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Perspective Essay

The social production of ecosystem services: A framework for studying environmental justice and ecological complexity in urbanized landscapes

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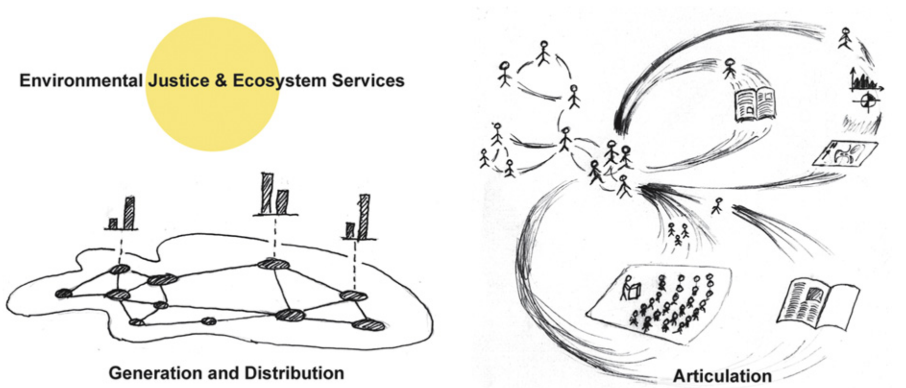
HIGHLIGHTS

- ► Two levels of analysis are interlinked to study justice and ecosystem services.
- ► Urbanized landscapes are modeled as social–ecological networks at the city-level.
- ► Social practices of value articulation are studied in local struggles over land-use.
- ► Ecological connectivity brings in crucial dimensions of complexity in studying justice.
- ► Combining methods and levels of analysis brings increased understanding in empirical work.

GRAPHICAL ABSTRACT



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ABSTRACT

A framework is constructed for how to relate ecosystem services to environmental justice. The benefits humans and society can derive from biophysical processes cannot be viewed as objectively existing "out there", but as entangled in social and political processes. This is unpacked through the analytical moments of generation, distribution and articulation of ecosystem services. Social practice moderates the generation of benefits from biophysical processes (through urban development patterns and day-to-day management of urban ecosystems), but also who in society that benefits from them, i.e. the distribution of ecosystem services (viewed here as the temporal and spatial scales at which it is possible for humans to benefit from biophysical processes). Moreover, for biophysical processes to attain value in decision-making, a social practice of value articulation is needed. The framework then moves between two levels of analysis. At the city-wide level, an ecological network translates how urban 'green' areas, viewed as nodes, are interconnected by ecological flows (water, species movement, etc.) where nodes have different protective and management capacities. The network captures spatial complexity—what happens in one location, can have effects elsewhere. At the local level, urban struggles over land-use are studied to trace how actors utilize artifacts and social arenas to articulate how certain biophysical processes are of value. Competing networks of value articulation strive to influence land-use, and multiple local studies bring understanding of how power operates locally, informing city-wide analyses. Empirical studies from Stockholm, Cape Town and other cities inform the framework.

1. Introduction

There is no limit to the variations of how urban nature is entangled with social and political processes. In Cape Town an accidental fire triggered a struggle over how to use green space—for local

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recreation under pine trees that provided shade, or to fell the pines to preserve endangered vegetation. In Stockholm, civic associations stopped the building of motorways and houses in a park by interlinking royal heritage values with animal habitat preservation. On the other side of town, however, a similar effort at a green area led to nothing—the Stockholm City Council ignored local resistance and previous decisions to invest in a landscape park and went ahead with plans to build 4000 flats. In Indianapolis, historical development has left fewer trees where the urban poor live, and many more with the rich. Thus, if urban nature comes with benefits, there is almost certainly an uneven social production of such 'ecosystem services'. Why choose preservation of endangered species rather than trees giving shade in Cape Town? How come certain groups can successfully defend their green areas, and others cannot? And how do these local struggles influence the citywide generation and distribution of ecosystem services? Practically all cities bring similar examples and questions, demonstrating the generality of these issues and the necessity of finding frameworks for their analysis. This essay aims to provide a framework for relating ecosystem services to environmental justice, and I will later return to the examples above. Before that however, a review of key concepts and a theoretical foregrounding is necessary.

The notion of urban ecosystem services is quite new. Viewed as the goods and services derived from biophysical processes that benefit human well-being and support societal functions (Daily, 1997), the concept travelled rapidly from research into policy (Gómez-Baggethun, de Groot, Lomas, & Montes, 2010). Especially the Millennium Ecosystem Assessment (2005) thrusted the concept onto policy arenas and popularized a categorization of provisioning, regulating, cultural and supporting services (Table 1). This impulse moved into urbanized landscapes. By focusing on urban ecosystems, oftentimes denoted as 'green' and 'blue' areas, for instance urban forests, parks, and wetlands, a wide range of services generated by urbanized ecosystems have been identified and described, from stress relief, improved air quality, food production, to heat mitigation and nitrogen retention and many more (Bolund & Hunhammar, 1999; Jansson, in press; Niemelä et al., 2011).

Environmental justice emerged as a normative concept and a social movement in the US in the 1970s (Schlosberg, 2007) and has often been referred to as the spatial distribution of environmental goods and ills amongst people, including the "fairness in the distribution of environmental well being" (Low & Gleeson, 1998: 102). Given the novelty and complexity of ecosystem services, little work exists on how to relate them to environmental justice (Boone, Cadenasso, Grove, Schwarz, & Buckley, 2010; Pham, Apparicio, Seĭguin, Landry, & Gagnon, 2012, and references therein). Here I will contribute by explicitly integrating aspects of ecological complexity, and by providing means to analyze the social practices and mechanisms that give rise to uneven patterns of distribution. The essay is thus primarily couched within a Rawlsian notion of distributive justice and it will not in detail analyze other dimensions of environmental justice and urban political ecology, including the politics of participation and recognition, debates concerning power and knowledge; and class, race and systemic oppression (Cook & Swyngedouw, 2012; Swyngedouw & Heynen, 2003). It also leaves outside the criticism that has been launched against the ecosystem services approach, for instance how it strengthens market-based and depoliticizing paradigms of decision-making (Kosoy & Corbera, 2010; Norgaard, 2010), which I have contributed to elsewhere (Ernstson & Sörlin, in press). Instead I have here chosen to stay within the conceptual apparatus of ecosystem services. The reason is that I see a possibility to move, rather than dismiss, the abundant but apolitical production of knowledge around ecosystem services—one which increasingly uses advanced technologies to produce figures, maps and numbers—so that such knowledge and artifacts can be used towards discussing environmental justice.

A premise for this essay is that the benefits humans and society can derive from biophysical processes cannot be viewed as objectively existing "out there", but as entangled in social and political processes. This provides the framework with three analytical moments, summarized as the generation, distribution and articulation of ecosystem services. Indeed, the entanglement of biophysical processes with social and political processes moderates and decides not only the generation of ecosystem services (through land-use and management of land), but also who in society that benefits from them, i.e. the distribution of ecosystem services. Just as the number of pupils in school classes, or the number of public libraries, can differ between poor and rich areas of a city, so can the distribution of the benefits from ecosystems. Distribution is thus viewed herein as the temporal and spatial scales—and physical sites in the landscape—at which it is possible for humans to benefit from, or access, ecosystem services. To moreover account for how biophysical processes attain value in decision-making, and thus how they can be contested and hierarchized by social groups, the framework recognizes that social practices are necessary for the articulation of ecosystem services. Somebody or something is needed to explain and demonstrate how certain biophysical processes are to be viewed as of value. Articulation is the practice and process through which for instance local groups or biologists construct their arguments to protect urban parks, creeks or wetlands and engage in planning processes—often in contestation to developers that articulate opposing values and arguments for how to use land. It is in these heightened moments of struggle, or formalized procedures of decision-making that the empirical researcher can understand how discourse, power and institutional procedures play out among different groups, and how this shapes biophysical processes and the composition of urban land use over time. Thus, while the analysis of generation and distribution allows for a citywide view into the uneven production of ecosystem benefits, a focus on articulation brings us close to place-based struggles and contested practices of city planning.

To move ahead, the essay starts with foregrounding the particular 'drivers' that organize urban landscapes and consequently the composition of urban ecosystems. Empirical examples are then used to illustrate how these drivers meet at the intersection of justice and ecological complexity, with examples drawn from the wider literature and my work in Stockholm and Cape Town. This is followed by a description of the framework and how to concretely move between a citywide and local level analysis. The concluding remarks reflect upon further developments and theoretical implications.

2. Moving ecosystem services into a contested geography of difference

The framework operates through a distinction between the generation and distribution of ecosystem services. To make this distinction two discourses will be brought together—systems ecology and critical geography. First, the study of dynamic social–ecological systems (Berkes, Colding, & Folke, 2003) has emphasized that it is simplistic to study ecosystems without recognizing the role of humans in influencing biophysical processes (a notion long entertained in geography and human ecology). An important emphasis from this literature is that humans—professional managers, volunteers, and 'local' users of natural resources—can indeed play an active and positive role as 'stewards' in supporting ecological functions, which opens for considering human agency in the generation of ecosystem services. For instance in Stockholm it was demonstrated how pollination depends not only on land use, but also on the knowledge, practice, networks and institutions upheld by urban community gardens (Andersson, Barthel, & Ahrné, 2007;

Table 1
The table shows the four categories of ecosystem services as described by the Millennium Ecosystem Assessment (MA, 2005: VI).

Category	Description
Provisioning services	Products obtained from ecosystems like food, fiber and energy.
Regulating services	Benefits from regulation of ecosystem processes like pollination, seed-dispersal, pest regulation, air- and water filtration.
Cultural services	Nonmaterial benefits from ecosystems, like spiritual enrichment, cognitive development, recreation, and aesthetic experiences.
Supporting services	Ecological functions such as nutrient cycling and soil formation seen as necessary for the production of all other ecosystem services.

Barthel, Folke, & Colding, 2010; see also, Krasny & Tidball, 2009). However, the discourse on social–ecological systems, partly since it originated from non-urban research has tended to play down the inherently conflictual character of urbanized landscapes, and has no general theory for how urban land is used, diminishing its capability to handle urbanized landscapes, and the notion of distribution of ecosystem services.

Critical geography and urban political ecology, on the other hand, have convincingly analyzed urbanized landscapes as emergent from the centrality they occupy in contemporary modes of capitalistic production of commodities, interlinking them via trade to other cities and ecosystems across the world (Harvey, 1996; Heynen, Kaika, & Swyngedouw, 2006; Swyngedouw, 2004; Swyngedouw & Heynen, 2003). When played out within cities, this perspective holds that a variety of functions, from transport and sewage systems, to housing and offices need to find their space, along with urban parks and greenery, to produce urban services craved by firms and people, all in a competition of which space can render highest profit on capital investment, being either private or public capital. When space is profit, the question of how to use land—and articulate the value of land—becomes to a large extent a matter of political struggle, partly regulated through urban planning.

Interestingly, the two discourses meet in that the pressure for urban development produces unjust geographies as analyzed by critical geographers, while moderating ecosystem functions and processes, as analyzed by system ecologists. Indeed, the effect of having a great concentration of economically strong interests that compete for land, produces on one hand a disturbingly stable "geography of difference" of where benefits and ills of human life are spatially distributed in the city (Harvey, 1996; Pirie, 1983), and on the other hand, an extreme heterogeneity of land use. The latter has ecological consequences since land-use influences both local ecological processes, and their networked interlinkages across space (Alberti, 2005; Andersson & Bodin, 2008; Pickett et al., 2008).

Together this suggests that benefits from biophysical processes are generated out of political and interlinked social–ecological processes that operate across various scales. However, it is also plausible that biophysical processes tend to distribute benefits at specific scales; some on the local scale and in the present, while others at greater scales. For instance, the effect of single trees, urban forests and green areas in reducing noise and wind, and providing shade, is primarily a local and immediate effect. Likewise is the cleaning of the air from pollutants and particles (Bolund & Hunhammar, 1999; Jansson, in press), which have been shown to reduce levels of human stress (Kuo, Sullivan, Coley, & Brunson, 1998), improve general health, and decrease levels of child asthma (Jackson, 2003). Simultaneously, local green areas can strengthen community life through providing space for informal meetings (Kuo et al., 1998), the hosting of cultural events, and give meaningful environments for sports, physical and recreational activities, and for children's play (Bolund & Hunhammar, 1999). Local green areas' ability to mitigate excessive heat is a local effect (Pham et al., 2012), but also impacts at the city-scale (Bolund & Hunhammar, 1999). Similarly, urban wetlands can mitigate local flooding events, but also retain nitrogen in streams to benefit a whole region, thus distributing a service at a greater scale (Jansson & Colding, 2007). On greater spatial and temporal scales, benefiting a larger but more abstract and even future population, vegetated land with pervious surfaces aid in draining rainwater and sustaining the ground water table (Bolund & Hunhammar, 1999), while also absorbing CO_2 emissions (Jansson & Nohrstedt, 2001). Urban ecosystems have also been shown to sustain biodiversity through providing substitute habitat for endangered species, and in creating new biological niches (Niemelä et al., 2011). Although a single scale of distribution is not clear-cut for all biophysical processes, this perspective helps to understand the politics of land-use and management prioritization, and which social groups can potentially access ecosystem services—from those living close-by in the local neighborhood, to city or regional populations, to all human kind.

Few have addressed ecosystem services distribution from a scale perspective. There is research on how urban biodiversity patterns correlate spatially with socioeconomic status (Kinzig, Warren, Martin, Hope, & Katti, 2005), trade-offs between (rural) ecosystem services (Goldman, Thompson, & Daily, 2007), and equity and efficiency in payment for ecosystem services (Pascual, Muradian, Rodríguez, & Duraiappah, 2010). Although others have started to address how urban green areas and their benefits are distributed in relation to where rich and poor and marginalized groups live in cities (Boone et al., 2010; Pham et al., 2012; Richardson, Pearce, Mitchell, Day, & Kingham, 2010), social scientists have generally neglected the complexity of ecosystems (as argued by Heynen (2003); but see Walker (2005) on non-urban studies). Oftentimes 'nature' has been simplified as a black box—a factory—that produces benefits and ills that should be equally distributed. This fails to account for, for example, how pollinating insects, or seed-dispersing animals that support the reproduction of ecological functions (and thus the generation of larger-scale ecosystem services) move across the landscape to interlink 'green' and 'blue' areas; and how local management practices in turn support such 'ecological' functions. One aim of this essay is to replace this black box perspective with a spatially sensitive ecological network model to better portray how ecological complexity is interlinked with social practices of management and protection, and how this complexity intervenes in discussions about environmental justice.

Taken together, the combination of justice and ecological complexity, or scales, comes out as important and less understood matters. How can both justice and ecological complexity be addressed simultaneously in empirical studies? Before describing the framework, I will return and expand upon the examples used in the Introduction.

3. Situating justice and ecological complexity through case studies

From Indianapolis, USA, Heynen (2003) brings a telling study that attends to environmental justice and ecological complexity. It deals with the uneven pattern of tree cover in the city where elite and high-income areas have more and larger stands of trees, mainly through planting, than lower income areas. Heynen argues (with reference to Marx) that this pattern can be understood through recognizing the benefits these trees distribute at the local level, their use-value, such as shading, noise protection, and air filtration. Through that decision-makers, residents, lobby groups and house buyers recognize this use-value, urban trees have become commodified and sucked into the political economy of the city in which stronger economic interests tend to dominate. This has produced uneven spatial tree patterns, either through that groups have influenced decisions regarding where to plant new trees, where to spend funds to manage existing trees, or through that certain areas have had a higher level of protection of trees. This indicates a reason why poorer neighborhoods in this particular city have less access to benefits from trees, and that the pattern of urban trees, and their locally distributed ecosystem services, has been moderated through a socio-political process.

However, Heynen acknowledges the complexity of ecosystems and notes an important trade off between the generation and distribution of ecosystem services. To sustain large-scale ecosystem services, most particularly the regional biodiversity associated with the State of Indiana's forests, but also citywide processes of pollination, seed-dispersal and pest control, it is important to plant trees so that larger forest islands become ecologically connected. Given a finite number of trees to plant, it seems better to place them where larger forest islands already exist so as to increase the landscape connectivity of trees. In Indianapolis this correlated with planting more trees in high income neighborhoods. To spread them out evenly in lower income areas would be a bad option seen from an ecological and functional management perspective, as each tree would benefit less to larger-scale ecosystem services such as seed-dispersal, pollination and upholding biodiversity. This can be read as a trade-off between the distribution of ecosystem services at different scales in which the power relations between different social groups could influence the outcome. Those groups articulating larger scale ecosystem services of pollination and biodiversity (often being experts, planners and conservation biologists) are in Indianapolis supported by high-income home owners, whereas low-income groups in areas with no trees have less possibility to build such powerful alliances. In a city with a different tree pattern, this line of arguments could of course be different, even reversed.

An accidental fire in the Tokai forest in Cape Town, South Africa, brings another example. Located in the wealthy southern suburbs, an accidental fire in 1998 created a struggle over which ecosystem services to prioritize. Originally planted in 1885 in a government effort to produce commercial timber and jobs, the area has since become a popular recreational site. The fire in 1998, however, led to that fire-triggered seeds of fynbos, an endangered and highly diverse bush vegetation, awoke and sprouted seedlings (Avlonitis, 2011). This physical proof of dormant and intact seed banks of fynbos under the pines, played into a powerful alliance that wished to remove the pines and 'resurrect' fynbos. This alliance had started to form in the 1980s when scientists had shown that pine trees and other "alien" vegetation not only undermined the world-acclaimed biological diversity of fynbos, but also reduced fresh water stream flows in this water-scarce region (Cowling, 1992; Pooley, 2012; other "aliens" include oak, poplar, weeping willow, and gum trees introduced over centuries from Europe and Australia). In the transition to democracy in 1994 this scientific work came to align conservation ecologists, NGOs and public agencies (again using job creation programs) to access workers and machines and form large state-funded programs to remove pine trees and other "aliens" in the Western Cape (Ernstson, 2012). In Tokai this animated a heated struggle. Conservation biologists and local "fynbos friends" argued for resurrection of fynbos, reasoning that this would sustain fresh water flows and ecological functions in the larger catchment area, while preserving biodiversity for intrinsic values and long-term ecosystem adaptation. Those groups that had used the forest, wanted to keep the pines, putting forward health aspects, access to mushroom picking and more generally recreation, seen as easier in a pine forest with shade and a minimum of underbrush. The latter was also linked to cultural values of belonging and identity as many had grown up with the forest, and not with fynbos. From a distribution perspective, although the story of the Tokai forest is more nuanced than this, a political struggle emerged over the scales of distribution of ecosystem services that this site should be managed for; either for serving present users with mundane desires of recreation, or to ensure citywide distribution of fresh water and long-term ecosystem functioning—through preserving biodiversity—for the whole population in some distant future.

These examples support the argument that ecosystem services are not something "out there" that scientists simply can measure, but rather they are contested and highly entangled with social and political processes, not least that of value articulation. It also makes clear that an entry point to understand the social production of ecosystem services is to move between broader views of distributive patterns of biophysical benefits, and analysis of place-based struggles.

4. A framework for analyzing the social production of ecosystem services

Having foregrounded and situated the intersection of ecological complexity and justice, what follows is an attempt to boil down the expressed insights into a framework for the analysis of the social production of ecosystem services. Fig. 1 outlines the framework and how it allows for two interlinked modes of analysis; one uses a spatial social–ecological network model aimed to gain a broader and citywide perspective on generation and distribution; the second is for analyzing value articulation in place-based struggles and urban planning.

4.1. Spatial social–ecological network analysis

A network perspective of an urbanized landscape works to avoid a too simplistic model of an ecological system. With a network perspective, an urbanized landscape can be translated into an ecological network of interconnected nodes of green and blue areas (or local ecosystems) surrounded by built-up areas. Linkages between nodes represent landscape *ecological connectivity*, or flows, such as species movement, or the flows of nutrients and water. These flows make possible certain ecological processes within the nodes that in turn sustain the generation and distribution of benefits. 'Social' features are folded into the network as attributes of the nodes—each node carries with it a certain level of protective capacity, and a certain level of management capacity. The former means roughly the ability to resist exploitation (and degradation/disappearance as node), while the latter aims to capture the ability to sustain landscape ecological connectivity or flows through the specific green area. This network approach has been shown to capture key aspects of the structure and dynamics of social–ecological systems (Bodin & Norberg, 2007), and can be seen as modeling how the generation of certain ecosystem services operates across various scales. The following paragraphs describe what ecological connectivity, protective capacity and management capacity can mean and how these properties of the network can be assessed.

4.1.1. Ecological connectivity

Ecosystem services depend heavily on the spatial structure of ecosystems (Alberti, 2005), and spatial ecological networks are an emergent field of study (Andersson & Bodin, 2008; Bodin & Norberg, 2007; Zetterberg, Mörtberg, & Balfors, 2010). Although not urban, an illustrative study is by Bodin, Tengö, Norman, Lundberg,

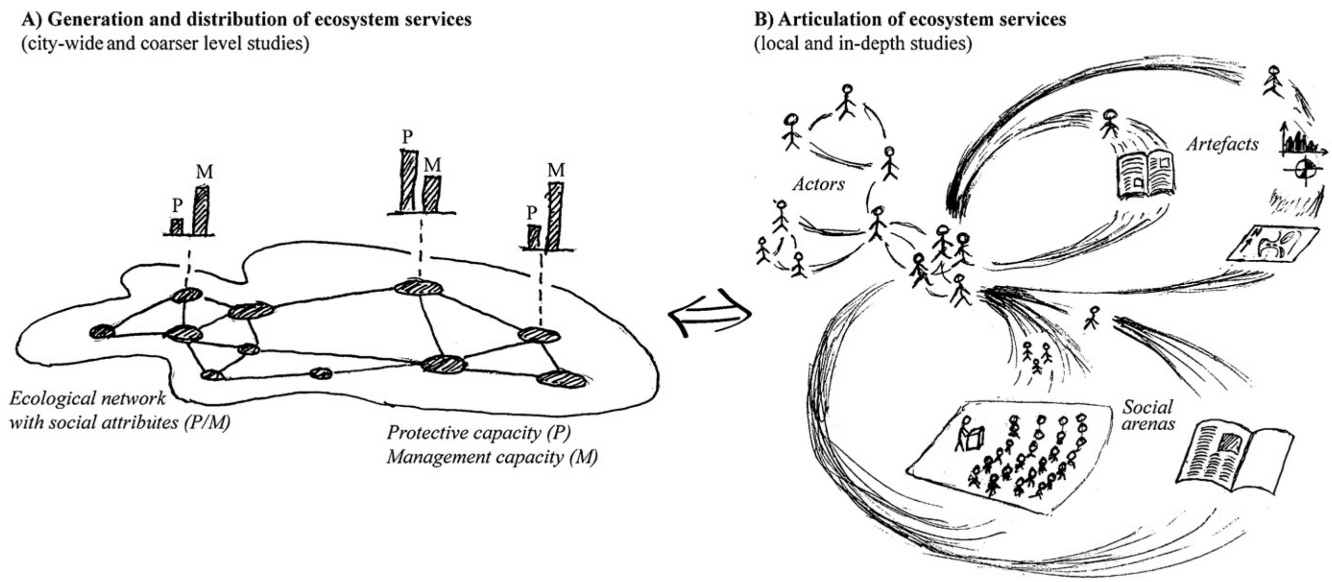

Fig. 1. The figure outlines a framework for studying the social production of ecosystem services. Three analytical moments—generation, distribution and articulation—are studied through moving between two different levels of analysis, with different sets of methods. (A) The citywide coarser level study focuses on generation and distribution of ecosystem services and uses landscape ecology and network analysis. The ecological dynamics of an urbanized landscape is modeled as composed of 'green' and 'blue' areas represented as nodes and interconnected by ecological functions or flows (water, species movement, etc.). Each node has due to social dynamics, different levels of protective and management capacities. This captures the spatial connectivity—or complexity—of socioecological processes; what happens in one location, can be felt elsewhere. (B) At the local level (within nodes), in-depth studies of struggles over land-use, traces how actors through social practice align artifacts and social arenas to explain how biophysical processes can be of value. Such competing networks of value articulation strive to influence land-use. Multiple local case studies in one city can bring more general understanding of how power relations play out locally, informing the citywide analysis. Value articulation can be studied using ethnography, interviews and archival methods drawing on Actor-Network Theory (ANT).

and Elmqvist (2006). They analyzed, using remote sensing satellite maps, a highly fragmented forest in a farming landscape on Madagascar in which remaining small forest patches (<1 to 95 ha) constituted "islands in a sea of agriculture". A local taboo system, that tended to protect larger patches, had moderated the expansive human land use to create an almost discrete use of land—either agriculture or forest—structurally comparable to urban landscapes.

Bodin et al. (2006) selected two ecosystem services, pollination and seed-dispersal, both important for local crop production, and for the regeneration of forest patches and biodiversity on a longer time-scale. Focusing on bees (for pollination) and lemurs (for seed-dispersal), their computerized map-based analysis showed that although the forest was fragmented, pollination processes for crop production and seed-dispersal for forest regeneration could be upheld through the potential movement of species between patches. Bees reached roughly 88 percent of the crop production, and lemurs could move to connect 70 percent of the forest patches into one component. However, the authors also encountered clear nonlinearities in the potential of generating ecosystem services. In simulating progressive agricultural development they sequentially removed the smallest patches (that were deemed having the weakest level of taboo), resulting in a step-wise and non-linear fragmentation of the ecological network. When removing patches less than 3 ha, pollination cover dropped some 36 percent, and the largest remaining forest component covered only 15 percent of the original total (based on medium movement distances for bees and lemurs of 900 m and 1000 m, respectively). In a follow-up paper, Bodin and Norberg (2007) showed that by removing patches that bridged between greater clusters of patches (i.e. with high betweenness centrality), pollination cover and forest connectivity dropped even more rapidly. These findings point to how connectivity adds complexity to ecological systems, and how patches of small size in fragmented landscapes, can have disproportionally high importance on large-scale processes and the generation of ecosystem services.

Andersson and Bodin (2008) adapted this approach to the urban landscape by analyzing the connectivity of bird habitat in Stockholm. Although similar, an urban landscape is more complex and has a less discrete land use than the farming landscape in Madagascar. The spaces between green areas, the built-up environment, are not completely 'blank' but contribute to ecological connectivity in different ways. Andersson and Bodin used computerized maps to incorporate such effects and calculated the relative cost of movement for species outside green areas (see also, Zetterberg et al., 2010). A similar approach was used for the Cape Town Biodiversity Network where green areas and dispersal corridors (or links between nodes) were identified for sustaining the diverse fynbos vegetation (City of Cape Town, 2007).

These urban examples have not gone so far as to account for ecosystem services per se, but have demonstrated that urban landscapes can be translated as ecological networks, resisting a too simplistic notion of ecosystems and how they support ecosystem services. Following the Madagascar case study, scholars can base networks on key ecological processes (for instance pollinators or seed dispersers) to reach a closer relation to how certain benefits from biophysical processes are dependent on ecological network structures.

4.1.2. Protective capacity

The protective capacity of an urban 'green' or 'blue' area is its level of resistance to disappear as a node in the ecological network, either by being replaced by built constructions or through complete ecological degradation for some reason. Protective capacity can be viewed as composed of civic, public and technical processes associated with particular green areas.

In the Madagascar case above, a local taboo system brought different levels of protective capacity to different forest patches, which was used to analyze future scenarios of ecosystem service generation (Bodin et al., 2006). For urban areas, and following how critical geographers have studied the contested nature of urban land use evolution, Walker (2007) made an historical analysis of the San Francisco Bay Area that supports the notion of protective capacity. Here civic groups have played a great role in shaping urban land use to include areas for farming, parks, recreation and species conservation. Detailed studies from Stockholm (Ernstson & Sörlin, 2009), Milano (Diani, 1995), and Cape Town (Ernstson, 2012; Ernstson & Sörlin, in press) bring further support to the view that protective capacity can rest upon an active civil society whose organizations and activists are attached, for some reason or another, to certain green areas. Through popularizing protective narratives, using protest events, lobbying and media, these groups can, in face of exploitation or other "disturbance", mobilize in collective action to stop or change decisions. This urban civic environmentalism also captures an important cultural dimension of urban landscapes in which physical sites form part of the co-construction of urban identities and places, which can trigger collective action towards protection.

A more 'top-down' example of protective capacity is the Cape Town Biodiversity Network mentioned earlier (comparable to zoning schemes, protected areas, and designated green belts in many cities). A computer model constructed by two municipal ecologists was used to mobilize protection for green areas deemed, according to the model, to support high biodiversity of the local fynbos and strandveld vegetation. This worked to increase the protective capacity of a certain set of green areas in the city, while leaving other areas outside. Through printing out maps of the network and showing them to other civil servants at city hall, the two ecologists could mobilize increased awareness of the biological value of these sites. The 'biodiversity map' was subsequently incorporated into strategic planning documents and used for assessing building plans (source: interview with senior environmental manager at the City of Cape Town in 2007).

A final example of protective capacity is due to biophysical constraints. For instance how steep hills, marshes or wetlands make it difficult to build, or how land in between motorways is more or less useless for urban exploitation, considered having no potential to generate profit on investment. However, the high protective capacity that this generates at one point in time, could later drop as technological development bring new techniques to more cheaply build on slopes and in water prone areas. (The latter shows with clarity how entangled sociotechnical processes are with ecological processes and services.)

4.1.3. Management capacity

Management capacity is defined primarily as the capacity to carry out management practices that sustain ecological flows through the individual green areas in the ecological network.

Many different actors interact intentionally with urban ecosystems, from regional and municipal planners, to local users and managers like allotment gardeners, urban farmers, private home owners and cemetery and park managers (Ernstson, Barthel, Andersson, & Borgström, 2010). Their day-to-day management practices, embedded in institutions and urban planning decisions, influence individual green areas and their vegetation cover, soil composition and the creation and sustenance of habitats for species. From Stockholm, Andersson et al. (2007) could assert that green areas managed by cemetery and park managers had lower levels of management capacity than those managed by allotment gardeners; the latter showed greater local ecological knowledge and the widest range of management practices that offered protection of species and improved habitat to sustain pollination and seed-dispersal processes. Although most green area managers tend to focus on their local areas (Borgström, Elmqvist, Angelstam, & Alfsen-Norodom, 2006), the network perspective shows how important it is to coordinate management across a landscape (Ernstson et al., 2010; Pickett et al., 2008). Consequently, how local ecosystems—the nodes in the network—are managed, influences ecological functions that tie the network together.

At the citywide scale, it is in summary the protective and management capacities of nodes, and their ecological interconnections, that strongly influence the generation and distribution of ecosystem services.

4.2. Value articulation processes

Interlinked with the first mode of analysis, there is a second mode that focuses on the social practice of articulating value. With practice is emphasized a processual, action-oriented and constructionist perspective on value. No object or biophysical process carries inherent value, and there is no innate order of value between objects—values are constructed and hierarchized through social processes, which can be empirically studied (Ernstson & Sörlin, 2009; Ernstson & Sörlin, in press; Sörlin, 1998).

This relates to protective and management capacity. The protection of urban land is about whether to sustain or keep a green area, while ecosystem management is about choosing (consciously or not) which ecosystem services to prioritize in certain spaces. The struggle surrounding the Tokai forest exemplified this with all clarity. What should be prioritized? Pine or fynbos; "alien" species or indigenous species; water-ignorant land use or "water-wise"; mundane recreational services for present users, or biodiversity as insurance for future human generations? While such a conundrum is often framed in the literature on natural resource management as "finding the right trade-off", to which a rational and often science-based solution can be found (Goldman et al., 2007), a value articulation perspective un-packs the inherent political and relational process that such problems entail. Focus becomes on how actors, including managers and scientists, with different and unequal abilities and resources, participate in constructing values around different and sometimes opposing ecosystem services. (The outcome of such processes in Tokai was the clearing of pines for fynbos rehabilitation, with some trees left for shaded walks.)

When 'values' or 'benefits' are not viewed as given or as objectively measurable, they instead become inherently contested and only established, or stabilized, through social practice (which includes scientific practice). This recognizes that in order for something to be seen as having a value, there need to be actors who can describe that something and explain its value (Sörlin, 1998). Indeed, historical and sociological research on how certain objects, landscapes and species have become protected point to that important actors in value articulation processes are artists, authors, and scientists (Ernstson & Sörlin, 2009; Ernstson & Sörlin, in press; Sörlin, 1998). These actors produce artifacts such as paintings, maps, and scientific reports that can be used (by other actors) to construct narratives able to describe a phenomenon, and attach and explain its value. Such narratives, in turn, can be performed on social arenas, especially media, public meetings, exhibitions, and in parliament, that serves to circulate and eventually establish, if successful, the value of a phenomenon. All these entities—actors, artifacts and social arenas—forms part of value articulation (Fig. 1).

With the rapid development of research and policy around ecosystem services, there are now both actors (especially scientists), artifacts, and social arenas involved in describing and explaining how biophysical processes can be seen as having value to humans; in monetary terms, as 'payment for ecosystem services' (Ring, Hansjurgens, Elmqvist, Wittmer, & Sukhdev, 2010), or as the amount of physical area (e.g. hectares of forest) needed to produce them in a wider landscape (Goldman et al., 2007). Even a "discourse-based valuation" of ecosystem services has been put forward by Wilson and Howarth (2002), which uses focus groups with different stakeholders to generate deliberative discussions to bring out more viewpoints on ecosystem services (seen as a complement to contingent valuation based on individual preferences alone). Yet none of these, not even the latter, offers a framework for analyzing the relational dynamics between actors, artifacts, positionality, and discourse that underpins the articulation of ecosystem services. In fact, all are good examples of value articulation process themselves, through their production of artifacts (numeric values, maps, scenarios, hierarchic lists of species and services), and social arenas (e.g. scenario workshops) to which actors have different access.

In this regard, Actor-Network Theory (ANT), developed initially in sociology in the 1980s to study scientific practices, provides a compelling framework (Latour, 2005). Here value articulation processes can be seen as a political program that gains power as actors 'pick up' artifacts (often produced by other actors) and align them with their program to give it 'weight'. For instance, a scientific report of red-listed species becomes an asset for environmentalists but an obstacle for developers. As can be noted, the idea of 'value' is in fact quite material; things and objects are enrolled together with humans to stabilize certain values (and not others). This alignment between humans and non-humans has been referred to as actor-networks, or a "sociology of translation" (Callon, 1986). Although actor-networks do not possess power in any formal sense, they can achieve a lot, i.e. gain power as they enroll yet more humans, artifacts and social arenas in their webs of articulation. In Stockholm a large park landscape was protected through the use of old maps of planned English parks, recent maps of biodiversity dispersal corridors, and public arenas where values of this particular green area could be articulated (Ernstson & Sörlin, 2009). The Capetonian ecologists used their biodiversity maps to mobilize support at city hall for their Biodiversity Network, and as the map was later reprinted in newspapers, bill boards and reports, it could attract yet more supporters to subscribe to the values it articulated for certain green areas.

In accounting for how ideas are in need of material objects to gain influence, a more relational and power-laden view can be achieved on how biophysical processes gain value and become prioritized in certain urban spaces. Empirical research can trace competing actor-networks that strive to translate values of different sets of ecosystem services for the same areas. Case study analysis can firstly be directed towards identifying the actors and artifacts involved, the practices used in linking these together, and how values are articulated on public arenas, including actors such as scientists, consultants, activists and others. Secondly, this allows for analysis of the structural conditions for different social groups to participate in assembling actor-networks (following a "weak" mode of ANT analysis, see Castree & MacMillan, 2001). What time, skills and resources do different groups have in participating in assembling actor-networks to articulate certain ecosystem services? What types of artifacts are associated with different green areas and what type of land use and ecosystem services do these artifacts favor? And what access do different groups have to public arenas? All these structural conditions would influence the shape and emergence of actor-networks and give analytical tools to understand why certain ecosystem services would be prioritized before others. These two steps of analyzing value articulation processes in case study analysis are demonstrated and discussed in a series of papers (Ernstson, 2012; Ernstson & Sörlin, 2009; Ernstson & Sörlin, in press).

5. Analyzing changes in social–ecological systems: the two modes together

Taken together the two modes of analysis can be used in analyzing changes in the production of ecosystem services in urbanized landscapes. The second mode of analysis, to analyze value articulation processes (using a constructionist perspective), aids in comprehending that the generation and distribution of a certain set of ecosystem services, both for a certain urban green area and for a whole landscape, is a result of a nested set of political socio-cultural processes expressed as actor-networks in which certain actors are more influential than others. By interlinking value articulation with analyzing social–ecological networks (using a structuralist perspective), it becomes possible to interrogate the effect of how socio-political processes moderate biophysical processes at different scales, and who that might effect. The adding, losing, or deterioration of nodes in the social–ecological network (through the levels of management and protective capacities), shows how local changes can have effects elsewhere. As noted, to lose central nodes in the network might have knock-on effects undermining a whole set of ecological functions.

To illustrate how the framework can be put to use, and how it can bring about important lines of interpretation in case study work, we will move back to Stockholm and two specific urban green space struggles between 1990 and 2009. In 1990, following the move by the state to support the building of motorways, conference centers and offices around a set of green areas in the central and northern parts of the city, an alliance of civil society organizations managed to protect 27 square kilometers of park areas in 1995 (Ernstson, Sörlin, & Elmqvist, 2008). Focusing first on the analytical moment of articulation, analysis made clear that as activists engaged the planning process, both formally and informally (through lobbying politicians, organizing public debates and exhibitions), a set of artifacts was put into use including historical maps of planned English parks, records of rare species tied to the areas, and surveys over how birds moved through the landscape. Through this relational process of 'picking up' artifacts, they started to articulate holistic values of a unified park that came to increasingly link a royal heritage with biological diversity, pulling in supportive experts from the humanities and biological sciences (Ernstson & Sörlin, 2009). This "protective story" was spread through interviews and op-ed articles in media, even in television, and mobilized an increasing public support for protecting the areas, eventually pushing the issue to the National Parliament where the park areas received protection.

In moving to a broader view of analyzing the social production of ecosystems services, there was an important city-wide effect in protecting this large park. While clearly securing attractive local ecosystem services for those (mainly high-income earners) living close by, other green areas, in other parts of the city, began experiencing a greater pressure to be developed, and this in locations where residents struggled to articulate resonate values. A case in point is a green field in a traditional working class and middle class area in southern Stockholm. Here the city has gone ahead in 2012 with a plan to build 4000 housing units on a green field, despite local resistance of a similar kind as above, and against a previous city decision from 2001 to develop a multi-use landscape park with no housing (Benson, 2009). One reason why this particular attempt of weaving a "protective story" failed was because the field had no royal heritage to claim, and had attracted little social and biological research. This had left less useful artifacts to craft arguments powerful enough to articulate values and intervene in the planning process (Benson, 2009). Although other factors, like the ability of local residents to mobilize collectively also played a role, the lack of useful artifacts illustrates a very tangible and almost structural 'geography of difference' in how the crafting of artifacts by elite professions (including biologists, artists, and heritage experts) interacted with the level of protective capacity for this green area.

The previous example demonstrates how the framework helps to move between scales of analysis and assemble—here through two local case studies—an understanding of the processes through which environmental injustice operates, and how the socio-cultural geography of difference in a particular city, interlinks with the generation and distribution of benefits from biophysical processes. Following on to this, an hypothesis based on this framework would be that the exploitation pressure, which is driven by socio-economic processes, would seek out those green areas with lowest protective capacity, and highest profit value. Crucially, if some of these areas have high centrality in the ecological network, their removal could trigger threshold effects in ecological connectivity and erode not just the distribution of local ecosystem services, but also the capacity to generate larger-scale ecosystem services and the ability to regenerate after disturbance, also known as spatial ecological resilience (Nyström & Folke, 2001). The removal of local green areas could also lead to an uneven distribution of at least local urban ecosystem services, which could correlate (or not) with other uneven spatial patterns of urban service distribution (Harvey, 1996); this was observed by Heynen (2003) in Indianapolis. In Cape Town, green areas and urban forests are almost exclusively found in higher income areas. At the same time, while high-income residential areas have been planted with non-indigenous trees and plants (following colonial traditions), a greater pressure to produce (i.e. conserve) biodiversity has fallen upon poorer areas. Important to note, and one of the key findings from studies in Stockholm (Ernstson et al., 2010), San Francisco (Walker, 2007) and Cape Town (Ernstson, 2012; Ernstson & Sörlin, in press) is that an active civil society is an important factor behind both protective and management capacities, and consequently that civil society plays an important role in the social production of urban ecosystem services (see also Krasny & Tidball, 2009).

To summarize, the conceptual framework of the social production of ecosystem services acknowledges that biophysical processes—and their often-unequal patterns of benefits—are mediated through political processes (Harvey, 1996; Swyngedouw & Heynen, 2003). However, it also sustains, within the framework, the issues of scales and ecosystem complexity. Ecosystem services are treated not just as the outcome of (non-human) biophysical processes, nor simply as outcomes of "trade-offs" or managerial and consensus-based "navigation" of social–ecological systems (Berkes et al., 2003), but inherently also as a result of value articulation, discourse, and political struggle.

6. Concluding remarks

In staying within the conceptual apparatus of ecosystem services, this article has developed a heuristic framework for analyzing the environmental justice of ecosystem services in urbanized landscapes, retaining a sensitivity to ecosystem complexity. Drawing on a wide and interdisciplinary set of theories and methods, empirical examples aided in gaining understanding of how social and ecological processes are entangled in urbanized landscapes, and how these can be studied through the analytical lens of generation, distribution and articulation of ecosystem services. Although the focus was on urbanized landscapes, the framework should have growing relevance on a planet ever more dominated by humans, which expands capitalist competition over land-use (Lefebvre, 1974 [1991]). Here follow some concluding remarks.

First, although questions remain on how to empirically use the framework in case study analysis, some notions on how to go about have been touched upon. This included how to assess management and protective capacity (Andersson et al., 2007; Borgström et al., 2006; Ernstson et al., 2010), and how to study value articulation (Ernstson, 2012; Ernstson & Sörlin, 2009; Ernstson & Sörlin, in press; Sörlin, 1998). Techniques for how to construct relevant ecological networks for urbanized landscapes have been briefed, which when based on functional species and ecological flows can translate between structural network changes to changes in ecosystem services (Andersson & Bodin, 2008; Bodin et al., 2006; Zetterberg et al., 2010). Methods for social–ecological network analysis are also emerging (Bodin & Tengö, 2012; Cumming, Bodin, Ernstson, & Elmqvist, 2010). Together, this assembles a first set of methods to analyze the social production of urban ecosystem services, which through iteration could be refined and expanded.

Second, and linked to the first, the analysis of the distribution of ecosystem services needs to be developed further to fully address justice (Cook & Swyngedouw, 2012). Ribot and Peluso (2003) usefully write about a "theory of access" viewed as "the ability to derive benefits from things" (in contrast to merely the rights to benefits, as in property theory). The framework developed here analyzed at which scales ecosystem services were distributed (seen as a precondition to access), but nothing was said about the additional power practices involved in constraining and facilitating the access to ecosystem services. At the local scale, a green area could be surrounded by a high wall excluding recreation for a certain group, thus constraining their access to this type of ecosystem service. However, on the other hand, the same group might still benefit from improved air quality that a green area generates.

Third, through analyzing value articulation processes around ecosystem services, two fallacies of contemporary thinking on natural resource management can be addressed: first an overly objectivist stance that ecosystem services exist "out there" in the landscape (independent of humans and social articulation); and secondly that the process of "finding the right trade off" between different ecosystem services is often simplified into a consensual process, or a rational choice game between actors with fixed interests (so called stakeholders) that can be steered/guided by economic incentives. These fallacies are grave since the analyses that follow from them will miss the processual and relational dynamics captured in actor-networks and value articulation, involving people, artifacts, knowledge, and power (Ernstson, 2012; Ernstson & Sörlin, 2009; Ernstson & Sörlin, in press). Closely associated with this, models of adaptive management and governance of ecosystems can be interrogated (Folke, Hahn, Olsson, & Norberg, 2005). In these models, knowledge about specific ecosystems, as held by different actors and users, are predominantly seen as merely "functional" or useful for building more complete understanding of ecosystem dynamics, a functionalist approach to knowledge. This tends to neglect the situatedness of knowledge as a product of social class and cultural processes (e.g. Shapin, 1995). Using the repertoire of Actor-Network Theory and value articulation, presumes that knowledge is constructed, and that certain ways of knowing might be silenced. This could open analytical pathways to better come to grips with how different stakeholders can bias management towards certain ecosystem services (Ernstson, 2012; Ernstson & Sörlin, 2009; Ernstson & Sörlin, in press).

Fourth, if the guiding rule of analysis and application of ecosystem management is to sustain social–ecological resilience, interpreted as the ability to maintain the generation of ecosystem services (Folke et al., 2002), then it could be argued that system resilience can be sustained by maintaining unjust, even oppressive social structures, i.e. in which the distribution of (and access to) ecosystem services falls unevenly among the present and future population. With a two-fold perspective on social–ecological systems—both distribution and generation of ecosystem services are equally appearing—this way of thinking about resilience can be scrutinized and challenged, and instead invite to creative and radical thinking on political actions to transform the system towards both increased ecological resilience and social justice (Fig. 2). For this, I offer a more critically formulated definition of system resilience:

> Resilience is the capacity of a social–ecological system to sustain a certain set of benefits from biophysical processes, in face of uncertainty and change, for a certain set of humans.

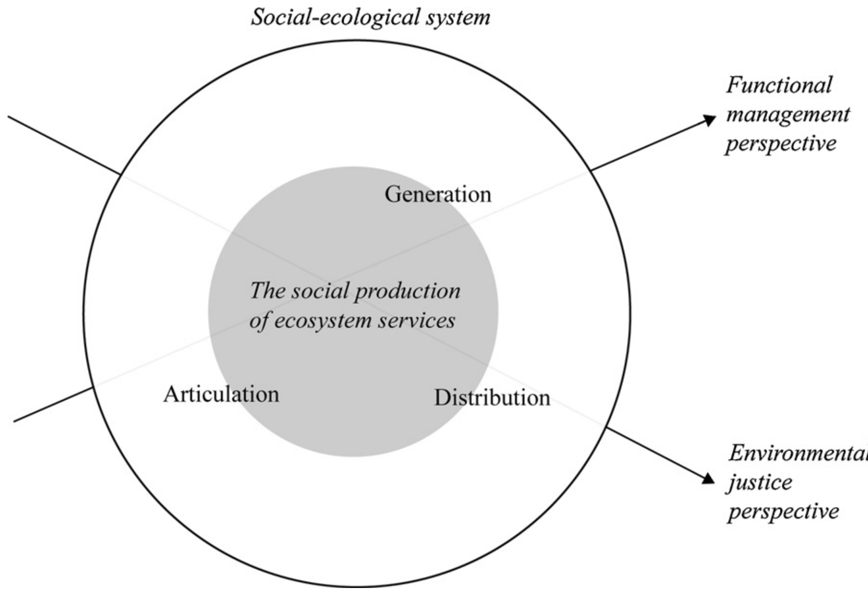

Fig. 2. The social production of ecosystems services can be related to resilience and social–ecological systems, i.e. integrated complex systems in which humans are seen as part (Berkes et al., 2003). In doing so, questions on justice, power and the distribution of benefits are necessarily arrested. While a more conventional 'functional management perspective' can be used to understand how humans can play a role as 'stewards' in supporting the generation of ecosystem services, the notion of distribution, or who can access these benefits can be brought in to complement social–ecological systems studies with an explicit environmental justice perspective. Articulation is used to understand contested processes of land use and which ecosystem services to prioritize in management.

Applying this definition to practical research begs the researcher to analyze not just how ecosystems are managed (as in most natural resource management literature), but also which ecosystem services that are prioritized (as in recent literature on trade offs)—and on top of that, who benefits from these services. This cracks open the social–ecological system and the concept of ecosystem services for environmental justice analysis, without losing the analysis of how to manage and interact with complex ecosystems in uncertainty and change. It also avoids the circular reference of those definitions that include the hypothetical solution to sustain resilience (e.g. the capacity to reorganize and innovate as in Berkes et al., 2003), or too normative suggestions that resilience and ecosystem services should benefit everybody, which, like the fate of "sustainability", precludes radical critique since nobody can be against it (Harvey, 1996: 148). Instead, this definition follows the original spirit of Buzz Holling's resilience definition from 1973, while it merely treats resilience as a property of a system (Holling, 1973). How that system operates to sustain resilience is left for analysis. This means that system resilience is not just good or bad, but that it can be good for some and bad for others, making this definition more useful in analyzing the question of "resilience for whom and for what" (Armitage & Johnson, 2006).

A fifth concluding remark pushes the essay outside the conceptual apparatus of the 'ecosystem services approach' and demarcates a boundary to more critical discourse. The notion of a 'social production of ecosystem services' can be related to Smith's notion of the "production of nature" (Smith, 1984: 34ff). Here social labor processes and the modes of production are seen as reshaping material reality, producing different natures along the way in historical process (see also "social nature" (Castree & Braun, 2001), "second nature" (Cronon, 1991), and "cyborg urbanization" (Swyngedouw, 1996; Gandy, 2005)). Harvey also reminds us that while the standard view is that natural resources have limits and can become scarce, he offers "a relational definition" in which natural resources (which would include ecosystem services) are seen "as a 'cultural, technical and economic appraisal of elements and processes in nature that can be applied to fulfill social objectives and goals through specific material practices"' (Harvey, 1996: 174). This definition recognizes that resources are part-and-parcel of society, not just as material resource, but also as a discursive resource. For instance, it is not until recently that the ability of vegetation to absorb carbon dioxide molecules is considered an "ecosystem service", which in turn is mobilized to construct particular forms of 'global' forms of governing the use of land in various countries. The biophysical mechanism of photosynthesis has of course existed for long, but due to the historical fossil-fuel industrial production of the West, this mechanism is now translated in policy arenas as an ecosystem service with a market-based monetary value, which risks silencing the West's historical debt in triggering climate change. Western Cape, as yet another example, is considered a "water-scarce" region. But, a great part of that scarcity is due to that some use much more water, which—when translated into a commodified ecosystem service—the rich can use more of (because they can afford it), while others are left with much less. Society produces scarcity (materially and discursively), and in its wake, society produces services (materially and discursively).

The framework presented here is for analyzing the generation, distribution and articulation of ecosystem services. It is designed to invite for systemic critique of current social order, while maintaining sensitivity to ecological complexity. Hopefully it can also aid in working out material political practices towards democratizing urban change and increase justice.

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