Challenges in Sustainability

Review

Knowledge Governance for Sustainable Development: A Review

Lorrae van Kerkhoff

Fenner School of Environment and Society, The Australian National University, Building 48 Linnaeus Way, Canberra ACT 0200, Australia; E-Mail: lorrae.vankerkhoff@anu.edu.au; Tel. +61 261252748

Abstract: Sustainable development is a knowledge intensive process, but plagued by persistent concerns over our apparent inability to connect what we know with more sustainable practices and outcomes. While considerable attention has been given to ways we may better understand and enhance the knowledge-based processes that support the governance of social-ecological systems, relatively few have examined the governance of knowledge itself. The institutions—rules and norms—that govern knowledge may shed light on the persistence of 'gaps' between knowledge and action. In this review I seek to answer the question: can interdisciplinary knowledge governance literature contribute to understanding and analysing the institutional knowledge-based dimensions of sustainable development? I present and analyse the concept of knowledge governance as it is emerging in a range of disciplines and practice areas, including private sector management literature and public regulation theory and practice. I then integrate the findings from this review into a model of sustainable development proposed by Nilsson et al. [1]. I show that knowledge governance (as a scale above knowledge management) can inform Nilsson et al.'s three "nested" dimensions of sustainability: human wellbeing (through access to knowledge and freedom to exercise informed choice); resource-base management (though enhancing regulation and innovation and transitions from exclusive to inclusive knowledge systems); and global public goods (by balancing public and private interests and fostering global innovation systems). This review concludes by presenting a framework that places sustainable development in the context of broader socio-political struggles towards more open, inclusive knowledge systems.

Keywords: global public goods; innovation; knowledge governance; knowledge systems; sustainable development

librello

1. Introduction

Public debates and political struggles over how to achieve sustainability, from climate change and biodiversity conservation to genetically modified organisms and food security, have been characterised by clashes and controversies over knowledge [2,3]—what do we need to know to meet sustainability challenges? Who should know it? Where should that knowledge come from? Who has authority or should be believed? How can different forms of knowledge be harnessed more effectively for action towards sustainability? Yet despite substantial work in these areas [3–10] there remains a view that efforts to improve the application of knowledge to inform sustainable development have fallen short of the urgent and compelling need. This is particularly so in relation to science; for example, a United Nations Environment Program Foresight report released in 2012 ranked "Reconnecting Science and Policy" as the fourth highest priority of 21 top challenges for sustainability in the 21st century. They stated that "...our society needs strategies and policies that are underpinned by a strong science and evidence base. But many believe the linkage between the policy and science communities is inadequate or even deteriorating, and that this 'broken bridge' is hindering the development of solutions to global environmental change. This problem requires a new look at the way science is organized and how the science-policy interface can be improved" [11]. Similarly, a report by the International Council for Science wrote "there appears to be a serious disconnect between scientific knowledge and the way that policy is formulated, leading to calls for improvements in the science-policy interface" [12]. A recent review of the usability of climate science for policy, including processes and techniques for enhancing the role of scientific knowledge in decision-making, concluded that: "in spite of these efforts to rethink and restructure science production, current approaches have not been able to surmount the usability gap" [9]. Beyond the science domain, arguments for more fully incorporating traditional ecological and indigenous knowledge into sustainability-related decision-making have long standing [13,14] with arguably increasing relevance in the context of global environmental change [15]. Other authors have highlighted the need for a range of knowledges to be brought together to address complex sustainability challenges, including contributions from local stakeholders (for a review, see Reed [16]), and dynamic and 'polycentric' governance arrangements to support adaptive management of "socio-ecological systems" [17,18]. Yet the difficulties of operationalising effective participation and adaptive governance arrangements have also been noted, suggesting that knowledge-oriented, learning-based approaches face substantial challenges in practice [16,19,20]. Taken together, the overall picture is that better understanding and enhancing the role of knowledge in sustainable development decision-making is widely held to be important, but there is a need for fresh insights and new ideas to 'bridge the gaps' between knowledge and action [21].

In this article I review the contribution one specific concept, "knowledge governance", may make to this broader task of understanding and enhancing the role of knowledge in sustainability decision-making. The origins of this review came about from a sustainability science project that ran in 2004–2006, titled "Knowledge systems for sustainable development". This project was made up of 9 case studies from around the world, where my colleagues and I sought to develop a systemic, actor-based understanding of knowledge processes in sustainable development projects [5,22–27]. While we developed a range of theoretical and practical insights from these projects, it became clear that the 'knowledge systems' we were identifying and describing emerged from complex governance arrangements that either supported or undermined efforts to build knowledge processes that could effectively support transitions towards more sustainable practices [23]. In other words, while we could describe the knowledge systems of our case studies, it was only by looking at the governance of these knowledge systems that we could start to explain how they actually came about or why they worked in the ways that they did. There seemed to be a middle layer, in between project-based knowledge management recommendations for improving communication and learning [28] or organisational recommendations regarding the importance of boundary organisations [27]; and analyses that address broader social, cultural and political aspects of knowledge [6,29], that was relatively un-developed. This middle layer was concerned with the institutional 'rules of the game' [30] that shaped the possibilities and choices available to decision-makers at organisational and project scales. Within that project, we had limited scope to develop these ideas further. In the intervening years, however, the term "knowledge governance" has emerged in a range of contexts and academic literatures to address this institutional layer—but not, by and large, in sustainable development (although other similar concepts have been used, which I will discuss shortly). Perhaps concepts that are gaining traction outside the sustainability domain can help to shed light on the persistence of the knowledge-action gaps identified earlier.

In this review I aim to see whether work conducted under the auspices of the term knowledge governance can offer new insights into the institutional and organisational challenges of sustainability, with regard to strengthening relationships between knowledge

and action. I seek to answer the question: can inter-disciplinary literature on knowledge governance contribute to understanding and analysing the institutional knowledge-based dimensions of sustainable development? I will first outline what is meant by knowledge governance, and how it relates to other knowledge-based concepts that have currency in sustainable development literature. I will then present a model of sustainability that highlights the foundational role of knowledge as proposed by Nilsson et al. [1], as a framework for analysing the literature. I will then review literature that discusses and develops the concept of knowledge governance in relation to private sector management and public sector regulation and legal frameworks. From this review I will return to Nilsson et al.'s model and suggest ways in which the knowledge governance literature may contribute to understanding and analysing the relationships between governance and knowledge for sustainable development.

2. What is Knowledge Governance?

Knowledge and governance are both contested terms with various definitions. Here, following our original project, I define knowledge simply as justifiable belief (where different forms of knowledge reflect different justifications) [8], and governance as a "system of formal and informal rules, rule-making systems, and actor-networks at all levels of human society (from local to global) that are set up to steer societies…" [31]. The essential proposition of knowledge governance is that the ways we conduct or engage in knowledge processes (such as creating, sharing, accessing, and using) are subject to formal and informal rules and conventions that shape our decisions and actions, and that these can be manipulated towards defined goals [32].

The different disciplinary contexts in which the specific concept of knowledge governance has been developed offer various definitions or interpretations of this broad idea. In the context of organisational economics, Foss [33] defines his "knowledge governance approach" as seeking to match knowledge transactions (or processes) with governance mechanisms, with a view to maximising economic efficiency. In relation to public problem-solving, Gerritsen ([34] p. 605) defines knowledge governance as "…the intentional achievement of societal and policy change through the purposeful production and dissemination of knowledge." Similarly, Burlamaqui describes knowledge governance as an approach that seeks "…to understand the interaction among knowledge production, appropriation and diffusion and, from a public policy/public interest point of view, to open up the space for a set of rules, regulatory redesign and institutional coordination which would favor the commitment to distribute (disseminate) over the right to exclude" ([35] pp. 4–5). These definitions point to

two distinct sets of concerns that sit rather uncomfortably under the banner of "knowledge governance"—from the economic view, a means to improving efficiency and maximising return through understanding, designing and deploying knowledge governance mechanisms and tools; and from the public policy point of view, as a base for re-conceptualising the public interest and promoting societal transformations.

The implications and limitations of these perspectives will be examined in the next sections. For now, however, there are two key points to be made. First, importantly for the purposes of this review, knowledge governance relates to the 'institutional layer' mentioned earlier. It is broader in scope than knowledge management [32], which sits within the domain of projects and organisations, and is concerned with the institutional structures, rules and norms that enable or constrain knowledge management decisions. As Gerritson et al. ([34] p. 605) have written, "whereas knowledge management focuses on the management of the specific processes of knowledge production, like making knowledge questions explicit, organizing funding or sharing knowledge in workshops, knowledge governance is about engaging actors in innovative ways of solving societal issues". An illustration of the distinction is the often-heard tension between researchers understanding the importance of collaborative research agenda-setting with communities and co-production of knowledge (a way of organising and managing knowledge processes); but sitting within academic institutions that reward disciplinary focus and publication in academic journals (institutional rules and norms that devalue and divert effort from collaboration and co-production) (see, for example, Wiek et al. [36]). Knowledge governance as conceptualised here is concerned primarily with the broader scale of institutional rules and norms. Second, knowledge governance is regarded here as both a noun and a verb. As a noun, it is a description of existing phenomena, seeking to shine an analytical spotlight on the range of governance structures that already shape our knowledge processes in relation to sustainability, but are often obscured or subsumed by more tangible concerns. As a verb, knowledge governance is a suite of actions that may re-design or re-formulate these processes, towards sustainability-related goals.

Knowledge governance as a specific concept has not be widely used in sustainability-related domains, but has strong resonance with a number of areas such as post-normal science [37], sustainability science [10,4] Mode-2 knowledge production [38,39], adaptive governance [18,20] and social-ecological systems analysis [17]. Each of these areas emphasises the importance of collaborative knowledge construction for addressing complex problems, the crucial role of reflexivity and learning in the face of uncertainty, and the need for transdisciplinary, problem-focused knowledge strategies. The origins of this work, as outlined in the introduction, came from a study that was

situated in the domain of sustainability science. A central concern of sustainability science has been to overcome the perceived 'gap' between knowledge and action [4]. The apparent intractability of shifting knowledge-based processes to models and practices that are better suited to tackling complex sustainability problems [9,12,40] is the area this review is intending to inform. The key point here is that this review focuses solely on the governance of knowledge processes, not on the role of knowledge in the governance of other issues related to sustainability (such as water, forests, energy etc). By drawing on literatures outside the more common sustainability parameters, I hope to complement the work that addresses knowledge processes related to sustainability science.

3. Sustainable Development: Knowledge Foundations

The potential connection between knowledge governance and sustainability can be framed in many ways. There are many definitions and constructs of sustainable development that have emerged since the popularisation of the term in 1987, and it is not possible to outline them here (but see, for example, Hopwood et al. [41]). In this review I draw on a model of sustainability proposed by Nilsson et al. [1] that was presented as a framework for sustainable development goals. It is particularly well suited to the purposes of this review as it specifically places both knowledge and governance as foun-

dations for sustainable development. In the 'layer cake' diagram developed by Nilsson et al. (see Figure 1), they present three nested "tiers" of the sustainability agenda—human wellbeing, resource base management, and global public goods—that represent the ultimate goals of sustainable development. These tiers are applied across multiple "enabling goals", of which capacity and knowledge form the base layer, and institutions and governance form the layer above (see Figure 1). Analysis can then be conducted for a range of sectors ("slices"), relating each of the three nested tiers, across all four layers, in relation to the specific sector (in their paper they illustrate with the energy sector).

I will use this framework to analyse the knowledge governance literature presented in the next sections. Specifically, I will draw out whether and how the perspectives covered offer insights relevant to the tiers of human well-being, resource-base management; and global public goods. Nilsson et al.'s conceptualisation offers a clear role for analysing the governance dimensions of capacity and knowledge—essentially, the interplay between the two base layers, indicated by the dashed line in Figure 1. I do not argue that knowledge governance is the only resource needed for such a task —a full understanding of the capacity and knowledge dimensions of sustainable development and their relations to governance will require a broader scope than this. It is, however, a useful way to structure the following review that makes a ready connection to a relevant sustainability framework.
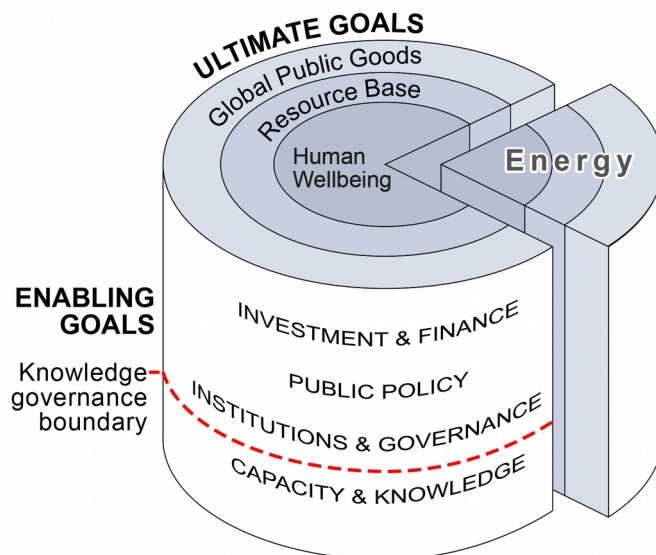

Figure 1. Sustainable development framework: three tiers of ultimate goals and four layers of enabling goals. Knowledge governance sits at the dashed line between the two base layers. Adapted from Nilsson et al. [1].

4. Review Methodology

The methodology for the review was to conduct a keyword text search for the string "knowledge governance" in the academic database SCOPUS, and the book catalogues of the National Library of Australia and the Australian National University, cross checked

against the US Library of Congress. Titles, keywords and abstracts were included. The review focused exclusively on the use of knowledge governance as a single phrase, so all returns that were revealed as "knowledge, governance" or similar were rejected. Computer science literature, where knowledge governance has a technical meaning, was also rejected. For

academic publications, only peer-reviewed material was included. Where keywords indicated knowledge governance but the phrase was not used in the title or the abstract of an article, it was rejected. Books with "knowledge governance" in the title were included, those without were examined for relevance in descriptions provided and/or table of contents.

This search strategy generated 47 articles and 3 books. They were grouped into private sector perspectives (31 articles and 1 book); public sector perspectives, including legal, policy and socio-political areas (15 articles and 3 books). Articles appear to demonstrate a growing interest and use of the term knowledge governance, from 1 article in 2001 and 2002, to 13 articles in 2013. Interestingly, for all the overlaps between well-established sustainability-related areas of inquiry described in the previous section, only two articles from this sample specifically related the term "knowledge governance" to sustainability. One of these [23] was developed from the original knowledge systems project mentioned in the introduction.

Each of these articles and books were analysed with a view to how they may inform the three nested sustainability goals of human well-being, resource base management, and global public goods. They were grouped into private and public sector perspectives; as indicted in the section outlining definitions of knowledge governance, these two literatures were quite distinct in their fundamental approach to knowledge governance, and so were best addressed separately.

5. Private Sector Perspectives

As indicated in the previous section, knowledge governance has received considerable academic attention in the private sector context. Early work by Grandori [42] drew linkages between knowledge and governance, with a particular emphasis on mechanisms for governing (setting institutional rules, incentives and processes) knowledge management activities. This was followed up by Foss and colleagues in the organisational economics context [32,33,43]. Foss's development of the concept [33] is tied to the private sector context, most clearly by using economic efficiency as the criterion by which to examine and assess knowledge governance. Foss presents an analytical approach that articulates how to go about investigating and analysing knowledge governance. He writes that knowledge governance "starts from the hypothesis that knowledge processes (i.e. the creation, retention and sharing of knowledge…) can be influenced and directed through the deployment of governance mechanisms, in particular the formal aspects of organization that can be manipulated by management, such as organization structure, job design, reward systems, information systems, standard operating procedures, accounting systems and other coordination mechanisms" [33]. These are described

as critical antecedents to the conduct of knowledge management processes. However, the primary concern of the knowledge governance approach proposed by Foss is to examine these organizational or institutional characteristics in relation to their effects on individuals' behaviour and choices. In Foss's words: "governance mechanisms are, of course, deployed in the belief that influencing the conditions of actions…in a certain manner will lead employees to take those decisions… that, when aggregated…lead to favourable organizational outcomes" ([33] p. 36). Important to note here is that these governance mechanisms are seen as the product of deliberate "deployment", in other words, they are not taken as given features of an institutional environment, but as structures and rules put in place to achieve certain goals.

Michailova and Foss's work [32], combined with that of Grandori [42], laid the foundations for a range of cases that developed the concept of "knowledge governance mechanisms (KGMs)". This work applied the knowledge governance concept to learn how different approaches to knowledge-based processes and relationships enhanced (or didn't enhance) firm creativity, innovation and ultimately, profitability. One case showed that mechanisms to enhance knowledge sharing based on a concept of transactions can actually increase individuals' hostility towards knowledge sharing, while those based on commitment were more successful [44]. Another [45] highlighted how knowledge governance can help firms organise to identify 'valuable' problems and search efficiently for their solutions. They argued that complex, ill-structured problems require very different governance arrangements than comparatively simple problems, where authority-based hierarchies become less efficient at finding solutions, the more complex the problems become. Similarly, a case study of a large, complex aerospace R&D collaboration [46] concluded that in complex cases knowledge governance may be more effective the more flexible it is. Rather than seeking the 'best' knowledge governance mechanisms, the authors suggest knowledge governance should adapt as the innovation process proceeds. This resonates strongly with adaptive governance approaches to complex social-ecological systems.

Research in China has examined knowledge governance in relation to the guanxi effect, the complex networks of interpersonal obligations and commitments that characterise Chinese business relations [47]. The authors found that guanxi partly mediated the relations between knowledge governance strategies and knowledge sharing actions. This highlights that cultural norms can play an important role in knowledge governance.

The private sector literature shows that active knowledge governance is relatively new, with only a small amount of empirical testing and theory development. It does, however, highlight some key features of knowledge governance in relation to the 3 tiers of sustainability goals. First, even at the scale of firms

and businesses, knowledge governance operates within socially and culturally shaped contexts. The role of interpersonal networks and individual agency remains important, but embedded within broader institutional norms. Second, the private sector interest in knowledge governance stems from seeking ways to enhance knowledge creation and to best capitalise on it. In the organisational economics context, this is driven by enhancing efficiency and comparative advantage; in the sustainability context, it can help to foster new solutions to natural resource-base challenges. The private sector literature suggests that actively deploying knowledge governance mechanisms can help foster knowledge creation and innovation. Third, the private sector knowledge governance perspective has started to make inroads on frameworks and analysis to help practitioners choose between different knowledge-based processes, based on different kinds of problems. More complex problems of sustainability may require quite different knowledge governance from simple problems.

6. Public Sector Perspectives

The public sector, legal and socio-political perspectives take a more critical approach to understanding and influencing knowledge governance than the private sector. While the private sector emphasis was largely on "mechanisms" to enhance knowledge processes and practices, the public sector perspective more commonly examines existing legal and socio-political knowledge governance through a critical lens. The public sector approach looks predominantly at the public regulation of private sector activity, from a perspective of protecting the public interest.

Knowledge governance in this context examines the tensions inherent in the need to protect 'private' knowledge as an asset to encourage innovation, alongside the public interest in accessible knowledge and the benefits from such innovations. In a major study of patent law, Drahos demonstrates the inequality of the 'global' knowledge system that is dominated by a small number of large patent offices [48]. He argues that their ability to create a knowledge governance system that favours the interests of transnational corporations is extended through 'technocratic trust', assisting developing countries to establish rules and procedures that favour the same groups.

In another major contribution drawing from evolutionary economics, patent law and other intellectual property regulation, the edited volume by Burlamaqui et al., Burlamaqui [35] places knowledge governance as an approach for re-thinking innovation and creativity, and how it may best be fostered in societies increasingly characterised by open source, inclusive knowledge practices. They are concerned with the question "how should government-issued intellectual property rules and regulations interact with competition policies, publicly funded R&D and other forms of technology policy in order to help craft and govern socially inclusive development strategies?" ([35] p. 6). They highlight the "tension and potential trade-off between private interests and the conception of knowledge as a global public good" ([35] p. 10). This trade-off relates directly to the sustainability framework and will be returned to later. In a later chapter in the same volume, Wilbanks and Rossini [49] use knowledge governance to shed light on why academia has been relatively slow to embrace distributed innovation such as open source publishing and wiki-style communications: "rewards, incentives and metrics for academic professionals are deeply tied to print-based metrics like citations, references and impact factors. The existing systems of knowledge governance and credit allocation are not well aligned with a distributed knowledge creation environment, and the kind of authority rewarded in academia (typically resulting from award of advanced degrees) is not always the same kind of authority rewarded in a distributed knowledge system". These studies point to the direct interplay between knowledge governance and creativity, innovation, access and sharing.

Lemmens [50] works through these issues in a critical analysis of how regulatory and legal structures shape the knowledge governance landscape in development and provision of new pharmaceutical drugs. She argues that the current knowledge governance arrangements favour industry to the detriment of populations who are excluded from the benefits of pharmaceutical discoveries due to proprietary law and regulation. She goes on to suggest that human rights obligations may be leveraged to challenge the existing governance of pharmaceutical knowledge, drawing particularly on the formalised human right to benefit from scientific progress. In an argument highly relevant to the sustainability framework, she contends that pharmaceutical knowledge should be regarded as akin to a public good, but that the global nature of knowledge production limits national capacities to regulate how that knowledge is shared or applied. Taking a human rights perspective highlights the rights of individuals to be able to exercise informed choice in relation to their health, and the role of knowledge governance in allowing or preventing such informed choice.

At the less legalistic end of the socio-political spectrum knowledge governance is related to the concept of "knowledge politics" described by Stehr as "strategic efforts to move new scientific and technical knowledge, and thereby the future, into the centre of the cultural, economic and political matrix of society" ([51] p. X). This edited volume analyses knowledge-related legal and policy processes from the perspective of broader social, political and philosophical agendas. For example, Fuller argues that the thrust of the concept of knowledge governance (as opposed to knowledge management or government) indicates a

collective and conscious endeavour that has autonomy from management and government, and hence that 'knowledge-bearing institutions' such as universities play a special role in self-regulating the governance of knowledge [52]. This has indeed played out in controversies over science, such as the so-called "climategate" scandal, where universities and related academic institutions sought to both defend and reform the governance of academic knowledge in response to external challenges [53].

Taking a less regulatory approach, Gerritsen et al. propose knowledge governance can be regarded as a form of governance, like 'network governance' or 'adaptive governance', rather than the governance *of* knowledge [34]. These authors see knowledge governance as an avenue for social change (see definition earlier). This leads them to identify a set of principles for knowledge governance such as self-organisation, transdisciplinary knowledge production, social learning, reflexivity and boundary management. Interestingly, these principles share many characteristics with approaches to sustainability science [54–56], although this connection is not made explicitly by Gerritsen et al. Their approach highlights the importance of learning as a fundamental 'knowledge process', a point that was rare in the previous studies that favoured terms like 'knowledge creation and sharing', but relates to the substantial sustainability literature on social learning [57]. In their application of their conception of knowledge governance to a case study of Dutch farmers, they highlight the importance of a collaborative approach to innovation and change, but also that they encountered resistance to social change based on entrenched views and habits of the communities involved.

In the first of the two studies in this review to directly relate knowledge governance to sustainability, Manuel-Navarette and Gallopìn [23] apply the concept analytically to agricultural research in Argentina. They document how a particular research agency transformed its knowledge-based processes from a simple, linear model of technology transfer to more complex knowledge governance arrangements that drew on a network of public and private actors, including universities and farmers' organisations. This network supported a highly effective strategy to promote no-till agricultural practices, and contributed to the rapid adoption of this method, from 2% to 66% of cultivated area between 1984 and 2006 (in 2006 the world average area of no-till cultivation was 6%). They highlight the ways in which a shift from a 'vertical' knowledge governance structure to a more 'horizontal' network arrangement increased the knowledge flows around no-till agriculture, and suggest that the development of effective public-private partnerships to facilitate these knowledge flows were crucial. The second sustainability-related study [58] examined how collaborative sustainability research approaches sought to include local knowledge on water management, but prevailing academic conven-

tions led to that knowledge being aggregated and standardised to conform to conventional standards of "epistemic authority", thereby losing its complexity and nuance.

The variety of perspectives, theoretical developments and applications shows that knowledge governance as a concept reflects its multiple origins, but also indicates a core set of ideas that remain reasonably consistent—enthusiasm for opportunities to design and manipulate knowledge processes for desired outcomes, coupled with an understanding of the broader constraints of the socio-political knowledge governance landscape. Both public and private sector perspectives demonstrate that existing knowledge governance arrangements, which are often embedded in broader institutional frameworks such as performance reward systems, economic imperatives, commercial law, or scientific norms, can impede or hinder the achievement of those goals. Understanding existing constraints imposed on knowledge processes, as well as strategies and institutional interventions for improving them, may hold considerable promise for addressing the "persistent gap" between knowledge and action for sustainability. This is where we now turn.

7. Implications of Knowledge Governance for Sustainable Development

In this section I will analyse the points that emerged from the previous review in relation to the three tiers proposed by Nilsson et al.: human well-being, resource-base management and global public goods.

7.1. Human Wellbeing

How might knowledge governance contribute to human wellbeing? In presenting well-being in their framework, Nilsson et al. express the importance of wellbeing as an individual, rather than an aggregate pursuit: "opportunity for each individual to pursue wellbeing and freedom". Dasgupta, cited in Nilsson et al. [1], included 'knowledge' as one of the determinants of wellbeing. The role of knowledge governance with regard to human well-being can therefore be regarded as facilitating opportunity and access to the knowledge-based processes that enable wellbeing.

The literature reviewed here offers some insights into the relations between institutions and governance and knowledge in the context of individual human wellbeing. There are clear wellbeing benefits from ensuring equitable access to the products generated by knowledge intensive practices such as research. Lemmens' [50] argument in relation to access to pharmaceuticals (knowledge-intensive products) is that access to these products enhances wellbeing through health. However recognising the right to knowledge itself, as a direct determinant of wellbeing, suggests that opportunities to learn and make

informed decisions is a broad concern of sustainability in its own right. The trade-offs between proprietary knowledge and public access speak directly to the role of knowledge governance in ensuring citizens have the freedom and opportunity to pursue wellbeing through access to knowledge. The example of no-till farming uptake demonstrates the specific opportunities that can be opened up by reforming knowledge governance institutions to support collaborations and connections between farmer associations, research institutions and producers. Evaluating whether and how access to knowledge contributes to wellbeing may be a promising area for sustainability research and practice.

7.2. Resource-base Management

As it becomes more urgently recognised that complex sustainability challenges require creative solutions [59], it would seem that knowledge governance to facilitate creativity and innovation in resource-use efficiency and transitions away from resource-intensive development is needed [21]. The literature confirms the sustainability science view that knowledge-based approaches that support collaboration, connections and learning appear to be better suited to addressing complex problems. More open, networked, horizontal approaches to organising knowledge processes facilitate collaboration and learning across interconnected groups. Within both public and private sector applications of knowledge governance, there was a recognition that protective approaches to knowledge that are 'hostile' to sharing stifle the development of more efficient outcomes. The private sector literature highlighted that knowledge governance can be used at organisational scales to encourage innovation and knowledge sharing, although empirical work in this area is in early stages.

At a broader scale, the public sector analyses showed knowledge governance shapes incentives or disincentives for creativity and innovation. Yet it also placed knowledge governance actions within a broader social and institutional context that remains largely hostile to knowledge sharing. Finding the most productive balance between openness for innovation and creativity and the privatisation of knowledge for profit ('inclusive' versus 'exclusive', to use Burlamaqui's [35] terms) is a core knowledge governance challenge that flows through legal and socio-cultural avenues to permeate sustainability. From resistance to collaborative

approaches by communities culturally embedded in existing knowledge practices to paper-bound academic reward systems and transnational corporations that exercise sophisticated strategies to maximise their gain from intellectual property, the broad context continues to favour exclusion over inclusion. Sustainability efforts to foster innovation and creativity through collaboration and openness should be understood to be struggling against these larger forces.

7.3. Global Public Goods

Finally, in relation to global public goods, the concept of knowledge as a global public good appeared in the literature both directly and indirectly. As noted in the Public Sector Perspectives section, Burlamaqui described the tension between knowledge for private gain and knowledge as a global public good. The overall struggle to reassert knowledge in the public interest across a wide range of social issues noted above, places sustainability efforts to support more collaborative approaches in a context of much broader political tension over what knowledge governance should be aiming for.

This issue has received attention in relation to sustainability. In their examination of whether current intellectual property rights help or hinder the production and dissemination of knowledge to address global sustainability challenges, Claude Henry and Nobel Prize-winning economist Joseph Stiglitz conclude that "the current global intellectual property regime, as well as serving the interests of the international electronic and pharmaceutical companies, is an impediment to the kind of global cooperation necessary in so many arenas, especially in development, global health, and even addressing the problems of global warming. Nor is it good for global science" ([59] p. 245). While they do not use the phrase "knowledge governance" (and hence were excluded from the previous sections of this review) their arguments relate strongly to those of the public sector knowledge governance perspective outlined earlier. They argue for a more holistic view of innovation systems that reform intellectual property laws and open up to other types of knowledge governance that stimulate and support innovative solutions to global sustainable development challenges.

The findings from this review in relation to the three tiers of Nilsson et al.'s model of sustainable development are summarised in Figure 2.

Figure 2. Knowledge governance for sustainable development—a framework for future research.

Analysing the findings of the review in relation to the layer cake framework demonstrates not only that knowledge governance is relevant to sustainable development, but also that it relates across the three scales of Nilsson et al.'s [1] model. From individual wellbeing and rights to organisational and institutional structures, through to global scale innovation systems, the knowledge governance literature presents a multi-scalar suite of issues. It helps to explain the 'persistence' of science-policy gaps [9], as efforts to overcome these gaps at project or organisational scales come into contact with broader social, cultural and legal systems that favour exclusion and private gain over inclusion and collaboration. This framework offers guidance to further examine this broader context of knowledge governance in relation to sustainability.

8. Limitations and Adaptations

In terms of the methodology of the review, there are immediate limitations in the scope of the material. For example book chapters that sit within volumes that did not have 'knowledge governance' in the title were not revealed through the search strategy. Material that was conceptually related but did not use the specific term of knowledge governance was also excluded, which helped to focus the study but meant that a wide range of associated topics were not covered. Grey literature was also excluded.

Conceptually, this review was deliberately limited to consideration of knowledge governance as a stand-alone concept. There are, of course, many overlaps with domains of sustainability-related research that are close but only summarily alluded to, such as adaptive governance and science and technology studies. Similarly, there is a fuzzy line between knowledge governance and knowledge management, which was particularly evident in the private sector literature. Hence one might argue that there are plenty of equivalent strategies or practices in the sustainability domain that speak to this fuzzy boundary. This is not

denied here—as a researcher involved in science-governance connections I am aware of many institutional and organisational innovations that have been made to facilitate better relationships between knowledge and practice [8,22]. Yet these are typically not presented as knowledge governance interventions or strategies. The point of this review was to examine specifically what knowledge governance as a concept might add to these areas of scholarship and practice.

There are likewise other related issues that readers may feel should be incorporated into the model presented in Figure 2 (education, empowerment and participation, de-coupling, adaptation come to mind, and there are no doubt many more). Incorporating these in any meaningful way would have been counter to the aim of keeping the governance of knowledge front and centre. Hopefully, this review may encourage others to examine more specific connections between established sustainability concepts and issues and the governance of knowledge processes.

9. Conclusion

The aim of this review was to answer the question: "can interdisciplinary knowledge governance literature contribute to understanding and analysing the institutional knowledge-based dimensions of sustainable development?" By analysing the existing knowledge governance literature through the construct of Nilsson et al.'s sustainability model [1], I have shown that knowledge governance offers a conceptual basis from which to think critically about knowledge processes as foundational to sustainable development, and to consider how they are shaped and influenced by formal and informal institutions. By bringing the governance of knowledge to the fore (rather than regarding knowledge as an input to other governance goals), a range of opportunities and constraints have emerged. Far from there being a 'gap' between knowledge and action, this review suggests that this space is thick with institutional arrangements that have little to do with

sustainability, but still strongly shape the knowledge-action landscape. This includes current formal and informal rules that tend to favour exclusion over inclusion, convention over innovation, and knowledge as a private asset rather than a human right.

The opportunities for enhancing sustainability outcomes through the knowledge governance domain are many [59]. From the deployment of knowledge governance mechanisms for greater efficiencies, to organisational and institutional reforms for enhanced innovation, to considerations of access to knowledge as a human right or a global public good, it brings the many rules shaping the dynamics of knowledge creation, sharing, access and use into consideration as a fundamental issue in sustainable development. It demonstrates that researchers may be able to develop knowledge governance strategies that address persistent challenges in sustainability, especially around access, innovation, and the re-conceptualisation of knowledge as a global public good. But more importantly, it places the challenges of doing so in a broader governance context.

Ultimately, the usefulness or otherwise of the concept of knowledge governance will be demonstrated in its application as guiding theoretical framework for sustainability research and implementation. Quantitative research could design metrics for assessing and comparing the sustainability impacts of different knowledge governance arrangements, as has been done in the private sector [47]. Empirical case studies could test the effects of new institutional arrangements on knowledge governance, and gather and compare different strategies for brokering or designing knowledge processes in the light of existing governance arrangements. Qualitative research could identify key constraints and facilitators to the effective application of knowledge either within or across organisations or sectors, considering the wide range of knowledge governance arrangements that affect practice. Such research would need to emphasise the practical utility of knowledge governance: has it helped researchers and practitioners to identify new interventions towards sustainability? Has it helped to enhance their functionality or performance? Has it helped people to navigate the difficult terrain that connects knowledge and action, and to generate new options for reconfiguring that landscape? Positive answers to these questions would support the rationale for viewing knowledge governance as underpinning efforts to achieve sustainable development, and start to build theoretical and practical tools to enhance these processes.

References

1. Nilsson M, Lucas P, Yoshida T. Towards an Integrated Framework for SDGs: Ultimate and Enabling Goals for the Case of Energy. Sustainability. 2013;5(10):4124–4151.

2. Bocking S. Nature's Experts: Science, Politics, and the Environment. New Brunswick, NJ, USA: Rutgers University Press; 2004.

3. Jasanoff S, Long Martello M, editors. Earthly Politics: Local and Global in Environmental Governance. Cambridge, MA, USA: MIT Press; 2004.

4. Clark WC, Dickson NM. Sustainability science: The emerging research program. Proceedings of the National Academy of Sciences of the USA. 2003;100(14):8059–8061.

5. Cash DW, Clark WC, Alcock F, Dickson NM, Eckley N, Guston DH, Jaeger J, Mitchell RB. Knowledge systems for sustainable development. Proceedings of the National Academy of Sciences of the USA. 2003;100(14):8086–8091.

6. Jasanoff S. A New Climate for Society. Theory, Culture & Society. 2010;27(2–3):233–253.

7. Hulme M. Problems with making and governing global kinds of knowledge. Global Environmental Change. 2010;20(4):558–564.

8. van Kerkhoff L, Lebel L. Linking Knowledge and Action for Sustainable Development. Annual Review of Environment and Resources. 2006;31(1):445–477.

9. Kirchhoff CJ, Carmen Lemos M, Dessai S. Actionable Knowledge for Environmental Decision Making: Broadening the Usability of Climate Science. Annual Review of Environment and Resource. 2013;38(1):393–414.

10. Board on Sustainable Development, National Academy of Sciences, editors. Our common journey: A transition toward sustainability. Washington, DC, USA: National Academy Press; 1999.

11. UNEP. 21 Issues for the 21 Century: Results of the UNEP Foresight Process on Emerging Environmental Issues. 2012. Available from: http://www.unep.org/publications/ebooks/foresightreport/ (accessed on 22 October 2013).

12. Glaser G, Bates P. Enhancing Science-Policy Links for Global Sustainability. 2011. Available from: http://www.stakeholderforum.org/fileadmin/files/ICSU%20Science%20Policy%20Final.pdf (accessed 2 December 2013).

13. Inglis JT, editor. Traditional Ecological Knowledge: Concepts and Cases. Ottawa, Canada: IDRC; 1993.

14. Knudtson P, Suzuki D, editors. Wisdom of the Elders: Native and Scientific Ways of Knowing about Nature. Vancouver, Canada: D&M Publishers; 2006.

15. Gómez-Baggethun E, Reyes-García V, Corbera E. Traditional Ecological Knowledge and Global Environmental Change: Research findings and policy implications. Ecology and Society. 2013;18(4)Art72.

16. Reed MS. Stakeholder participation for environmental management: A literature review. Biological Conservation. 2008;141(10):2417–2431.

17. Ostrom E, Cox M. Moving beyond panaceas: A multi-tiered diagnostic approach for social-ecological analysis. Environmental Conservation. 2010;37(4):451–463.

18. Folke C. Social-ecological systems and adaptive governance of the commons. Ecological Research. 2006;22(1):14–15.

19. Rijke J, Brown R, Zevenbergen C, Ashley R, Farrelly M, Morison P, van Herk S. Fit-for-purpose governance: A framework to make adaptive governance operational. Environmental Science & Policy. 2012;22:73–84.

20. Olsson P, Gunderson LH, Carpenter SR, Ryan P, Lebel L, Folke C, Holling CS. Shooting the Rapids: Navigating Transitions to Adaptive Governance of Social-Ecological Systems. 2006;11(1)Art18.

21. Cornell S, Berkhout F, Tuinstra W, Tàbara JD, Jäger J, Chabay I, de Wit B, Langlais R, Mills D, Moll P, Otto IM, Petersen A, Pohl C, van Kerkhoff L. Opening up knowledge systems for better responses to global environmental change. Environmental Science & Policy. 2013;28:60–70.

22. van Kerkhoff L, Szlezák NA. The role of innovative global institutions in linking knowledge and action. Procdings of the National Academy of Sciences of the USA. 2010, EarlyEdition. pp. 1–6.

23. Manuel-Navarrete D, Gallopín GC. Feeding the world sustainably: Knowledge governance and sustainable agriculture in the Argentine Pampas. Environment, Development and Sustainability. 2011;14(3): 321–333.

24. McCullough EB, Matson PA. Evolution of the knowledge system for agricultural development in the Yaqui Valley, Sonora, Mexico. Proceedings of the National Academy of Sciences of the USA. 2011, Early Edition.

25. Jacobs K, Lebel L, Buizer J, Addams L, Matson P, McCullough E, Garden P, Saliba G, Finan T. Linking knowledge with action in the pursuit of sustainable water-resources management. Proceedings of the National Academy of Sciences of the USA. 2010, EarlyEdition. pp. 1–6.

26. Buizer J, Jacobs K, Cash D. Making short-term climate forecasts useful: Linking science and action. Proceedings of the National Academy of Sciences of the USA. 2012, Early Edition.

27. Clark WC, Tomich TP, Van Noordwijk M, Guston D, Catacutan D, Dickson NM, McNie E. Boundary work for sustainable development: Natural resource management at the Consultative Group on International Agricultural Research (CGIAR). Proceedings of the National Academy of Sciences of the USA. 2011, Early Edition.

28. van Kerkhoff L, Szlezák N. Linking local knowledge with global action: Examining the Global Fund to Fight AIDS, Tuberculosis and Malaria through a knowledge system lens. Bulletin of the World Health Organization. 2006;84(8):629–635.

29. Miller CA. Climate science and the making of a cglobal political order. In: Jasanoff S, editor. States of knowledge: The Co-Production of Science and Social Order. Abingdon, UK and New York, NY, USA: Routledge; 2004. pp. 46–66.

30. Young OR. The institutional dimensions of environmental change: Fit, interplay, and scale. Cambridge, MA, USA: MIT Press; 2002.

31. Biermann F, Betsill MM, Gupta J, Kanie N, Lebel L, Liverman D, Schroeder H, Siebenhüner B. Earth System Governance: People, places and the planet. 2009. Available from http://www.earthsystem governance.org/publications/science-plan (accessed on 21 November 2013).

32. Michailova S, Foss NJ. Knowledge governance: Themes and questions. In: Foss NJ, Michailova S, editors. Knowledge governance: Processes and Perspectives. Oxford, UK: Oxford University Press; 2009. pp. 1–24.

33. Foss NJ. The Emerging Knowledge Governance Approach: Challenges and Characteristics. Organization. 2007;14(1):29–52.

34. Gerritsen AL, Stuiver M, Termeer CJAM. Knowledge governance: An exploration of principles, impact, and barriers. Science and Public Policy. 2013;40(5):604–615.

35. Burlamaqui L. Knowledge Governance: An Analytical Approach and its Policy Implications. In: Burlamaqui L, Castro AC, Kattel R, editors. Knowledge governance: Reasserting the public interest. London, UK and New York, NY, USA: Anthem Press; 2012. pp. 3–26.

36. Wiek A, Withycombe L, Redman C, Mills SB. Moving Forward on Competence in Sustainability Research and Problem Solving. Environment: Science and Policy for Sustainable Development. 2011;53(2): 3–13.

37. Funtowicz S, Ravetz R. Science For The Post-Normal Age. Futures. 1993;25:739–755.

38. Gibbons M, Limoges C, Nowotny H, Schwartzman S, Scott P, Trow M. The New Production of Knowledge: The Dynamics of Science and Research in Contemporary Societies. London, UK: SAGE; 1994.

39. Nowotny H, Scott P, Gibbons M. Re-Thinking Science: Knowledge and the Public in an Age of Uncertainty. Cambridge, UK: John Wiley & Sons; 2001.

40. Bradshaw GA, Borchers JG. Uncertainty as information: Narrowing the science-policy gap. Conservation Ecology. 2000;4(1)Art.7.

41. Hopwood B, Mellor M, O'Brien G. Sustainable development: Mapping different approaches. Sustainable Development. 2005;13(1):38–52.

42. Grandori A. Neither Hierarchy nor Identity: Knowledge-Governance Mechanisms and the Theory of the Firm. Journal of Management and Governance. 2001;5(3–4):381–399.

43. Foss NJ. Knowledge Governance: Meaning, Nature, Origins, and Implications. In: Grandori A, editor. Handbook of Economic Organization: Integrating Economic and Organization Theory. Cheltenham, UK and Northampton, MA, USA: Edward Elgar; 2012.

44. Husted K, Michailova S, Minbaeva DB, Pedersen T. Knowledge-sharing hostility and governance mechanisms: An empirical test. Journal of

Knowledge Management. 2012;16(5):754–773.

45. Heiman B, Nickerson J, Zenger T. Governing Knowledge Creation: A Problem-Finding and Problem-Solving Perspective. In: Foss NJ, Michailova S, editors. Knowledge Governance: Processes and Perspectives. New York, NY, USA: Oxford University Press; 2009. pp. 1–23.

46. Scarbrough H, Amaeshi K. Knowledge Governance for Open Innovation: Evidence from an EU R&D Collaboration. In: Foss NJ, Michailova S, editors. Knowledge governance: Processes and Perspectives. Oxford, UK: Oxford University Press; 2009.

47. Cao Y, Xiang Y. The impact of knowledge governance on knowledge sharing: The mediating role of the guanxi effect. Chinese Management Studies. 2013;7(1):36–52.

48. Drahos P. The Global Governance of Knowledge: Patent Offices and Their Clients. New York, NY, USA: Cambridge University Press; 2010.

49. Wilbanks J, Rossini C. An Interoperability principle for Knowledge Creation and Governance: The role of emerging institutions. In: Burlamaqui L, Castro AC, Kattel R, editors. Knowledge governance: reasserting the public interest. London, UK and New York, NY, USA: Anthem Press; 2012.

50. Lemmens T. Pharmaceutical knowledge governance: A human rights perspective. The Journal of Law, Medicine & Ethics. 2013;41(1):163–184.

51. Stehr N, editor. The Governance of Knowledge. New Brunswick, NJ, USA: Transaction Publishers; 2004.

52. Fuller S. In search of vehicles for knowledge governance: On the need for insitutions that creatively destroy social capital. In: Stehr N, editor. The Governance of Knowledge. New Brunswick, NJ, USA: Transaction Publishers; 2004. pp. 46–71.

53. Heffernan O. "Climategate" scientist speaks out. Nature. 2010;463(860).

54. van Kerkhoff L. Developing integrative research for sustainability science through a complexity principles-based approach. Sustainability Science. 2013;1–13.

55. Lang DJ, Wiek A, Bergmann M, Stauffacher M, Martens P, Moll P, Swilling M, Thomas CJ. Transdisciplinary research in sustainability science: Practice, principles, and challenges. Sustainability Science. 2012;7(S1):25–43.

56. Wiek A, Ness B, Schweizer-Ries P, Brand FS, Farioli F. From complex systems analysis to transformational change: A comparative appraisal of sustainability science projects. Sustainability Science. 2012;7(S1):5–24.

57. Ison R, Blackmore C, Iaquinto BL. Towards systemic and adaptive governance: Exploring the revealing and concealing aspects of contemporary social-learning metaphors. Ecological Economics. 2013;87:34–42.

58. Duncan R. Converting Community Knowledge into Catchment Nutrient Limits: A Constructivist Analysis of a New Zealand Collaborative Approach to Water Management. Nature and Culture. 2013;8(2):205–225.

59. Henry C, Stiglitz JE. Intellectual Property, Dissemination of Innovation and Sustainable Development. Global Policy. 2010;1(3):237–251.