrients and allows water to drain away rapidly (Mendelsohn & El Obeid, 2003). Land is and was, with very few exceptions, not fertilized – neither by manure nor chemical fertilizers. In the absence of improved technologies, many small-scale farmers rely on newly cleared and fertile forest lands as a cheap production input (Benhin, 2006).

A subsidiary traditional authority system prevents outsiders effectively from accessing forests and land. Customary law places, however, few clearing restrictions on community members, mainly because of the

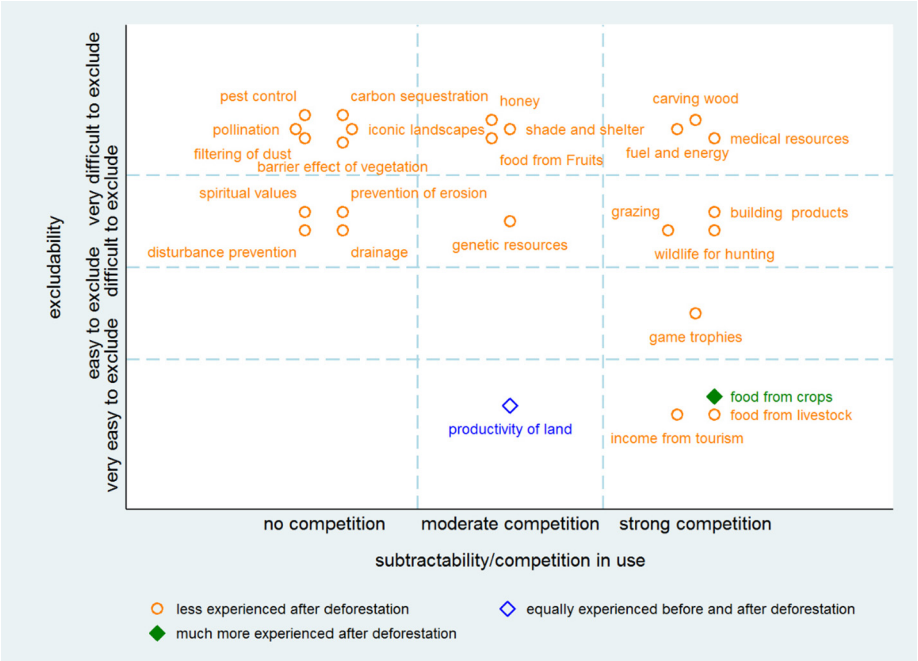

Fig. 3. Mapping types of and changes in the provision of ESSs in the SASSCAL deforestation scenario.

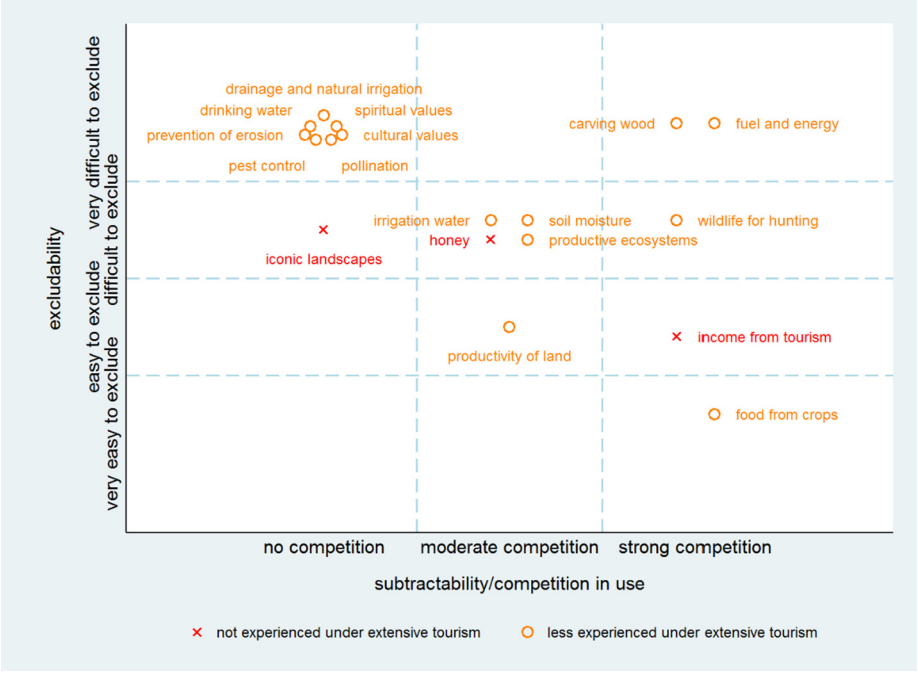

Fig. 4. Mapping types of and changes in the provision of ESSs in LEGATO's unsustainable tourism development scenario.

perception of low scarcity/subtractability. While this perception could be justified in the past, accelerating deforestation rates due to smallholder clearings indicate that these rules need adjustments. The government introduced new statutory laws controlling shifting cultivation patterns. New land tenure laws are, however, not implemented in the research region due to strong resistance by the population and traditional authorities (Falk, 2008, Falk and Kirk, 2011).

We observed clear trade-offs between keeping and using forested lands and using these lands as agricultural fields. Fig. 2 shows that specific PG ESSs (difficult exclusion/low competition) would be reduced as a consequence of continuous deforestation. A wide range of ESSs, specifically regulating and cultural ESSs, fall into this group.

CPR ESSs such as firewood, construction wood, fruits, medicinal plants, thatch grass, or game meat would also be diminished due to deforestation. These are provisioning ESSs appropriated by local communities (RoN, 2004, Falk, 2008, Pröpper, 2009). At the same time, land-use transformation to agriculture would favour a limited number of provisioning PRG ESSs which can be easily capitalised in markets. Civil society organisations and the state would try to mitigate conflicts between PRG and CPR ESSs by strengthening community forest rights. These would be the precondition for designing improved community rules for the enhancing and appropriation ASs of the CPR ESSs. This is theoretically possible because PRG and CPR ESSs are mainly enjoyed at a local scale while the beneficiaries of PG ESSs are scattered across

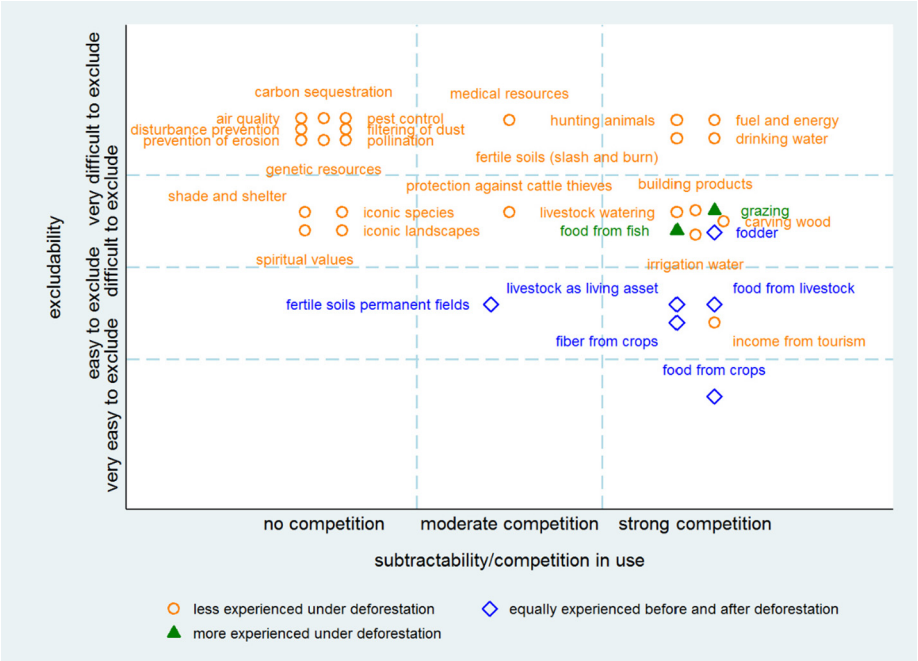

Fig. 5. Mapping types of and changes in the provision of ESSs in the SULAMA deforestation scenario.

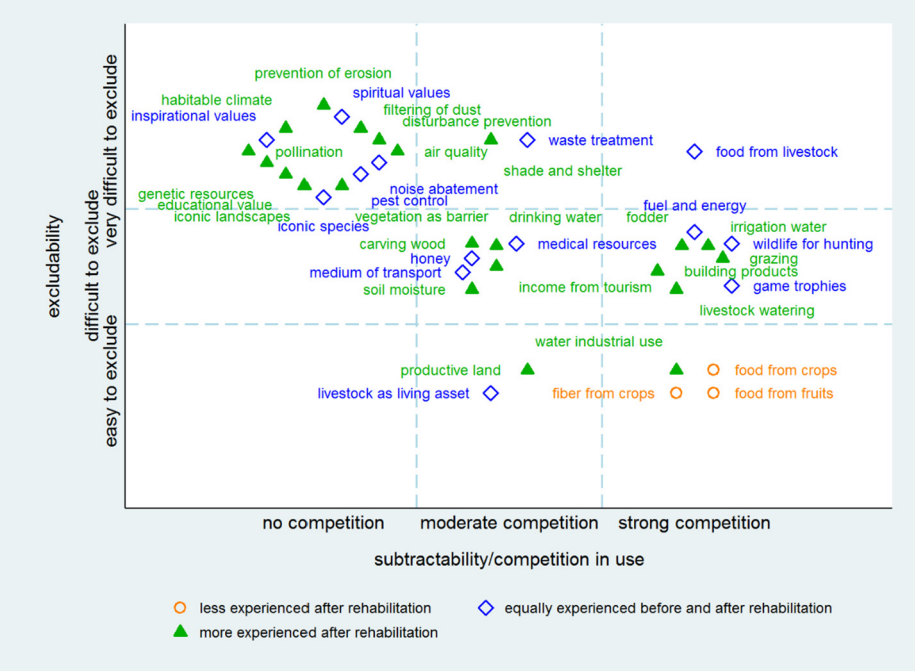

Fig. 6. Mapping types of and changes in the provision of ESSs in the SuMaRiO rehabilitation scenario.

different scales.

4.2. The SASSCAL case

The SASSCAL case analysed deforestation through smallholder agriculture in Mumbwa District in the Central Province of Zambia, approximately 160 km from the country's capital Lusaka. In Zambia, smallholder agriculture is considered a main driver of deforestation, contributing to a total annual forest loss of more than 250,000 ha (Vinya et al., 2012). The research area is part of a dedicated buffer zone of the Kafue National Park, the Mumbwa Game Management Area. Even though a community-based natural resource management regime had been established, communities are scarcely benefiting from PRG ESS tourism (Nkhata and Breen, 2010). Deforestation is mainly driven by agriculture. The project interviewed 320 households and the analyses showed that between 2010 and 2014 49% of them cleared forest (Vorlaufer et al., 2017). In 2014 alone, 22% of the households extended their fields. Current low-input agricultural practices lead to a rapid depletion of soil fertility (de Blécourt et al., 2018). In response, most households rely on a continuous clearing of fertile forest land as production input (Benhin, 2006). This dynamic is further aggravated by a growing demand for agricultural lands due to population growth and an increasing influx of migrants from southern Zambia. Considering these dynamics, the most likely future scenario would be continuing

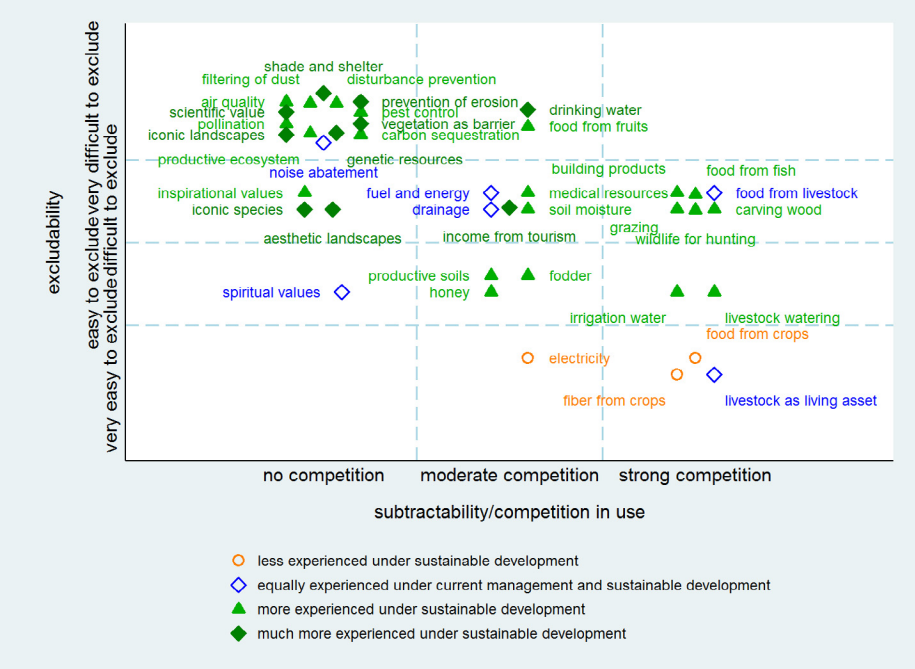

Fig. 7. Mapping types of and changes in the provision of ESSs in the INNOVATE sustainable development scenario.

deforestation that would eventually lead to the disappearance of the current forest-agricultural mosaic. The associated changes in the ESSs are illustrated in Fig. 3.

Under this scenario, the provision of PRG ESS food from crops would increase. Tourism related PRG ESSs would decrease due to the loss of scenic landscapes and wildlife. Farmers would continue to neglect its value in ASs as underdeveloped market opportunities allow only a few households to benefit from their appropriation. Most tourism businesses would continue to be run by outsiders and would provide very limited local employment opportunities. Food from livestock, another PRG ESS, was also expected to decrease along a loss of grazing areas. CPR ESSs mainly relate to forest related livelihood activities such as collecting timber and non-timber forest products. Without any exceptions, these ESSs would decrease. Historically they were managed by customary law which was largely replaced by poorly enforced state regulations. Community-based natural resource management regimes, established in the early 2000s as part of the Mumbwa Game Management Area, shifted resource rights to the community. Nevertheless, blueprint governance approaches initiated top-down by the government were assumed to continue being incapable of effectively governing the ESS ASs.

PG ESSs are mostly enjoyed at the regional scale (e.g., pest control and drainage) or even global scale (e.g., carbon sequestration, genetic resources, iconic landscapes). These ESSs were expected to be experienced less. There are currently no institutions in place to create incentives for their enhancement.

4.3. The LEGATO case

The LEGATO project studied, amongst other things, irrigated rice systems in Banaue/Philippines (Settele et al., 2015, Spangenberg et al., 2017). The site is located in the Luzon mountain range that has a humid climate, low temperatures and a short growing season. Most of the rice terraces are a main tourist attraction and UNESCO world heritage sites (Tekken et al., 2017). Many mountain tops are covered with forests that are either owned by the state or by family clans; forests have been managed more sustainably under the latter tenure system. At the same time, the pressure on forests is increasing specifically due to mounting market demand for CPR ESSs, resulting in unsustainable hunting as well as logging for firewood, carving and construction. The LEGATO case experts explored the effects of a worst case tourism development pathway in comparison to the current resource management system (Settele et al., 2018).

Under this scenario (Fig. 4), low budget tourists were assumed to be attracted to the area, resulting in a substantial expansion of tourism (while little money is spent in the region) and in destruction of the landscape due to inappropriate construction and unsustainable appropriation of PRG and CPR ESSs. The profits from tourism were expected to be insufficiently shared with local residents, and only low-qualified jobs would be offered to them. This situation would stimulate social tensions between local residents and outside investors and tourism operators.

Unsustainable tourism development would negatively affect all types of ESSs as it would put high stress on the region's scarce renewable resources – especially water and wood. CPR ESSs irrigation and drinking water was assumed to be privatized at high exclusion costs and become expensive, reducing access for local residents. The growing tourist numbers would enlarge the market for souvenirs. Wood carving would flourish and CPR ESS wood would be appropriated from the local forests. Family forest tenure systems would be challenged by powerful market actors, and their institutional weakness would result in selected tree species being harvested in an almost uncontrolled manner. As they became scarce, even less suitable tree species and more remote areas would be exploited. This process would reduce forest PG and CPR ESSs, in particular water retention and biodiversity. This would decrease the reliability of CPR ESS irrigation water supply and reduce not only PRG ESS harvests but also the PG ESS stability of the rice terraces. Increasingly, terraces collapse, and the cultural landscape would transform. As a result, the UNESCO World Heritage status was projected to be withdrawn and tourism breaks down. The local population would be left with their sources of income devastated. The costs of losing all these ESSs was not taken into account in the wood market transactions.

Our analyses suggest that in particular the unsustainable extraction of CPR ESSs can lead to a chain of degradation. Historically, the family tenure system played a key role in the appropriation ASs of water and forest. It managed the costly exclusion of these ESSs more efficiently than the state. The state already increased its capacity but is still well advised to strengthen family tenure security as new powerful actors enter the ASs.

4.4. The SuLaMa case

The SuLaMa project investigated sustainable land-use alternatives on the Mahafaly Plateau in southwestern Madagascar (Kobbe et al., 2017). The region faces the challenge of reconciling biodiversity conservation with sustainable land management. Economic development is extremely low, and land use is dominated by agriculture. The local population depends to a large degree on natural resources especially during lean times. Under unfavourable soil and climatic conditions, people currently see no alternatives but to maintain the low-input/low-output cropping system by rapid slash-and-burn cycles. This practice, in combination with charcoal production and overgrazing, has led to a 45% forest loss during the last four decades, resulting in an increasingly fragmented landscape mosaic (Brinkmann et al., 2014). At the same time, forest CPR ESS such as construction materials, firewood and medicinal plants provide important complements to smallholder farmer livelihoods, and wild plants and animals contribute directly to people's food security, especially during times of crop failures (Noromiarilanto et al., 2016). Forest resources further play a critical role in Malagasy culture (Neudert et al., 2015).

In addition to cultivation, livestock plays a key role in the livelihoods of the people. The very extensive animal husbandry system is susceptible to seasonal shortages of CPR ESSs water and forage. The expansion of croplands leads to an increasing potential for conflict between pastoralists and crop farmers. During the recent years of political instability, cattle rustling strongly increased, and forests also served as protection against cattle thieves, adding a new component to the forest ESSs (Ratovonamana et al., 2013, Feldt et al., 2016, Goetter, 2016).

The SuLaMa experts described a development scenario assuming that the aforementioned dynamics are not addressed, and rather accelerate due to population growth, climate change, political instability and market failures related to forest ESSs. This scenario would lead to an even more fragmented and disturbed landscape mosaic comprising considerably less natural forest area and much more agricultural land (Fig. 5). Like the other African cases, mainly PG and CPR ESSs would be reduced under this development scenario. Agricultural intensification is unlikely and the ongoing deforestation at the cost of forest ESSs would stabilize, at best, but not increase PRG ESSs related to agriculture.

In the SuLaMa case, conflicts create much insecurity in all ASs. Even generally easy to exclude ESSs are negatively affected. The state is specifically weak and sets priorities other than ecosystem management. Traditional authorities fill some of the gaps but are also challenged. There are in particular low incentives to invest in enhancing ESSs.

4.5. The SuMaRiO case

The SuMaRiO project studied land and related water-use challenges within the Tarim River Basin in China. Globally, this arid region is the most remote area from oceans; hence, rainfall is extremely low and does not exceed 50 mm per year. Thus, all types of economic activities, especially agriculture, industry and the domestic sector and urban life,

as well as the natural ecosystems, depend on the CPR ESS river water (Feike et al., 2017). The Tarim River, which is the largest river of the Tarim Basin, is fed from snowmelt and glacier-melt in the mountains. Water discharge into the Tarim River has increased over the past decade. However, global climate change is likely to result in a shrinking future water supply making the area even more vulnerable (Farinotti et al., 2015). Since the 1950s, irrigated agriculture has extensively extended into pristine areas along the rivers (Feike et al., 2015). As a result of the increasing appropriation, river flows have strongly decreased, leading to degradation in floodplain vegetation and salinization of agricultural lands. There is a trade-off between generating income from irrigated agriculture – mainly cotton – at the cost of diverse ESSs.

Continuous population growth in the Aksu-Tarim Region exerts increasing pressure on its natural resources including surface and groundwater quantity and quality, riparian forests, and soil quality. Positive price developments for various crops motivate the local farming communities to expand their agricultural activities. Consequently, riparian ecosystems degrade due to clearing and disturbances to the hydrological system. Government authorities are aware that current land- and water-use patterns are unsustainable but do not take the necessary, vigorous actions (Mamitimin et al., 2014).

Starting from the status quo of this strongly disturbed ecosystem, the SuMaRiO case expert formulated a rehabilitation scenario assuming improved regulations on the expansion of agricultural land and water use (Fig. 6). This rehabilitation scenario would lead to an improvement in the natural riparian ecosystems and partially restored ecosystem functions resulting in the enhanced provision of multiple PG and CPR ESSs. Achieving this goal would require considerable efforts such as a more efficient use of the CPR ESS water for instance through state regulated water pricing creating water saving incentives in the appropriation ASs (Feike & Henseler, 2017). The area used for cultivation would have to be reduced. This could be achieved through land use planning and strictly enforced restrictions. All such measures would have to be introduced against strong market incentives for PRG ESSs related to crop production (Khor & Feike, 2017). Hence, an opportunity cost based payment for ecosystem service mechanism to provide incentives for enhancing larger scale PG ESSs would require massive public investments. The social and economic sustainability of the region would therefore strongly depend on the development of alternative sources of income rather than increasing the local benefits of PG and CPR ESSs.

4.6. The INNOVATE case

The INNOVATE project identified and developed ecosystem-friendly and economically viable land and water management options in the São Francisco River Basin (Siegmund-Schultze et al., 2015a). The basin covers approximately 630,000 km^2, spans several states of Brazil and is affected by involuntary resettlement due to the construction of dams a few decades ago. Current reservoir management is dominated by a historical focus on generating hydroelectricity, providing power as a PRG ESS. This system is increasingly contested, as it reduces e.g. the availability CPR ESS water for alternative use options specifically in the semi-arid portion of the watershed.

Many land-use decisions are typically taken at the municipal level, but the planning and implementation capacity of the responsible officials is low and responsibilities are sometimes unclear (Rodorff et al., 2015). Regulations especially on the appropriation of CPR ESSs are poorly enforced. This results in uncoordinated individual decisions that often do not take unintended consequences especially on PG and CPR ESS into account. For instance, dominant grazing practices on the natural range (Caatinga dry forest) threaten multiple PG ESSs such as carbon sequestration (Schulz et al., 2016). More integrated approaches including rotational grazing, reducing stocking densities, and forage cultivation (Schulz et al., 2018) could enhance their provision. There are, however, no strong institutional incentives for enhancing PG, CPR or PRG ESSs (Siegmund-Schultze et al., 2018). The federal government introduced a decentral participatory governance system through river basin committees. Water is the major concern of such committees addressing also interrelations between water and land. One task of the committee of the studied river basin is to question the focus on PRG ESSs and to harmonize in particular the enhancement and appropriation of CPR ESSs in the face of multiple socio-economic, political, ecological, and cultural differences in the basin (Siegmund-Schultze et al., 2015b).

Under a sustainable development scenario (Fig. 7), the case experts assumed that participatory water management is successfully implemented improving both the appropriation and enhancement of ESSs. The compliance with environmental laws, such as the Brazilian Forest Code, would be consequently monitored and enforced reducing especially the pressure on forest CPR ESSs in the appropriation ASs. Environmental education would be integrated and mainstreamed in the curricula, and sustainable land management practices would be effectively promoted by different stakeholders. This would encourage enhancements of forest ESSs for instance by reforesting and preserving sources and river banks. As a result, the Caatinga dry forest would recover. The CPR ESS water quality and availability would improve in the semi-arid region over the long term. Strategic planning of nature conservation (Koch et al., 2017) would result in the establishment and maintenance of interconnected conservation areas that safeguard the biodiversity of the biome and ultimately enhance PG ESSs such as iconic landscapes. Nevertheless, despite all the new ESS related benefits, sustainable management of a dry forest for productive purposes would be rather space-intensive, allowing only few people to directly sustain their livelihoods. Therefore, alternative income generation options would have to be promoted to decrease the dependency of the growing population on the ecosystem.

5. Discussion

Mapping ESSs according to their excludability and subtractability revealed similar patterns across forest cases in different parts of the world. Typically, there were trade-offs between a low number of cultivation-related PRG ESSs and diverse forest related PG and CPR ESSs (see also Loft et al., 2015, Verburg et al., 2016). This result fits the general pattern that Howe et al. (2014) describe: trade-offs are more frequent when PRG provisioning ESSs are involved. In the three African cases, deforestation is accelerating, which was expected to lead to an increase in food and income from cultivation but to deterioration in collective goods. In the Chinese and Brazilian cases, forests are already altered to a degree that a meaningful change would require rehabilitation measures. In these cases, decisions would have to be made to reduce food and income from cultivation to enhance the provision of other ESSs. The Philippine case is special as there is a risk of development, which diminishes the overall resource base due to short-sighted exploitative strategies.

Often, the value of the food and income produced through agriculture over the short term is high enough to drive decisions towards agricultural land-use. Ecosystem service valuations can help to estimate whether this is in the interest of overall welfare or whether in a specific case regulating and cultural ESSs have a higher value compared to agricultural production. If these benefits are not highlighted they will easily be ignored in decision-making. Our approach responds to the urgent need of considering synergetic bundles of ESSs rather than single selected ones (Costanza et al., 2017, Cook et al., 2016).

Our cases showed that locally enjoyed agricultural PRG ESSs compete with locally enjoyed CPR ESSs such as grazing, timber or wild fruits, and PG ESSs such as spiritual values and pest control. The first question to ask is whether the CPR ESSs can be of greater local value than the PRG ESSs. If this is the case, the solution could be effective governance of CPR ESSs which are prone to be unsustainably

appropriated (Ostrom, 1990). Land and ESS rights security and local-level governance mechanisms are likely to improve the interactions in the appropriation ASs (Ostrom, 1990, Costanza et al., 2017, Cook et al., 2016). This is most prominent in vulnerable political situations such as our Madagascar case. There is a potential for increasingly degrading customary institutions to play a key role (Primmer and Furman, 2012, Mann et al., 2015, Barau and Stringer, 2015). Opportunities for co-operation have to be emphasised (Barnaud et al., 2018). In the Brazilian case for instance, many owners of small land units would have to co-operate to establish any meaningful forest management. We observe across all our cases that statutory laws and regulations are difficult to enforce given that costs of exclusion are high for CPR ESSs. Nevertheless, they can play an important role in a subsidiary governance system whenever the local level institutions need back-up, for instance when new powerful actors enter the appropriation ASs such as tourism operators in the Indonesian and Zambian cases or timber traders in Namibia. Improved governance of the appropriation ASs of CPR ESSs could provide positive incentives in the enhancing ASs motivating for instance reforestation in the Brazilian and Chinese cases.

Nevertheless, too often, a local win-win situation is assumed without evidence (Verburg et al., 2016). Cost-benefit calculations indicate, for instance, that in the Namibian case even in the mid-term the per-hectare subsistence and cash income received from the forest is lower than that from agriculture. This suggests that communities improve at least their material group welfare when shifting land use towards cultivation PRG ESSs rather than managing forest CPR ESSs. Under such conditions, local land users have weak incentives to enhance/maintain forest CPR resources (see also Pham et al., 2015). At this point, it can be explored whether there is a mechanism to sustainably increase the value of appropriated CPR ESSs to give them more weight in decisions on land use transformations. Again in the Namibian case, timber and thatch grass markets leave hardly any income with the communities who through their management enhance the provision of the ESSs. Regulating respective markets to improve benefit sharing could increase sustainable management incentives in the enhancing ASs.

Our analysis suggested that in most of our cases local-level governance of enhancing ASs of CPR ESSs is unlikely to generate sufficient incentives for sustainable forest management given the strong trade-offs between PRG and CPR ESSs. We see, however, that provisioning CPR ESSs are more compatible with regulating and cultural PG ESSs than with provisioning PRG ESSs. Across all our cases, enhancing provisioning PRG ESSs related to agriculture requires fundamental land-use changes while interactions between CPR and PG ESSs can be managed within the same land-use system. The logical next step would therefore be to explore whether improved local level governance of CPR ESSs together with state interventions or hybrid conditional payments for enhancing PG ESSs can motivate land users to maintain or rehabilitate forests. All our cases show a large pool of PG ESSs that are often not translated into incentives in the local enhancing ASs.

Many PG ESSs are enjoyed at large scales by many people (Polasky et al., 2014, Howe et al., 2014, Loft et al., 2015). Each beneficiary receives only an infinitesimal benefit e.g., from carbon sequestered in a specific forest. Transaction costs for translating these benefits into locally effective enhancement incentives are typically high (Barnaud et al., 2018). In addition, beneficiaries cannot be excluded from the benefits and are therefore tempted to hide their preferences and free-ride on the efforts of others (Hinkel et al., 2015, Costanza et al., 2017). Thus, the governance of the enhancing AS requires special attention for PG ESSs.

Researchers and policy makers search for instruments to create incentives for investments into PG ESSs in order to align resource use decisions with the society's wellbeing (Costanza et al., 2017, Cook et al., 2016). Traditional state-centred institutions are resource use regulations, taxes and subsidies (Loft et al., 2015). More innovative mechanisms are conditional payment schemes often built around state regulated markets such as for carbon or pollution credits and tradeable permits (Cook et al., 2016, Mann et al., 2015). Currently, such payment schemes focus on only a few ESSs. The main reason is that, with few exceptions, their enhancement is difficult to monitor – which is a precondition for the mechanism to be effective (Howe et al., 2014, Loft et al., 2015, Pham et al., 2015). Land tenure is another critical constraint in harmonising CPR and PG ESS governance. For instance, customary lands and forests are state-owned in most of our cases, while communities have use rights, and traditional authorities play a key role in land and forest governance. Under such configurations, incentive schemes are required to reflect both the individual and community land and forest property rights (Vorlaufer et al., 2017) preventing rent seeking by powerful stakeholders and ensuring that local ESS beneficiaries are motivated to enhance ESSs (Mann et al., 2015).

Mapping ESSs according to their excludability and subtractability and detecting focal ASs was only the first steps in analysing governance. The next step would be to identify the stakeholders in the appropriation and enhancing ASs. This step would help in understanding whose appropriation needs to be balanced. The structured approach can help to better understand how alternative decisions affect ESSs and who may be the winners and losers (Ruckelshaus et al., 2015, Förster et al., 2015, Howe et al., 2014). The classification would further facilitate the identification of stakeholders who make efforts to enhance the provision of ESSs – or the ones who benefit but do not contribute.

In addition, stakeholders take or do not take enhancing actions that have an impact on ecosystem production capacity – even if they do not intend to do so. In our cases, most appropriating actors also made some type of contributions to the enhancement of ESSs. These are mainly avoided actions such as reducing pesticide use, pollution, or logging. Some governance actors enhance the ESSs provision mainly by designing and enforcing institutions which create (dis-)incentives to reduce such actions.

It is worth mentioning that most ESSs were classified in the same way in the different cases. The few exceptions reflected different levels of scarcity (affecting the degree of perceived subtractability) and biophysical conditions (affecting excludability). This highlights that even for the same ESS different governance solutions may have to be identified depending on the context (Primmer et al., 2015).

Our approach helped to link SES thinking to the acknowledgement of the multi-functionality of ecosystems and to look beyond current land-use practices towards potential ecosystem benefits and potential contributors to ESS governance. Our approach also linked local land-use decisions to trade-offs experienced at multiple temporal, spatial and societal scales (Seppelt et al., 2013, Ban et al., 2015). The ESS classification demonstrated the need to shift the perspective from finding the best suited institution to govern an ecosystem (Reed et al., 2013) toward acknowledging that each ESS produced by the SES has its institutional fit that is likely to produce a sustainable management outcome (Cox, 2012, Loft et al., 2015). The governance of an ecosystem emerges from a messy web of institutions related to enhancing and appropriation ASs of bundles of complementary ESSs (Woodhill, 2010, Costanza et al., 2017, Cook et al., 2016). Integrated ecosystem management should therefore focus on harmonising these institutions (Mann et al., 2015, Barau and Stringer, 2015, Verburg et al., 2016). Our approach further highlighted the need to assess the interaction between ESSs as well as between ASs related to diverse ESSs (Cole et al., 2014).

For this paper, only well-informed case experts classified ESSs and interpreted the emerging patterns. Our deliberations are inevitably based on subjective judgments in diagnosing specific situations. However, we see the potential to use the approach in multi-stakeholder co-creation processes supporting the development of case specific institutional innovations (Woodhill, 2010). Identifying uninvolved beneficiaries can help detect untapped willingness-to-pay potentials and motivate governance actors to provide incentives for more sustainable development pathways (Mann et al., 2015). This process can be a critical step towards achieving fairer and more sustainable economic well-

being as advocated by Costanza & Folke (1997).

6. Conclusion

Our first contribution to the ESS governance discussion is to create awareness that a smart matching of types of ESSs and types of institutions more likely leads to sustainable ESS management. This understanding can guide more strategic SES analyses to find institutions best fitting to specific ESSs. The classification of ESSs further helps to identify focal ASs which can guide better targeted ESS valuations. This again helps structuring the assessment of stakeholders within the enhancing and appropriation ASs. Of special interest should be ESSs whose values are not yet (sufficiently) translated into incentives. The critical challenge is to understand when governance leads to tipping the locally perceived attractiveness of alternative land-use options.

Our second contribution to the ESS governance discussion is to create awareness about the fact that ecosystem governance must simultaneously address different types of ESSs and trade-offs between them. We observe across all our cases that provisioning CPR ESSs are more compatible with regulating and cultural PG ESSs than with provisioning PRG ESSs. This can be a pattern to be searched for in other cases as this could having implications on more general patterns of ecosystem governance designs. Nevertheless, we also observe context-dependency. Hence, multiple SES assessments related to multiple ESSs are required to find the best-suited bundle of institutions.

We want to highlight the relevance of our findings in the context of polycentric ecosystem governance (Ostrom, 2010, Cook et al., 2016, Barnaud et al., 2018). Naturally, there will be multiple centres of decision making if ecosystem governance emerges from interactions between multiple ESS-specific institutions. Coordinating these decision making centres is the next higher governance challenge.

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References

Ban, N.C., Evans, L.S., Nenadovic, M., Schoon, M., 2015. Interplay of multiple goods, ecosystem services, and property rights in large social-ecological marine protected areas. Ecol. Soc. 20 (4). https://doi.org/10.5751/ES-07857-200402.

Barau, A.S., Stringer, L.C., 2015. Access to and allocation of ecosystem services in Malaysia's Pulau Kukup Ramsar Site. Ecosyst. Serv. 16, 167–173. https://doi.org/10.1016/j.ecoser.2015.10.021.

Barnaud, C., Corbera, E., Muradian, R., Salliou, N., Sirami, C., Vialatte, A., Choisis, J.-P., Dendoncker, N., Mathevet, R., Moreau, C., Reyes-García, V., Boada, M., Deconchat, M., Cibien, C., Garnier, S., Maneja, R., Antona, M., 2018. Ecosystem services, social interdependencies, and collective action: a conceptual framework. Ecol. Soc. 23 (1). https://doi.org/10.5751/ES-09848-230115.

Benhin, J.K.A., 2006. Agriculture and deforestation in the tropics: a critical theoretical and empirical review. AMBIO J. Hum. Environ. 35, 9–16. https://doi.org/10.1579/0044-7447-35.1.9.

Brinkmann, K., Fanambinantsoa, N., Ratovonamana, R.Y., Buerkert, A., 2014. Deforestation processes in south-western Madagascar during the past 40 years: what can we learn from settlement characteristics? Agric. Ecosyst. Environ. 195, 231–243. https://doi.org/10.1016/j.agee.2014.06.008.

Carpenter, S.R., Mooney, H.A., Agard, J., Capistrano, D., DeFries, R.S., Díaz, S., Dietz, T., Duraiappah, A.K., Oteng-Yeboah, A., Pereira, H.M., Perrings, C., Reid, W.V., Sarukhan, J., Robert, J.S., Whyte, A., 2009. Science for managing ecosystem services: beyond the millennium ecosystem assessment. Proc. Natl. Acad. Sci. 106 (5), 1305–1312. https://doi.org/10.1073/pnas.0808772106.

Cook, D.C., Kristensen, N.P., Liu, S., 2016. Coordinated service provision in payment for ecosystem service schemes through adaptive governance. Ecosyst. Serv. 19, 103–108. https://doi.org/10.1016/j.ecoser.2016.01.008.

Cole, D.H., Epstein, G., McGinnis, M.D., 2014. Digging deeper into Hardin's pasture: the complex institutional structure of 'the tragedy of the commons'. J. Inst. Econ. 10 (03), 353–369. https://doi.org/10.1017/S1744137414000101.

Costanza, R., Folke, C., 1997. Valuing ecosystem services with efficiency, fairness, and sustainability as goals. In: Nature's Services Societal Dependence on Natural Ecosystems, pp. 49–70.

Costanza, R., de Groot, R., Braat, L., Kubiszewski, I., Fioramonti, L., Sutton, P., Farber, S., Grasso, M., 2017. Twenty years of ecosystem services: How far have we come and how far do we still need to go? Ecosyst. Serv. 28, 1–16. https://doi.org/10.1016/j.ecoser.2017.09.008.

Cox, M., 2012. Diagnosing institutional fit: a formal perspective. Ecol. Soc. 17 (4). https://doi.org/10.5751/ES-05173-170454.

Biodiversity & Ecology 6, 242–250. https://doi.org/10.7809/b-e.00330.

Eppink, F.V., Werntze, A., Mäs, S., Popp, A., Seppelt, R., 2012. Land management and ecosystem services: How collaborative research programmes can support better policies. GAIA 21 (1), 55–63. https://doi.org/10.14512/gaia.21.1.14.

Falk, T., 2008. Communal farmers' natural resource use and biodiversity preservation – a new institutional economic analysis from case studies in Namibia and South Africa. Cuvillier Verlag, Göttingen.

Falk, T., Kirk, M., 2011. Enforcement of statutory and customary forest management regulations in the Kavango region of Namibia. In: Ruppel, O.C., Winter, G. (Eds.), Justice from within: Legal Pluralism in Africa and beyond. Verlag Dr. Kovač GmbH, Hamburg.

Farinotti, D., Longuevergne, L., Moholdt, G., Duethmann, D., Mölg, T., Bolch, T., Vorogushyn, S., Güntner, A., 2015. Substantial glacier mass loss in the Tien Shan over the past 50 years. Nat. Geosci. 8 (9), 716–722. https://doi.org/10.1038/ngeo2513.

Feike, T., Henseler, M., 2017. Multiple policy instruments for sustainable water management in crop production – a modeling study for the Chinese Aksu-Tarim region. Ecol. Econ. 135, 42–54. https://doi.org/10.1016/j.ecolecon.2016.12.012.

Feike, T., Mamitimin, Y., Li, L., Doluschitz, R., 2015. Development of agricultural land and water use and its driving forces along the Aksu and Tarim River, P.R. China. Environ. Earth Sci. 73, 517–531. https://doi.org/10.1007/s12665-014-3108-x.

Feike, T., Khor, L.Y., Mamitimin, Y., Ha, N., Li, L., Abdusalih, N., Xiao, H., Doluschitz, R., 2017. Determinants of cotton farmers' irrigation water management in arid Northwestern China. Agric. Water Manag. 187, 1–10. https://doi.org/10.1016/j.agwat.2017.03.012.

Feldt, T., Neudert, R., Fust, P., Schlecht, E., 2016. Reproductive and economic performance of local livestock in southwestern Madagascar: potentials and constraints of a highly extensive system. Agric. Syst. 149, 54–64.

Fisher, B., Turner, R.K., Morling, P., 2009. Defining and classifying ecosystem services for decision making. Ecol. Econ. 68 (3), 643–653. https://doi.org/10.1016/j.ecolecon.2008.09.014.

Förster, J., Barkmann, J., Fricke, R., Hotes, S., Kleyer, M., Kobbe, S., Kübler, D., Rumbaur, C., Siegmund-Schultze, M., Seppelt, R., Settele, J., Spangenberg, J.H., Tekken, V., Václavík, T., Wittmer, H., 2015. Assessing ecosystem services for informing land-use decisions: a problem-oriented approach for place-based ecosystem service assessments. Ecol. Soc. 20 (3). https://doi.org/10.5751/ES-07804-200331.

Goetter, J.F., 2016. The cattle raiders leave us no choice: new transhumance in the Mahafaly Plateau region in Madagascar. Madagascar Conserv. Dev. 11 (1), 12–22.

Haines-Young, R., Potschin, M., 2010. The links between biodiversity, ecosystem services and human well-being. In: Raffaelli, D., Frid, C. (Eds.), Ecosystem Ecology: A New Synthesis. Cambridge University Press, Cambridge, pp. 110–139.

Hinkel, J., Cox, M., Schlüter, M., Binder, C., Falk, T., 2015. A diagnostic procedure for applying the SES framework in diverse cases. Ecol. Soc. 20 (1), 32. https://doi.org/10.5751/ES-07023-200132.

Howe, C., Suich, H., Vira, B., Mace, G.M., 2014. Creating win-wins from trade-offs? Ecosystem services for human well-being: a meta-analysis of ecosystem service trade-offs and synergies in the real world. Global Environ. Change 28, 263–275. https://doi.org/10.1016/j.gloenvcha.2014.07.005.

IPBES Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, 2015. Preliminary guide regarding diverse conceptualization of multiple values of nature and its benefits, including biodiversity and ecosystem functions and services, doc. no. IPBES/4/INF/13. IPBES, Bonn, Germany.

Kobbe, S., Kübler, D., Ratovonamana, Y., Fricke, R., Andriamparany, J., Brinkmann, K., Götter, J., Rakotomalala, D., Wesselow, M. 2017. SuLaMa – Participatory research to support sustainable land management on the Mahafaly Plateau in southwestern Madagascar – Final report (01.01. 2011–31.12.2016), 62 pages.

Koch, R., Almeida-Cortez, J.S., Kleinschmit, B., 2017. Revealing areas of high nature conservation importance in a seasonally dry tropical forest in Brazil: Combination of modelled plant diversity hot spots and threat patterns. J. Nat. Conserv. 35, 24–39. https://doi.org/10.1016/j.jnc.2016.11.004.

Khor, L.Y., Feike, T., 2017. Economic sustainability of irrigation practices in arid cotton production. Water Resour. Econ. 20, 40–52. https://doi.org/10.1016/j.wre.2017.10.004.

Loft, L., Mann, C., Hansjürgens, B., 2015. Challenges in ecosystem services governance: multi-levels, multi-actors, multi-rationalities. Ecosyst. Serv. 16, 150–157. https://doi.org/10.1016/j.ecoser.2015.11.002.

Mamitimin, Y., Feike, T., Seifert, I., Doluschitz, R., 2014. Irrigation in the Tarim Basin, China: farmers' response to changes in water pricing practices. Environ. Earth Sci. 73 (2), 559–569. https://doi.org/10.1007/s12665-014-3245-2.

Mann, C., Loft, L., Hansjürgens, B., 2015. Governance of Ecosystem Services: Lessons learned for sustainable institutions. Ecosyst. Serv. 16, 275–281. https://doi.org/10.1016/j.ecoser.2015.11.003.

Maynard, S., James, D., Davidson, A., 2015. Determining the value of multiple ecosystem

services in terms of community wellbeing: Who should be the valuing agent? Ecol. Econ. https://doi.org/10.1016/j.ecolecon.2014.02.002.
McGinnis, M.D., Ostrom, E., 2014. Social-ecological system framework: initial changes and continuing challenges. Ecol. Soc. 19 (2), 30. https://doi.org/10.5751/ES-06387-190230.
Mendelsohn, J.M., El Obeid, S., 2003. Sand and Water: A Profile of the Kavango Region. Cape Town, Struik.
Millennium Ecosystem Assessment, 2005. Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC.
Neudert, R., Goetter, J.F., Andriamparany, J.N., Rakotoarisoa, M., 2015. Income diversification, wealth, education and well-being in rural south-western Madagascar: Results from the Mahafaly region. Dev. Southern Africa 32 (6), 758–784. https://doi.org/10.1080/0376835X.2015.1063982.
Nkhata, B.A., Breen, C.M., 2010. Performance of community-based natural resource governance for the Kafue Flats (Zambia). Environ. Conserv. 37 (3), 296–302. https://doi.org/10.1017/S0376892910000585.
Noromiarilanto, F., Brinkmann, K., Faramalala, M.H., Buerkert, A., 2016. Assessment of food self-sufficiency in smallholder farming systems of south-western Madagascar using survey and remote sensing data. Agric. Syst. 149, 139–149. https://doi.org/10.1016/j.agsy.2016.09.005.
OECD, 2003. Harnessing Markets for Biodiversity: Towards Conservation and Sustainable Use. Canongate US.
Ostrom, E., 1990. Governing the Commons – The Evolution of Institutions for Collective Action. Cambridge University Press, Cambridge, UK.
Ostrom, E., 2007. A diagnostic approach for going beyond panaceas. Proc. Natl. Acad. Sci. U.S.A. 104 (39), 15181–15187. https://doi.org/10.1073/pnas.0702288104.
Ostrom, E., 2009. Understanding Institutional Diversity. Princeton University Press.
Ostrom, E., 2010. Beyond markets and states: polycentric governance of complex economic systems. Am. Econ. Rev. 100 (3), 641–672.
Pham, T.T., Loft, L., Bennett, K., Phuong, V.T., Brunner, J., 2015. Monitoring and evaluation of payment for forest environmental services in Vietnam: from myth to reality. Ecosyst. Serv. 16, 220–229. https://doi.org/10.1016/j.ecoser.2015.10.016.
Polasky, S., Lewis, D.J., Plantinga, A.J., Nelson, E., 2014. Implementing the optimal provision of ecosystem services. Proc. Natl. Acad. Sci. 111 (17), 6248–6253. https://doi.org/10.1073/pnas.1404484111.
Primmer, E., Furman, E., 2012. Operationalising ecosystem service approaches for governance: do measuring, mapping and valuing integrate sector-specific knowledge systems? Ecosyst. Serv. 1 (1), 85–92. https://doi.org/10.1016/j.ecoser.2012.07.008.
Primmer, E., Jokinen, P., Blicharska, M., Barton, D.N., Bugter, R., Potschin, M., 2015. Governance of ecosystem services: a framework for empirical analysis. Ecosyst. Serv. 16, 158–166. https://doi.org/10.1016/j.ecoser.2015.05.002.
Pröpper, M., 2009. Culture and Biodiversity in Central Kavango. Namibia, Berlin, Reimer.
Pröpper, M., Gröngröft, A., Falk, T., Annette, E., Fox, T., Gessner, U., Hecht, J., Hinz, M.O., Huettich, C., 2010. Causes and perspectives of land-cover change through expanding cultivation in Kavango. In: Hoffman, M.T., Schmiedel, U., Jürgens, N. (Eds.), Biodiversity in Southern Africa. Volume 3: Implications for Landuse and Management. Klaus Hess Publishers, Göttingen & Windhoek.
Ratovonamana, Y.R., Rajeriarison, C., Edmond, R., Kiefer, I., Ganzhorn, J.U., 2013. Impact of livestock grazing on forest structure, plant species composition and biomass in southwestern Madagascar. Scripta Botanica Belgica 50, 82–92.
Raudsepp-Hearne, C., Peterson, G.D., Bennett, E.M., 2010. Ecosystem service bundles for analyzing tradeoffs in diverse landscapes. Proc. Natl. Acad. Sci. 107 (11), 5242–5247. https://doi.org/10.1073/pnas.0907284107.
Reed, M.S., Hubacek, K., Bonn, A., Burt, T.P., Holden, J., Stringer, L.C., Beharry-Borg, N., Buckmaster, S., Chapman, D., Chapman, P.J., Clay, G.D., Cornell, S.J., Dougill, A.J., Evely, A.C., Fraser, E.D.G., Jin, N., Irvine, B.J., Kirkby, M.J., Kunin, W.E., Prell, C., Quinn, C.H., Slee, B., Stagl, S., Termansen, M., Thorp, S., Worrall, F., 2013. Anticipating and managing future trade-offs and complementarities between ecosystem services. Ecol. Soc. 18 (1). https://doi.org/10.5751/ES-04924-180105.
Rodorff, V., Siegmund-Schultze, M., Köppel, J., Gomes, E.T.A., 2015. Governança da bacia hidrográfica do Rio São Francisco: desafios de escala sob olhares inter e transdisciplinares. Revista Brasileira de Ciências Ambientais 36, 19–44. https://doi.org/10.5327/Z2176-947820151003.
Republic of Namibia, 2004. Namibia Vision 2030: Policy Framework for Long-Term National Development. Windhoek.
Revermann, R., Finckh, M., 2013. Okavango basin – vegetation. In: Oldeland, J., Erb, C., Finckh, M., Jürgens, N. (Eds.), Environmental Assessments in the Okavango Region. – Biodiversity & Ecology, pp. 29–35. https://doi.org/10.7809/b-e.00240.
Reyers, B., Biggs, R., Cumming, G.S., Elmqvist, T., Hejnowicz, A.P., Polasky, S., 2013. Getting the measure of ecosystem services: a social–ecological approach. Front. Ecol. Environ. 11 (5), 268–273. https://doi.org/10.1890/120144.
Rodríguez, J.P., Beard Jr., T.D., Bennett, E.M., Cumming, G.S., Cork, S., Agard, J., Dobson, A.P., Peterson, G.D., 2006. Trade-offs across space, time, and ecosystem services. Ecol. Soc. 11 (1), 28.
Ruckelshaus, M., McKenzie, E., Tallis, H., Guerry, A., Daily, G., Kareiva, P., Polasky, S., Ricketts, T., Bhagabati, N., Wood, S.A., Bernhardt, J., 2015. Notes from the field: Lessons learned from using ecosystem service approaches to inform real-world decisions. Ecol. Econ. 115, 11–21. https://doi.org/10.1016/j.ecolecon.2013.07.009.
Schulz, K., Voigt, K., Beusch, C., Almeida-Cortez, J.S., Kowarik, I., Walz, A., Cierjacks, A., 2016. Grazing deteriorates the soil carbon stocks of Caatinga forest ecosystems in Brazil. For. Ecol. Manage. 367, 62–70. https://doi.org/10.1016/j.foreco.2016.02.011.
Schulz, K., Guschal, M., Kowarik, I., Almeida-Cortez, J.S., Sampaio, E.V.S.B., Cierjacks, A., 2018. Grazing, forest density, and carbon storage: towards a more sustainable land use in Caatinga dry forests of Brazil. online first. Reg. Environ. Change. https://doi.org/10.1007/s10113-018-1303-0.
Seppelt, R., Lautenbach, S., Volk, M., 2013. Identifying trade-offs between ecosystem services, land use, and biodiversity: a plea for combining scenario analysis and optimization on different spatial scales. Curr. Opin. Environ. Sust. 5 (5), 458–463. https://doi.org/10.1016/j.cosust.2013.05.002.
Settele, J., Spangenberg, J.H., Heong, K.L., Burkhard, B., Bustamante, J.V., Cabbigat, J., Chien, H.V., Escalada, M., Grescho, V., Hai, L.H., Harpke, A., Horgan, F.G., Hotes, S., Jahn, R., Kühn, I., Marquez, L., Schädler, M., Tekken, V., Vetterlein, D., Villareal, S.B., Westphal, C., Wiemers, M., 2015. Agricultural landscapes and ecosystem services in South-East Asia – the LEGATO-Project. Basic Appl. Ecol. 16 (8), 661–664. https://doi.org/10.1016/j.baae.2015.10.003.
Settele, J., Heong, K.L., Kühn, I., Klotz, S., Spangenberg, J.H., Arida, G., Beaurepaire, A., Beck, S., Bergmeier, E., Burkhard, B., Brandl, R., Bustamante, J.V., Butler, A., Cabbigat, J., Le, X.C., Catindig, J.L.A., Ho, V.C.H., Cuong, L.Q., Dang, K.B., Escalada, M., Dominik, C., Franzén, M., Fried, O., Görg, C., Grescho, V., Grossmann, S., Gurr, G.M., Hadi, B.A.R., Le, H.H., Harpke, A., Hass, A.L., Hirneisen, N., Horgan, F.G., Hotes, S., Isoda, Y., Jahn, R., Kettle, H., Klotzbücher, A., Klotzbücher, T., Langerwisch, F., Loke, W.H., Lin, Y.P., Lu, Z., Lum, K.Y., Magcale-Macandog, D.B., Marion, G., Marquez, L., Müller, F., Nguyen, H.M., Nguyen, Q.A., Nguyen, V.S., Ott, J., Penev, L., Pham, H.T., Radermacher, N., Rodriguez-Labajos, B., Sann, C., Sattler, C., Schädler, M., Scheu, S., Schmidt, A., Schrader, J., Schweiger, O., Seppelt, R., Soitong, K., Stoev, P., Stoll-Kleemann, S., Tekken, V., Thonicke, K., Tilliger, B., Tobias, K., Trisyono, Y.A., Dao, T.T., Tscharntke, T., Le, Q.T., Türke, M., Václavík, T., Vetterlein, D., Villareal, S., Vu, K.C., Vu, Q., Weisser, W.W., Westphal, C., Zhu, Z., Wiemers, M., 2018. Rice Ecosystem Services in South-East Asia (in press). Paddy Water Environ. https://doi.org/10.1007/s10333-018-0656-9.
Siegmund-Schultze, M., Köppel, J., Sobral, M.C., 2015a. Balancing ecosystem services and societal demands in a highly managed watershed: Setup and progress of a comprehensive research project. Revista Brasileira de Ciências Ambientais 36, 3–18. https://doi.org/10.5327/Z2176-947820151001.
Siegmund-Schultze, M., Rodorff, V., Köppel, J., Sobral, M.C., 2015b. Paternalism or participatory governance? Efforts and obstacles in implementing the Brazilian water policy in a large watershed. Land Use Policy 48, 120–130. https://doi.org/10.1016/j.landusepol.2015.05.024.
Siegmund-Schultze, M., Köppel, J., Sobral, M.C., 2018. Unraveling the water and land nexus through inter- and transdisciplinary research: sustainable land management in a semi-arid watershed in Brazil's Northeast. online first. Reg. Environ. Change. https://doi.org/10.1007/s10113-018-1302-1.
Spangenberg, J.H., Beaurepaire, A.L., Bergmeier, E., Burkhard, B., Van Chien, H., Cuong, L.Q., Görg, C., Grescho, V., Hai, Heong, K.L., Horgan, F.G., Hotes, St, Klotzbücher, A., Klotzbücher, T., Kühn, I., Langerwisch, F., Marion, G., Moritz, R.F.A., Quynh Anh, N.T., Ott, J., Sann, C., Sattler, C., Schädler, M., Schmidt, A., Tekken, V., Truong, Đ.T., Thonicke, K., Türke, M., Vaclavik, T., Vetterlein, D., Westphal, C., Wiemers, M., Settele, 2017. The LEGATO cross-disciplinary integrated ecosystem service research framework: an example of integrating research results from the analysis of global change impacts and the social, cultural and economic system dynamics of irrigated rice production. Paddy Water Environ. PAWE. https://doi.org/10.1007/s10333-017-0628-5.
Spangenberg, J.H., Görg, C., Truong, D.T., Tekken, V., Bustamante, J.V., Settele, J., 2014a. Provision of ecosystem services is determined by human agency, not ecosystem functions. Four case studies. Int. J. Biodivers. Sci. Ecosyst. Serv. Manage. 10 (1), 40–53. https://doi.org/10.1080/21513732.2014.884166.
Spangenberg, J.H., Görg, C., Settele, J., 2015. Stakeholder involvement in ESS research and governance: Between conceptual ambition and practical experiences–risks, challenges and tested tools. Ecosyst. Serv. 16, 201–211. https://doi.org/10.1016/j.ecoser.2015.10.006.
Spangenberg, J.H., Haaren, C.V., Settele, J., 2014b. The ecosystem service cascade: Further developing the metaphor. Integrating societal processes to accommodate social processes and planning, and the case of bioenergy. Ecol. Econ. 104, 22–32. https://doi.org/10.1016/j.ecolecon.2014.04.025.
Tallis, H., Kareiva, P., Marvier, M., Chang, A., 2008. An ecosystem services framework to support both practical conservation and economic development. Proc. Natl. Acad. Sci. 105 (28), 9457–9464. https://doi.org/10.1073/pnas.0705797105.
Tekken, V., Spangenberg, J.H., Burkhard, B., Escalada, M., Stoll-Kleemann, S., Dao Thanh, T., Settele, J., 2017. "Things are different now": Farmer perceptions of cultural ecosystem services of traditional rice landscapes in Vietnam and the Philippines. Ecosyst. Serv. 25, 153–166.
Verburg, R., Selnes, T., Verweij, P., 2016. Governing ecosystem services: National and local lessons from policy appraisal and implementation. Ecosyst. Serv. 18, 186–197. https://doi.org/10.1016/j.ecoser.2016.03.006.
Vinya, R., Syampungani, S., Kasumu, E.C., Monde, C., Kasubika, R., 2012. Preliminary Study on the Drivers of Deforestation and Potential for REDD+ in Zambia. A consultancy report prepared for Forestry Department and FAO under the national UN-REDD+ Programme Ministry of Lands & Natural Resources. Lusaka, Zambia.
Vorlaufer, T., Falk, T., Dufhues, T., Kirk, M., 2017. Payments for ecosystem services and agricultural intensification: Evidence from a choice experiment on deforestation in Zambia. Ecol. Econ. 141, 95–105. https://doi.org/10.1016/j.ecolecon.2017.05.024.
Weber, T., 2013. Mashare - Climate. In: Biodivers. Ecol. 5, S. 103.
Williamson, O.E., 2000. Ronald Harry Coase: institutional economist/institution builder. In: Menard, C. (Ed.), Institutions, Contracts, and Organisations: Perspectives From New Institutional Economics. Edward Elgar Publishing.
Woodhill, J., 2010. Capacities for institutional innovation: a complexity perspective. IDS Bull. 41 (3), 47–59.