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Co-production of knowledge–action systems in urban sustainable governance: The KASA approach

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ARTICLE INFO

Available online 11 November 2013

Keywords:

Co-production
Knowledge–action systems
Science–policy interface
Sustainability
Urban governance
Social networks
Boundary work
Epistemic cultures
Future visions
Tropical city

ABSTRACT

This paper examines how knowledge–action systems – the networks of actors involved in the production, sharing and use of policy-relevant knowledge – work in the process of developing sustainable strategies for cities. I developed an interdisciplinary framework – the knowledge–action system analysis (KASA) framework – that integrates concepts of the co-production of knowledge and social order with social network analysis tools to analyze existing configurations of knowledge–action systems in the city of San Juan, Puerto Rico, and how these are shaping both what we know and how we envision the future of cities. I applied KASA in the context of land use and green area governance and found that a diverse network of actors are contributing diverse knowledge types, thus showing potential for innovation in governance. This potential is conditioned, however, by various political and cultural factors, such as: (1) actors dominating knowledge about land use are the same ones that control urban land resources, (2) conventional planning expertise and procedures dominate over other alternative ways of knowing; (3) multiple visions and boundary arrangements co-exist in the city, and (4) boundary spanning opportunities limited by assumptions that knowledge and action should be done in distinct spheres of city planning. This study shows that developing adaptive and innovative capacities for sustainability is not solely a matter of harnessing more science, but about managing the politics of knowledge and visions that emerge from complex governance systems.

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1. Introduction

This paper presents the knowledge–action systems analysis (KASA) framework, an approach to examine the complex dynamics of the relationship between knowledge and decision-making. Knowledge–action systems are the networks of actors, their visions and expectations of the future, and the practices and dynamics underlying the production of knowledge to advance specific policies, decisions, and actions related to sustainability (Muñoz-Erickson, 2012).

Although the traditional linear model that separates science and policy is still pervasive in many institutions today, numerous scholars now recognize that this relationship is more complex and distributed (Hegger et al., 2012; Clark et al., 2011; Edelenbos et al., 2011; McNie, 2007; Van Kerkhoff and Lebel, 2006). As Chilvers (2007) has noted “the science–policy interface is being extended to include new actors, new forms of expertise, and new knowledge practices, under conditions of radical uncertainty, contestation and distrust of science in late modern society.” (p. 2991).

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1462-9011/\$ – see front matter. Published by Elsevier Ltd.

<http://dx.doi.org/10.1016/j.envsci.2013.09.014>

A growing literature on ‘knowledge-to-action’ is exploring how to make knowledge systems – or the institutions that harness science and technology for natural resource management – more effective at supporting action in complex and networked political landscapes (Cash et al., 2003; Matson, 2008). A key finding of this research is that knowledge systems are most likely to be effective if they are perceived to be salient, credible and legitimate to stakeholders (Cash et al., 2003). For the most part, however, this literature concerns itself with the interaction of knowledge and action as they meet at the border separating the domains of science and policy. The assumption that scientific knowledge is the primary source of credible knowledge is still central to this literature (Hegger et al., 2012) and rarely is the way in which that science was created, validated, or contested as a knowledge claim questioned. Therefore, the embeddedness of scientific knowledge within larger systems of knowledge, power, and cultural dynamics is largely ignored. Finally, frameworks to analyze these interactions in urban systems are virtually non-existent. Most of the topical areas covered in the literature have focused on climate change, agriculture, and watershed management, to name a few (see McNie, 2007). Yet, nowhere is this challenge more pressing than in urban areas. With nearly 70% of the world’s population expected to live in cities by 2050 (World-watch Institute, 2007) city managers need knowledge and tools to transition to sustainability.

The approach presented in this paper builds upon recent efforts to better understand the relationship between knowledge, power, and culture by drawing insights from interpretative approaches in policy analysis and science and technology studies (STS) (Wessenlin et al., 2013; Jasanoff, 2004). Specifically, I use the framework of the co-production of knowledge and social order as a lens through which to explore the complex co-existence of multiple rationales and expertise (including tacit and experiential), and the reciprocal relationship between these and the visioning, planning, and making of cities. Co-production is here understood as the mutual construction between knowledge and forms of social organi-

zation (Jasanoff and Wynne, 1998). This framework has a broader analytical foci than related frameworks such as knowledge co-production (Pohl, 2008; Roux et al., 2006), joint knowledge production (Hegger et al., 2012), or boundary management (Guston, 2001), which focus on more specific efforts or policy arrangements to produce knowledge collaboratively. In other words, co-production is concerned with the macro societal processes that shape and are shaped by the production of knowledge. The use of the term ‘knowledge-action system’ is meant to capture the co-evolution of these social processes taking place at the broader social system and that serve as the context for the specific dynamics that can be observed in micro efforts or policy programs such as joint-knowledge production.

The paper proceeds in five parts. First, Section 2 reviews the literature addressing the various treatments of knowledge and decision-making and discusses how the co-production framework and KASA approach contribute to this understanding. Next, I illustrate the application of KASA using a case study of land use and green area planning in a complex institutional setting in the city of San Juan, Puerto Rico. In Section 4, I discuss the implications of case study results more broadly in terms of how we should conceptualize knowledge-action systems and the contribution of a co-production lens to the environmental science and policy literature. Section 5 concludes the paper and discusses the utility of the KASA framework to future research.

2. Re-conceptualizing complex knowledge-action systems: a co-production framework

To shift from simple conceptions of science-policy interfaces and two-way knowledge-to-action models (see Fig. 1A), we need systemic approaches to help us capture a more realistic model of knowledge-action systems (see Fig. 1B). Recent developments in the literature on innovation using a systems perspective are instructional to this shift in the

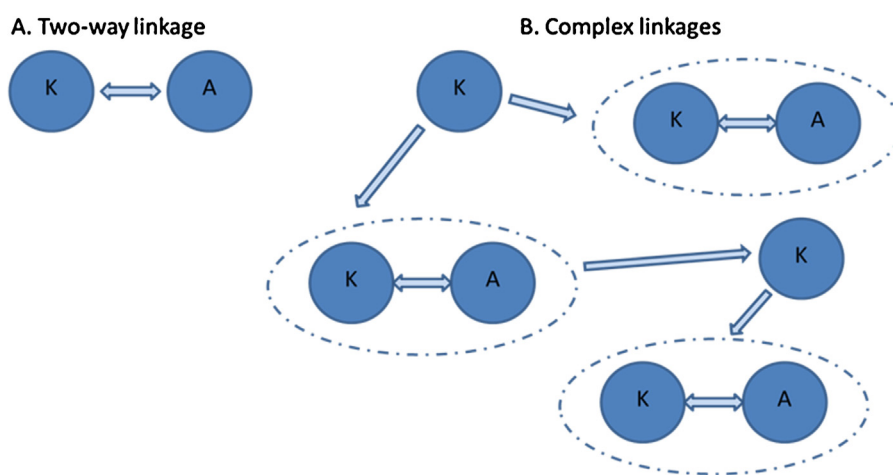


Fig. 1 – Different views of the linkages between knowledge and action for sustainability. (A) is one illustration of how a knowledge system (e.g., climate model) can be linked to action (e.g., reduction in greenhouse gases). (B) shows a more complex landscape of knowledge-action interactions where different configurations of knowledge-action systems co-exist and in which multiple political and epistemic cultures are interacting (reflected by the dashed-lines) (Miller et al., 2010).

conceptualization of knowledge–action systems (see for instance Klerkx et al., 2012; Leeuwis and Aarts, 2011). In particular, studies by Wieczorek and Hekkert (2012) where they apply a coupled structural–functional approach to capture organizational interactions in innovation systems have established that weaknesses or strengths in pre-existing institutional dynamics can shape how innovation evolves in a particular place and time. This literature emphasizes the importance of the broader institutional system to understand particular policy initiatives or projects.

A drawback of the innovation systems approach, however, is that while it considers multiple knowledges beyond just science, knowledge is mostly treated as a neutral resource and not a central force in explaining policy innovation, much as rules, interests, and incentives are. In order to get at the interwoven relationship between knowledge, power, and culture, one must treat knowledge beyond simple statements of truth or fact. A co-production framework treats knowledge as a conglomeration of ideas, beliefs, tacit skills and values that shape what we know. More importantly for sustainability, co-production treats knowledge, including knowledge about nature, not as the exclusive preserve of any particular domain of society (i.e., science), but rather of different policy cultures (i.e., civic-social, bureaucratic-political, economic, and scientific) (Jasanoff and Wynne, 1998). These policy cultures differ in the judgments, reasoning styles, and ways of reviewing policy-relevant knowledge such that they also differ in their expectations and acceptability of social problems (Miller, 2005). Much like other interpretative approaches that examine knowledge production (e.g., Wessenlin et al., 2013), the co-production framework seeks to understand the role of human cognition, cultural discourses and practices, and the social goals and politics surrounding environmental expertise.

Co-production accounts allow for a more focused examination of how knowledge and power dynamics play out in the knowledge–action systems than previous frameworks. This framework gives primary importance to knowledge-in-the-making of different actors because it is understood that social and power dynamics already at work in a given place shape how knowledge is created, transmitted, and used in decision systems (Miller et al., 2010). This is because social processes are involved in knowledge such that its production is a result of the articulation, deliberation, negotiation, and valorization of particular knowledge claims. These dynamics, in turn, influence whose knowledge claims matter and how claims are constructed, evaluated, contested, and sanctioned as knowledge (Jasanoff, 2004). Thus, key to the co-production framework is that there should be no *a priori* assumptions about which actors are knowledge producers and which are knowledge users.

The idiom of co-production then invites an interdisciplinary examination to capture these structural, functional, and cultural elements of knowledge–action systems. By acknowledging that the reality of knowledge–action systems is more like Fig. 1B than Fig. 1A, this framework provides a useful lens with which to understand how complex knowledge–action systems work. To operationalize ideas of co-production, the KASA approach draws from three social science analytical concepts: (1) *social network analysis*, (2) *visions and epistemic cultures* and (3) *boundary work*. KASA employs an

interdisciplinary approach of the case study by combining multiple disciplinary perspectives, as well as inductive and deductive approaches, for a thorough understanding of the case study context and system dynamics (Yin, 1994). This approach allows us to capture the elements for understanding the coupled structural–functional dynamics espoused by innovation systems scholars, but by encompassing concerns of interpretative approaches in the policy and science and technology studies (STS) traditions, it adds crucial political, cultural, and epistemological layers (dashed lines in Fig. 1B).

Social network theory investigates patterns of social relations among actors interlinked through social exchanges, such as information flows, resources, and friendships, among others (Wasserman and Faust, 1994). These interactions give rise to emergent social structures that can be analyzed mathematically in the forms of graphs of nodes (actors) and links (e.g., information flows). Recent studies that have applied social network analysis as a tool to analyze knowledge–power relationships in natural resource management have established that network structures can affect circulation of knowledge and power asymmetries involved in governance (Crona and Bodin, 2010; Muñoz-Erickson et al., 2010). The term *vision* is used here to represent desired future states for the city. Examining visions allows an understanding of the way people think and talk about the future and can be represented in numerous ways such as through scenarios, storylines and images (Wiek and Iwaniec, 2013). The shared ways that diverse groups conceive of the future and their expectations can bring to light the plurality of values trade-offs, uncertainties, and potential conflicts inherent in envisioning the city. Making these visions explicit becomes useful to assess the dominant ideas fueling mainstream planning and development efforts, and thus assess potential conflict among various pathways to sustainability (Leach, 2008). Furthermore, understanding what knowledge, reasoning styles, technologies and practices – *epistemic cultures* – come to bear in the making and communication of these visions provides a window into the rationale and capacities to actualize these visions (Miller et al., 2010). In other words, it is not enough to understand the political motivations or priorities that create these visions. To assess if capacities are available to implement ‘actions’ for sustainability it is also crucial to examine the ways of knowing producing these visions.

Finally, how experts derive their status in contemporary political processes through *boundary work* – or how authority and credibility over knowledge are attributed to that person and distributed across society – has long been a concern to sociologists and historians of science (Gieryn, 1983; Shapin, 1996). Examining the dynamics and practices of boundary work in a knowledge–action system provides a window into how politics of expertise play out in a given place. Boundary work is a term used to describe the tendency to separate science and policy and give the appearance of a rigid boundary between knowledge-making and decision-making as distinct and unconnected human activities, such that scientific expertise maintains its credibility and authority in policy-making (Gieryn, 1983; Jasanoff, 1987). Particularly, examination of boundary work helps explain how expertise is distributed across the system and how power dynamics actually work in the production, sharing, and use of policy-relevant knowledge.

3. Steps in the application of KASA: illustration from the San Juan case study

3.1. Case study: land use change and green areas in the city

Because of its insular nature and high population density, land use is a crucial policy issue for Puerto Rico. In San Juan specifically, urban sprawl and development of green areas along the city's main watershed has become contested issues in the planning and political landscape (Muñoz-Erickson, 2012). Extensive land use development has created a host of social and ecological effects (e.g., water pollution, displacement of upstream communities, and increasing flood risks) that increase the vulnerability of city residents, such as to climate change. Contrary to the mainland U.S., urban planning in Puerto Rico has been at the state (Commonwealth) level until recently in 2009 when San Juan became an autonomous municipality as a result of decentralization of government across the island. However, because municipalities are still large administrative units (similar to counties in the mainland U.S.), cities manage both urban centers and hinterlands, thus conflicts between urban and rural interests over urban development are common throughout Puerto Rico. In response, various city and civic initiatives show promise that the San Juan's vision and structure is re-configuring itself to address these issues and seek more sustainable options. The municipality, for instance, developed a Territorial Ordinance Plan that includes protection of soil and water resources to protect watershed functions as well as re-vitalization strategies for urban cores.

Transitioning to sustainability has been unsuccessful, however, and the city continues to face rampant development (sometimes illegal) of its open spaces and its population continues to be vulnerable to extreme flooding due to unsustainable land use practices. City planners, bureaucrats, and local stakeholders in San Juan have identified failures in the knowledge systems informing planning as a factor impeding their ability to attain sustainable outcomes. I have published elsewhere a more extensive description of San Juan's planning context and detailed accounts of the approach and techniques used in the application of KASA to this city (Muñoz-Erickson, 2012). Here I provide a synthesis of the techniques and results found in San Juan to illustrate how the KASA framework can be applied and what we can learn from its application.

3.2. Steps and tools in the application of KASA

3.2.1. Step 1: knowledge mapping

In a complex governance context as San Juan we need to understand the 'lay of the land' by casting a wide net of actors. I used knowledge mapping with social network analytical (SNA) tools as the first technique to locate, analyze, and visually portray various sources of knowledge in the network of organizations (Chan and Liebowitz, 2006). To gather data I distributed a survey in 2009 to 110 different stakeholder organizations, public and private, working on land use and green area issues identified through existing public lists and

snowball sampling procedures (Bernard, 2006). I used free list methods (Wasserman and Faust, 1994) in which I asked survey participants to list the five organizations they consult with greater frequently to obtain knowledge (information, data, and ideas). Sixty-three organizations responded (57% response rate) and from their responses I created the network using SNA software (Muñoz-Erickson, 2012).

Twenty-six different organizations emerged as sources of knowledge in San Juan's land use and green area governance landscape (Fig. 2). In addition to conventional knowledge-producing organizations, such as academic and governmental research institutions, various other governmental, non-profit, and civic organizations were identified as knowledge sources (nearly a quarter of the sample). Most of these organizations collect their own information or data, suggesting that they have a role as knowledge producers and not just recipients of information. This diverse network is contributing multiple knowledges to the governance system in addition to science, including planning, organizational, legal, and local knowledge. Based on social network theory, a greater diversity of actors and knowledge reflects a potential for multi-scalar creative and innovative capacities to address sustainability.

3.2.2. Step 2: identify central actors and examine knowledge-power relations in the network

Even with a diverse network, it is the structural relationships underlying this diversity that affects the flow and integration of knowledge among actors and their capacities for action (Ernstson et al., 2008). To understand how the network structure affects knowledge flow and integration, this step involved using SNA to analyze actor's (nodes) power position, identify central actors (those with greater number of linkages), and examine how the linkages among them are shaping how knowledge circulates in the system. Using the same network data and software as in step one above, I calculated the number of links a node has as an indicator of dominance over information flow (centrality), the number of unique groups only connected through that individual as an indicator of knowledge brokering (betweenness), and the nodes that are linked with bi-directional ties as an indicator of two-way interaction of knowledge flow (reciprocity) (Brass and Burkhardt, 1993).

Fig. 3 shows the central actors and their links (knowledge exchanges). The network analysis revealed two key findings about the knowledge network in San Juan. First, contrary to expectations, neither the city of San Juan, nor local academic institutions like the University of Puerto Rico, resulted as primary knowledge sources for the network. Instead, they have a secondary role because of their reciprocal relationship with other central actors in the network. The primary central actors, and hence sources of knowledge and brokers of that knowledge, were the main state agencies responsible for land use planning and natural resource management (including the Puerto Rico Planning Board), a federal research organization (International Institute of Tropical Forestry) and a local non-governmental organization (Sustainable Development Initiative). State agencies, however, are not connected to actors at the city level, and to a small extent between each other. This suggests that there are both vertical and horizontal breakdowns of information flow between governmental and civic

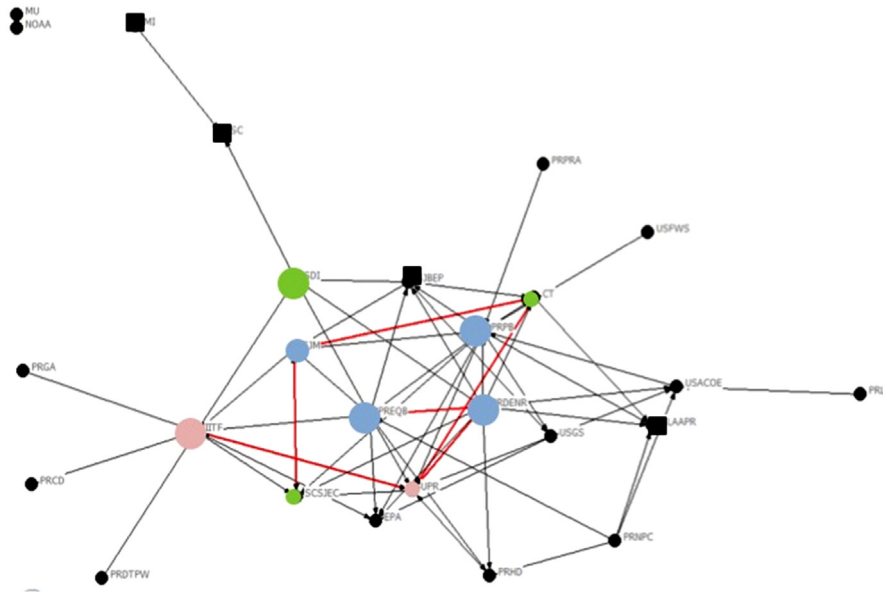


Fig. 2 – Visual depiction of the whole knowledge network for San Juan. Nodes represent organizations and lines represent flow of knowledge and information (with the direction of the arrow indicating the direction of the flow). Red lines represent the bi-directional ties (reciprocity). Nodes in color indicate central actors in the network (blue color indicates local or state agency, green color indicates local NGO, and pink color indicates research/academic institution), with the larger colored nodes indicating central actors with highest degree and betweenness centrality. Black squared-shaped nodes indicate non-governmental organizations (NGO's), and black circle-shaped nodes indicate governmental agencies.

actors. Similarly, while there is greater horizontal flow among city level actors, they are not connected to upper level institutions. This step reveals that the San Juan landscape consists of a diverse and inter-linked network of multiple knowledge systems that also overlap with power relations in decision-making—hence, a knowledge–action system.

3.2.3. Step 3: analyze dominant and marginal visions for the future of the city

Because of their dominant position in the network, central actors have more influence over information flow (Brass and Burkhardt, 1993). It is likely that the central actors described in step 2 are opinion leaders in the network and that they have influential power over the knowledge, ideas, and beliefs that circulate through this network. Step 3 involves analyzing future visions of the central actors, as well as alternative discourses in the public that may be envisioning different strategies and thus counteract dominant ideas of sustainability. Future visions of the central actors were analyzed qualitatively using survey data, interviews, and planning documents. Alternative visions were uncovered from the public discourse through content and image analysis of the media (e.g., newspapers, magazines, website), public comments, and interviews.

In the context of San Juan, I found four different visions that co-exist for the city, including: (1) the Economically Sustainable City; (2) the Livable City; (3) the Modern City; (4) and the Ecologically Sustainable City. These visions differ in their emphasis of sustainability, spatial and temporal scales, participatory processes, and the epistemic cultures supporting

each vision. The dominant visions of the state and the city – the Economically Sustainable City and the Modern City – place more emphasis on sustaining economic viability and growth for the city and region. Alternative visions, such as the Ecologically Sustainable City, offer a comprehensive assessment of natural resource distribution and long-term renewal, yet it does not clearly articulate economic and social dimensions of a sustainable city. The Livable City vision more closely represents popular concerns over social development, especially of poor and marginal populations, and presents the closest integration of the economic, social, and ecological dimensions for planning the city. The strategies presented in this vision, however, focus primarily on improving current conditions, while a clear articulation of future strategies in light of external environmental and economic change is not addressed. In sum, while sustainable development is a term found across all four visions, each vision optimizes one dimension of sustainability. More importantly, I found that none of these visions were developed through an active public participation process nor they offer a comprehensive pathway to sustainability that integrates economic, social, and ecological dimensions into a current and long-term development strategy for the city of San Juan.

3.2.4. Step 4: explore influences of epistemic cultures on vision divergence

An in-depth look at the epistemic cultures underlying the city visions reveal that divergences can be explained by the way that city actors ‘see’ and ‘know’ the city. Each of the visions found in San Juan is supported by distinct epistemic cultures. I

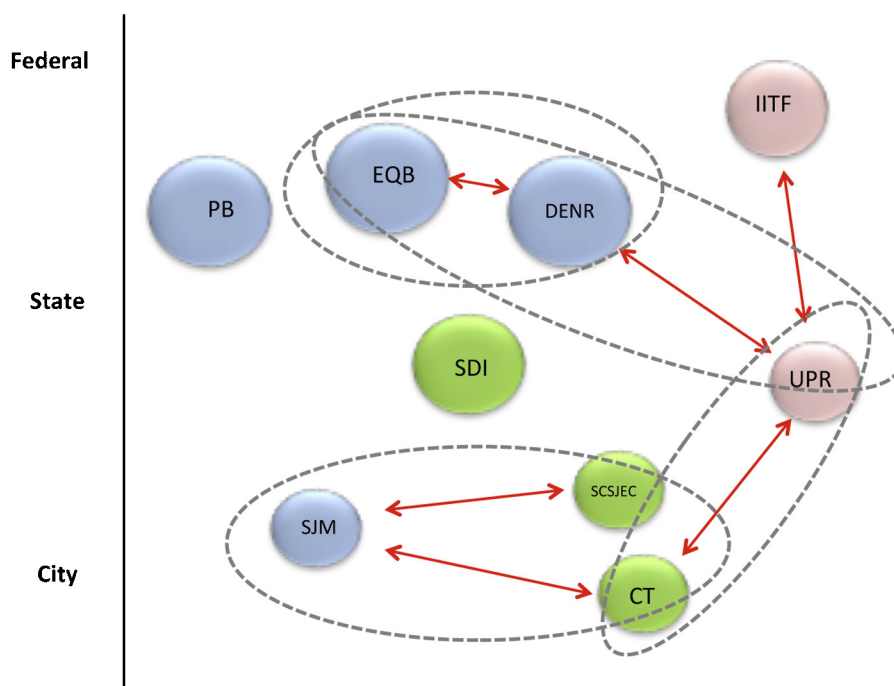


Fig. 3 – Detailed picture of the central actors that dominate knowledge flow (larger circles) and the actors that reciprocate knowledge (subset of the network in Fig. 2). IITF, International Institute of Tropical Forestry; PB, Planning Board; EQB, Environmental Quality Board; DENR, Department of the Environment and Natural Resources; UPR, University of Puerto Rico; CT, Conservation Trust; SJM, San Juan Municipality; SDI, Sustainable Development Institute; SCSJEC, Special Commission for the San Juan Ecological Corridor. Blue color indicates local or state agency, green color indicates local NGO, and purple color indicates research/academic institution. Gray circles with dash lines represent configurations of knowledge–actions systems where different political and epistemic cultures are interacting.

examined these epistemic cultures through content analysis of organizational and planning documents, technical and scientific reports, website and media content of central actors in the network and broader public discourse. The following epistemic cultures emerged from the analysis: (1) bureaucratic-planning; (2) bureaucratic-esthetic; (3) civic-stewardship; and (4) scientific-managerial. These epistemic cultures align with the future visions described in step 3. For instance, the dominant visions of the state and the Mayor's office (Economically Sustainable City and the Modern City) are both supported by conventional urban planning visions that emphasize economic efficiency and simplicity in design through their planning practices and ways of thinking (bureaucratic-planning and bureaucratic-esthetic cultures). The ecological vision is supported by a scientific-managerial culture that privileges the natural sciences and thus lacks the social science integration needed to understand the city as a complex social-ecological system. The livable city vision incorporates a social planning perspective and local knowledge with the urban planning tradition but also lacks a dynamic perspective of the city as a complex social-ecological system.

Fig. 3 shows the knowledge–action systems where different political and epistemic cultures are interacting as reflected by the dashed lines. This figure illustrates how a knowledge–action system for one dimension of urban sustainability (green

areas and land use) can have a diverse configuration. Dominant policy actors also influence the circulation of ideas and knowledge, and marginal actors have different notions of what the city is and how it should be. This complexity challenges traditional notions of knowledge-to-action for sustainability because it shows that sustainability not only involves values trade-offs, but politics of knowledge as well. Therefore, dynamics of knowledge production and use also affect capacities for sustainability.

3.2.5. Step 5: boundary assessment: dynamics in the knowledge–action system

Observing boundary work in the making through a specific event allowed first-hand observations of co-production dynamics that are difficult to assess at the coarser level of the whole city. I used ethnographic approaches such as interviews, field observations, and document analysis, to get an in-depth perspective on the politics of expertise. I focused on a contemporary event in San Juan's planning process—the implementation of the Río 2012 project by the city's former Mayor Jorge Santini Padilla for one of the city urban cores—to observe and engage first-hand with actors as they interacted in producing, debating, and validating knowledge claims, future visions, and institutional roles. I found two key boundary dynamics shaping the politics of sustainability in this case: boundaries between different ways of knowing

(epistemologies), and boundaries between knowledge and action.

The first dynamic relates to boundaries being drawn by local actors between the epistemic culture that was informing the Mayor's vision (bureaucratic-esthetic) and the local knowledge drawn from experiences, locality, and expertise of residents and professionals from the University of Puerto Rico (civic-stewardship culture). The Río 2012 project sought to address the long term social, economic, and physical decline of Río Piedras through re-vitalization projects in housing, public spaces, infrastructure, and local economic activity. The vision and plans for the Río 2012 project were developed by a Boston-based expert architectural firm, Antonio DiMambro and Associates, which the Mayor views as credible for its expertise and award-winning urban design projects in the US and Europe. Community leaders and local professionals, however, contested that the visioning and planning process for Río 2012 was 'closed' to public participation and thus did not produce a vision of sustainability that benefits the town's marginal populations. To them, outside expertise was not as valid as local knowledge to develop a plan fit for the local context. In this case, both city and local actors created rhetorical boundaries between bureaucratic-esthetic and

civic-stewardship cultures in order to gain power over the planning and development process.

The second type of boundary dynamic evident in the Río 2012 case was a distinction between who should have the responsibility over the functions of knowledge production and action in the implementation of re-vitalization projects. Prior to Río 2012, legal responsibility to coordinate the re-vitalization of Río Piedras was given to the Urban Action Center (or CAUCE as it is locally known for its Spanish acronym), a university-based organization designed to link the university with the community (see Fig. 4a). CAUCE was in charge of coordinating research and strategies between the university, the Municipality, an Interagency Working Group and a community Advisory Group. As the Río 2012 vision came into the scene and controversy arose over what knowledge, visions, and strategies should count in the planning process, the Mayor made a request to the state's Legislature to transfer the coordinating responsibilities from the university to the Municipality. Actors from all sides argued to the Legislature that CAUCE only has research and not implementation responsibilities, albeit for different reasons. The Mayor argued that CAUCE was not being effective at implementing strategies and that it should not have the responsibility because it is not a

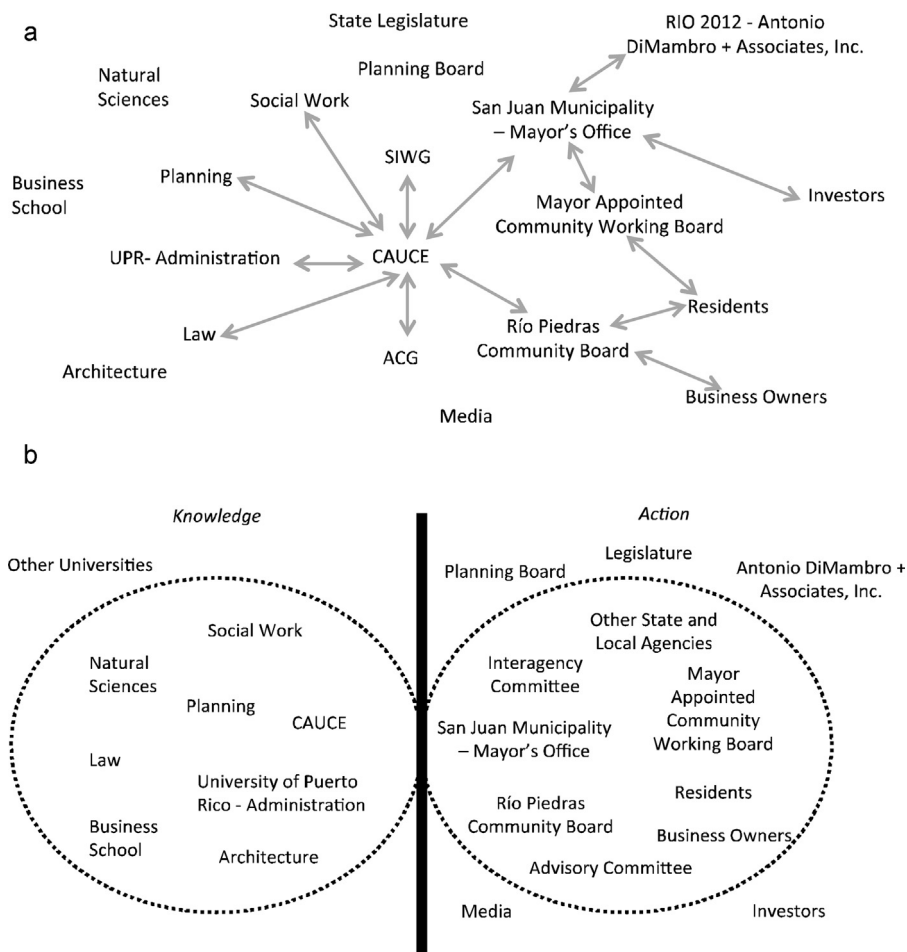


Fig. 4 – The knowledge-action system landscape of the re-vitalization of Río Piedras. (a) Illustrates the political landscape and main actor interactions (arrows) prior to the passing of the Legislature's proposal to transfer coordinating responsibilities from CAUCE to the Municipality. (b) Illustrates the simplification of the landscape following the imposition of a boundary that divides knowledge and action functions of the actors.

planning or administrative entity. CAUCE and community leaders, on the other hand, argued that it should keep the responsibilities because it was created to coordinate studies and not action, therefore, the claim that it has not achieved outcomes was not well founded. In a clear strategy of boundary work, the Legislature ultimately decided that knowledge and actions responsibilities should be separated (see Fig. 4b). The claims made by the various actors revealed an implicit assumption and belief that knowledge and action should be separate spheres in governance, and the decision for the Legislature to separate them institutionalized this belief.

4. Discussion

Overall, the findings in San Juan suggest that building knowledge for sustainability in San Juan is not solely a matter of quantity or building *more* knowledge, but also about addressing problems of social and political order. Actors in San Juan are already producing diverse knowledge relevant to urban sustainability. The real issue concerns the cultural and institutional factors that condition how this knowledge is evaluated, validated, and used to inform a public conversation about the future of the city. Next I draw insights from the findings of this case study that can enhance the ability of environmental scientists, decision-makers and practitioners in their efforts to address knowledge and decision-making interactions in the complex context of natural resource management and sustainability.

4.1. Multiple configurations of knowledge–action systems

As demonstrated in this study, social network and innovations studies have much to contribute to understanding how network function and structure can shape the performance and outcomes of the system, an aspect that has not been fully captured in previous studies on science–policy interfaces and knowledge-to-action. In addition, this study shows how knowledge systems beyond science interact in the policy process, thus demonstrating that multiple actors have knowledge relevant to political and social change. Mapping of the knowledge network in San Juan without *a priori* assumptions about which actors are knowledge producers or knowledge users demonstrated that multiple knowledge–action systems can co-exist in a given place. Through this approach I was able to empirically confirm the existence of a complex knowledge–action system landscape in San Juan as hypothesized in Fig. 1b.

4.2. Power and boundary strategies in knowledge–action systems

In this case study the co-production framework was useful to understand the role of power in knowledge–action system dynamics. For instance, in the San Juan network I found that actors dominating knowledge about land use are the same ones that hold power over the resource. This suggests that much of what we know about land use patterns and dynamics is filtered (intentionally or unintentionally) by the values, beliefs, and ideologies, of the actors that control city resources

and space. Examining power in knowledge–action systems also explains why more science does not always lead to change or innovation. On the contrary, knowledge practices that are culturally and politically embedded can inhibit innovation by not allowing new ideas and creative solutions to gain access and traction in the network. As co-production scholars suggest, knowledge production is a historically contingent process, thus what we know can be a reflection of established institutional dynamics, or alternatively, help perpetuate dominant structures and ideas of social order (Jasanoff, 2004). As such, even when new knowledge is created that can support novel solutions, this knowledge may not proceed to be used in the political process because there are other already established and powerful knowledge systems informing the policy process as well (e.g., use of economic indicators in state planning agencies). Moreover, assumptions about what knowledge is more credible in decision-making can ultimately affect how well we understand the dynamics of the system under study (e.g., ecosystems) (Leach, 2008).

Boundary work emerged in the San Juan political landscape as a strategy to manage power among the various actors involved. Specifically in the Río 2012 example, boundaries are drawn around different types of epistemic cultures so as to privilege some expertise over others. The Mayor of San Juan at the time legitimized his vision for Río Piedras through a power move that purposely re-bounded political roles and re-instated his authority over the implementation of the plan. He successfully argued to the Legislature that these functions were out of order and consequently simplified topography of this knowledge–action system. This study supports previous descriptions of the key role that boundary work plays in the development of policy-relevant knowledge, but it provides further evidence that boundary making happens outside the conventional science–policy interface, involving multiple actors and knowledge systems (Klerkx and Leeuwis, 2008; Schut et al., 2013). This type of boundary strategy and implication to social learning and innovation, however, has barely been explored in the recent literature (see for instance, Michaels, 2009 typology of brokering strategies). Because assumptions about the co-production of knowledge and society can influence how we structure specific interventions to co-produce knowledge it is crucial for environmental and sustainability scientists and policy scholars to examine these power dynamics prior to creating new interventions toward knowledge co-production and social learning (e.g., joint-knowledge production or boundary organizations) as these dynamics will shape their outcomes. This study offers the analytical framework and tools to empirically examine how these knowledge–power relationships are playing out in real places and in real cities.

4.3. Knowledge–action systems co-produce novel visions of the city

Following the co-production framework, this study shows how different groups come to ‘know’ the city cannot be separated from the expectations and political goals that society has for the future of the city. And vice versa, visions of the future of the city are shaped by the epistemic cultures that different social groups employ in ‘knowing’ the city. Hence,

this study supports previous co-production studies that show that knowledge–action systems are not only composed of information, technologies, and practices of producing knowledge, but it is where imaginations, ideals, and beliefs of social order are being forged by different social groups (Miller, 2005). This process of co-production of visions also resembles joint vision creation processes for optimizing innovation systems as described by innovation scholars applying complex systems perspectives (e.g., Klerkx et al., 2012; Leeuwis and Aarts, 2011; Wieczorek and Hekkert, 2012).

The co-existence of a diversity of visions of social order for cities, however, has been not been explored in the science and technology studies (STS) literature nor in the environmental science and policy literature. As mentioned in the introduction, cities have not been the focus of studies on environmental science–policy interfaces or knowledge-to-action. Yet, one of the key insights that the San Juan case study offers is that governance actors are re-configuring themselves in addressing sustainability, and it is in these moments of flux when processes of co-production of knowledge and social order are most transparent. Thus, while the mechanisms of co-production can be hard to discern (Hegger et al., 2012), analyzing knowledge–action systems in cities can be a particularly useful analytical approach to make evident how multiple knowledge and visions of social order are being co-produced and the implications of these novel pathways to innovate toward sustainability.

5. Conclusion

Crucial to our ability to transition to sustainability are knowledge–action systems that can navigate today's complex challenges. Using the lens of co-production I untangled the intricate relationship between knowledge and decision-making in the context of land use planning in San Juan. I revealed the complex mechanisms with which different social groups draw boundaries and how these are being expanded and re-defined outside of the narrow conception of the science–policy interfaces. The co-production literature, however, lacks empirical studies in urban contexts. This study sought to address this empirical gap through the application of the KASA approach in the city of San Juan.

The KASA approach offers a combination of analytical concepts and tools to get at some approximation of how these complex systems operate, or at least a starting point. Through social network analysis it is evident that the connections between actors can have an effect on how knowledge systems work in a given place. Scientists, planners, and practitioners working toward building capacities for sustainability would benefit greatly from this structural understanding of knowledge networks in the city. Network analysis, however, is limited because it provides only a static picture of social structure and its outcomes, thus lacking the ability to capture how these social relationships and dynamics have come to be or how they will change in the future. Future research on how knowledge–action systems in San Juan are changing over time will contribute to our understanding of novel processes of co-production that link epistemic, social, and political contestation and innovation toward sustainability.

The KASA approach also made explicit the values and epistemic assumptions underlying dominant and marginal visions of the city. It also made apparent the boundary strategies that different actors use to provide credibility and legitimacy to their expertise in the process of planning the city, thus providing a more nuanced understanding of the functioning of knowledge–action systems in addition to their structural and epistemic elements. From a practical perspective, I suggest that capturing the existing configurations, dynamics, and cognitive dimensions of knowledge–action systems through the KASA approach can help anticipate and evaluate the success of popular knowledge production arrangements emerging in sustainability science and policy. Looking forward, the design of new knowledge–action systems to enhance the ability of decision-makers and practitioners to achieve sustainable strategies begins with this knowledge about knowledge.

Acknowledgements

Special thanks to Clark Miller, Sheila Jasanoff, Charles L. Redman, Kelli L. Larson, Thaddeus R. Miller, and the Knowledge Systems Analysis Group for the insights they contributed to this research. This work was supported by the National Science Foundation under Grant numbers 0948507 (Urban Long-Term Research Area Exploratory) and 0504248 (Integrative Graduate Education and Research Training). Any opinions, findings and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation (NSF).

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