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Cities, Complex Systems, and Climate Governance: A Critical Review of the Literature

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Complexity theory has returned to vogue particularly within the environmental change literature. Much urban climate resilience literature suggests that cities are complex adaptive systems, so governance and planning must draw on insights from the complexity literature. In the context of climate change, this means that governance must be flexible, participatory, and adaptive in order to confront climate change's unpredictable effects. This working paper critically reviews the literature at the intersection of complexity and urban climate change governance. It argues that complexity theory's contributions are more modest than recent interest suggests. While complexity theory brings much-needed attention to dynamic ecologies upon which cities depend and the realities of uncertainty in policymaking – particularly important in contexts of climatic change – it is inadequate for theorizing urbanization and environmental change, which are contested social processes. As critics suggest, complexity theory tends to portray urban change as occurring through relatively neutral evolutionary dynamics that can be objectively understood and managed by actors involved in governance who share similar goals. This disregards important insights from political ecology on how knowledge, power, and urban ecologies are co-produced. How we understand a city is important because these understandings underpin climate change responses with real world effects, particularly for the most vulnerable urban residents.

KEY WORDS: Complex systems theory; climate change; adaptive governance; political ecology; urbanization; urban governance; resilience

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1. Introduction

Cities have been called the "quintessential example of complexity" (Batty et al. 2004, i). This complexity makes it difficult to implement climate change responses. City governments are struggling to both reduce their carbon emissions and to adapt to the effects of climate change, such as sea-level rise, heat waves, and extreme weather events. Particularly in cities of the Global South, climate change intersects with rapid urban change including demographic growth and global and regional integration. In the face of such "wicked" problems, complexity theory has returned to vogue in the environmental change literature. Complexity theory understands cities as complex adaptive systems that are open, dynamic, and composed of multiple interacting subsystems. Climate change will interact with urban systems to produce non-linear, and unpredictable effects; and change may quickly cascade across subsystems. To better manage these change dynamics, urban governance – it is argued – can benefit from insights from complex systems theory (Boyd and Juhola 2015; Burch et al. 2014; Da Silva, Kernaghan, and Luque 2012; Davidson and Venning 2011; Moench, Norton, and Venkateswaran 2015; Ruth and Coelho 2007).

I was invited to write this paper for the UCRSEA project to outline the state of knowledge on complexity theory and urban climate governance, with a particular focus on adaptation/resilience. Based on my critical review of the literature, I argue that while complexity theory brings neglected themes into governance scholarship in the face of environmental change, flawed assumptions about the nature of urban environments mean that complexity theory paints an incomplete picture of how cities might be changed in ways that address the climate vulnerability of poor and marginalized residents: a key concern of UCRSEA. This is also essential since the urban poor are widely expected to be the most affected by climate change. Political ecology can be more useful for understanding links between urbanization, vulnerability, and governance. As argued by other scholars, complexity contributes to governance scholarship by (1) paying attention to the dynamic ecological processes upon which cities depend, and which actors try to govern; and (2) by bringing much-needed attention to risk and uncertainty in policy-making, which is key in an era of unpredictable climate change (e.g., Boyd and Juhola 2015; Da Silva, Kernaghan and Luque 2012; Duit and Galaz 2008; Leach et al. 2007).

With its roots in the natural sciences, however, complexity theory is ill-equipped to analyze politics and social change. This theory tends to portray urban change as occurring through neutral evolutionary dynamics like an ecosystem. In this view, such dynamics can in turn be objectively understood and managed by actors involved in governance who share goals such as system resilience. Urban political

ecologists, by contrast, have shown how urban environments are highly contested spaces. Knowledge of the cities is not objective, but reflects and reinforces power relations along lines of race, class, gender, sexuality, citizenship, and their intersection (e.g., Kaika 2005; Rice 2014; Swyngedouw and Heynen 2003). Urbanization across the global South has been elite-driven and the way cities themselves have developed has been key to producing vulnerability for some and relative security for others in the face of environmental change. These debates are not just academic, but assumptions about what a city is and should be underpin climate change responses. Without fully engaging with urbanization as a power-laden process, urban climate change solutions may have limited effectiveness, or even exacerbate existing inequities. This particularly true since environmental governance intervenes in power geometries by delineating who can and cannot participate in decision-making (Himley 2008; Perreault 2008; Zerah 2009) and producing specific types of climate actors.

Part one of the paper introduces the foundations of complex systems thinking and explores how cities have been theorized from a complex cities perspective. Contrasting theories from urban political ecology/economy and postcolonial theory illustrate the limitations of complex systems thinking for understanding the urbanization process. Section two explores the implications of seeing cities as "complex adaptive systems" for urban governance in the contexts of climate change, highlighting work on "adaptive governance." Section two suggests that, given the critical understandings of cities and urbanization as discussed in section one, the literature on complex systems underestimates the challenges and limitations of translating adaptive governance to the context of urban climate change. Urban political ecology (UPE) – with its emphasis on the political constitution of urban ecologies and political struggles over nature and how we define it – can provide a more useful framework for understanding climate governance challenges. Based on insights from UPE, the paper concludes by echoing recent calls for transformative urban climate governance, and for a cross-fertilization with the radical planning and critical development literatures. As a working paper, this review explores key concepts of complexity theory and serves as a starting point for debate. This paper does not attempt to fully synthesize all of the different variants of complexity theory and much less the vast literature on urban governance.

2. Cities as Complex Adaptive Systems?

2.1 Understanding complex systems theory

Complexity theory emerged in mathematics and the natural sciences, with later variants taken up in many different disciplines across the natural and social scientists. Despite severe critiques by social scientists (see section 1.3), proponents of complexity theory today see the renewed relevance of its holistic, systems-level approach in an era where social actors are involved in governance (Kooiman 2003; Pierre and Peters 2005), and where global processes affect multiple sectors and scales (Bulkeley and Tuts 2013).

For complexity theorists, the world is composed of multiple interacting agents, relationships, and processes that together form a "system." These are thus best understood together at the system scale. Biophysical and human systems such as institutions, networks, bureaucracies, and policies are inextricably linked. Together, they form dynamic complex systems where individuals and groups, or "adaptive agents," respond to external and internal drivers with unpredictable effects emerging from these interactions (Duit et al. 2010). Because the whole of a system is greater than the sum of the parts, complexity theory rejects the idea of isolating individual variables to identify linear cause-and-effect relationships (Berkes, Colding, and Folke 2003). Rather, complexity theorists claim to adopt a holistic view, attempting to characterize systems with reference to their component parts "in a non-reductionist manner" (Manson 2001, 406).

Early scholarship on complexity built on insights from general systems theory, as well as cybernetics and information theory. General systems theory was concerned with "wholes and wholeness," emphasizing system relationships rather than system components (Berkes et al. 2003, 5). Its proponents assumed that systems reached a single equilibrium through the interactions between key variables (Duit and Galaz 2008; Manson 2001). The theory's emphasis on stability was a major drawback of systems thinking, as it was weak in its ability to account for system change. It was also seen as problematic by social scientists, who critiqued it for being overly functionalist and tautological: system functions could only be explained with reference to their contribution to overall system stability (Duit et al. 2010). Since then, complexity theory has evolved in different directions, being taken up in evolutionary biology and ecology, computational theory, and physics, and more recently in the governance, public administration, and organizational theory literatures (e.g., Klijn 2008; Schneider 2012).

Particularly important to climate change research – and especially work on climate resilience – is a body of complexity theory called social-ecological systems theory (SES). Based in the pioneering work of ecologist C.S. Holling (1973), SES was the first framework to propose that social and biophysical systems could be seen together as complex adaptive systems (CAS) that are composed of several interlocking sub-systems at different scales (Berkes et al. 2003; Folke et al. 2005). Unlike in general systems theory, SES theorists argued that CAS could move to alternative states if they passed critical thresholds, rather than being static entities that gravitated towards an equilibrium (Gunderson and Holling 2002a; 2002b; Holling 1973). Thresholds, for example, have been documented by climate scientists who warn that beyond an additional 1-2 degrees Celsius of global warning, many natural systems are at risk of abrupt and irreversible changes. Beyond 3 degrees biophysical systems may pass critical thresholds due to arctic sea ice melt (IPCC 2015, 72). For example, drying trends and increased frequency of forests fire may cause an abrupt change in the species composition of Amazonian forests (70).

Gunderson and Holling (2002) portray a complex social-ecological system (SES) as a panarchy: a hierarchical structure in which different scales of a system are interlinked and each move through evolutionary cycles of growth, re-organization, and renewal (see graphic representation here: http://www.resalliance.org/panarchy). SES, like complex adaptive systems more generally, exhibit several key characteristics:

- Nonlinearity. Complex systems are composed of non-linear relationships between changing entities (people, plants, animals, objects, etc.) (Manson 2001). As described above, this differs from general systems theory, which viewed systems as composed of relationships between static entities. Rather than change being linear and predictable – where x directly causes y – system change is characterized by more complex relationships such as positive and negative feedback loops and multiscalar processes that are not well understood. Positive feedback drives change and negative feedback balances and moderates the system (Klijn 2008, 302). In climate science, the ice-albedo feedback loop is one example of a positive feedback. When a glacier melts, for example, darker ground is exposed. Since dark ground absorbs more solar radiation than the snow/ice surface, melting is accelerated (Roeckner et al. 2012). Systems also exhibit threshold effects, which means that at certain key points, small events can trigger changes that are difficult or impossible to reverse.

- Emergence. Complex system behaviour “emerges” from localized interactions between actors and system components over time (Duit and Galaz 2008; Klijn 2008). Local actors follow local rules, and act on locally available information. They change their behaviour over time to improve their fit with their environment or to “adapt”

through evolution or learning. These local choices and events in turn shape the new positions of actors and their relationships (Klijn 2008). Emergence essentially means that a system is greater than and different from the sum of its parts. However, it is important to note that local behaviours are conditioned by processes at higher scales in a panarchy.

- Self-organization. Another implication of emergence is that systems are not governed by centralized control. While a few core processes may be key to system organization and maintenance, no single actor or group controls the system. Markets, for example, are cited by complexity theorists as an example of self-organization because the "interaction of agents, institutions, and infrastructure systems results in a highly organized and efficient distribution of goods and services" (Krugman 1996, cited in Tyler and Moench 2012, 320).

- Connectedness, or the tightness of coupling between a system's internal variables and processes is key to understanding change in a system. In tightly coupled systems and sub-systems – i.e. where there is a high degree of interconnectedness and interdependence among its parts – such interactions can help protect from external change, but also lead to rigidity. Internal interdependence can increase a system's ability to control its own destiny and make it more self-sufficient. On the other hand, components can "form mutually reinforcing relationships which give rise to sustaining structures and processes that reinforce their own expansion and functionality" (Gunderson and Holling 2002b, 30). This occurs, for example, when institutional memory acts as a "conservative, sustaining force" (Gunderson and Holling 2002b, 43), or when technologies lead to social path dependency or "lock-in." In a natural system, tightness might refer to the degree to which specific nutrient sources are linked to specific species (Holling 2001). An urban population's reliance on interconnected infrastructures is one example of tight coupling in urban systems.

- Cascade effects are also influenced by the tightness of coupling. Cascade effects occur when threshold effects or surprises "cascade" across scale, time, and/or whole systems. Tightly coupled systems are more prone to cascade effects than loosely coupled systems (Duit and Galaz 2008, 313-15); however, in general, they are more rigid and less influenced by normal levels of external variability (Gunderson and Holling 2002b, 30).

- Uncertainty. Together, emergence, self-organization, and non-linear and cascade effects mean that system behaviour is highly unpredictable.

Resilience is an additional property of SES, which has received particular attention in climate change scholarship and policy communities. While a full discussion of this highly debated concept is beyond the scope of this paper, resilience is typically defined as the ability of a system to maintain its functions following shocks or stress (Gunderson and Holling 2002a). The functions to be maintained can be narrowly defined in terms of providing ecosystem services, or expanded to include broader definitions of human well-being (Adger 2000). Many scholars see resilience as a desirable end goal in governance processes in contexts of environmental and economic change (e.g., Boyd and Juhola 2015; Chricton 2007; Jabareen 2013; Leichenko 2011; Muller 2007). Governments and development organizations have also adopted resilience as an overarching policy or development goal [among others, the Rockefeller Foundation (Ibrahim and Tanner 2010; Tyler and Moench 2012); ICLEI-Local Governments for Sustainability (ICLEI 2016), and the World Urban Forum (UNHabitat 2014), and the city of Johannesburg (Peyroux 2015)] even while the concept's meanings remain contested and often ill-defined (Jabareen 2013; Rigg and Oven 2015).

2.2 Cities as complex systems

For urban complexity theorists, cities – like ecosystems – are complex adaptive systems that are dynamic, adaptive, and open to their external environment. Similarities in urban form across different world cities, for example, are cited as evidence of their self-organizing, evolutionary, and adaptive behaviours. Social-ecological scholarship on cities marked a turning point in seeing urban areas as part of the broader ecology rather than as separate from it (Boyd and Juhola 2015). Cities, however, are often labeled as socio-technical systems to stress how human-ecosystem interactions in cities are heavily mediated by interconnected networks of infrastructure, knowledge, and institutions (Da Silva et al. 2012).

An urban system is typically defined in terms of the jurisdictional boundaries of the city. Urban systems are composed of multiple institutional and environmental sub-systems that interact with each other and with external systems and together exhibit different behaviours than they would individually (Alberti 1999). Cities have "porous boundaries" with goods, services and information flowing into and out of the city through networks (Barnett and Bai 2007; Da Silva et al. 2012). They are also reliant on and impact systems outside of their geographical boundaries, e.g., agricultural systems (Tyler and Moench 2012), and an urban system's resilience is affected by institutional, policy, and socio-economic factors beyond city boundaries, sometimes referred to as its "enabling environment" (see Twigg 2007 11).

Usefully, complex systems theorists pay attention to the interconnections between the urban "sub-systems" and processes that support city functions. This includes, for example, both physical infrastructures (e.g., water, energy) and the built environment, as well as the institutions that ensure supply and mediate demand for services (Bulkely et al. 2011). A key challenge for urban systems theorists is to understand how systemic processes respond to external changes such as climate change (Boyd and Juhola 2015). Such a systems perspective is valuable for understanding climate change, since its effects will often be felt indirectly through urban systems failures (Da Silva et al., 2012), and the cascading effects of natural and human-made disasters (Birkmann et al. 2010; Tyler and Moench 2012, 318). Such indirect systems failures include how events such as flooding may indirectly affect transportation, electricity, water systems, food distribution, waste management, and telecommunications (Da Silva et al. 2012, 128).

In highly interconnected infrastructure systems, for example, failures in one component can impact on the whole network, and disruptions in one infrastructure system can spillover into another system (Bollinger et al. 2014; see also Marvin and Graham 2010). Flooding of key transportation hubs, for example, may in turn affect peoples' abilities to work and access food (Da Silva et al. 2012, 128). Drought can lead to both water and electricity shortages in cities that are reliant on hydroelectricity with further spillover effects into virtually every sector. Some systems theorists also address the interconnections between the technical and social elements of infrastructural systems, drawing on insights from development studies on entitlements (e.g., Sen 1981; Moser 1998). Institutions, such as the rights and entitlements that enable people to access different services will influence the effects of shocks to the system (Tyler and Moench 2012, 317).

Scholars struggle with how to represent urban systems. Many efforts seek to portray these complex relationships through computer models that predict the emergent effects of the interactions between different system relationships to assist in planning. Typically, such models are based on ecological models that are modified to accommodate the social and spatial organization of humans (Pickett and Burch 1997). They allow researchers to explore different scenarios – e.g., different climate projections – and how they will affect the system as a whole. Measuring urban metabolism is one systems-inspired approach to modeling cities popularized with the global interest in sustainable development in the 1990s (Evans 2011, 227), and subsequently with global climate change and low carbon development. From a systems perspective, metabolism refers to the material throughput of a city such as water, energy, materials, and wastes. Calculating a city's metabolism involves measuring its inputs and outputs of matter and energy to measure the efficiency of these flows. In

climate change mitigation, studies have used urban metabolism to measure the flow of carbon through an urban system to inform municipal decarbonization strategies (see discussion in Rice 2014).

2.3 Complexity's critiques: Alternative ways of conceptualizing the urban

Urban systems theory has brought much-needed attention to how urbanization depends on various interdependent systems of provisioning, and especially on dynamic ecological processes. These systems of provisioning both contribute to climate change – e.g., through their greenhouse gas emissions and changes in urban land use that affect carbon absorption – and will also be affected by adverse climate impacts. However, as some critics and critical supporters of complex systems theory have suggested, it is much too ambitious in attempting to capture urbanization itself – a complex social-ecological process – in a single framework with its roots in ecology (Evans 2011; Moench et al. 2015; Reed et al. 2013). As discussed in section two, a failure to adequately engage with the complexities of human behaviour mean that it suffers from some limitations in analyzing governance and informing governance responses.

The core issue with complexity theory is that it tends to wrongfully assume that social and economic systems function like ecosystems (Welsh 2014). This downplays how, unlike feedback processes in ecological systems that permit evolution and adaptation, feedback and learning in social systems are not neutral evolutionary processes that ensure "best fit" with the environment but are shaped by conscious human agency (Olsson, L. et al. 2015; Ernston et al. 2010b). Understanding the drivers and effects of urban change thus requires robust theories of social structure and agency. Yet this literature has largely failed to incorporate key insights from the social science literature, especially concerning social power (Cote and Nightingale 2012, cited in Brown 2014).

With its focus on emergence and self organization, complexity privileges a portrayal of cities and urban infrastructural systems as being created through neutral system behavior or evolutionary dynamics rather than political drivers such as social struggles across scales (Moench et al. 2015). Systems theory's more technocratic portrayal of the urban "system" can obscure the fact that urban development and planning is often elite-driven, exploitative, and violent, with the voices of poor and marginalized rarely included (Moench et al. 2015). Models are furthermore unable to capture the full complexity of human behaviour because they represent individuals as "anonymous drivers of pollution and urban development," rather than critically engaging with how different social groups "intentionally interact with ecosystems," which limits our understanding of how "actor groups could be drawn upon in

governance processes" that support goals such as sustainability or resilience (Ernston et al. 2010a, 2; see also Evans 2011).

Based on a review of the literature, I group the limitations of complexity theory for understanding the political ecological dynamics of urban environments and urbanization into three categories: 1) inadequate attention to political, economic, and other translocal drivers of urbanization; 2) a failure to take seriously how different actors' positionalities shape how systems are understood and represented (e.g., delineated, defined, mapped) and how goals such as resilience are formulated; and 3) a tendency to be ahistorical, ignoring the diverse historical trajectories of urban development across the global North and South.

1. Inadequate attention to political economy and tendency towards "methodological cityism"

First, complexity theorists tend to naturalize social change as the adaptive action of self-organizing individuals and groups, which makes it difficult to recognize persistent inequalities and how they are maintained through coercion and violence (Moench et al. 2015). An emphasis on the city scale – defined in terms of jurisdictional boundaries – also makes it difficult to recognize broader political economic drivers of urbanization. Angelo and Wachsmuth (2015) refer to this common tendency in urban scholarship as "methodological cityism". Cityism is apparent when complexity theorists treat the city as a discrete unit that must then adapt to turbulence in the external or "enabling" environment (for a critique see Ernston et al. 2010b, 537; McKinnon and Derickson 2012). By contrast, established approaches to space and place in geography emphasize how local places such as cities are both constituted by and constitutive of global relations and processes (e.g., Harvey 1982, 2001, for a Marxist view and Massey 2005, for a poststructuralist account).

In his path-breaking work, Marxist geographer David Harvey (1982) has emphasized how urbanization is central to the reproduction of global capitalism because the urbanization process – for example, the construction of the urban built environment and urban infrastructures – is a key means through which surplus capital gets absorbed, staving off crises of over-accumulation. The latter occur when there is too much capital relative to opportunities for its profitable employment. The agglomeration of capital in urban areas also promotes capital accumulation by reducing capital costs. Across the globe, this process is highly uneven, with some populations and urban areas adversely incorporated into the global economy, for example as sites of precarious and low-waged labour or sinks for waste (e.g., electronic wastes from the Global North).

Importantly, capitalist (urban) development is not neutral or automatic but involves conscious political decisions and sometimes even violence at a variety of scales. Thus capitalist markets cannot be seen as an example of self-organization that emerge from the bottom-up behaviour of individuals, as some complexity theorists have previously suggested (see Tyler and Moench 2012, 320) Rather the introduction and perpetuation of supposedly "free" market dynamics have always involved substantial state support, as well as highly top-down forms of extra-economic coercion, such as through the enclosure of common property resources and the disciplining of labour and social movements (e.g., de Angelis 2001; Marx 1976; Polanyi 1944). In cities of the Global South, for example, this includes how elite-led urban development is often predicated on slum clearance and military and police repression of marginalized groups. Advocates of Henri Lefebvre's concept of the "right to the city" have critiqued how urban development under capitalism is driven by "exchange value" (i.e. economic profits) rather than "use values," or the goods and services needed and desired by the many urban residents who contribute the daily labour that goes into building a city (e.g., Harvey 2008).

Marxist urban political ecologists (UPE) draw on these ideas but emphasize how capitalist urbanization is also an environmental process, which transforms nature in ways that advantage the elite at the expense of the poor (Heynen et al. 2006). In this view, cities are socio-ecological "hybrids," neither purely natural nor social. Nature and society are not merely interdependent as in the social-ecological systems approach discussed above, but they are also co-constituted. To demonstrate this, urban political ecologists have used Marx and Engels' concept of metabolism, which differs from its definition in complexity scholarship. Complex systems models conceive of metabolism in terms of empirically measurable material throughput in a city – e.g., carbon or waste – typically with a goal of measuring the efficiency of such flows as a basis for policymaking (e.g., Rice 2014). By contrast, in Marxist theory metabolism refers to the process through which humans transform both themselves and the biophysical world through their labour. In capitalist societies most productive activities are organized based on a division between capital and labour, with livelihoods also situated within and contributing to broader gender and race relations.

The above points to a key difference between complexity and UPE's understandings of the nature-society relationship. From a political ecology perspective, social power and authority do not operate over an independent and objectively given material world as in the complexity approach – e.g., over flows of carbon, or over flows of water – but rather power and authority are constituted through such flows and their appropriation, production, or regulation. I.e. resource control and environmental management produce specific "geometries of power" at various scales that

simultaneously advantage some and disadvantage others along lines of race, class, gender, citizenship, and others. Participation in governance can also be productive of gender, class, and racial hierarchies, since such spaces are key sites where identities are formed and hierarchies are produced and maintained. Thus political ecologists go beyond complexity theorists' attention to the efficiency of inputs and outputs to understand how these metabolic processes are power-laden (Swyngedouw 2006), and specifically how "'natural metabolisms and transformations […] become discursively, politically and economically mobilized and socially appropriated to produce environments that embody and reflect positions of social power" (Heynen, Kaika, and Swyngedouw 2006, 6). For scholars of urban governance, this draws our attention to "who directs these metabolic circulatory flows within and beyond the bounds of the city, for what purposes, and with what effects" (Lawhon 2012, cited in Rice 2014, 382).

A political ecology perspective brings valuable insight to climate change adaptation scholarship because it understands how vulnerability is relational (Taylor 2013; Watts 1983). The production of urban environments inherently produces security for some and vulnerability and dependence for others in the face of environmental and other forms of urban change. This is true within cities, between cities and their peri-urban/rural areas, as well as between cities on a wider scale. Within cities, urban real estate development for the wealthy often forces marginalized populations to crowd into high risk zones. These practices increase overall flood risk in the city by making surfaces less permeable (Padawangi and Douglass 2015, 518). The destruction of coastal mangroves for real estate development in Mumbai, for example, has created security for some (e.g., developers and middle class residents) while exacerbating the vulnerability of coastal slum dwellers who no longer benefit from storm protection provided by the forests (e.g., Boyd and Gosh 2013). In Bangkok, floodwalls built to protect the city centre have pushed water to the outskirts, increasing the vulnerability of peri-urban and rural residents (Marks 2015). Water shortages can create complex relationships of dependency where those who control water sources can exploit the vulnerability of those who do not, such as when water vendors are able to charge exorbitant because residents have no other option (e.g., Swyngedouw 2004), or where residents rely on wealthier neighbours (Kooy, Walter and Prabaharyaka 2016). As further discussed in section 2.5, complexity's system-level view can obscure these inequalities, as well as the inherent tradeoffs involved in efforts to promote resilience or sustainability.

2. Inadequate attention to the politics of knowledge production in representing systems and framing system goals

A political ecology perspective also highlights how knowledge of nature or the "system" is also produced through and reproduces inequitable social relations. This differs from a complexity approach, which is more positivist in orientation. For complexity theorists there is an objectively given system that must merely be empirically understood to be managed effectively. By contrast, poststructuralist approaches and most "non-dogmatic" Marxist approaches recognize that there is no a priori or universally recognized system or nature separate from society, but these are always defined from the position of an observer who is socially situated in specific ways and that characterizations of the system do political work: supporting arrangements that benefit certain groups over others (L. Olsson et al. 2015).

Political ecologists' view of nature and society as co-constituted also implies that that the "environment" and "nature" are socially constructed (Robbins 2004). This does not mean that biophysical/ecological processes do not exist independently of human knowledge. Rather, it acknowledges first, that these have been highly altered by humans based on certain goals and ideas of what nature is and should be. Secondly, and more importantly, it emphasizes that biophysical processes are only ever knowable and understood through the lens of human theories, concepts, and languages, which themselves are both reflective and productive of unequal social relations. At different points in time, different qualities of nature are deemed important or valuable, and are thus become managed in certain ways (Swyngedouw 2015). For example, with an increased global concern over climate change, carbon has entered public discourse and policies in novel ways. The so-called "carbonization of urban governance" has entailed new techniques for measuring carbon and has simultaneously reinforced the authority and influence of public and private actors who claim the power and knowledge to be able to govern carbon (e.g., Rice 2014).

It is thus essential that claims to knowledge of the "system" be evaluated for the political work the claims do and how they produce winners and losers. Rather than seeing categories such as resilience or sustainability as neutral, natural, or possessing a single definition, political ecologists ask: what is to be sustained, why, and for whom? (Swyngedouw 2004). These are key governance questions that tend to be glossed over in the complexity literature.

3. Inadequate attention to context, history, and local processes of state formation

Finally, critical urban scholars have argued that complexity's focus on self-organization and emergence downplays the importance of diverse local histories of urban development. Urbanists and poststructural scholars from the Global South in particular have highlighted the variety of ways of "being urban" across the globe, and thus how common global processes like global capitalism are also marked by moments of difference, fragmentation, and splintering (Rao 2006; Roy 2011). Postcolonial urban scholars, for example, emphasize the importance of distinct local histories of state formation, which have received less attention in complexity and resilience literatures which tend to focus on the city scale (McKinnon and Derickson, 2012). Indeed, an emphasis on self-organization also means that complexity sometimes pays more attention to fluid, horizontal forms of social organization (e.g., networks, informal or community-based organizations) at the expense of an analysis of vertical forms of power such as the state. This is particularly inappropriate in the Southeast Asian context, where many governments remain highly centralized.

For scholars of "southern urbanisms," relations of governance with roots in a colonial past continue to inform contemporary patterns of citizenship and the urban form and so northern theories and practices cannot be applied uncritically to southern contexts (e.g., Kooy and Bakker 2008; Lawhon, Ernstson, and Silver 2013; Parnell and Robinson 2012). This work also pays attention to the different everyday ways that people come together to inhabit and create urban spaces they desire, which cannot be reduced to neutral, adaptive action alone. This includes the creative everyday practices through which people link together to struggle and provide for their lives and livelihoods (Anand 2011; Bayat 1997; Lawhon, Ernstson, and Silver 2013). As discussed in section two, this diversity also means that blueprint and top-down governance solutions will likely be ineffective (e.g.,, Scott 1998).

3. Complexity Theory and Urban Governance

3.1 Defining governance: From government to governance

Debates on what constitutes a city are important for climate change governance, because how we understand a city influences our understanding of how to change it in ways that support resilience, sustainability, or vulnerability-reduction. How we theorize a city thus strongly influences adaptation and mitigation strategies. In this section we focus on the implications of different ways of understanding cities for urban climate change governance with a particular focus on climate change adaptation. First, I consider complexity theorists' arguments for "adaptive governance," and how transitions to more adaptive governance may be brought about. Secondly, I consider

some of the limitations of these approaches given the critical urban perspectives discussed above.

Increasingly, governance processes themselves are seen as a challenge towards sustainable development or climate "resilience" because governance defines "the very capacities by which societies shape and transform themselves" (Voß & Bornemann 2011, 9). Governance encompasses the processes and institutions that shape how scientific and technical processes are directed, how issues are defined and solutions identified, and how social consequences are distributed (Leach et al. 2007, 1). Governance includes who makes decisions, at what scales, and to whose benefit (Perreault 2008, 835), and governance processes are constituted by and constitutive of the dynamic relationships between people, technology, and the environment (Leach et al. 2007). Importantly governance includes both government and other public and private actors involved in the management of society's economic and social resources (World Bank 1991, 1). Urban climate governance specifically, refers to the ways in which private, public and civil society actors and institutions articulate climate goals and exercise power and authority through urban climate planning and implementation processes for adaptation and mitigation (Anguelovski and Carmen 2011, cited in Boyd and Juhola 2015, 1234).

The shift from government to governance in academic and policy discourses was inspired by a recognition that previous frameworks were inadequate, as well as an observed increase in the role of non-state actors in governance processes. Up until the last few decades, most mainstream political theories viewed the state and civil society as two separate and oppositional spheres, with theorists either privileging an analysis of the state ("state-based approaches") or civil society ("civil society-based approaches") (Leach et al. 2007). Governance perspectives, by contrast, emphasize that state and society are not unitary and completely separate, but that the boundaries between them are blurry and political processes are messy. Multiple actors are involved in governance, connected by overlapping networks that work across the public, private, and community divides (Bakker 2010; Leach et al. 2007; Pierre and Peters 2005).

Governance perspectives are also frequently normative, rooted in a belief that multiple actors outside of the state should be involved in governance. For example, neoliberals have embraced a role for private and civil society actors in previously state functions such as service delivery, while also promoting democratic decentralization (e.g., World Bank 1991; 2004). While governance is sometimes associated with neoliberalism, critical theorists also use governance analysis to understand relationships between state and non-state actors and their effects (Leach et al. 2007).

For example, Marxist scholars highlight how the formal "separation of powers" between state, market, and society is central to liberal ideology (e.g., Gramsci 1971), and how the view of the state as the site where politics occurs obscures important sources of power in the private sector. Postcolonial theorists have drawn attention to the inadequacy Weberian state theory in accounting for relations of authority in the global South. Weberian theory, which informs many mainstream perspectives on government, sees the state as a coherent, unitary bureaucracy suspended above society. By contrast, postcolonial scholars have illustrated diversity and conflict within the state, and how the boundaries between state and society are "blurred," such as when bureaucrats are embedded in communities or non-state actors serve ostensibly state functions (e.g., Ferguson and Gupta 2002; Gupta 1995).

3.2 Complexity theory's contributions to governance scholarship

Approaches that emphasize the multi-leveled and networked nature of governance overlap with how complexity theorists have interpreted governance regimes and policy processes, particularly their emphasis on non-linearity, uncertainty, and emergence. For example, several scholars draw on the concept of emergence in complex systems theory to explain how institutions (Ernston et al. 2010a; Klijn 2008), social networks (Ernston et al. 2010a), and entire "social orders" (Schneider 2012) emerge from the interactions between individual agents or groups, which in turn also exert lasting effects on behaviour. Work that combines social network and complexity theories focuses on how network structures emerge from localized interactions between pairs of actors, with no one actor fully controlling the emergent structure (Ernston et al. 2010a): an example of self-organization. Governance regimes also exhibit cascade effects: bottom-up agency can cascade across the "system" under certain circumstances, but that agency is always mediated or constrained by system processes at higher scales (ibid., Gunderson and Holling 2002a, Schneider 2012).

These perspectives are not specific to complexity theory, and indeed have many parallels in institutional theory (e.g., Ostrom 1995). Complexity's novel contribution arguably concerns less how governance regimes work, but rather how it characterizes the complex adaptive systems that societies try to govern with a view to finding more effective ways of governing them (Duit and Galaz 2008). For governance in the context of climate change, complexity theorists draw attention to two key gaps in the mainstream governance literatures, which are present in both the older political science traditions and newer work on networked governance. First, many mainstream governance literatures have failed to take the biophysical world seriously in terms of fully understanding the ecological processes that governance seeks to influence. Second, in most mainstream politics literatures and in policy processes, risk, uncertainty, and limits to human knowledge of processes that society tries to govern

are often sidelined (Boyd and Juhola 2015; Jasanoff 2007; Leach et al. 2007). This is a key point in the context of climate change. Climate change effects are likely to be both unprecedented – with few past experiences to draw from – as well as unpredictable and nonlinear, characterized by threshold effects.

3.3 Adaptive co-management and adaptive governance

The adaptive management (AM) and adaptive governance (AG) literatures address the inadequate attention to ecology and uncertainty in environmental management. They prescribe strategies for governing complex adaptive systems based on an understanding of their properties. Because systems are dynamic, self organizing, and "emergent," proponents of adaptive governance suggest that top-down centralized control is likely to be ineffective. Rather than seeking to fully control the system, governance should support its ability to adapt to complex, unpredictable change. In other words, AG emphasizes the importance of building the adaptive capacity of a governance regime or its ability to "first alter processes and, if required, convert structural elements in response to experienced or expected changes in the societal or natural environment" (Pahl-Wostl 2009, 355). While adaptive co-management and adaptive governance were not originally formulated as responses to climate change, insights from this work have been taken up in the climate change literature (Pelling 2011, 30).

Adaptive management (AM) became influential in natural resource management scholarship and practice in the 1970s. Later, adaptive management was expanded to "collaborative adaptive management" or "adaptive co-management" (ACM) to recognize the importance of involving multiple stakeholders in resource management. Advocates of adaptive co-management take issue with conventional resource management approaches that attempt to control change in systems for example by imposing inflexible maximum limits on resource harvests. Instead, they propose that systems need to be managed for resilience. This, they argue, is achieved through adaptive co-management systems: context-sensitive and flexible, community-based systems, supported by a variety of different organizations at different scales (Folke et al. 2005). ACM departs from the understanding that because SES are characterized by non-linear feedback processes and cross-scale interplay, they cannot be planned and controlled easily by a central organization such as a national government (Ernston et al. 2010b; Folke et al. 2005; Ostrom 1995). Governance regimes should thus be multi-scalar and convene a variety of social actors (Armitage et al. 2009; see also Ernston et al. 2010a).

A core tenet of adaptive management is the need to accept and live with uncertainty as an inherent property of complex system dynamics (Berkes et al. 2003; Gunderson and Holling 2002a). Therefore, the literature emphasizes the need for knowledge of system behaviours to be constantly updated, and for management actions to be viewed as an opportunity to learn about how to adapt to changing conditions, i.e. to gain "adaptive expertise" (Folke et al. 2005, 447). Adaptive responses are then tested and monitored closely, and actions and hypotheses are adjusted accordingly in an iterative process. Through "social learning" over time, it is assumed that the system will continuously get better at pursuing its management objectives, and build the capacity to change course if the context changes (Lebel et al. 2006). Learning is enhanced when AG is participatory and inclusive because bringing together different forms of scientific and local knowledge is essential for understanding system complexities (Armitage et al. 2009; Baird et al. 2014; Birkmann et al. 2010; Burch et al. 2014; Folke et al. 2005; Ostrom 1995).

Concepts of adaptive management have been expanded under the label adaptive governance, which is a broader lens than adaptive co-management because it considers the wider social context of environmental management (Folke et al. 2005). Like the ACM literature, the adaptive governance literature emphasizes that governing multiscalar complex adaptive systems requires interconnected networks of actors at various scales, frequently referred to as "polycentric," "multistakeholder," and "multiscalar" institutional arrangements (Lebel et al. 2006; Olsson et al. 2006). In addition, observers stress for the need for a certain degree of organizational redundancy or overlapping functions in governance regimes to spread risk in the system (Folke et al. 2005; Ostrom 1995). This is akin to genetic diversity in ecosystems, where multiple species performing the same function supports resilience as conditions vary (Gunderson and Holling 2002a). This contradicts some governance scholarship, which sees overlapping functions as inefficient.

Created as it was for contexts of dynamism and uncertainty, AG has obvious relevance to contexts of climate change (Pelling 2011, 30). Given that climate change effects are uncertain and unprecedented, conventional predict and plan paradigms of planning and governance that draw on past trends are likely to be inadequate (Quay 2010; Ruth and Coelho 2007; Tyler and Moench 2012). A more adaptive approach to climate governance would emphasize experimentation and continuous adjustment as new information becomes available, rather than viewing climate projections as an end-product that can linearly feed into decision-making (Ruth and Coelho 2007).

3.3.1 Adaptive governance of urban systems

Extending adaptive governance with its origins in common property resources management to urban climate governance, however, poses specific challenges which have yet to be fully addressed in the emerging literature on adaptive urban governance. The literature on adaptive co-management or adaptive governance cited above reflects the experiences of governance experiments in relatively bounded systems with clearly defined actors such as protected areas or specific resource sectors. These differ in important ways from urban contexts where human-nature interactions are heavily mediated by technology, infrastructure, and knowledge, and where governance processes are highly contested, particularly for controversial issues such as climate change.

Nonetheless, some have argued that adaptive governance insights can be valuable for urban governance. Tyler and Moench (2012) argue that institutional redundancy can support the resilience of urban systems. The presence of a variety of different institutional and infrastructural arrangements for service access may help to buffer against failure in one provisioning system. Birkmann et al. (2010) argue that an adaptive urban governance's emphasis on multistakeholder networks works well in cities of the Global South where governance often operates through a complex meshwork of institutional arrangements, many of which are informal.

It is less clear, however, how informal governance would or should relate to existing structures of vertical authority in urban areas, including legislation and government regulation (Boyd and Juhola 2015, 1253). Some scholars argue that these would ideally be complementary to and not replace conventional, bureaucratic state organizations (Folke et al. 2005; Pierre and Peters 2005). This is because networked governance has a weak capacity to supply public goods where there is little private benefit to be derived (Duit and Galaz 2008; Tschakert and Dietrich 2010, 17). Yet important concerns about the democratic character of "networked governance" in terms of legitimacy, transparency, and equity have not been fully addressed in the complexity literature (Voβ and Bornemann 2011), or indeed much of the urban literature which romanticizes informality (see Roy 2005 for a critique). In reality, many forms of "informal" governance are highly undemocratic and unjust such as processes of clientelism and corruption that reproduce inequities, or the presence of violent criminal organizations in supplying services such as security, housing, and infrastructure.

Another challenge with applying adaptive governance in urban areas is that relatively enduring infrastructures and the built environment create path dependencies, and so many elements of urban decision-making may not be conducive to continuous monitoring and adjustment (Ruth and Coelho 2007, 333). Some observers therefore suggest that governance must strive to be as anticipatory as possible in the face of uncertain and complex climate effects (Fuerth 2009, 29, cited in Quay 2010, 498). Anticipatory governance is not the same as conventional predict-and-plan approaches, because it emphasizes using a range of possible futures in planning – such as different warming scenarios – rather than a single scenario, and retains adaptive management's concern with flexibility and ongoing processes of monitoring and adjustment (Quay 2010). Based on scenario-building exercises, a series of flexible adaptation strategies of actions are developed to adapt to a range of possible futures.

In section 2.5 I consider broader concerns with the AG literature. In 2.3.2 and 2.4, I further consider offshoots of the AG literature: assessments of "adaptive capacity" in governance regimes, and the ways in which transitions to adaptive governance occur.

3.3.2 Considering the adaptive capacity of "ideal type" governance models

In addition to prescribing changes to governance models, theorists have applied complexity theory to understand the adaptive capacity of ideal type governance models. Duit and Galaz (2008) measure the adaptive capacity of governance regimes in terms of their capacities for "exploitation" and "exploration." Exploitation is the capacity to improve overall social welfare through collective action, for example delivering services. Exploration is a rough parallel of "social learning" in the SES literature. It involves the capacity of a community to gather and analyze information about its environment, and to engage in experimentation and innovation. Exploration is important because in contexts of uncertainty such as those posed by climate change maximizing collective welfare or "exploitation" requires trial and error. However, such learning can be "costly" in terms of time and resources, and the stability-enhancing role of institutions may be at odds with flexibility and learning.

Drawing on the work of governance scholars Pierre and Peters' (2005) work, Duit and Galaz (2008) characterize four different governance types according to their capacities for exploitation and exploration, and for adapting to different types of change: rigid, robust, fragile, and flexible systems (see Table 1 below). They find an inherent trade-off between rigidity and flexibility. Rigid top-down systems are highly effective and coordinated in normal situations, but their lack of flexibility and weak feedback from society inhibit their adaptability in the face of changing circumstances such as rapid climate change (see also Pahl Wostl 2009).

Robust systems have a high capacity for both exploration and exploitation and can thus deal with both steady state conditions or sudden change. In robust systems, the "rigidity-inducing effects of institutions are kept from obstructing necessary processes of exploration" (321). The authors consider them to be an ideal model, with few if any real world examples. Fragile regimes have weak capacities for both exploitation and exploration, and these weaknesses are mutually re-enforcing such that the failure to accumulate new capital and knowledge and adapt to changing circumstances further undermines the potential for collective action (321).

Finally, flexible or networked-based governance (NBG) regimes, which frequently correspond with neoliberalism, have well-developed capacities for exploration (e.g., learning processes, feedback loops, and monitoring) but lack the capacity to translate the gains of innovation and experimentation into public goods or general well-being. Duit and Galaz (2008) find that in flexible regimes, adaptation will likely be piecemeal, incremental, and lacking coordination, with limited contributions to overall well-being (322).

The authors then consider how their four models respond to different types of change based on their speed and predictability in terms of the likelihood of change and its effects. They assume that robust systems perform well across all types of change and fragile systems perform poorly. Networked-based governance (NBG) is seen as producing low public welfare when conditions are stable and predictable because these regimes have low capacities to produce public goods (324). However, the authors argue that flexible governance can perform well in cases of localized and fast change such as a local disaster because actors can adapt to changing circumstances without central coordination – i.e. they have a high capacity for self-organization – drawing on a "richer set of knowledge, institutional diversity and policy alternatives" than state-dominated governance (324). However, the authors argue that NBG may not be effective when fast change also occurs on a large-scale, because this requires rapid, unilateral responses that cut across spatial scales and policy arenas. The state may be the only actor capable of achieving this since achieving large-scale coordinated action in networks requires considerable time for actors to develop shared understandings as well as domestic and international legitimacy.

The authors also argue that it is important to consider how governance regimes behave in concert with one another, such as when different models exist at different scales. For example, rigid governance at one scale and flexible governance at another scale can be complementary, producing adaptive capacity in the face of unexpected shocks without sacrificing performance in situations of slow change. This has parallels with the polycentricity and diversity ideas discussed above.

Table 1. The adaptive capacity of ideal type governance regimes (based on Duit and Galaz 2008)

Type of Governance Regime	Equivalents in Pierre and Peter's (2005) framework	Capacity for Exploitation (collective action for well-being)	Capacity for Exploration (learning, experimentation)	Change Dynamics Under which Models Perform Best
Rigid	*Etatiste*, state-centric, liberal democratic state	High (high capacity for cooperation)	Low (weak or biased feedback)	Steady state (stability or slow change)
Robust	N/A - Unclear if real world example exists	High	High	High performance in all conditions
Fragile	N/A	Low	Low	Low performance in all conditions
Flexible (networked-based)	Dutch governance; "Governance without government"	High	Low	

3.4 How transitions to adaptive governance can be brought about

If adaptive governance is assumed to be desirable, how are we supposed to get there? Literature from multi-level governance theories, socio-technical transitions theories, and complexity theory emphasizes the importance of "windows of opportunity," and the presence of networks and leaders that are poised to take advantage of them. This work observes that governance reform is typically preceded by a "trigger" or "window of opportunity," which prompts system learning and re-organization (e.g., Pahl-Wostl 2009). Windows of opportunity can be politically-driven or problem-driven, with the latter sometimes called "triggers" (Folke et al. 2005; Olsson et al. 2006). Whether a trigger will compel change depends on both system characteristics, such as the organizational capacities and influence of internal and external actors, as well as the nature of the change dynamic (Matthew 2012; Olsson et al. 2006).

Climate change has been characterized as a significant or trigger or "transformative stressor" because it may lead organizations to re-organize their activities in order to better manage social, economic, and environmental impacts (Matthews 2012, 1093). Yet, most precedents suggest that it is harder to trigger change in anticipation of climate effects than after a major disaster such as a drought or flood. For example, a study of urban climate governance in Asian cities found that the motivation for governance reforms typically came from devastating past experiences of environmental and economic disaster, and importantly political pressure from citizens

in response to disasters or political crises (Tanner et al. 2009, 32). A key question therefore concerns how radical change could be achieved in the context of slow change, i.e. before a disaster or crisis (Garschagen 2013). Systems-inspired sociotechnical transitions, resilience, and multi-level governance literatures argue that social networks and leadership are key for building capacities for this type of anticipatory adaptation.

3.4.1 Shadow spaces and "scale-crossing brokers"

Informal networks or "niche spaces," it is argued, have a particularly high capacity for experimenting with new governance models, practices, and technologies. A niche or shadow space is "space of informal interaction that lies outside of but interacts with formal institutions and relationships" (Pelling et al. 2008, 869). Networks are seen as important in transitions towards adaptive governance because they build trust or social capital, manage conflicts, and enable knowledge and practice sharing (Olsson et al., 2006). Learning is accelerated in networks because their more open and flexible membership structure encourages interaction between people who are socially distant. This means that they accelerate information flows and promote new ideas (Ernston et al. 2010b). For the same reason, Ernston and co-authors (2010b) argue that governance innovations are likely to occur in urban areas because of the density of "weak ties." Since cities tend to be more diverse and less tightly knit, this can help break up the type of "closed group thinking" or tendency to conservatism and uniformity that might be characteristic of more homogeneous communities (5).

Shadow or informal networks can afford to be more creative and experimental because they are free of the scrutiny of agencies and political constituencies (Olsson et al. 2006). More formal or "canonical" organizations such as government bureaucracies have more rigid rule structures and checks and balances, which makes it difficult for them to deviate from customary response paths in the face of change. Informal networks, by contrast, can experiment with alternative actions and system configurations (Ernston et al. 2010a; Olsson et al. 2006; Pahl-Wostl 2009; Pelling et al. 2008), and are therefore more likely to question the status quo (Pahl-Wostl 2009, 361). Informal networks can also react more quickly in times of crisis, enabling faster flows of information and resources (Pelling et al. 2008), and because relationships fostered in these spaces can be drawn on in times of abrupt change or crisis (Ernston et al. 2010a). Pelling and co-authors (2008) cite the example of a strong shadow system in the agricultural system in Wales, which provided the flexibility needed to respond quickly to challenges such as the Foot-and-Mouth Disease. A survey analyzing the ability of water governance structures in Europe to face climate change impacts and develop adaptation measures identified cooperative structures and information management

as key contributors to learning and adaptation (Huntjens et al. 2008, cited in Pahl-Wostl 2009, 362).

Climate change governance in particular requires coordination across scales of governance. For example, climate change policy is typically set nationally but most adaptive actions occur locally. Climate change also requires multisectoral action since it will impact sectors as diverse as health, water, transportation, and the built environment. For this reason, AG literature sees a role for bridging actors or "scale-crossing brokers" that can promote cooperation among groups, sectors, or levels of government that would not otherwise interact. They can also bring in outside resources, knowledge, and incentives (Folke et al. 2005; Olsson et al. 2006). Scale-crossing brokers include groups that work in both shadow networks and formal policy circles. This is relevant to the UCRSEA project which seeks to play a bridging role between local governments, communities, and researchers.

From a complex systems perspective, it is argued that scale-crossing brokers can help governance systems to switch between the two "modes" of governance required for adaptation: centralized and flexible. This is because scale-crossing practices can promote responsiveness and flexibility by bringing together a diversity of actor groups to innovate, thereby enabling a "greater range of purposeful collective actions" (Ernston et al. 2010a, 16), while maintaining the existing bureaucratic governance structure, which is important for collective goods provision, and responding to large-scale rapid change (Duit and Galaz 2008). Bridging organizations can resolve problems of scalar mismatch in governance for climate change adaptation, where national level policy processes may be out of touch with local adaptive actions (Bowen et al. 2014), or help address the fact that jurisdictions rarely correspond with ecosystem boundaries (Ernston et al. 2010a, 11-12).

"Boundary work" or "boundary actors" also describes bridging activities that connect scientific and non-scientific communities, for example between experts and decision-makers, which is key to translating complex climate data in a language accessible to policymakers (Corfee-Morlot et al. 2011; Folke et al. 2005; Ernston et al. 2010b). Moreover, climate change knowledge is contested and different actors will hold incomplete knowledge on system characteristics and vulnerabilities (Ernston et al. 2010b; Tyler and Moench 2012). Where climate change assessments and vulnerability studies are "coproduced" with decision-makers as well as local communities, it is argued that these assessments can help frame questions so that the assessments are informed by local concerns. This increases the likelihood that these assessments will be relevant and legitimate (Vogel et al. 2007, cited in Corfee-Morlot et al. 2011).

3.5 Limitations and challenges for adaptive governance

I believe that adaptive governance is attractive because it is intuitive and practice-oriented. It offers clear suggestions that can be taken up by decision-makers and organizations in a variety of contexts in order to better address uncertainty and support and live with dynamic ecologies. Yet its over-emphasis on institutional and behavioural change is arguably also a weakness. As the political economy/political ecology perspectives on urbanization discussed above stress, vulnerabilities to climate change are frequently rooted in deeper, structural forms of marginalization such as an inability to control urban resources or a lack of political voice, which will not be easily changed through small changes in institutional practice. With its pragmatic approach, the adaptive governance literature has also rarely addressed the normative goals of governance. What should the goal of governance processes be in the context of climate change? What kind of cities do we want? And if we accept resilience as a goal, then what is to be sustained, for whom, and why?

Implicit in the adaptive governance literature is the assumption that consensus on the goals of adaptive governance or a desired system state is possible (Beymer-Farris et al. 2012, cited in Brown 2014). Yet if we take seriously insights from PE and critical urban theory that cities are produced through conscious human agency in ways that benefit some groups over others, it is clear that diverse urban actors will not share common goals and interests. Climate change responses – whether it is adaptive governance, or decarbonization – inevitably influence urban "power geometries" because they change the configurations of actors with authority over urban space and flows in ways that benefit some at the expense of others. These trade-offs, however, are obscured because complexity and resilience discourses often refer to the system-level without reference to specific actors (Bahadur and Tanner 2014). Trade-offs may be especially pronounced in densely populated urban areas where projects that increase the resilience or adaptive capacity of one group may directly undermine the resilience of another group (Swanstrom 2008), and in contexts of heavy contestation over property rights to land and resources (e.g., Armitage, Marschke, and Plummer 2008) where one group's control relates directly to the dependency and vulnerability of other groups.

Critics also argue that the adaptive governance literature fails to account for the role of political authority in shaping adaptive governance institutions (Bahadur and Tanner 2014; Swanstrom 2008; Voβ & Bornemann 2011, 6). A failure to engage with the broader political context of adaptive governance is notable, for example, in the literature on transitions to adaptive governance, where it is often assumed that "knowledgable argument and favourable conditions will convince powerful actors to come into line" (Leach et al. 2007, 26-27). Little consideration is given to the complex

historical and political trajectories of existing governance arrangements – e.g., the local histories of state formation emphasized by southern urbanists – and how they influence windows of opportunity. Notably, powerful interests may resist adaptive governance, particularly where bringing in other stakeholders is seen as a threat to their own authority (Nasdasdy 2007, cited in Brown 2014). Public sector officials derive benefits from their positions, so institutions tend to be oriented to reproducing themselves. They are thus by nature conservative, and particularly reluctant to cede their power to other social actors through increased public participation (Irazábal and Foley 2010), which is a key element of adaptive governance. This is important to the UCRSEA project since the AG literature may understate the barriers to introducing adaptive governance in practice. This, of course, means that attempts to introduce more participatory processes such as UCRSEA's shared learning dialogues need to be based on a keen understanding of the existing lines of authority and potential allies and windows of opportunity for policy change.

The types of policy experimentation demanded by adaptive governance may also be seen as politically undesirable. For example, in Vietnam, where top-down, hierarchical, command-and control organization are the norm, government officials consider testing new organizational paradigms "a highly sensitive issue, since it may expose existing practices as inadequate or outdated" (Garschagen 2013, 38). More broadly, governance reform can be a resource-intensive strategy for confronting climate change and less politically rewarding than more visible displays of state power such as infrastructure. Perhaps for this reason, in their approaches to climate change adaptation, governments in Southeast Asia have tended to focus on "hard" infrastructural improvements (Reed et al. 2013). Siloed donor financing and institutional cultures may also discourage the types of cross-sectoral partnership building called for by AG advocates (Bowen et al. 2014). In their global review of experiments with urban climate transitions, Boyd and Juhola (2015) found that local governments were the primary actors involved and found little evidence of partnership-building with other sectors.

Even where there is a genuine desire on the part of state officials to work with other actors and windows of opportunity do open up for adaptive governance, spaces for collaborative governance are fraught with power differentials, especially since the ability, willingness, and capacity to participate and benefit from such institutional openings are distributed unevenly (Armitage et al. 2008, 93). For example, community involvement is key to adaptive governance, but engaging communities is difficult in urban areas where communities are dynamic and heterogenous (Korf 2002, cited in Bahadur and Tanner 2014). In addition, the poor may be unable or unwilling to experiment with different approaches such as livelihood strategies given that this may

involve short-term risks and high costs in terms of time and resources (Armitage et al. 2008; Tschakert and Dietrich 2010). Where these inequities are not taken seriously in participatory practice, participation may serve to further entrench inequities through the "elite capture" of participatory spaces (e.g., Cooke and Kothari 2001).

Like the systems literature more broadly, the adaptive governance literature is only beginning to engage with the politics of knowledge production. For example, while adaptive governance stresses the importance of incorporating different forms of knowledge into environmental governance, it retains a relatively instrumentalist view towards local knowledge, embracing it to the extent that it can improve our understanding of an objectively knowable system. From this positivist perspective, local knowledge is empirically verifiable, rather than stemming from different values, assumptions, worldviews, or positionalities (e.g., race, class, gender) (Smith and Stirling 2010, cited in Bahadur and Tanner 2014). More critical perspectives, by contrast, pay attention to the connection between idea construction and social position and the pursuit of interests. Different people or groups frame and seek systems that are resilient to pursue their own ends, which means that researchers must be attentive to how certain resilience or sustainability discourses acquire legitimacy and power and the political work that they perform.

The inattention to the politics of knowledge production reflects a bigger issue: the fact that much of the adaptive governance literature sometimes treats governance processes – including the definition of the governance object and problems – as somewhat external to the processes to be governed. In other words, "systemic relations are to be managed, but not shaped politically" (Voβ and Bornemann 2011, 6). For example, the complexity and resilience literatures tend to portray climate change stresses as coming from the outside of the system – i.e. from unpredictable changes in nature alone (Bahadur and Tanner 2014, 203). This externalization of risk means there is a tendency to naturalize risk or "shocks to the system," rather than acknowledging the political dimensions of risk and uncertainty (Welsh 2014). By contrast, a political ecology approach views disturbances such as "natural disasters" as socially constructed because whether a biophysical process such as flooding or drought leads to disaster is heavily conditioned by prevailing governance arrangements, including the social entitlements and livelihoods which determine people's vulnerability, and also control over key productive resources and assets such as land (e.g., Sen 1981; Taylor 2013). Importantly, this perspective recognizes that vulnerability and security are relational. Unequal and dependent relationships through which cities are produced create security for some while simultaneously producing vulnerability for others (Taylor 2013).

However, rather than addressing such trade-offs head-on, and tackling such root causes of environmental risk and vulnerability in uneven economic development and other persistent forms of marginalization, the adaptive governance literature focuses narrowly on behavioural change at the level of individuals and institutions. At best, this means that its benefits may be somewhat limited by the persistence of enduring structures of inequality; at worst, that adaptive governance may unwittingly help reinforce them. Radical critics, for example, suggest that discourses that favour community-level resilience through "self-help" or that embrace networked forms of governance can serve to justify a neoliberal retreat of the state from providing public goods. The result is that risk and responsibility are downloaded away from government and onto individuals – particularly the poor – who are effectively charged with building their own resilience (MacKinnon and Derickson 2012; Peyroux 2015; Welsh 2014). Drawing on Foucault's insights on governmentality, these critics emphasize how resilience discourses can inculcate subjectivities that emphasize individual responsibility and adaptability rather than challenging inequities. By contrast, they stress the need for a more transformative adaptation agenda that emphasizes collective action for social empowerment alongside more meaningful forms of redistribution and social recognition (Peyroux 2015, 363).

4. Conclusion: Towards Transformative Urban Climate Governance?

Where does this leave us in terms of governance solutions? The following discussions point to a fundamental tension in the climate change governance literature. Climate change is occurring now. Many of the world's cities are already feeling its effects in terms of warmer temperatures, and more extreme and unpredictable weather events such as droughts and flooding. There is a need for immediate responses to protect the poor and vulnerable that can also be easily translated to policy. On the other hand, political ecologists and others highlight how vulnerability to the environment is relational. It is produced through inequitable relationships which create relative security for some and vulnerability for others (e.g., Taylor 2013). Many of these relationships are highly persistent: related to uneven urban capitalist development as well as enduring structures of marginalization based on race, gender, citizenship, and others. For these theorists, governance must deliberately seek to reduce these vulnerabilities, which requires deeper transformations and longer-term work (Pelling 2011). This is not easy, however, because challenging vulnerability also means tackling privileges of powerful groups.

This paper has argued that the complex systems and systems-inspired adaptive governance literature makes two contributions that can be central to analyzing urban climate change governance: 1) a recognition that urbanization is dependent on dynamic urban ecologies and other interconnected systems of provisioning; and, 2) a

recognition of risk and uncertainty in policy-making. These two contributions are essential for improving and researching urban climate change governance since cities are both major contributors to carbon emissions and, particularly in the Global South, will be adversely affected by climate change. The impacts of climate change are both unpredictable and unprecedented, challenging conventional predict-and-plan approaches. They will also have cascading effects across the multiple physical and social infrastructures that support urban development, demanding multi-sectoral approaches and an understanding of these interactions. Adaptive governance offers useful ideas and tools for governing in these contexts.

Yet, while the systems perspective can help us understand the dynamic ecologies and interconnected infrastructures on which urbanization depends, it fails to adequately theorize urbanization as a contested social process, which means that it makes it difficult to see how cities might be changed in ways that reduce vulnerability for those urban residents most affected by climate change. Complex systems theories tend to be ahistorical, portraying urbanization as the outcome of neutral evolutionary dynamics. As urban political ecologist have pointed out, the production of urban areas has largely been elite-driven, producing relative security for some at the expense of others. Power and authority in this view do not operate over the material flows of the city – over sub-systems such as infrastructure – but are constituted through them at various scales, from the everyday urban practices through which the poor secure their livelihoods to the larger-scale economic processes driving rapid urbanization and regionalization. At its most fundamental, governance is a matter of who directs these flows, how, and with what ends. In this context, concepts such as “resilience” or “sustainability” are not objective categories but defined from specific positions and policies and projects promoted in their name will inevitably produce winners and losers.

New spaces for adaptive governance, like all governance arrangements, are inevitably constituted through existing power geometries, and will also affect them by changing the constellations of actors involved in urban decision-making and helping to produce different kinds of climate change actors or “subjects”. Although the literature frequently acknowledges this, the implications are frequently downplayed. Much of the complexity and adaptive governance literature implicitly assumes that goals such as “resilience” or “sustainability” of the system are shared by all actors who share a common definition of what the system is and should be. Sidelined are important questions about what kind of cities do we want to live in? And, importantly, who should have the right to produce the city and control urban flows? (e.g., Harvey, 2008). This is a key question since in the Global North and South alike, the voices of the poor have been consistently marginalized in decision-making processes.

Recognizing this, some theorists have called for more "transformative" forms of climate governance, or "transformative adaptation," that specifically seeks to work with marginalized groups to alter their conditions and improve their influence over governance process (Pelling 2011). A transformative approach aims not only to attenuate the adverse effects of existing system arrangements, but to eventually transform the underlying structures and processes that produce inequities. For practitioners of adaptive governance approaches such as the UCRSEA project's shared learning dialogue approach, this means simultaneously working to improve the everyday conditions of marginalized groups, while also paying explicit attention to creating environments that can allow different groups to transform disadvantageous relations in the longer term (Armitage et al. 2008). This would include working to improve the control of marginalized groups over urban land and productive resources, improving labour and housing conditions and public services, and securing a greater voice in policymaking for those previously excluded. More equitable urban development can support not only help reduce climate vulnerabilities but can arguably mitigation by helping to build denser and more efficient cities (e.g., Cohen 2015; Davis 2010).

Towards these goals, adaptive governance practice can fruitfully cross-fertilize with insights from critical development studies and alternative development practice (see also Tschakert and Dietrich 2010), as well as the literature on "radical planning." For example, practitioners of adaptive governance or social learning approaches might learn from critical pedagogies of the Brazilian educator Paulo Freire, which have been embraced by some scholars and practitioners of alternative development. While working to materially improve participants' lives, the Freirian approach aims to raise critical consciousness of oppression and build the capacity of marginalized groups to participate and assert their citizenship rights. Importantly, they deliberately aim to promote a critical interrogation of oppression and its causes with a few to fostering collective action (e.g., Hickey and Mohan 2005), rather than simply creating more adaptable subjects responsible for their own resilience. Similarly, radical planning seeks to transform the social, political, and economic structures that maintain unjust arrangements. Radical planning practice begins with a critique of the status quo and then works to develop solutions. Like in the adaptive governance model, knowledge for social change is achieved through an iterative process of social learning (Friedmann 1987, cited in Beard 2003). Radical planning literature recognizes that regular citizens can and should be "planners," and expert planners committed to supporting progressive planning must guide, but not manage, the process.

The critical development and radical planning literatures also recognize the need for building on the existing strategies of poor and marginalized groups to

promote more just forms of urban development, referred to as "invited" spaces of participation (Miraftab 2004; 2009). This includes the plethora of community-based organizations working to improve housing, access to public services, working conditions, and social and environmental justice across the Global South. "Invited" spaces created with the goal of adaptive governance can help institutionalize more participatory models and secure resources for scaling up, particularly when participatory programs are led by groups with an explicit commitment to incorporating the poor in governance such as UCRSEA. Nonetheless, given widespread urban inequities, bottom-up "invited" spaces will continue to be important since they can challenge status quo arrangements and are spaces where marginalized groups assert their "right to the city." Indeed, rather than a "trigger" that will inevitably spark more adaptive and just governance, meaningful change will depend on the concerted efforts of the urban poor and other marginalized groups as well as their allies.

The UCRSEA project can contribute important insights on how such "invited spaces" or bottom-up forms of radical planning might be nurtured and supported in Southeast Asia. There is relatively little literature on how radical planning or transformative adaptation might emerge in the top-down and centralized political contexts characteristic of some Southeast Asian nations (Beard 2003). Based on her study of collective action in slums in Indonesia, Beard (2003) suggests that in more rigid political environments social learning for transformative change will likely occur incrementally. For example, citizens may initially build critical and organizational capacities through participation in state programs and then be motivated to pursue more ambitious goals in other spaces. Similarly, in more repressive contexts, citizens may engage in more subtle, seemingly mundane, or even covert acts of planning that nonetheless begin to challenge the status quo. These practices can build social capital and critical capacities for deeper forms of transformation when a window of political opportunity opens (ibid.).

One case where citizens successfully built organizational capacities through their participation in government urban development programs is in Thailand's Community Organizations Development Institute (CODI). CODI, established in 2000, is a quasi-governmental body dedicated to slum upgrading and tenure security. Its work departs from the understanding that slums are not an aberration that will eventually go away, but a key part of the urban fabric, and so CODI prioritizes in situ upgrading rather than relocation. For example, CODI's Baan Mekong ("secure housing") project initiated in 2003 provides infrastructure subsidies and loans for housing and service improvements to community organizations and their networks. Together with local government authorities, communities develop and implement a community improvement plan, with community groups administering the finances. Boonyabancha

(2005) argues that the program has moved beyond physical upgrading towards improving state-society relations. Communities have developed organizational capacities and the confidence to negotiate with authorities and to assert land tenure rights. By fostering the creation of community networks, communities have also built valuable horizontal linkages that slowly help to reverse longstanding vertical relations of clientelism and patronage.

Similarly, Padwangi and Douglass (2015) describe how in Jakarta, Indonesia, flood resistance initiatives have become a key way to link everyday experiences with broader struggles around the "right to the city." For example, the Ciliwung Community Network, which grew from local grassroots initiatives, provides community services that reduce flood risk and improve neighbourhoods, while also engaging in more political activities that critique the underlying development trajectories that produce flood vulnerability. Community activities include restoring riverbanks, as well as providing trash collection. The network also demands for more environmentally and socially responsible development and generates evidence to support their claims. For example, the members have mapped the activities of industrial polluters and documented riverbank land-use conversion. In this way, they are directly addressing flood risk, while also gaining the "social and political capacities to better secure the right to live and flourish in the city" (544). Like in the CODI model, the network modality has helped the Ciliwung Community Network to scale up, although there is often a tension between going to scale and maintaining each organization's individual mandate.

A challenge for groups such as UCRSEA and others is how to support, but not manage, these efforts to build more climate just cities, and also to scale up without sacrificing the local accountability and knowledge that are at the core of adaptive governance.

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