



Infrastructural nature

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Abstract

The assertion that ‘ecosystems are infrastructure’ is now common in conservation science and ecosystem management. This article interrogates that claim, which we argue underpins diverse practices of environmental investment focused on the strategic management of ecosystem functions to sustain and secure human life. We trace the genealogies and geographies of infrastructural nature as a paradigm of investment that coexists (sometimes in tension) with extractivist commodity regimes. We draw links between literatures on the political economy of ecosystem services and infrastructure and highlight three themes that hold promise for future research: labor, territory, and finance.

Keywords

ecosystem services, finance, infrastructure, labor, territory

I Introduction

In September 2016, the California legislature passed an apparently dull bill dealing with new revenue-raising mechanisms for watershed management. With a variety of environmental regulatory funding tools in place – from the state’s carbon market revenue to the highest gasoline tax in the United States – a law that allows the state to issue special purpose revenue bonds for watershed restoration projects garnered little attention. Yet this mechanism is underpinned by a critical epistemological move: AB2480 establishes that ‘source watersheds are recognized and defined as integral components of California’s water infrastructure’, and makes their ‘maintenance and repair’ through forest restoration eligible for the same kinds of financing as other, conventional

infrastructure (California Legislative Information, 2016). California’s water infrastructure is no longer considered just the pipes, treatment plants, and reservoirs on which the state’s residents and industries depend but also the streams, soils, and trees that coregulate the water flowing into these sociotechnical systems. These natural systems are not being redefined as just any kind of infrastructure but as *rent-bearing* infrastructure whose maintenance can be funded and accounted for through the same processes as ‘gray’ infrastructure.

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The assertion that ‘ecosystems are infrastructure’ (TNC, 2016: n.p.) is now relatively uncontroversial in mainstream conservation science and advocacy, but its policy and political economic implications are only starting to emerge. The terms natural, green, blue, and ecological infrastructure have proliferated in scientific and planning literature since the late-2000s, used to describe the management of ecosystems to ensure the delivery of various ecosystem services (Cardoso da Silva and Wheeler, 2017; Seiwert and Rößler 2020). Ecosystems’ infrastructural properties are said to be manifest in their ability to provide services while mitigating environmental risks (TNC, 2016); the ‘resilience’ and ‘regenerative processes’ that enhance their flexibility in dealing with environmental threats, often at a lower cost than conventional infrastructure (The Case for Green Infrastructure, 2013: 2); and their interconnectivity with other critical infrastructures (Cardoso da Silva and Wheeler, 2017). This understanding of natural infrastructure is now explicit in environmental policies in the United States and European Union (Cardoso da Silva and Wheeler, 2017), is ubiquitous in planning discourse (Seiwert and Rößler, 2020), and is promoted by major environmental institutions and intergovernmental bodies, often under the heading of ‘nature-based solutions’ to climate change and other environmental urgencies (Global Commission on Adaptation, 2019; IPBES, 2019; IPCC, 2019: 46; Xie and Bulkeley, 2020).

This article aims to define the epistemological and material processes, along with the ontological claims, that underpin this reframing of nature as infrastructure. We use the term *infrastructural nature* to describe policy approaches, scientific practices, discourses, and investment strategies that make ecosystems legible, governable, and investable as *systems of critical functions that sustain and secure (certain forms of) human life* (see also (Nelson et al., 2020)). Our use of this term is distinct from adjacent terms like green or natural infrastructure. We emphasize that nature is not simply infrastructure, but – in keeping with

the fundamental insights of political ecology – it takes work to make it function that way and to govern it as such (Wakefield, 2019). This includes the scientific work of monitoring and modeling ecosystem functions, regulatory and managerial work to guide investment, and the physical work of ecosystem restoration and stewardship (Carse, 2012; Wakefield, 2019). Further, we find infrastructural natures – contiguous socationatures managed in situ for their instrumental anthropocentric functions – even where we do not find them explicitly named as such; for instance, in many payments for ecosystem services (PES) and related programs that draw infrastructural connections among upstream ‘providers’ and downstream ‘users’ of ecosystem services. We argue that infrastructural nature is an ascendant feature of environmental governance far more widespread than terms such as ‘green infrastructure’, generating new ways that landscapes, ecosystems, and their complex materialities are ‘rendered investable’ (Ouma et al., 2018).

Understanding investments in infrastructural nature and the political terrain they articulate, we argue, requires drawing links between the political economy and ecology of ecosystem services, and interdisciplinary critical studies of infrastructure. We forge links between these fields to explain how ecosystems are made investable as infrastructure for sustaining capitalist (re)production, to highlight the biopolitical, territorial, and futurological dimensions of ecosystem management, and to make visible its continuities with other kinds of infrastructure investment – principally through knowledge transfer from infrastructure investment to conservation finance. This is not to assert that infrastructural natures can only serve the reproduction of capitalism; they simultaneously have other political lives, as does any infrastructure. While efforts to render nature infrastructural are often emblematic of technocratic environmental post-politics, they also reveal possibilities for articulating postcapitalist socationatures through

scientific and political contestation over how environmental functions and their values are socially recognized. Learning from infrastructure studies, we argue, helps us to navigate the paradoxical existence of infrastructural natures as capitalist assets and life-support systems, revealing political dynamics and continuities of struggle not visible through the lens of nature's marketization or commodification. The value of this perspective on infrastructural nature is a more comprehensive understanding of the terrain of 'infra-politics' (Anand, 2011) and a more precise engagement with the epistemological and ontological claims underpinning capitalist natures as they shape landscapes and lives.

We begin by more thoroughly defining infrastructural nature and the need to attend to the multiple ontologies of capitalist nature. We then trace the genealogy of infrastructural nature through systems ecology and economic analyses of ecosystem functions emerging in the 1960s and 1970s and the evolution of infrastructure as a strategy for development. Next, we examine the diverse forms of work and investment involved in producing infrastructural nature and identify three themes in the political economy of conservation on which we gain purchase through the lens of infrastructure: territory, labor, and finance. Throughout, we bring together literature in infrastructure studies and environmental political economy to highlight fruitful intersections and promising research gaps. The conclusion reflects on the political possibilities opened (or closed) by thinking and doing infrastructural nature.

II Ontologies and Genealogies of Infrastructural Nature

The explicit naming of nature-as-infrastructure in the scientific literature calls attention to a reality already evident in contemporary environmental governance: the valuation and management of nature as a provider of instrumental services to humans. The quantification and

monetization of ecosystem services have been the empirical bread-and-butter of the neoliberal natures literature for most of the 21st century, understood as a symptom of, and vehicle for, 'accumulation by conservation' (Büscher and Fletcher, 2015; Castree, 2008a, 2008b; Doane, 2014; Kolinjivadi et al., 2019; McAfee, 1999; Robertson, 2006). But the language of ecosystems *qua* infrastructure offers a further evolution of this idea: In keeping with Carse's (2016) observation that the term infrastructure – unlike its close relatives system and network – implies 'relationships of depth or hierarchy', natural infrastructure is understood as situated behind or below ecosystem services. The idea shifts attention to the work required to design and manage ecosystems or entire landscapes in such a way that they produce the bundle of services required of them and to invest in their maintenance in the most cost-effective (or even lucrative) way possible. For instance, a recent article on ecological infrastructure investment argues that nature's ability to 'act[] as capital' by 'stor[ing] wealth and pass[ing] it through time' depends in turn on the institutional and material ability 'to change an ecosystem to produce a greater level of service . . . that is, to supply ecological infrastructure' (Adamowicz et al., 2019: 5254).

Proponents of green infrastructure noted recently that 'the value of [green infrastructure scholarship] arises from its substantial consolidation of ideas rather than from entirely new arguments' (Seiwert and Rößler, 2020: 1). Such discourses engage infrastructure as a 'form of calculative reason . . . [that] promises to collect a heterogeneous, changing group of elements 'beneath' some higher-order goal' (Carse, 2016: 35–36). But this epistemological move entails ontological claims about nature's complexity and resilience that differ from, and interact with, other capitalist ontologies of nature (for instance, as a predictable supplier of standardizable commodities (Prudham, 2005)). The rise of infrastructural nature thus demands a

renewed focus on the multiple ontologies underpinning capitalist natures.

Even while it has been constantly troubled in scholarship on neoliberal natures, the category of nature can remain underexamined as an object undergoing neoliberalization: for instance, Bigger and Dempsey's (2018: 30) reflection on neoliberal natures charts a number of 'aspect[s] of nature being subjected to new(ish) financial practices', among them private equity farmland acquisition, municipal debt for low-carbon infrastructure, or tradable permit systems for ecosystem services. But the diversity of 'bits of nature' (p. 29) covered in this scholarship raises the question of what, exactly, we talk about when we talk about nature in the context of contemporary capitalism. Even where these ontologies have been meticulously traced in empirical literature on ecosystem service markets and other environmental commodities (e.g. Bumpus, 2009; Robertson, 2018), these insights do not always carry over to broad definitions of the 'neoliberal natures' subfield, where diverse forms of environmental investment are often united by reference to 'nature', whose materiality is understood as somehow uniquely consequential (Castree, 2008a).

The problem is also evident in recent discussions of value as a central theoretical problem in geographical critiques of capitalist natures (Andueza, 2020; Huber, 2018; Kenney-Lazar and Kay, 2017; Robertson and Wainwright, 2013). For instance, Huber (2017: 47) argues that Marx's theory of value helps us to understand both the devaluation of nature under capitalism and the 'parts of nature' that capital does value. Huber writes that '[o]nly paying attention to the nature capital does not value led [James] O'Connor to theorize nature as a set of external ecological 'conditions' somehow 'outside' the relations/forces of production' (p. 48).

But this statement reveals a crucial problem with the terms of analysis: while we should certainly pay attention to the 'internal materiality of nature's role in the production and reproduction

of social life' (Huber, 2017: 48), arguments about value (and in turn capital as a social relation) become nonsensical when we start talking about how capital relates to 'nature' in a general sense.¹ 'Nature' is not something that biodiversity offsets, board feet of lumber, or acres of farmland have in common. What investments in infrastructural natures share is not that they are uniquely concerned with nature nor that they utilize market-like mechanisms, but that they (1) manage or construct *ecosystems* at various scales, to (2) *engage ecological complexity and resilience* for the production of (3) spatially explicit *environmental functions* that sustain or secure human lives, industry, or commerce. Here, 'environmental' is not synonymous with 'natural' but signals those human and nonhuman forces externalized and objectified by capital in the process of putting value in motion – part of capital's constitutive outside (Gidwani, 2012; Nelson, 2015). It is, like O'Connor's (1988) production conditions, a relative term describing how various entities and relations are positioned *from the perspective of capital*. Infrastructural natures thereby find common ground with gendered reproductive labor also selectively de- and revalued by capital, more so than with resource commodities such as coal or timber (Battistoni, 2017).

Emphasizing ecological scales of intervention and an ontology of ecological complexity that underpins these interventions, our definition of infrastructural nature is distinct from, on the one hand, small, gray-infrastructure add-on projects like roof gardens and, on the other, 'cultural' or ecosystem services associated with habitat for protected species or recreation. Key here are the spatial relations established among particular ecologies and populations for the delivery of instrumental services, which marks an operational distinction between infrastructural nature and some tradable or compensatory ecosystem services schemes based on regulatory requirements that ensure 'no net loss' of habitat for protected flora and fauna (see Robertson, 2006). In

contrast, infrastructural natures are designed to restore or enhance instrumental ecosystem functions for particular populations, which are interoperable with gray infrastructure (Christophers, 2018).

What is new about infrastructural natures is not that 'nature' has never before been subject to market logics but that those reproductive processes whose very naturalization and externalization has been essential to capitalist reproduction are themselves made into sites of investment and value extraction without, however, 'denaturalizing' them. Infrastructural nature is therefore also a naturalization of infrastructure as a social relation that tethers socioecological reproduction to the dynamics of capital circulation and investment. It transforms complex ecologies into systems for the delivery of anthropocentric services while simultaneously obscuring the work, and therefore the politics, involved in this transformation.

We can understand the lineage of infrastructural nature by looking more closely at the concept of ecosystem services at its roots. A first meaning, based in welfare economics of John Krutilla (1967), built on the idea that the true end of all economic activity is the 'service' provided in the form of increased welfare for the consumer. It is based in the neoclassical understanding of value as individual preferences expressed as willingness-to-pay, for example, to preserve a specific viewscape, or even the knowledge that a particular landscape exists (e.g. Blomquist and Whitehead, 1995). A second version of ecosystem services entailed a new economic analysis of ecosystem function (Huetting, 1980; Westman, 1977). This idea is operationalized in diverse forms of ecosystem function valuation including carbon sequestration, flood mitigation, water availability, or other 'regulating' or 'provisioning' services within the typology established in the Millennium Ecosystem Assessment (MA, 2005). It entails an ontological repackaging of nature as a suite of services already integral to

(re)production, a regime of recognition for capital to 'see' the free gifts of nature and attempt to incorporate their cost as a factor of production.

While these two concepts – that of the 'cultural value' of landscapes and the economic analysis of ecosystem function – are often rolled together (e.g. Costanza et al., 1997), it is the second that is our primary interest here. This version of ecosystems services is conceptually distinct from ideas of cultural and recreational services insofar as it is concerned with the definition and measurement of ecosystems in terms of the instrumental functions they produce, requiring new scientific tools to 'characterize the functional traits and functional importance of populations, communities, guilds, and interacting networks of organisms that deliver services' (Luck et al., 2009: 224). In other words, our use of infrastructural nature refers to the management of in situ ecosystems for the delivery of instrumental environmental functions to sustain and secure specific human populations or industries, distinct from other economic values that may flow from ecosystems – such as aesthetic or recreational values.

Geographical thinking on capitalist ontologies of nature has long sought to problematize visions of nature as a stable and standardizable producer of commodities and their attendant management practices (e.g. Prudham, 2005). But, while it may be a feature of industrial monoculture, the production of equivalence in exchange-values should not be conflated with the 'flattening' or homogenization of ecologies themselves (Joseph, 2013; Prudham, 2009). Contemporary articulations of infrastructural nature are rooted in ideas of ecological complexity, resilience, and quantitative analysis of environmental functions characteristic of modern ecological science. Not simply flattening ecological complexity in the service of standardized commodity production, infrastructural natures aim to govern and direct complexity toward specific, instrumental ends. In this process, multiple 'ruling ontologies' of nature (as resilient infrastructure; as standardizable commodity) coexist in tension (cf. Yates

et al., 2017), and diverse materialities of nature are drawn into circuits of exchange through overlapping and potentially contradictory regimes of valuation.

Infrastructural natures do not replace extractivist projects; rather, they introduce new values that overlap, and are in potential contradiction with, ongoing imperatives to other commodity values. For instance, Lansing (2012) has shown how Costa Rica's national PES program functions as an implicit subsidy for the forestry sector and export agriculture. In turn, forests' infrastructural functions must be managed through the continued exploitation of forests-as-timber. Infrastructural natures can also be integrated with existing gray infrastructure to remediate the impacts or enhance the resilience of extractive industries. For example, Shell conducted wetland and oyster reef restoration to protect oil and gas infrastructure from storm surges and erosion (Kupers, 2014: 157–159), and the integration of 'green' infrastructure solutions is an increasingly common repair strategy for aging or insufficient gray urban stormwater infrastructure.

In these cases, the revaluation of degraded landscapes as infrastructural natures might be described as a socio-ecological fix for previous fixes gone bad (Ekers and Prudham, 2017), whereby particular places and ecosystems cycle in and out of accumulation strategies. Collard and Dempsey (2017) outline five 'orientations' of capitalist natures by which humans and non-humans are positioned in relation to accumulation, ranging from 'officially valued' to 'outcast surplus' and 'threat'. Infrastructural natures move between these categories, repositioning previously 'outcast' landscapes as both the source of risks – such as flooding or forest fire – and their potential mitigation via the pricing of undervalued ecosystem services. West (2016) analyzes this motion by reading Luxemborg's theory of imperialism through Smith's rent gap, emphasizing the tidal character of exploitation – a spatial fix that requires periodic redefinition of external nature and the types of accumulation it

can be enrolled to support. Through this process spaces, species, and people surplus to the immediate needs of capital accumulation become discursively coded as waste in need of the rectifying power of investment (Dempsey and Bigger, 2019), which can increasingly be structured as infrastructural investment. Infrastructural nature emerges through these dynamics of de- and revaluation. It coexists in tension with other value regimes, both past and present, and their institutional, ecological, and social legacies.

Contemporary discourses and practices of infrastructural nature are a further evolution of the term infrastructure, which in the 20th century came to embody the promise of the developmentalist state while securing its territorial control and the conditions of accumulation (Carse, 2016; Gandy, 1999, 2006; Escobar, 1995). In her study of the reconstruction of oyster beds to mitigate storm surges in New York City, Wakefield (2019: 7–8) argues that the turn to natural infrastructure following Hurricane Sandy entails a 'problematization' of infrastructure that recasts the relation between nature and the city:

Modern infrastructures with their city/nature binaries were immediately cast as outdated, the source of the problem, and the need to experiment with new infrastructures based in a view of the city as an interlinked social-ecological-technical system was forefronted as key to survival . . . The *New York Times* summed up the new mantra: 'the era of big infrastructure is over.'

The invocation of ecological infrastructure to refigure the city as its own solution is symptomatic, Wakefield suggests, of the rise of 'resilience infrastructures' in response to the 'new urgencies' posed by anthropogenic environmental change (Wakefield, 2019: 7). In this way, infrastructural nature's currency should be understood in the light of the general crisis of faith in the modernizing project heralded by the Anthropocene, as efforts to reconfigure nature–

society binaries become matters of ‘disaster management’ (Wakefield, 2018, 2019). Infrastructural nature seeks to mobilize the regenerative power of biotic life to reinvigorate the liberal promise of infrastructure, aiming to demonstrate ‘that natural capital can be leveraged rather than liquidated through the development process’ (Steer and Tuck, 2019: 1). But as Wakefield (2018; Wakefield and Braun, 2019) describes of other ‘resilience infrastructures’, infrastructural natures do not promise to renew progress but to sustain life in its ruins.

III Labor, territory, and finance in infrastructural natures

The concept of infrastructural nature makes visible new continuities and differences among the diverse forms of public and private investments and institutional arrangements that characterize environmental governance in late liberal capitalism. Infrastructural nature is at work, for instance, in some PES and related schemes that offer incentives to ecosystem service ‘providers’ to perform conservation activities designed to produce vital services (such as water provision or carbon sequestration) for other populations. Annual transactions in the 500+ PES programs globally are, according to a 2018 assessment, around US\$30–50 billion (Salzman et al., 2018). While few of these schemes resemble the efficient markets of neoclassical theory (Muradian et al., 2010; Shapiro-Garza et al., 2020), many take ecological functions that are figured as infrastructural as their object of management: provision and regulation of water flows for irrigation and drinking water; flood and erosion control; sequestration of carbon (Salzman et al., 2018). Infrastructural nature provides a lens through which to comprehend the socio-spatial relations established in such programs between ecosystem service ‘users’ and ‘providers’, which rescale environmental governance and revalue rural spaces and livelihoods (Nelson et al., 2020; Shapiro-Garza, 2013).

The scales at which infrastructural natures operate depend on the service(s) in question. Figured as carbon sinks – an infrastructural function predominant within conservation agendas since the United Nation’s Reducing Emissions from Deforestation and Degradation (REDD and REDD+) initiatives – forests can deliver services to users around the globe, the service being performed in the abstracted atmospheric space of carbon accounting. Carbon offsetting has been widely critiqued for reinscribing colonial relations inherent in previous regimes of development infrastructure, that transform (mainly tropical) landscapes in the global South in the interests of continued emissions in the global North (Asiyanbi, 2018; Beymer-Ferris and Bassett, 2012). Despite donor aid for REDD schemes at around US\$2 billion/year, these projects have programmatically failed to produce a global arboreal carbon sequestration infrastructure while effectively undermining decarbonization agendas in the global North and capturing bi- and multilateral funding that could otherwise produce better mitigation or adaptation infrastructure (Atmadja et al., 2018; Lang, 2018).

Local or regional investment in infrastructural natures for the delivery of provisioning ecosystem services has shown more growth than stalled forest carbon plans. Perhaps, the most widespread application of infrastructure nature ideas is in freshwater management, despite persistent uncertainty in the science behind such interventions (Andréassian, 2004; Brauman, 2015). The conservation industry analyst Forest Trends identified nearly US\$25 billion in transactions for watershed protection in 2015, not counting direct investments in watershed protection by governments or private landholders (Bennett and Ruef, 2016: 1).² These transactions impacted 486 million hectares of land in 62 countries – an area ‘roughly 1.5 times the size of India’ (Bennett and Ruef, 2016: 2). Ninety-eight per cent (US\$24.4B) of the value of these transactions fit our definition of

infrastructural nature, involving the direct protection or restoration of source watersheds. The vast majority of this spending came in the form of public subsidies to landholders for watershed protection or restoration activities (US\$23.7B), signaling a broader trend: the monies flowing into infrastructural nature are overwhelmingly public (Bennett and Ruef, 2016: 2). We exclude from this accounting water quality trading; offsets not linked to instrumental, infrastructural functions (i.e. most wetland credits); and buy-backs and retirement of water rights, which do not constitute investments in infrastructural nature as defined here.

Aside from governments, multinational companies (principally in the beverage sector) are important actors driving watershed investments. For instance, the Latin American Water Funds Partnership, a joint venture between The Nature Conservancy (TNC), the Inter-American Development Bank, and the philanthropic arm of the Mexican CocaCola subsidiary FEMSA, has established 24 water funds across Latin America, where conservation priorities in upstream territories are driven by municipal utilities and industrial water users downstream (Bremer et al., 2016). In the United States, utilities are increasingly adopting a proactive approach to land management for ecosystem services: aligned with the California legislation described in the introduction to this article, the nonprofit Blue Forest Conservation is currently piloting Forest Resilience Bonds in locations across the Sierra Nevada that aims to generate large-scale private investment in forest restoration on public lands by monetizing the ecosystem benefits to downstream water and hydropower utilities, including reduced sedimentation, reduced wildfire risk, and increased water flows by managing complex ecological systems in-place (BFC, n.d.). This model transfers debt-structuring strategies from infrastructure finance to forest management, bringing private capital to address shortfalls in federal land management and introducing a new calculus of value to public lands.

In addition to landscape conservation, there is a trend toward the incorporation of natural or reconstructed ecosystems into traditional ‘gray’ infrastructures. Such ‘Natural and Nature-Based Features’ (NNBF, Bridges et al., 2018), like wetlands for flood control, are intended to both reduce the cost of gray infrastructure construction and maintenance and expand ‘the range of services (to include environmental and social benefits) provided by infrastructure systems’ (Bridges et al., 2018, 6). In such interventions, ecosystems’ ‘regenerative’ qualities and their greater resilience to some risks constitute their use-value at managing risks to populations and supply chains (Hawkins and Prickett, 2016: 97). NNBF occupy a spectrum of ‘green-gray infrastructure hybrids’ (Bennett and Ruef, 2016: 7), illustrating how nature becomes infrastructural in part through its integration with other forms of infrastructure. The difficulty of teasing apart green and gray is evident where green interventions are driven by ‘gray’ epistemologies that reproduce the socio-ecological inequities generated through previous rounds of infrastructure development (Finewood, 2016).

Despite the growth of infrastructural nature as a management and investment strategy, it would be premature to declare that it is dramatically transforming environmental outcomes, although it may do so on specific landscapes. Nevertheless, it is inaugurating new rationalities for public and private investments in conservation, and new criteria by which land can be rendered investable (Goldstein and Yates, 2017) – not as itself a commodity, but as a provider of essential services. As older modes of market-driven conservation continue to fail across both ecological and economic registers (Dempsey and Suarez, 2016), environmental finance is increasingly adopting models from infrastructure finance that are coincident with the privatization of public goods over the last 40 years. The production of infrastructural nature sheds light on three key themes in conservation investment: territory, labor, and finance.

I Territory

Public investments in infrastructural nature – like other types of infrastructure – inscribe new geographies of territorial power and new spatial relationships among populations. In regions with high government ownership of forest lands, REDD+ programs have strengthened state authority over forests, often at the expense of customary use by forest-dependent populations (Asiyanbi, 2018; Milne et al., 2019; Setyowati, 2020). Lansing et al. (2015: 207) show how, in Costa Rica, “‘carbon’ . . . emerged as an economic object in ways that have enabled the state to emerge as the regulator of its flows within its own territory – a territory that is now enframed as a space of carbon neutrality’. Conversely, visualization and social recognition of rural land stewardship has been an opportunity for some Indigenous and local communities to strengthen claims and over traditional territory (Jackson et al., 2017; Shapiro-Garza, 2013). In Indonesia, participatory mapping for REDD+ became an opportunity for the expression of ‘acts of citizenship’ that asserted rights claims and contested the use of the program to enhance government control over territory (Setyowati, 2020: 146). Like other forms of infrastructure, the case-study literature shows infrastructural natures to be potent sites of territorialization – the process of establishing and contesting territorial boundaries and authority, by states, citizens, or nongovernmental entities (Corson, 2011; Peluso and Lund, 2011). These processes extend and transform the influence of government and corporate actors over outlying territories (for instance watersheds) and further embed ecosystem management in terrains of governmental practice such as security, biopolitics, and circulation (e.g. Lansing et al., 2015).

Cities are a driving force behind conservation’s infrastructural turn. The discourse of infrastructural nature is tightly linked to the reimagining and rescaling of the city as ecologically integrated with its environmental conditions

(Cardoso da Silva and Wheeler, 2017: 33; UNESCO, 1984; Cohen and McCarthy, 2015). It expresses a transformation of the biopolitical relation between the received categories of built and natural environments: environmental risks are no longer managed chiefly by keeping nature out, but by (selectively) bringing it in (Wakefield, 2019). Initiatives such as the Latin American Water Funds Partnership and Cities4Forests, which together advance infrastructural nature in 77 cities globally, establish new institutional arrangements among environmental NGOs, municipal governments, and development institutions to remake rural spaces and livelihoods in service of urban water users.³ Such programs offer a renewed push for urban political ecology to move beyond ‘methodological cityism’ (Angelo and Wachsmuth, 2015) and attend to the relational processes by which infrastructural natures transform political and discursive connections among urban and rural spaces, both intra-regionally and internationally (Lewis and Ernstson, 2019).

These connections also offer possibilities for territorialization ‘from below’, as marginalized peoples may make claims to political and territorial recognition based on the strategic importance of their environmental stewardship (Bétrisey et al., 2018; Shapiro-Garza, 2013). We can read the rich case-study literature on PES to understand how infrastructural natures become potent sites of ‘infrapolitics’ (Anand, 2011; Scott, 1990) – including sabotage, tinkering, or redirection of service flows, as well as rights claims (Carse, 2012; Harrell et al., 2016; Kauffman and Martin, 2014). For example, in California, the Yurok tribe has used a combination of debt financing and revenue from landscape-scale carbon offsetting to reacquire stolen land (Manning and Reed, 2019). This effort has brought 60,000 acres under Indigenous sovereign control, inaugurating stewardship regimes that incorporate traditional knowledge and practices, such as seasonal burning, that were expressly prohibited in settler modes of landscape (mis)management.

This example shows how infrastructural natures, and flows of investment into them, are not politically closed but are objects of strategic engagement for diverse actors and interests.

Corporate actors are also engaging strategically with markets for infrastructural nature, calling attention to the role of ecosystem management in efforts to secure supply chains and logistical networks. For instance, Dow Chemical has partnered with TNC to develop tablet-based software for rapid site-based assessment of ecosystem service values. Unlike other corporate greening initiatives aimed at mitigating environmental impacts, this software aims to comprehend the economic value of Dow's *dependencies* on ecosystems such that these can be incorporated into the company's net present value calculations. Here, accounting for infrastructural nature offers tools for capital to assess its ability to control its own conditions of reproduction. If conventional PES programs aim to subsume some aspects of nature in the real sense, making their reproduction contingent on interest-bearing capital, then infrastructural nature provides a more flexible set of tools for drawing a full suite of landscape functions into that economic relation. In Dow's Freeport, TX facility, marshlands, tidal zones, floodplains, and the activities of farmers and city residents far upstream become sites of infrastructural management that aims to mitigate both sociopolitical and ecological risks to Dow's control over water in the region (Reddy et al., 2015). Corporate engagements in the production of infrastructural nature may present new possibilities for disruption or 'logistical resistance' (Folkers and Stenmanns, 2019), but they also embed logistical networks further into the reproductive infrastructures that sustain human and nonhuman communities, potentially increasing the collateral damage of such disruptions.

2 Labor

As Wakefield (2019: 8) has argued, the turn to infrastructural nature is frequently framed as a

return to a lost relationship with nature – naturalizing, for instance, the (re)construction of oyster reefs for flood mitigation on the basis that 'oysters have *always* been infrastructure'. Such framings, of course, belie the technical and managerial work of making nature into infrastructure, a point that Wakefield (2019: 8) illustrates through New York City's new-found 'engineering partnership' with the oyster. Nevertheless, as Neimark et al. (2020: 515) note, 'few studies engage with the role of precarious labour which is essential for the standardization and social abstraction needed for valuation in the green economy'.

Literature on infrastructure has highlighted three dimensions of labor with regard to infrastructural systems: labor *and* infrastructure, including the ways that infrastructures reproduce precarity and the differential valuation of labor through their 'displacements and inequities' (Strauss, 2019: 7); labor *of* infrastructure, including the construction, maintenance, and repair of infrastructural systems (Barnes, 2016; Carse, 2012; Mills, 2019); and labor *as* infrastructure, including the ways that care work itself can be conceptualized as a 'social infrastructure' that sustains social reproduction (Strauss, 2019: 6). Each of these offers a distinct vantage point onto the politics of infrastructural natures and their role in reproducing the social relations of production.

Case-studies illustrate how infrastructural natures can reproduce social difference and precarity along class lines, through displacement and distributive environmental injustices. In China's Sloping Lands Conversion Program – a publicly funded PES program – 'successes' (in the form of converted agricultural land) are partially dependent on maintaining manufacturing labor markets in urban centers, accelerating processes of deruralization (Li et al., 2015). Reframing landscapes as infrastructural can also shape populations' access to other infrastructures: in the Panama Canal watershed, '[t]he redefinition of a former agricultural

frontier as natural infrastructure has meant that ‘hard’ infrastructure like roads and power lines arrive slowly, if at all’ (Carse, 2012: 556). Similarly, ‘trade-offs’ between ecosystem services may mean that efforts to maximize a single service (such as water supply) for some users may diminish other services (such as nutrient cycling) for others; conflict thus revolves around the question of ‘whose natural infrastructure?’ (Carse, 2012: 544). This pattern also holds in the co-deployment of green and gray infrastructures within incumbent institutions. Finewood (2016) shows how Pittsburgh’s natural infrastructure program for stormwater management nests into existing democratically deficient management practices, entrenching socio-ecological disparities and reproducing infrastructure – gray or green – as systems for not just environmental service provision but also rent extraction.

Geographical encounters with science and technology studies have demonstrated the imprecisions, contradictions, and exploitation involved in producing ‘abstract social natures’ (Lave, 2012; Moore, 2015). Landscapes and ecologies are made visible as infrastructural relations through scientific labor at multiple scales, involving digital knowledge infrastructures that visualize, model, and monitor through remote sensing; on-the-ground species censuses for biodiversity and carbon offsetting (Lansing, 2012; Robertson, 2006); and the production of formulae rendering greenhouse gases commensurable for carbon trading (MacKenzie, 2009). This knowledge is often produced by precarious workers (Neimark et al., 2020) through increasingly privatized conditions via corporate-nonprofit partnerships (Lave, 2012), as are the standards used to verify ecosystem service delivery. In Forest Trends’ recent market analysis of watershed investments, the plurality of standards used to certify voluntary water restoration projects (36 per cent) were proprietary, developed through partnerships between environmental NGOs or consultancies and

companies like MillerCoors (Bennett and Ruef, 2016). The tools and expertise generated through these collaborations in turn influence the way that environmental values are recognized in public policy.

These diverse labor processes and practices demonstrate that there is nothing ‘fictitious’, in the Polanyian sense, about ecosystem services; they are ‘co-produced by human labour’ (Battistoni, 2017; Depietri et al., 2016: 83). This calls for greater attention to the labors of maintenance and repair through which this vision is enacted on the ground (Barnes, 2016). PES and related initiatives often portray conservation jobs as ‘co-benefits’, such as in South Africa’s Working for Water, which deliberately offers low wages to attract underemployed workers, primarily black women (McConnachie et al., 2013). The language of ‘co-benefits’ papers over the precarious and undervalued labors underpinning the ‘business case’ for infrastructural nature (Nelson et al., 2020), reframing conservation jobs as altruistic benefits rather than value-producing labor. Critical dismissals of ecosystem service values as fictitious or unreal from the perspective of the labor theory of value likewise ignore the labor politics of conservation (cf. Brockington, 2011; Huber, 2017).

This account highlights the relations among different labors involved in producing and maintaining infrastructural natures: through the scientific and regulatory work that renders ecosystem service values appropriable, ecological capacities – and the practices of stewardship that sustain them – are disciplined *as work* that can generate value to be appropriated for investor returns. In other words, this scientific and political work makes visible the ‘hybrid labors’ (Battistoni, 2017) of ecosystem service provision as itself a social-ecological infrastructure of care, to paraphrase Strauss (2019). We have seen demands emerging around the value of this reproductive work in PES (Bétrisey, 2018; Fisher et al., 2018; Shapiro-Garza, 2013), and

the relations among various types of labor implicated in landscape-scale management is a key site for further research on infrastructural natures.

As Singh (2015) has shown, efforts to monetize environmental care work can paradoxically curtail the social relations that sustain it. This has been a perennial concern in the literature on ‘value crowding’ in PES or the risk that monetary incentives for ecosystem stewardship can ‘crowd out’ other values that motivate environmental stewardship (Akers and Yasué, 2017). We should indeed be wary of how such schemes interact with extant environmental management institutions, but we should also resist romanticizing this labor in a way that would perpetuate its ‘unjust appropriation’ (Singh, 2015: 57). We can see PES participants’ demands for monetary compensation (e.g. Fisher et al., 2018) not just as ‘value crowding’ but also as claims to just compensation as workers. Such claims call us to ask how that work might be valorized differently through institutions of the commons (Battistoni, 2017; Besky and Blanchette, 2019; Nelson, 2015). Given that infrastructure has a long history as a strategic site for mass politics – be it pipeline workers in colonized West Asia (Labban, 2013), waste workers across the Global South (Fredericks, 2018), or community solar initiatives coupled with anti-racist organizing in New Orleans (Luke and Heynen, 2020) – infrastructural natures offer opportunities to link labor politics with struggles over the provision of public goods and the (re)production of landscapes. After all, both infrastructure (Larkin, 2013) and nature (Fairhead et al., 2012) are ‘unruly’ – difficult to govern, operating in unpredictable ways, and always an incipient site of conflict; the combination of the two as infrastructural nature creates potentials to mobilize that unruliness to progressive ends. Further empirical research is needed on these spaces of unruliness and the specific forms of politics in they co-constitute.

3 Finance

Learning from the infrastructural turn in critical social sciences, we can see how infrastructural natures – like other socio-technical systems for managing populations – are increasingly, or at least more directly, linked to extractive financial practices. As Furlong (2019: 3) notes, ‘[p]rocesses of infrastructure degradation in contexts of austerity form the central justification for financialization’. This is also true for siconatures that are being recast as infrastructure, as states, financiers, and NGOs are increasingly attuned to degraded spaces that both fail to deliver desired ecosystem functions *and* pose a threat to gray infrastructural services. This danger produces opportunities for socioecological fixing accomplished through a revaluation of degraded landscapes, which can be made investable in similar ways as conventional infrastructure (Peck, 2012). That is, the definition of siconatures as rent-bearing systems serves particular social and political goals that are increasingly defined through marketized modes of governance, legible through familiar tropes of ‘internalizing externalities’ or private-sector efficiency.

The move to recast nature-as-infrastructure is coincident with both increasing infrastructural needs for development and climate resilience and the push for alternative, uncorrelated asset classes from financiers (Bigger and Webber, 2021). This mirrors broader moves to make infrastructure investable as an asset uncorrelated with broader market trends (O’Neill, 2017), coupled with declining state investment. Models for infrastructure investing – gray or green – are now a borderline mainstream asset class for institutional investors, like pension and sovereign wealth funds, as investor ownership of systems for the provision of public goods becomes more common (Liu et al., 2017). Even without wholesale privatization, tools like public–private partnerships (O’Brien and Pike, 2017), land value capture schemes (Aveline-DuBach and Blandeau,

2019), and tax-incremental financing (Baker et al., 2016) have enabled private rent capture from infrastructure for the provision of public goods. In the long shadow of neoliberalism, any suggestion that infrastructure, natural or not, should be designed or paid for in egalitarian ways is met with a cold blast of capitalist realism (cf. Fisher, 2009).

The justification for private infrastructure finance depends on the ideological dogma of austerity and the material realities of infrastructural decay that austerity has coproduced over the last 40 years (Silver, 2019; Whiteside, 2019). In the United States, reports on the condition of infrastructure are usually titled something to the effect of ‘Our Crumbling Infrastructure’ (Vincent, 2017). Meanwhile across the Global South, infrastructure, particularly in the form of mega-projects like dams, has been portrayed as the promise of a bright future in the post-independence era; a promise that has receded as states were burdened first through predatory debt, then Structural Adjustment, then ongoing punitive terms of trade (Gupta, 2018; Hickel, 2017). One response to crises of infrastructure at a time when austerity logics remain firmly entrenched is to delegate infrastructure provision and funding to more purely private-sector actors, in line with the widening and deepening of financialization (Krippner, 2005), particularly the built environment (Fields, 2015), now extended to its other – the natural environment – through infrastructural nature.

If austerity is a pull factor that draws return-seeking capital into the provision of public goods, then the concentration of wealth in a high liquidity, low yield world, is a key ‘push’ factor (Ahlers, 2020). With chronically low interest rates and highly concentrated ownership of capital, money is searching for profitable, predictable assets like public goods with public-qua-customers reliant on those infrastructural services (Vecchi et al., 2017). In the wake of the 2008 financial crisis that further entrenched austerity, formerly public assets like ports,

airports, roadways, parking facilities, and land have either been outright privatized or rendered public/private assets with public ownership and rents flowing to private investors (Whiteside, 2013). But as Hannigan (2019, n.p.) notes, ‘until recently, infrastructure was not a political or financial entity; it was regarded as a bureaucratic necessity to drive growth’. As infrastructure has become financialized, investors have acquired tremendous power in defining what infrastructures are produced and reproduced (O’Neill, 2019), raising questions about democratic deficits exacerbated by financialization (Peck and Whiteside, 2016).

The financialization of infrastructure under austerity parallels the marketization of environmental management, which is likewise justified through the impacts of austerity itself as manifest in landscape degradation. The confluence of infrastructural needs, austere states, and hegemony of market approaches to environmental management serves as the material basis for the rise of investable infrastructural nature. Building on experiments for applying financial logics and capital to individual infrastructural resilience projects like London’s Thames Tideway Tunnel (Grafe and Hilbrandt, 2019) or Jakarta’s Urban Flood Management Project (Betteridge and Webber, 2019), the institutional protagonists of financializing urban resilience through both green and gray infrastructure are sharing ‘best practices’ through international networks and multilateral development banks (Bigger and Webber, 2021). Additionally, cost recovery models that make other infrastructural assets desirable to investors are also present in some ecosystem management programs, as, for instance, in water funds financed through water tariffs on urban ratepayers (Goldman-Benner et al., 2012). Infrastructure finance offers a cautionary tale for such models, where increasing user fees are extracted to repay ballooning debts taken out in response to austerity appropriations, as often witnessed in public transportation (Bigger and Millington, 2019).

However, we should not overstate the potential for infrastructural nature to become a ‘mainstream’ asset class. There is ample literature from both infrastructure studies and the market governance of nature that demonstrates that (A) neither infrastructure nor nature is easily rendered investible (Bakker, 2005), (B) there is not a bottomless well of capital waiting to rush into any given project because investors have exacting requirements and both risks and transaction costs are high (Langley, 2018), and (C) much of the low-hanging fruit for privatization has already been picked and the application of finance to infrastructure (green or otherwise) often requires generous state subsidy in the form of return guarantees, first loss agreements, or other forms of risk-offtake (Klagge and Nweke-Eze (2020).

Nevertheless, the ongoing transfer of knowledge and practice among gray and green infrastructure finance, and the attachment of landscape-scale ecosystem management to infrastructure financing schemes, is an area for future research at the intersection of political ecology, environmental political economy, and infrastructure studies. For example, in October 2020, the water utility that serves Little Rock, AR announced a US\$30.6 million labelled green bond to finance both green and gray infrastructure for municipal water delivery. On the green side of the ledger, the bond will finance land acquisition and forest restoration to act as riparian buffer for drinking water supplies, while on the gray side the bond will fund conventional water infrastructure, like pumps (CBI, n.d.).

This turn toward water quality management through infrastructural nature may be a positive development that reduces the lifecycle impacts of operating water quality treatment plans or the construction of further gray infrastructure. However, it comes at a time of lingering austerity accompanied by the economic tumult of the pandemic; only a month before the announcement of this bond, the utility cut the quantity of unmetered water per household in half,

disproportionately raising water charges for the lowest (often poorest) users, almost certainly with associated raced and gendered consequences. In this case, we can see both the promise and perils of rendering nature as debt-bearing infrastructure and the uneven landscapes of resilience it presents. In this version of resilience, adaptation is reducible to questions of access to finance, as the redefinition of nature as infrastructure is prompting experimentation with applying models from conventional infrastructure investing toward the creation of rent-bearing landscapes. This is one potential direction of travel for the consolidation of infrastructural natures but not the only one.

IV Conclusion: Politics of infrastructural nature

This is our critical infrastructure.

– Freda Huson, *Wet’suwet’en* matriarch describing her ancestral territories threatened by the Coastal Gaslink Pipeline, in the film *Invasion* (2018).

We have defined infrastructural nature as a wide-ranging and increasingly pervasive paradigm in environmental management, in which ecosystems are valued for their instrumental ecological functions that sustain and secure particular forms of human life and industry. Here, it is nature not (only) as timber or land, but as complex adaptive system, that is instrumentalized and subjected to new forms of management by capital and state to mitigate environmental risks that are immanent to ecosystems themselves. In their current iterations, infrastructural natures are incorporating the dominant tools of financialized capitalism to grapple with socioecological degradation that threatens the conditions of (re)production. But this is not their only possible trajectory. As indicated in the above epigraph from Freda Huson, recognition of the ecological systems underpinning our survival – in general as

a species, and for particular place-based forms of life – can also stand against extractivist modes of infrastructural development (in this case, the framing by the Canadian government of the Coastal GasLink Pipeline as ‘critical infrastructure’). While infrastructural depictions of nature center instrumental and anthropocentric environmental functions, their political implications inhere in how these functions are conceptualized, valued, and incorporated into projects of survival or (more or less hopeful) visions of the future. Following LaDuke and Cowen (2020: 245; original emphasis), infrastructural natures may support either extractivist infrastructure or ‘*alimentary infrastructure* . . . that is life-giving in its design, finance, and effects’.

These diverse political potentials are linked to histories of infrastructural nature as an epistemological and empirical project. The ideas of ecosystem complexity and resilience that underpin infrastructural visions of nature originated as a critique of modern environmental management practices – such as maximum sustained yield – that presumed stability in ecosystem functions, and the failure of modern infrastructures to guarantee survival (Holling, 1973; UNESCO, 1984). These failures came to matter because they were politicized by social movements that resisted social and ecological decimation. The revaluation of nature as infrastructure is, like other socioecological fixes, a result of political struggle (Nelson, 2015).

The three themes we highlight in literature at the intersection of economized nature and infrastructure – territory, labor, and finance – offer overlapping lenses through which to locate the political implications of specific versions of infrastructural nature. The production of infrastructural nature can articulate new terrains of politics, turning attention to struggles over the production and distribution of ecosystem services, the labor politics of ecosystem service provision, the biopolitical implications of ecosystem management, and the dangers posed by subjecting public goods to the priorities of

return-seeking investors. The rich case-study literature on neoliberal natures offers ample examples of these processes, but they have not generally been theorized as instances of infrastructural politics (cf. Carse, 2012; Finewood et al., 2019; Nelson et al., 2020). Labor is an especially key area in need of further research that has received too little attention in discussions of the value of capitalist natures (Neimark et al., 2020; Wakefield, 2019): What kinds of labor markets and processes are involved in producing and managing ecosystem service flows, and how do these intersect with other regimes of waged or unwaged labor? What kinds of affective and intellectual capacities are cultivated and valorized in the management of infrastructural nature – including the increasing emphasis within science-policy institutions on place-based knowledges (often termed traditional ecological knowledge or Indigenous and local knowledge)? What kinds of solidarities and antagonisms are articulated through infrastructural natures?

Keeping the conflicted history of infrastructure in mind cautions us against an often-implicit desire for state regulation against the rampages of unrestrained capital. Histories of infrastructure remind us that the promise of infrastructural development for some has often come at the cost of state violence and displacement for others (Getzoff, 2020). Strategic engagements with infrastructural natures must reckon with the actual states that we have, which are, in many instances, agents of ongoing settler colonialism that are ravaged by austerity and ideologically predisposed to market management (Christophers, 2018; Finewood, 2016). Nevertheless, the predominance of public funding and state action in producing infrastructural natures in many parts of the world indicates that, like other forms of infrastructure, it is a powerful site for demanding ‘historically attentive state-enabled redistribution along persistent axes of difference’ (Routledge et al., 2018: 78).

Like other economizations of ecosystem services, infrastructural natures privilege instrumental and anthropocentric values, and the rich and varied relations that elude monetization or fail to deliver services efficiently may easily be disregarded (Brauman et al., 2015; Dempsey, 2016). But the turn to infrastructural nature is important as much for what it reveals about the capitalist present as for what it conceals. It describes – albeit in insufficient terms – the work of reproducing social and ecological life; work that, as feminist political economy has long established, has been historically devalued under capitalism (Battistoni, 2017; Collard and Dempsey, 2017). As Kallis et al. (2013) argue regarding the economization of ecosystems, to value or not to value is not the question. Similarly, we are bound to engage with the production and valuation of infrastructural natures, even while refusing to take them at face value.

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Notes

1. O’Connor (1988) is clear that the conditions of production do not align cleanly with nonhuman nature but also encompass social conditions.
2. That report defines a watershed investment as ‘any transaction between a buyer and a seller where financial value is exchanged for activities or outcomes associated with the maintenance, restoration, or enhancement of watershed services or natural areas considered important for watershed services’ (p. 2).
3. See <https://www.fondosdeagua.org/en/> and <https://cities4forests.com/>

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