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SPECIAL FEATURE: ORIGINAL ARTICLE

Sustainability science: bridging the gap between science and society

Governance for sustainability: knowledge integration and multi-actor dimensions in risk management

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Abstract Sustainability has many dimensions, including various aspects of environmental, social and economic sustainability. This paper proposes an analytical framework of risk-related governance for sustainability, based on literature review, focusing on two dimensions—knowledge integration and multi-actor governance. Knowledge integration necessitates wider coverage of predicted and anticipated risks and information on those risks. Multi-actor governance necessitates mechanisms that enable cooperation among actors. The relevance of this analytical framework is then checked using concrete cases of governance for reducing emission from deforestation and forest degradation (REDD+), and the possible case of governance for sustainable phosphorus management.

Keywords Governance · Risk management · Knowledge integration · Multi-actor governance · REDD+ · Phosphorus

Introduction

To achieve sustainability in society, it is necessary to recognize that sustainability has many dimensions including various aspects of environmental, social and economic sustainability. The eminent report by the Brundtland Commission, *Our Common Future* (WCED 1987), stated that sustainability requires the achievement of policy objectives in many dimensions, among them population and human resources, food security, species and ecosystems, energy, industry, and urbanization challenge. A few decades on, these concepts have spurred many researchers to work on further dimensions of sustainability, including integration at all scales from local to global, the need for context specific elaborations and open-ended processes (Kemp et al. 2005). Recent literature also acknowledges the limits of traditional ways of "prediction and planning" due to the increasing uncertainty of the problems that management and policy attempt to solve. Such limits stress the need for contemplation of multiple ways to anticipate and adjust to the changes, surprises and disruptions caused by known and unknown risks (Quay 2010). In addition, it is worth noting that different actors within society hold different viewpoints on sustainability, thus there is a need for governance. In this paper, governance means to influence policy decisions and actions without necessarily having sovereign power. This asks that players are able to coordinate views and interests among a variety of actors, including experts in different academic disciplines, different ministries, various levels of government (international organizations, national government, and local government), firms, groups (such as professional groups and employers' associations) and citizens. One of the characteristics of sustainability issues is the wide range of players involved, including NGOs or others who sometimes claim to represent the interests of future generations or even nature, even though it is very difficult to ensure the accountability of such players to those who have no voice in the real world, and it is not always possible to

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coordinate players' interests, implying there will have to be trade-offs between them (Kemp et al. 2005).

Governance and traditional government are often thought of as opposing forces. Government is taken to mean the official institutions for governing, while governance is understood to encompass a wide range of systems—including the customs of society and markets—and actors that operate outside the official institutions of government, or, in other words, "the whole range of institutions and relationships involved in the process of governing" and "self-organizing, inter-organizational networks" (Rhodes 1997). Whereas the organization of government is based on an internal vertical hierarchy, governance allows for structures that include formal and informal horizontal relationships among entities such as various societal groups and companies, and among various levels of government (Wiek et al. 2007). Here, the concept of governance does not necessarily exclude formal and hierarchical/power relationships, but includes a wider range of informal and horizontal interactions. In the context of studies for sustainability, Biermann defines Earth system governance as "the sum of the formal and informal rule systems and actor-networks at all levels of human society that are set in order to influence the co-evolution of human and natural systems in a way that secures the sustainable development of human society" (Biermann 2007).

Governance for sustainability can be defined here as formal and informal networks/interactions among actors, and systems composed by them, that influence sustainability by integrating various dimensions. Governance for sustainability asks for knowledge integration as a means to deal with multiple dimensions of sustainability and uncertainty. Multi-actor governance involves public–private and multi-level interactions, which are needed to get agreement on sustainable actions among actors for designing and establishing resilient systems (Scholz 2011; Ostrom 2009). A theoretical framework of governance for sustainability, focusing on these two dimensions will be discussed in "Theoretical Framework of Governance for Sustainability" utilizing political science, innovation study, and sustainability science literature. Concrete cases are then analyzed in "Appraisal of Cases with the Proposed Analytical Framework" before concluding remarks in "Conclusion".

Theoretical framework of governance for sustainability

Knowledge integration

Having knowledge of the inherent risks to be tackled is necessary for sustainability. Without some kind of knowledge and information about risks, including "anticipatory knowledge" (Guston 2008), it is not possible to initiate action for sustainability. Thus, incorporating knowledge and information is an indispensable part of epistemic efforts of governance for sustainability (Lang et al. 2012), as the role of epistemic communities (Haas 1992) and the role exemplified by the IPCC (Agrawala 1998) shows.

It must be emphasized that there are different types of risks; unpredictable risk and known specific risk. Governance for sustainability must deal with both of these risks. The rising awareness of the limit of the governance systems to predict surprises points to the danger of paying too much attention to "specific risks" and calls for a systematic view to cope with multiple risks (Nelson et al. 2007) including unpredictable risks. In the management of such risks, a reflexive approach that emphasizes the importance of learning is important (Guston and Sarewitz 2002). This is true but, looking at the real world, even the known multiple specific risks are not well managed.

Regarding risk assessment, scientific knowledge inevitably involves uncertainty, which is inherent in real world systems and knowledge itself. It is, of course, possible that uncertainty will recede as science progresses. However, it will be difficult or impossible to eliminate it completely, as the cases of climate change or nuclear power show. For society, the question of how to define and assess an acceptable level of uncertainty thus arises. The choice between the "precautionary principle" and the "no-regrets policy" expresses a difference in attitudes towards this uncertainty. The precautionary principle refers to the attitude of taking preventive control measures (even without scientific evidence that an undesired outcome is likely to occur), especially if the cost of control measures are small in proportion to an event whose resulting damage could be enormous. The no-regrets policy is more rigid and refers to the act of taking only safe measures (even if nothing is going to happen), instead of reacting in response to uncertainty on the assumption that something will happen. Which of these policies is adopted depends not on science but on politics (Litfin 1994).

In general, risks to be tackled for sustainability are also multifaceted. For example, many risks, such as climate change risk, energy security risk and safety risk, relate to the use of energy. So there is a need for knowledge integration among experts in various academic fields and stakeholders in society who have different knowledge about various risks (Scholz 2011). Depending on the framing of risks, the range of actors involved varies. And depending on manner in which actors frame risks, attitudes of actors toward the same policy measure are different. Nuclear energy can be beneficial for mitigating climate change and energy security risks but detrimental to mitigating human health and safety risks.

Various tradeoffs among risks must be considered in governing for sustainability (Graham and Wiener 1995).

Some policy areas have so much disagreement of framing among political actors that conflict is not resolved even after a collective policy decision has been reached. It has been suggested that, in such intractable policy areas, policy processes be viewed in terms of framing, frame conflict and reframing. They focus on the dynamic aspects of frame conflicts (Schön and Rein 1994).

Knowledge integration is possible through inter-sectoral regime coordination. Inter-sectoral regime coordination takes place between regimes across the boundaries of policy fields at domestic and international levels. Regimes have evolved within specific functional issue-areas (Keohane 1984; Kemp et al. 2007). The concept of the policy network in political science is also used to refer to this phenomenon (Rhodes and Marsh 1992). As a consequence, most existing regimes act to promote their own mandates within a sector-based issue area, which makes sustainability governance appear to be fragmented when faced with sustainability issues that require inter-sectoral action.

On the other hand, there is no single hierarchical entity that oversees the consistency of the rules and legislation created across the sectoral regimes. Current sectoral regimes exist in a fragmented, diverse and dispersed manner. Some have a narrow scope but others have a broader scope. Inter-sectoral regime coordination is imperative in this context. Without coordination, relations among regimes remain competitive and inconsistent due to their conflicting objectives, and policies are rendered ineffective by overlapping or duplicated responsibilities.

It is often pointed out that fragmentation is a serious obstacle when attempting to cope with increasingly multifaceted issues, which require coordination across issue areas. In the case of modern biotechnology, for example, the food safety aspect is discussed in the Codex Alimentarius and its risk assessment body FAO/WHO expert consultation, the environmental aspect is treated through the Cartagena Protocol, trade-related disputes are raised before the WTO, and more general aspects have long been discussed in the OECD (Matsuo et al. 2011). Sometimes the themes overlap, and sometimes themes such as specific concerns related to OLF ("other legitimate factors"—factors other than science which includes, social ethical factors) are not really treated seriously in any forum. So the reality of international relations is well depicted by the term "regime complex." Regime complex can be defined as "an array of partially overlapping and nonhierarchical institutions governing a particular issue-area" (Raustiala and Victor 2004), or "a loosely coupled set of specific regimes… linked more or less closely to one another, sometimes conflicting, usually mutually reinforcing" (Keohane and Victor 2011).

But there is also the advantage of fragmentation as a source of diversity. The concept of resilience, which has emerged from ecology and is now used widely in sustainability science and policy, is of use in explaining the advantages of a regime complex. Folke (2006) has reviewed the evolution of the concept of resilience in the existing literature, and has identified two notable attributes regarding the definition of "resilience"; (1) the capacity of the system to absorb disturbance and still function, and (2) the capacity for re-organization and development that allows adaptive interplay between sustaining and developing with change.[1] In this paper we apply the concept to institutional learning and organization, recognizing that institutions also belong to social systems that exhibit similar properties of resilience originally described in ecosystems. For example, organizations that are capable of "double loop" learning learn and adapt to changes in the social environment around them, using this knowledge to update decision making (Armitage et al. 2007). For the system to be resilient, it is crucial for it to allow diversity as diversity of functional groups can (1) offer multiple solutions to disturbances from divergent points of view, and (2) diversity is more flexible in responding to dynamic change than a single rigid institution. Fragmentation sometimes creates open and diverse channels for knowledge involvement. The resilience literature framework also contributes conceptually by offering that fragmentation is nothing undesirable. It argues that the system can be organized around multiple possible states, which effectively increase the range of adaptation options (Nelson et al. 2007). However, linking diversified elements requires the emergence of what is called "bridging organizations" (Folke et al. 2005) or "brokers" (Bodin et al. 2006).

The governance function for sustainability can be regarded as achieving a balance between efficiency and resilience (Lietaer et al. 2009; Ulanowicz et al. 2009). Efficiency is defined as a network's capacity to perform in a sufficiently organized and efficient manner so as to maintain its integrity over time. Resilience is considered to be the network's reserve of flexible fallback options and range of actions and strategies that can be employed to meet the exigencies of novel disturbances and the novelty needed for on-going development and evolution. Diversity is the existence of different types of agents acting as "nodes" in the network. The system's resilience will be enhanced by increasing diversity, with more channels to fall back on in times of trouble or change. Efficiency (in the short term) tends to increase through streamlining, usually reducing diversity.

Understanding the tradeoffs between efficiency and resilience for sustainability helps us to move our policies toward a more appropriate balance. To design our governance systems, however, we also need to understand the dynamic mechanism of positive feedback growth, which

[1] For a formal definition and the relationship between risk and resilience see Scholz et al. (2011).

can erode systemic sustainability (Goerner et al. 2009). In a number of natural as well as social processes, system dynamics tend to accelerate efficiency and growth in a way that actively drains the broader system (Ulanowicz 1995). There are many examples that show this dynamic of positive feedback (Goerner et al. 2009). Fertilizer and agricultural wastes flowing down the Mississippi River caused by the agricultural regime triggered massive algae growth that has depleted nearly all the oxygen in water, which caused an equally massive die-off of marine life, notably fish, shrimp and shellfish in the fishing regime. Unintended secondary feedback loops, which are often slight changes in the environment that reduce the characteristics and feedback potential, are also essential for understanding sustainability (Scholz 2011).

The view of seeing fragmentation in terms of the concept of "resilience" is not debated explicitly in the international relations literature but a similar discussion occurs in the context of "regime complex". Keohane and Victor (2011) suggest that regime complex may not necessarily be superior to the comprehensive integrated regime but they stress that it has advantages in terms of (1) flexibility across the issues, and (2) higher adaptability over time.

Based on the above discussion, it can be stated that (1) the range of risks predicted and anticipated, and (2) information about the genesis and levels of those risks, are two important elements in the knowledge integration and resilience dimension of governance for sustainability.

Multi-actor governance

A key insight of multi-actor governance for sustainability is that it is not necessary for all the actors involved in governance to share a common framing. The notion of "sharing the same bed, dreaming different dreams" (*doushouimu* in Japanese) is salient (Shiroyama 2011). As has been emphasized, actors in society have different framing and concerns, and it is rare for the framing of these various actors to be in accord. For example, some actors may be interested in nuclear power or biomass energy as measures to combat global warming, while others may be interested in these technologies as a means to achieving energy security. Thus, finding a common framework for the simultaneous achievement of various policy objectives is necessary for sustainable development, and it is in such circumstances that the notion of "same bed, different dreams" serves as a relevant axiom.

Some "dreams," however, need to be adjusted because their coexistence with the dreams of others may turn out to be a "nightmare" for the others. In such cases a value judgment for gaining legitimacy must be made to decide which value or dream should be discarded. Human rights and fairness related issues are examples of such cases.

Understanding sustainable development as the co-evolution of different subsystems (Kemp et al. 2007; Voss et al. 2009) shares the notion of "same bed, different dreams." Each subsystem has its own objectives but those objectives, although some adaptation is needed, can coexist under the system-wide change for sustainability. Tools and methods such as *Problem Structuring Methods and Consensus Building* (Komiyama et al. 2011, Part 2) are useful to assess the viability of "doushouimu" in specific local contexts.

Even when there are inherent trade-offs, innovation, by increasing the pie to be allocated, can ease the adverse effects of trade-offs among various actors (Kemp et al. 2005). Interaction and partnership with non-state actors is the intended and unintended source of innovation (Yarime 2009). Non-state actors include firms and NGOs. Involving business is becoming more important, including in developing countries undergoing rapid economic growth. NGOs also play important roles as advocates of the perspectives of minorities, the South and even future generations. There is also a movement toward industry–NGO partnerships. One of the challenges associated with sustainability governance is to examine how to facilitate innovative interaction among actors, balance interests among actors, make use of voluntary initiatives, and incorporate expertise and technical/indigenous knowledge as well as answer the legitimate concerns of non-state actors, particularly where public action is lacking.

It is also necessary to understand what kinds of mechanisms govern the interactions between relevant actors, for example, whether they involve commercial profits, intellectual priorities, or ethical considerations (Ostrom 2009). These rules of the game will influence the processes and outcomes of innovation (Nelson 1994). The notion of innovation system is useful to explain the mechanism of innovation in which knowledge is transformed through complex interactions of various actors in an institutional environment (Yarime 2010). A technological innovation system can be defined as "a dynamic network of agents interacting in a specific economic or industrial area under a particular institutional infrastructure and involved in the generation, diffusion, and utilization of technology" (Carlsson and Stankiewicz 1991).

Innovations for sustainability create products, processes, or services that are accepted in society in terms of economic, social, and environmental dimensions (Yarime 2010). Many theoretical as well as empirical studies show a significant influence of environmental policies and regulations on innovation and technological change (Magat 1978; 1979; Ashford et al. 1985; Downing and White 1986; Milliman and Prince 1989; Kemp 1997; Popp 2003; Taylor et al. 2005; Yarime 2007; del Rio González 2009; del Rio et al. 2010; Kemp and Pontoglio 2011). These previous studies considered mainly how environmental policies influenced innovation in the domestic context. For example, the introduction of stringent automobile emission standards in Japan influenced the innovation of emission control technologies such as the catalytic converter for reducing NOx in 1970s–1980s (Shiroyama 2002). As globalization of economic activities has increasingly intensified, however, interactions between policy intervention and corporate behavior are not confined within national or regional boundaries. International influences of environmental regulations are especially important in the case of the automotive industry, where many of the major automakers are multinational enterprises (Dijk and Yarime 2010).

Sometimes firms promote innovation without the introduction of regulation. For example, one of the reasons why Toyota became a strong leader in introducing hybrid technology in 1997 relates to the lessons the company learned in the 1970s, i.e., when stringent environmental regulation of NOx emissions began in Japan the company was reactive and developed a bad image. The decision to introduce hybrid technology was taken not because of regulatory requirements but because of market strategy (Shiroyama 2002; Yarime et al. 2008). At the international level, the automobile industry in Japan, Europe and US voluntarily led the process for harmonizing environmental standards at higher levels and pushed for international governmental standards through a UN organization (Shiroyama 2007).

In addition, because sustainability issues have many dimensions concerning spatial scale, governance for sustainability requires action at local and national levels, in addition to action at international level. For example, emissions of SOx and NOx cause acid rain, which requires action at an international level, but also causes urban environmental pollution, which requires action at a local level (Shiroyama 1999). In this case, requirements at an international and local level reinforce each other. But there can be tension between them too.

Multi-level governance is a special form of multi-actor governance that requires coordination between multiple institutional and spatial levels—international, national and local. There has been much debates on multi-level governance in recent literature spanning various disciplines, including international relations, global environmental studies, commons theory, resilience literature and political ecology (Hooghe and Marks 2003; Gupta 2008; Armitage 2008).

Finally, though innovation eases trade-off decisions, trade-off decisions concerning multi actor governance for sustainability still remain. For those trade-offs decisions to be socially acceptable, fairness of allocation of decision is important. Where there are trade-off issues, it is considered very important that the governance structure ensures explicit rules and processes for decision on compensation for any negative effects (Kemp et al. 2005; Gibson 2006). It is also important to consider the governance mechanism for the allocation of resources so as to mitigate the gap of winners (beneficiaries) and losers of the issues involving trade-offs. The controversy over genetically modified crops may be due largely to the fact that the benefit is shared unevenly between the huge biotech companies, consumers and poor farmers in developing countries (Gaskell et al. 2004). There are concerns that impact of future technological development is not sustainable because it will need less labor and allocate less to workers (Alic 1997). It must also be noted that, during the process of allocation, some actors are not well equipped with the capacity to govern (“powerless spectators”) or have the capacity but are more captured by the short-term issues and have less capacity to manage systematically (“coping actors”) (Fabricius et al. 2007).

Based on this discussion, it can be stated that there are three important elements of the multi actor governance dimension of governance for sustainability: (1) mechanisms that enable “doushouimu”, (2) mechanisms of innovation that produce benefits to be allocated among actors and different spatial levels of governments, and (3) transparency and fairness of rules of allocation.

Analytical framework of governance for sustainability: check list

Here, we would like to present an analytical framework of governance of sustainability, as a check list for designing governance institutions, based on the major elements of discussion above in this section.

Concerning the knowledge integration dimension of governance for sustainability, two elements, i.e., (1) range of risks predicted and anticipated, and (2) information about the genesis and levels of those risks, are important. Concerning the multi actor governance dimension of governance for sustainability, three elements are important: (1) a mechanism that enables “doushouimu”, (2) a mechanism of innovation that produce pies to be allocated among actors and different spatial levels of governments, and (3) transparency and fairness of rules of allocation.

Putting those elements together, the following checklist of governance for sustainability can be proposed (Table 1).

Appraisal of cases with the proposed analytical framework

Characteristics of cases

Two cases below, reducing emission from deforestation and forest degradation (REDD+) and global phosphorous management, are shown to demonstrate the relevance of the analytical framework of governance for sustainability

Table 1 Analytical framework for governance for sustainability

Dimensions	Elements	Definition	Question	Reference
Knowledge integration	Risk	The chance of an adverse outcome to human health, quality of life, or quality of the environment	Is a wide range of risks considered?	Graham and Wiener (1995)
	Information	Technical knowledge as well as vast bodies of knowledge and practice implicated in turning discoveries into actual innovation or policy decisions	Is relevant and sufficient information considered?	Guston (2008)
Multi-actor governance	Doushouimu	Agreement on options among actors having different framings and interests	Is the possibility of doushouimu considered?	Shiroyama (2011)
	Innovation	Creation of products, processes, or services that are accepted in society in terms of economic, social, and environmental dimensions	Is the possibility of innovation considered?	Yarime (2010)
	Fairness	Equitable distribution of gains and losses	Is fairness in the distribution of gains and losses considered?	Kemp et al. (2005)

that incorporates two dimensions of governance for sustainability: knowledge integration and multi-actor governance.

REDD+ is the governance initiative already taken by governments and evaluated according to elements of the analytical framework. On the other hand, global phosphorous management is a potential governance initiative, the function of which non-governmental research projects are trying to perform informally. Evaluation of the phosphorous case is made not on the aspiration of non-governmental research projects but on the current situation.

Governance challenges in REDD+

Deforestation has come increasingly into focus as a major contributor to rising global greenhouse gas (GHG) emissions. Deforestation is currently estimated to account for 13–17% of annual global GHG emissions (van der Werf et al. 2009; Eliasch 2008). Deforestation and forest degradation occur mainly in tropical forest countries which are non-Annex 1 countries under the 1992 UN Framework Convention on Climate Change (UNFCCC) and thus do not have binding emission reduction obligations under the 1997 Kyoto Protocol. Deforestation and forest degradation are also not included in the Kyoto Protocol, as they were deemed too controversial at the time.

The 2007 Bali Action Plan took up the idea of creating incentives to keep forests intact by making trees more valuable standing than felled and launched the designing of a mechanism to reduce emissions from deforestation in developing countries (REDD). The 2009 Copenhagen Accord committed to funding activities toward REDD as well as conservation, sustainable management of forests and enhancement of forest carbon stocks (REDD+). The 2010 Cancun Agreements include provisional language on social and environmental safeguards, and provide guidance on REDD+ readiness activities.

While the rules and provisions are still being negotiated, initial funding has been flowing to tropical forest countries to engage in REDD readiness activities. Multiple actors (e.g., international agencies and NGOs, national governments, timber consumers and local communities) and sectors (e.g., forestry, agriculture, energy and transport), all operating at different levels of governance (local, regional, national and international) have become part of the emerging REDD+ regime. New public–private interactions and partnerships, such as the multi-stakeholder Roundtable for Sustainable Palm Oil (RSPO) have emerged to address the challenges of mitigating the drivers of deforestation.

It has been acknowledged widely that governance issues are the central challenge for REDD+ to become operational (Porrúra et al. 2007; Gregersen et al. 2010; Corbera and Schroeder 2011). REDD+ is a quintessential global environmental governance "process with multiple actors, interests and activities, involving several sources of formal and informal power and authority (UN bodies, multilateral organisations, governments, but also community and indigenous organisations), which all influence each other" and may or may not share interests and visions regarding the way forward (Corbera and Schroeder 2011). REDD+ will cause social and environmental harm unless a number of crucial governance challenges at both the international design stage and the country and on-the-ground implementation stage are addressed sufficiently. Some of these challenges are outlined below.

REDD+ is unfolding rapidly into multi-level, multi-purpose and multi-actor projects and initiatives, and permeates through multiple spheres of decision-making, creating contested interests and claims and translating into multiple and uncoordinated implementation actions. This puts REDD+ in a rather unpredictable predicament, rendering it difficult to foresee what benefits and what harms it will unleash, and for whom. Much of the fate of REDD+ lies in the adoption and implementation of effective and equitable governance arrangements.

Knowledge integration

REDD+ focuses on deforestation as a major contributor to absorbing rising global greenhouse gas emissions (GHG). But it also pays attention to the local ecological impacts of deforestation, as the fact that the 2010 Cancun Agreements included provisional language on social and environmental safeguards related to REDD+ guideline.

One issue requiring knowledge and information governance is leakage (national and international). Leakage refers to the possibility that deforestation reductions achieved in one location might simply cause higher levels of deforestation elsewhere, resulting in no overall reduction in deforestation. Addressing leakage requires not only effective and transparent national carbon accounting and an international coordination of efforts. It also necessitates addressing the global drivers of deforestation and finding effective ways to reduce the human pressure on forests (e.g., changing land use practices) and the demands that drive deforestation (e.g., timber, palm oil, soy production and cattle ranching).

Another issue in need of knowledge and information governance is achieving permanence of avoided deforestation. Deforestation reductions may not be permanent, meaning that deforestation activities may just be postponed into the future. To avoid this, reductions will need to be monitored continually and payments can be made only for permanent deforestation reductions; hence continued measuring, reporting and verification of emissions will be of utmost importance. It will also be crucial to engage local stakeholders in this endeavor and ensure their compensation is tangible and meaningful.

Another key issue requiring knowledge integration is additionality. Reductions in deforestation under REDD should be additional to any reductions that would have happened under a business-as-usual scenario. This is not always easy to verify. Robust comparisons depend on transparent, reliable and consistent methodologies that are tested, adapted to local circumstance, coordinated internationally and implemented nationally, regionally and locally.

Multi-actor governance

Forestation is an instrument for facilitating "doushouimu" and innovation for simultaneous countermeasures against global warming and local ecological conservation.

One important element of multi-actor governance is good governance (transparency, accountability, inclusiveness) in institutionally fragile countries, which is the key to a successful REDD+ process in terms of overall emissions reduced. This is because deforestation rates are often highest in the most institutionally fragile countries where corruption and illegal logging are especially prevalent. This compounds the need not only to support REDD+ activities in countries that are already relatively stable, but also to channel efforts into building transparency, accountability and inclusiveness in less stable countries, if global deforestation rates are to be noticeably reduced.

The other important element is ensuring fair distribution of benefits among actors. It will be crucial for the legitimacy of REDD+ to have a distribution mechanism that actually compensates—monetarily and/or through better access to resources or decision-making—those who have contributed to preserving the forest, including remote, impoverished communities and indigenous peoples. If this does not happen, REDD+ is likely to generate perverse incentives that would lead to misappropriation of funds, elite capture, land grabs, displacement of people, thereby rendering the REDD+ mechanism meaningless in terms of achieving carbon emissions and additional environmental and social benefits. This issue is tied closely to implementing social safeguards and clarifying tenure rights.

Governance challenges of sustainable phosphorus management[2]

Phosphorus (P) is a key human, animal and plant nutrient of great significance for world food security. P is non-substitutable and dissipates readily into waterways through processes such as erosion and run-off, making it difficult to recover. The biogeochemical cycle of P has been changed significantly by human activities (Smil 2000; Carpenter and Bennett 2011). This has led to excess P polluting fresh waters and coastal areas, creating eutrophic and hypoxic zones. While phosphorus pollution has been discussed for many decades internationally, phosphate rock scarcity discussions have surfaced from time to time only during the last decade (Ulrich 2011). The question of how long supplies of phosphate rock will last, or when a "peak" will occur, has been controversially discussed recently (Cordell et al. 2009; van Kauwenbergh 2010). Further, the issue of whether P is a critical element for future human development has emerged (Erdmann and Graedel 2011). From a sustainability perspective, one critical issue is the globally unequal access to, and availability of, P (Ekardt et al. 2011).

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For instance, smallholder farmers in areas that need high input of P because of low soil concentrations (e.g., areas with highly weathered soils in tropical areas) have a much higher nutrient input need but less financial potential to gain access to P than farmers from northern areas with calcareous soils (Dumas et al. 2011).

Thus, sustainable P management has become a serious, worldwide concern (Ulrich et al. 2009; Allenby et al. 2011). Responding to this situation, the Global Transdisciplinary Process for Sustainable Phosphorus Management (the Global TraPs project) was established as a new form of sustainability think tank, which provides a precompetitive, non-politicized (i.e., excluding day-to-day policy questions) discourse arena encompassing key agents and people concerned with a transdisciplinary process. This process should serve to provide: (1) capacity building for understanding and action upon sustainable and unsustainable P flows, (2) consensus building on which flows should be altered primarily and what options may help to adapt these flows, (3) mediation between the different interests that may be affected by sustainable transitions, and (4) legitimization for policy makers when referring to decision options that may lead to sustainable P management. Success of this kind of new governance initiative depends on following elements.

Knowledge integration

Just as the organism of a human body may be better understood if we have in depth knowledge of the different organs, sustainable P management may be better understood if we have in depth knowledge of the components of the supply chain, i.e., the exploration, mining, processing, use, and dissipation and recycling of P. Thus, the Global TraPs project is "facetted" or organized along this supply chain.

Knowledge of P is currently fragmented amongst different social actors, such as companies, universities and research institutes; though there are various projects and initiatives working towards sustainable P use (Eilittä 2011; Schröder et al. 2010). By integrating this knowledge, we see that many open questions remain, such as fuzzy and opaque knowledge of reserves and resources, pools and sinks of P along the supply chain, recycling opportunities and their economic feasibility, etc.

The complexity of sustainable P management cannot be solved by a pure disciplinary or even interdisciplinary approach, but asks for socio-technological system analysis that accurately reflects the properties and constraints of natural resources systems. However, practitioners from industry or industry organizations (e.g., IFA), non-profit institutions (e.g., IFDC), national agencies (such as geological surveys or agricultural agencies), NGOs (e.g., Greenpeace), international organizations (such as FAO, UNEP), farmers organizations, and many other stakeholder groups are literate about the various challenging domains and overlapping layers of the P supply chain. Thus, integrating knowledge and acknowledging the interests and values of such diverse stakeholder groups is one of the most challenging and necessary tasks in designing sustainable P management options.

Multi-actor governance

The basic principles of transdisciplinarity—according to the Zurich 2000 definition (Thompson Klein et al. 2000)—refer to mutual learning based on science and practice through collaboration on an equal footing. This is based on processes being conducted through co-leadership, identification of what stakeholder knowledge should be incorporated to address which questions, and through sorting out what disciplinary and value-related components are involved in what type of problem (Krutli et al. 2010; Scholz 2011; Scholz et al. 2006; Thompson Klein et al. 2000). Different types of knowledge are to be integrated in a transdisciplinary process, i.e., knowledge from different disciplines, (sub-)systems, perspectives or stakeholder-groups, types of epistemics (e.g., intuitive or analytic thinking), and from different cultural systems. Integrating qualitative and quantitative knowledge should best be driven by a method-driven process (Scholz and Tietje 2002).

The goal of the Global TraPs project is to provide options for "socially robust solutions" to policy makers through transdisciplinary processes. By socially robust solutions we mean (1) "state of the art scientific knowledge that (2) has the potential to attract consensus, (3) acknowledges the uncertainties and the incompleteness inherent in any type of knowledge, (4) generates processes of knowledge integration of different types of epistemics (e.g. scientific and experiential knowledge), and (5) considers the constraints of generating and utilizing knowledge" (Scholz 2011).

A critical issue in such joint transdisciplinary processes is that they may become over-politicized, interest-driven, and lobbied by business agents and policy makers. The Global TraPs introduced rules of communication and excluded day-to-day politicized issues. The case of P, as in many other cases of resource management, asks for reflection, identifying hot spots of unsustainable P management, proper priority setting and concerted action.

A joint problem definition and guiding question was formulated. It reads: "What new knowledge, technologies and policy options are needed to ensure that future phosphorus use is sustainable, recognizing the need to improve food security and environmental quality, and benefits for the poor?" "Doushouimu" and/or innovation for simultaneous achievements of food security and environmental quality, and benefits for the poor have to be discovered.

Conclusion

This paper proposed an analytical framework of governance of sustainability, as a check list for designing governance institutions. Those two cases considered—REDD+ and global phosphorous management—demonstrate the relevance of an analytical framework of governance for sustainability that incorporates two dimensions of governance for sustainability: knowledge integration and multi-actor governance/interaction.

In the REDD+ case, the multi-stakeholder round table for sustainable palm oil is an example of multi-actor governance. Comprehensive knowledge on carbon accounting and monitoring is a prerequisite for a resilient system, which has few side effects in related areas, such as forest ecosystem management. Effective governance of fragile states and fair distribution of benefits among actors is also important for effectiveness and legitimacy. In the global phosphorous management case, a transdisciplinary project like Global Traps itself exemplifies multi-actor governance. Comprehensive knowledge of the P supply chain, from exploration, mining, processing and use to recycling, is necessary to establish a resilient system that pays attention to multiple issues such as scarce mining and eutrophication. Moreover, distributional issues of access to P for farmers in developing countries are also important from a legitimacy perspective.

Concerning the possibility of "sharing the same bed, dreaming different dreams" (*doushouimu* in Japanese), some have an interest in REDD+ as a measure to reduce GHG emissions, and others may be interested in enriching forest ecological resources. Concerning the P management case, fertilizer companies may have an interest in recovering P from sewage for resource recycling, and waste water management agencies may have an interest in recovering P from sewage as a measure to reduce eutrophication caused by waste water discharge into the sea. A more detailed comparison between these two cases is shown in Table 2.

Table 2 Appraisal of two cases within the analytical framework

Dimensions	Elements	REDD+	Phosphorus
Knowledge integration	Risk	Well considered	Partially considered
	Information	Partially considered	Partially considered
Multi-actor governance	Doushouimu	Well considered	Partially considered
	Innovation	Not considered	Partially considered
	Fairness	Partially considered	Not considered

It was made clear that those two dimensions are important when institutions of governance for sustainability are designed. We still need to tackle further challenges. First, it is necessary to analyze more deeply the relationships among various elements in each dimension. Second, we need to apply the framework to a variety of cases to check its relevance.

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