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Down to Earth: Contextualizing the Anthropocene[☆]

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A B S T R A C T

The 'Anthropocene' is now being used as a conceptual frame by different communities and in a variety of contexts to understand the evolving human–environment relationship. However, as we argue in this paper, the notion of an *Anthropos*, or 'humanity', as global, unified 'geological force' threatens to mask the diversity and differences in the actual conditions and impacts of humankind, and does not do justice to the diversity of local and regional contexts. For this reason, we interpret in this article the notion of an Anthropocene in a more context-dependent, localized and social understanding. We do this through illustrating examples from four issue domains, selected for their variation in terms of spatial and temporal scale, systems of governance and functional interdependencies: nitrogen cycle distortion (in particular as it relates to food security); ocean acidification; urbanization; and wildfires. Based on this analysis, we systematically address the consequences of the lens of the Anthropocene for the governance of social-ecological systems, focusing on the multi-level, functional and sectoral organization of governance, and possible redefinitions of governance systems and policy domains. We conclude that the notion of the Anthropocene, once seen in light of social inequalities and regional differences, allows for novel analysis of issue-based problems in the context of a global understanding, in both academic and political terms. This makes it a useful concept to help leverage and (re-)focus our efforts in a more innovative and effective way to transition towards sustainability.

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1. Introduction

In 2000, Paul Crutzen and Eugene Stoermer proposed that human activities had so profoundly altered the planet as to push it into a new geological epoch—the Anthropocene (Crutzen and Stoermer, 2000; Crutzen, 2002). The concept is now widely used in a variety of contexts, communities and connotations (see Brondizio et al., 2016). Geologists explore the chemical, physical and biological characteristics of the Anthropocene, and debate whether and when this new geological epoch has started (Dean et al., 2014). For earth-system scientists, the concept encapsulates the radical anthropogenic alteration of the planet's natural cycles and systems (e.g. Zalasiewicz et al., 2010). More recently, the concept has also attracted the attention of social scientists and humanists, who seek to take the Anthropocene concept beyond its biophysical confines (e.g. Biermann, 2014; Castree et al., 2014; Galaz, 2014; Palsson et al., 2013; Jahn et al., 2015).

In this article, we argue that at a time when the notion of an 'Anthropocene' is being used increasingly by different communities and in a variety of contexts, it is critical to clarify as well as to add depth to the concept. Indeed, the Anthropocene notion – in its most common formulation as Earth's newest epoch in which humanity has collectively transformed the planet – has been criticized for picturing an overly simplistic and globalized view on human agency (e.g. Malm and Hornborg, 2014; see also Brondizio et al., 2016; Bai et al., 2015; Lövbrand et al., 2015). Major conference declarations that compare the impact of humanity to "planetary-scale geological processes such as ice ages" (2012 Planet under Pressure Declaration, see Brito and Stafford-Smith, 2012) or speak of "human-driven change" without differentiating between diverse social groups and regions (2001 Amsterdam Declaration, see Moore et al., 2001) have contributed to an image of 'humanity' as a global, unified 'geological force' (see for similar examples also Schellnhuber, 2001; Markl, 2001). While we recognize that the Anthropocene concept can be powerful in raising awareness of the overall human impacts on our planet, we claim that it risks being framed and understood in a way that is too 'global' and monolithic, neglecting persistent social inequalities and vast regional differences.

Instead, as we argue here, the Anthropocene can be a useful conceptual frame *only when* it is viewed from a cross-scalar perspective that takes into account developments at local, regional and global levels, variant connections among these levels and issue domains, as well as societal inequality and injustice. Using the Anthropocene lens must not mask the diversity of local and regional contexts and situations, nor the diversity and disparities in the conditions, contexts, and distribution of wealth, consumption and environmental impact across human societies. It must not ignore that merely 20% of the world population consumes about 77% of all goods and services on Planet Earth (as measured by their total value, see World Bank, 2008, p. 4) or that, while much industrial production has been moved to emerging economies, the lion's share of today's consumption remains in the hands of a small fraction of the global population, largely those living in industrialized countries (Steffen et al., 2015). This vast human inequality that characterizes the 21st century, we argue, should be recognized within the conceptual frame of the Anthropocene if the concept is to be operationalized in research practice and policy development.

For this reason, we attempt in this article to 'break down' the globality and uniformity of the construct of a 'humankind in the Anthropocene' and transform it into a more context-dependent, localized and social understanding. In so doing, we synthesize different strands of research to add to a new, more sophisticated and nuanced understanding of the Anthropocene. We show that the sum and interconnections of local changes (both environmental and societal) have become so great that they lead to global risks and consequences. Yet the drivers or sources of change are in many cases not necessarily the societies or environments affected by those changes. The contextualized Anthropocene lens that we suggest in this article supports a view of the planet as an interconnected, interdependent social-ecological system while taking into account both local variation and social inequalities. Such a contextualized, localized and social conceptualization of the Anthropocene helps to better understand global interconnections and disparities and to develop effective multilevel and polycentric governance solutions that decrease the human impacts on the planet and increase societal well-being particularly in the most impacted societies.

Our analysis draws on detailed study of four issue domains that we selected for their variation in terms of spatial scale (local vs. global); temporal scale (long-term vs. short-term); systems of governance (highly integrated governance systems in place vs. largely unregulated issues); and functional interdependencies (e.g. global economic integration through trade vs. largely local occurrence with global cumulative impact). These issue domains are the *nitrogen cycle* as it is affected by human action, with major impacts notably on food security, and with limited overall governance responses in place so far; *ocean acidification*, a long-term issue with multiple local impacts, partially covered by global governance mechanisms; *urbanization*, as a socially and economically driven transformation process that hugely impacts most social- ecological systems of the planet; and *wildfires*, as an essentially localized, often human-induced activity that impacts global systems through the increasing scale of its occurrence, with major relevance in particular for poorer communities and regions. These four issue domains do not represent an attempt at a controlled empirical research exercise through case studies (which would require a more limited choice of variables), but rather serve as empirical illustrations of what we see as typical examples of highly connected problems of the Anthropocene. Also, the presentation of these four issue domains in separate sections does not deny that the four domains are in themselves interdependent (though to variant degree), as we detail later in the concluding part of this article.

In section 2, we explore the relevance and value of the concept of the Anthropocene by synthesizing our existing knowledge from social and natural sciences on these four issue domains. Regarding these domains, we investigate three points: first, we explain the societal relevance of each issue domain in the Anthropocene and explore current and future impacts on societies, emphasizing vast differences and disparities that are often hidden behind the general notion of a uniform 'humankind'.

Second, we break down the broad notion of the Anthropocene by exploring the social-ecological complexities of each issue domain regarding issues of scale, distribution and interdependencies, which we see as key features of the complex human–environment systems that characterize the Anthropocene. *Scale* refers to the different spatial, temporal and institutional levels, where these issues play out and have different effects. Research and policy on these issues has traditionally focused on a specific geographical scale, whereas an Anthropocene lens requires taking the full range from local to global developments into account, recognizing processes and effects over different time horizons, and engaging all levels of institutions for effective governance. *Distribution* refers to issues of wealth, scarcity, access and allocation. Not all people and communities are equally affected by the challenges of the Anthropocene, nor are all equally able to cope. We discuss for each issue why certain communities are more vulnerable than others, what options they have to adapt to changes in environmental systems, and what the costs of inaction will be. *Interdependence* concerns issues of synchronicity, feedbacks, and 'teleconnections' (defined here more broadly than in meteorology, including also societal and economic long-distance connections and feedbacks). In other words, interdependence acknowledges the highly interrelated and interconnected nature of the issues that societies face in the Anthropocene.

Third, we explore to what extent an Anthropocene lens, within the social-ecological complexities that we emphasize, can contribute to developing novel insights into questions of governance and the political challenges of 'navigating the Anthropocene' (Biermann et al., 2012; Biermann, 2014). What implications, for example, can we identify regarding the most appropriate levels of governance for each issue domain? In what way does the notion of the Anthropocene help to develop new ideas and insights? Finally, we conclude each section with an exploration of the usefulness of the concept of the Anthropocene for addressing pressing challenges in the particular issue domain.

2. Challenges of the Anthropocene

2.1. Nitrogen cycle disruption and its relation to food security

2.1.1. Societal relevance

One key issue of the Anthropocene is the interlinkage between the nitrogen cycle and food security. Food production critically depends on nitrogen availability. Biologically, nitrogen has always been available, and plants and ecosystems have thrived on it, but its natural availability has been limited. Humans were able to change this through the Haber–Bosch process that allowed creating an endless source of reactive nitrogen for use as fertilizer (e.g. Smil, 2004; Erisman et al., 2008). The growing availability of nitrogen allowed some countries to dramatically increase food production (Erisman et al., 2008), often followed by socio-economic commercialization, the rise of major multinational corporations in the food sector, and the support of vast monocultures. But this unprecedented and unbounded use of nitrogen has critically disrupted its natural cycle, with numerous harmful effects such as pollution and eutrophication (Galloway et al., 2003). At the same time, a significant share of the human population still lacks sufficient access to food. Policies to address this global food insecurity, often directed at increasing food production, may further exacerbate disruptions of the nitrogen cycle. Overall, the increasing connections among food production, food insecurity and the nitrogen cycle are prominent signals of the Anthropocene epoch.

2.1.2. Distribution, scale and interdependence

The relationship between nitrogen use and food security, however, is far from straightforward. On the one hand, there is a clear local to global signal that disruption of the nitrogen cycle due to human activities negatively affects human health through air and water pollution; the climate through release of the greenhouse gas nitrous oxide; crop productivity through ozone exposure; and ecosystem health through pollution and eutrophication (e.g. Galloway et al., 2003, 2008; Erisman et al., 2013; Vermeulen et al., 2012a,b; Poppy et al., 2014; Seitzinger et al., 2010). On the other hand, while increased nitrogen fertilizer use has almost doubled global crop production, close to one billion people remain food insecure (Barrett, 2010), despite the existence of a global food market and decreasing global rates of poverty (World Bank, 2010). In 2008, 842 million adults were undernourished, and 98% of those were living in low-income countries (Bager, 2014). Overall, food prices are rising, making sufficient and healthy food unaffordable for many people (Godfray et al., 2010). Food insecurity is partly caused by agricultural production deficits related to lack of technology, insufficient affordability of fertilizers, and unsustainable use of inputs, especially in poorer regions. Paradoxically, therefore, in the Anthropocene we face the problem of an increasing imbalance between 'too low nitrogen areas' and 'too much nitrogen areas'. The global alteration of the nitrogen cycle by humans has thus been highly unequal. Especially wealthy societies have benefitted from increased food production, while all people are affected by the negative impacts of nitrogen cycle disruptions, including climate change.

2.1.3. Governance in the Anthropocene

Resolving the issues detailed above is only conceivable through multilevel and polycentric governance approaches that take account of numerous heterogeneous drivers. Key drivers include population growth combined with changing diets and increased consumption of food, especially animal protein. Other important drivers are trade and markets that shape food production, distribution and accessibility. Moreover, extreme events and climatic change increasingly affect production, cost, access and utilization of food. Finally, alternative uses of nitrogen and agricultural land to produce crops for renewable energy along with technology advances and technology transfer add new influences on overall system dynamics (Erisman et al., 2001; Vermeulen et al., 2012a,b; Barrett, 2010; Godfray et al., 2010). Response policies and governance mechanisms thus require an integrated, multi-level, multi-sector and multi-actor approach that effectively connects and reinforces local and global policies and governance systems.

First, an integrated understanding of the nexus of nitrogen and food security points to the need for *specific local action*. Effective local governance needs to increase the efficiency of nutrient use for food production by avoiding waste and low utilization. To achieve this, it is essential to improve availability of, and access to, technology in poorer regions. Moreover, education and training of farmers that links experience and knowledge from outside with local and regional characteristics can further improve the resilience of local food production (Settle et al., 2014). In terms of interconnections, smart extensification in nitrogen-polluted areas (that is, to reduce excessive nitrogen inputs while accepting potentially lower production) needs to be combined with smart intensification in low nitrogen areas (that is, the increase of nitrogen to increase local production while minimizing environmental impacts). Moreover, local governance of agricultural production and nutrient use should be complemented with optimized access and distribution of food, and stimulation of healthy and sustainable diets (e.g. Van Grinsven et al., 2015).

Second, an Anthropocene lens that takes into account local contexts as well as social inequalities, may suggest that it is equally important to develop *integrated policies that cut across sectors and include larger regions*. Such policies need to help, for instance, to minimize runoff of nutrients, chemicals and waste products into downstream ecosystems, including freshwater and marine environments. Integrated policies to improve local and regional food security are also needed to optimize nutrition and access to food; minimize production, post-harvest and consumer waste; and increase income and well-being of farmers.

Third, such strategies imply a *global responsibility for food production and integrated nitrogen management*. The Anthropocene lens, as we conceptualize it here, makes visible that local and national policies to improve food security and minimize negative effects of increased nitrogen use require global coordination and integration to connect policy domains and governance systems. For example, from an institutional perspective, the issue of the nitrogen cycle and food security touches upon the regulatory competencies of institutions as diverse as the Convention on Biological Diversity, the UN Food and Agriculture Organization, the World Food Programme, the UN Framework Convention on

Climate Change, or the World Trade Organization, as well as numerous regional institutions that address marine pollution.

There are already some initiatives that seek to help bring governance domains together in order to increase effectiveness and efficiency of the overall system. For example, for over a decade the International Nitrogen Initiative has brought the international scientific, agricultural and industrial sectors together to share information and begin to address the challenges of optimizing nitrogen use in food and energy production and minimizing the consequent harm to humans and the environment. Under the United Nations Economic Commission for Europe, a Task Force on Reactive Nitrogen was formed as a first body to work towards regional nitrogen policies. Building on this initiative, the UN Environment Programme has formed the Global Partnership on Nutrient Management as a global platform to steer dialogues and actions to promote effective nutrient management. Such global coordination mechanisms that build on local diversity and global disparities within a globally integrated understanding are a logical consequence of a holistic Anthropocene lens and require further support and strengthening.

We conclude here that an Anthropocene lens that takes into account local contexts as well as social inequalities proves useful to improve our understanding of the interconnections between food security and the nitrogen cycle, through allowing us to move from local visibility and global invisibility to visibility at all scales. Importantly, this has major implications for the need for better cross-scalar integration of knowledge, cooperation and policies.

2.2. Ocean acidification

2.2.1. Societal relevance

Our second example of key Anthropocene issue domains is ocean acidification. The oceans are undergoing a vast array of synchronous, interconnected changes that are driven by humans. Many of these changes are connected with climate change. Carbon dioxide emissions are acidifying the oceans at the same time that climate change is creating stresses such as warming, de-oxygenation and sea-level rise. On a local scale, acid rain amplifies the effect of ocean acidification, and increasing nutrients from fertilizers and sewage that enter coastal waters – as discussed in the previous section – are causing eutrophication. Ocean acidity is projected to increase by about 170% in 2100 compared with preindustrial levels if high carbon dioxide emissions continue, with major implications for ecosystems and the societies that rely on them (IGBP, IOC, SCOR, 2013). Already today, ocean acidification impacts marine organisms, with far reaching consequences for food webs, biodiversity, and eventually for societies through reduced ecosystem services. Shells and skeletons of calcifying organisms such as shellfish and corals are particularly vulnerable. As marine ecosystems are affected by ocean acidification this may ultimately affect coastal communities. For example, declines in mollusc shellfisheries worldwide could cost 130 billion USD per year by 2100 (Narita et al., 2012).

2.2.2. Distribution, scale and interdependence

Since ocean acidification is linked to global warming and hence the excessive emission of greenhouse gases, it is in the end a problem that has been caused, predominantly, by the richer, heavily industrialized countries in the North, although the contribution of emerging economies in the South to global greenhouse gas emissions is increasing rapidly in recent decades. The impacts of ocean acidification on societies are also unequally spread across the globe, yet differently from the causation. To a large extent, societies that are highly vulnerable to ocean acidification are located in developing countries and small island states (Cooley et al., 2012). Regional 'hotspots' of ocean acidification seem to occur in parts of the ocean where water naturally upwells to the surface, around coral reefs, and in polar regions. Here, coastal communities often rely on marine harvests of fish or shellfish, or coastal tourism, activities that are negatively affected by the consequences of ocean acidification.

The first of such ocean acidification 'hotspots' are upwelling areas such as the California Current, the Humboldt Current off Peru and Chile, and the Benguela Current off South Africa, all of which are naturally rich in nutrients, productivity and fisheries and support vibrant fishing and shellfish industries. The upwelling of water from the deep oceans, naturally high in carbon dioxide but with a low pH value, makes the surface water here harmful to corals, shellfish and some other organisms. If the prey of fish are affected and hence fish populations and commercial fisheries, this could have a devastating effect on both local communities and global trade of fish. For instance, the oyster industry in the California Current has had to adapt to low pH waters periodically affecting the oyster harvests (Barton et al., 2012). Some businesses are relocating the larval reproduction to Hawaii, where the pH conditions are more stable.

A second ocean acidification 'hotspot' are coral reefs (Ricke et al., 2013). The degradation of coral reefs due to ocean acidification could result in economic losses of over 1 trillion USD per year at 2010 price levels according to one estimate (Brander et al., 2012). The impacts of such losses are highly unequally distributed. Most will be borne by the over 500 million people that live on tropical coasts where they rely on the biodiversity, coastal protection, fisheries and tourism supported by coral reefs. The repercussions of this inequitable distribution of the impacts and costs of ocean acidification include the further impoverishment of small-scale coastal and reef fishers who are already among the world's poorest.

The polar regions form a third ocean acidification 'hotspot'. Arctic waters are acidifying faster than the global average because cold water is richer in carbon dioxide and melting ice worsens the problem (Orr et al., 2005). Increasing areas of the deep sea are affected as the aragonite saturation horizon is moving upwards with resulting dangers for cold water corals (Gattuso et al., 2011). The shells of some small marine snails, which are key species in the food web, are already dissolving in some spots around Antarctica (Bednaršek et al., 2012).

2.2.3. Governance in the Anthropocene

Governance solutions are limited inasmuch as the effects of ocean acidification cannot be reversed on human time scales. And yet, ocean acidification can still be slowed down by reducing carbon dioxide emissions or by removing carbon dioxide from the atmosphere. This calls for effective multilevel climate governance, reducing the concentration of carbon dioxide in the atmosphere. Here, ocean governance is linked to the broader issue of climate change. In addition to global governance approaches, regionally defined ocean acidification 'hotspots' point to the parallel need for effective regional governance. Local and regional regulation of nutrient runoff, for instance, is an effective mitigation measure for ocean acidification in some coastal areas, linking ocean acidification to nutrient management that we discussed in the previous section.

Overall, our analysis shows that while ocean acidification is an issue of global interdependence and global concern, it also needs to be analysed and approached in its regional and local circumstances. The different types of ocean acidification 'hot spots' that we identify present different governance issues, with particular challenges and opportunities for each specific region. To address the issue of ocean acidification in the California Current upwelling area, for example, a regional Blue Ribbon Panel was formed, bringing together scientists, shellfish industry representatives, public opinion leaders, conservation leaders, the state, and local, federal and tribal policymakers to prepare an adaptation plan to respond to ocean acidification (Washington State Blue Ribbon Panel on Ocean Acidification, 2012). Yet, while different stakeholders in the United States have begun to address problems around ocean acidification, similar responses have not yet spread to South America, where oyster farms – notably in Chile – are now experiencing similar negative effects on larvae.

The effect of ocean acidification on coral reefs generates different governance challenges. Since the global distribution of reefs is biased towards vulnerable societies, the reduction of reef-based ecosystem services requires social and economic policy responses tailored towards distinct coastal regions. Such regions often also receive development assistance from national or international sources. Connections between global governance mechanisms that reduce carbon dioxide emissions, compensate for acidification-linked losses, and development assistance for local communities are therefore required—a complexity that we see as typical for the emergence of the Anthropocene. Finally, uncertainties associated with ocean acidification in the polar regions require governance approaches that emphasize precaution and anticipate ecosystem change.

Novel types of multi-scale ocean governance are thus needed that recognize connections across system levels and issues (Glaser and Glaeser, 2014). Also here, global and local governance approaches must be developed simultaneously in an integrated manner, while disentangling geographically diverse impacts, incentives and options. Effective policies should consider the different exposure of regional ecosystems. Yet equally relevant is the relative importance of ecosystems for affected human populations and economies, notably with a view to local fisheries in developing countries. Possible local and national governance responses include reducing sources of acidification through controlling nutrient runoff; increasing resilience of coral reefs by reducing other stressors such as sediment load, river runoff and fishing pressure; addressing overfishing and destructive fishing; reducing pressures by the introduction of marine protected areas; and controlling acid rain by limiting sulphur dioxide and nitrogen oxide emissions from power plants. At the same time, however, global solutions are required for reducing carbon dioxide emissions, as well as for the support of particularly affected communities in poorer regions in the South.

The Anthropocene concept, as interpreted here, proves useful in focussing on human societies as the major driver of increased ocean acidification, yet with the added need of emphasizing the regional and local diversity in these drivers and resulting impacts, including vast differences between the richer and poorer parts of the world. The analysis shows that major sources of atmospheric carbon dioxide are not located where the greatest negative effects are likely to occur, which calls for multilevel integrated governance solutions within a global context. Adequate governance solutions can only be developed when the social, ecological and economic context at lower spatial and institutional levels becomes an integral part of global, multi-level ocean governance.

2.3. Urbanization

2.3.1. Societal relevance

Another key trend in the Anthropocene – possibly even one of the most defining ones – is urbanization. Today's urbanization differs markedly from past urbanization in terms of its scale, rate, distribution, teleconnections and process (Seto et al., 2010, 2012). Urbanization is a multifaceted phenomenon that involves economic, biophysical, political, social and cultural transformations (Friedmann, 2006). The reach of urbanization is so pervasive now that only few social-ecological systems worldwide are untouched by some component of its process, be it the extraction of raw materials and energy, production of food and other goods, waste assimilation, or changes in values and consumption patterns. A salient feature of modern urbanization is that physical and economic landscapes are becoming more intertwined, and that we see a greater integration of rural and urban economies. Urbanization is thus a classic manifestation of the changing human–environment relationship conceptualized by the Anthropocene.

2.3.2. Distribution, scale and interdependence

Historically, urbanization and economic development occurred in parallel, and were tightly and inextricably linked (Henderson, 2003; Dobbs et al., 2013; Bloom et al., 2008; Bai et al., 2011). High proportions of urban populations, or more urban built-up areas, were correlated with high levels of per capita GDP. Urbanization, with its relative concentration of people and activities, enabled economies of scale and the development of infrastructure such as transportation, waste management and power supply. Thus, urbanization has historically been both an indicator and a driver of higher per capita incomes and improvements in living conditions and well-being. Today, however, urbanization and local and national economic growth have become decoupled in some countries (Bloom et al., 2008); with the added complexity that urbanization may affect the economic activity in non-urban places through trade, teleconnections, or labour flows. In the context of the Anthropocene this means that urbanization takes place also at overall lower levels of economic development, and is not necessarily linked to better municipal infrastructure, services or improvements in sanitation and living conditions. Particularly in rapidly developing cities in low-income countries, infrastructural deficiencies and industrial pollution may thus negatively affect local well-being.

Cities have far-reaching impacts through multiple interdependencies (Alberti, 2008; Bai, 2003; Grimm et al., 2008; Seto et al., 2012), which suggests an opportunity and responsibility of cities to act as stewards of the planet (Seitzinger et al., 2012). For example, the most recent IPCC report concluded that urban areas are responsible for about 70% of fossil fuel carbon emissions (IPCC, 2014a). Given the large economic disparities in development among urban regions around the world, it is clear that the majority of urban emissions come from high-income countries or rapidly industrializing countries. Yet, it is largely the urban areas in low-income countries that are most vulnerable to climate change impacts, owing to weaknesses in institutions and governance, finance and human capacities (IPCC, 2014b).

Whereas for centuries, the 'urban' was conceptualized as a place bounded by administrative borders, urbanization is rather a dynamic process not limited to fixed geographic locations (Seto et al., 2012). Also, urban systems are increasingly dependent on a global hinterland of resources for material input and waste assimilation. Moreover, policies in one country may affect other countries through multiple dimensions of urbanization (e.g. flows of energy, food, water, waste, pollution, investments, remittances, tourists, migrants, knowledge, communication, and construction materials) (Güneralp et al., 2013; Erb et al., 2009). As a result, today's urbanization breeds new inequalities, not only in its immediate location but also beyond.

Urbanization thus involves contemporaneous change in thousands of places worldwide, putting the phenomenon at the centre of the Anthropocene. In each of these places, urbanization involves simultaneous change across multiple dimensions. These include an increase in the urban proportion of the total population (Dorélien et al., 2013; Montgomery, 2008), expansion of built-up areas and infrastructure (Berry et al., 1970; Blanco et al., 2011; Bai et al., 2011; Seto et al., 2011), a structural shift from agriculture and forestry to manufacturing and services (Davis and Henderson, 2003), as well as changes in social interactions and a growing complexity in political, social and economic institutions (Berry, 1974; Healey, 2003; Friedmann, 2006; Sampson et al., 2002). Finally, urbanization can accelerate inequalities, both within cities locally (particularly in low-income countries and rapidly developing cities) and between cities globally, as a result of teleconnections and differentiated vulnerabilities.

2.3.3. Governance in the Anthropocene

Cities face multiple governance challenges that are inherently bound by spatial, temporal and institutional scales (Bai, 2007; Bulkeley, 2005), while cities are increasingly connected globally (Sassen, 2011). For example, urban infrastructures often extend beyond a city's territory and hence require coordinated policies across adjacent municipalities. Cities also operate within regional and national authorities, and thus have varying degrees of autonomy and authority. These scale issues require governance and institutions for the design and implementation of effective policy frameworks that address multiple administrative levels and extend beyond a single city's jurisdiction. Without fully accounting for interdependencies and teleconnections, solutions in one place may lead to externalities and leakage of costs to other places. A key example is the relocation of polluting industries from cities to the countryside or from one country to another (Bai, 2002).

But urbanization also offers opportunities for transformative change. The concentration of people and economic activities make cities ideal settings for innovation and job and wealth creation (Bettencourt et al., 2007; Puga, 2010; Rosenthal and Strange, 2004; Sassen, 2001). The majority of the world's future population growth will be living in urban areas in the developing countries, where emerging infrastructures and high-emissions lifestyles are not yet locked-in. The need to design and construct the cities of tomorrow presents a major window of opportunity, but also a challenge to existing values and power relations. Recognizing the interdependencies of resources, activities and economies offers a new lens to understand connections and impacts on the planetary scale. Importantly, the global links among cities, as well as the strong global impact that they have, suggests new ways of organizing political discourses and governance. One way for instance could be to strengthen the existing networks of city governments. Transnational city networks, such as the C40 Cities Climate Leadership Group, are already acknowledged as an important arena for the governance of climate issues (Betsill and Bulkeley, 2007; Rosenzweig et al., 2010). Turning such alliances into powerful sources of knowledge exchange as well as venues for novel types of political cooperation and coordination of the world's vast urban spaces could be an essential step towards better governance in the Anthropocene.

The prism of the Anthropocene can thus provide useful framing for moving towards better or alternative models of urbanization that are more cognisant of complex system interactions and interconnections and that encapsulate a more nuanced understanding of sustainability. Urbanization draws on and concentrates resources, thereby generating wealth and 'growth' for some more than others. It is thus intimately linked with the creation or sustenance of global and local inequality. Overall, the history of urbanization in the Anthropocene is in many ways the history of the Anthropocene itself (e.g. Industrial Revolution and technological advances coupled with colonization and trade, etc.). Indeed, the urbanization ratio is seen as a key indicator of the Anthropocene (Steffen et al., 2007). A process-based conceptualization of urbanization requires us to move away from a focus on only local and placed-based approaches towards sustainability and to explore instead new global frameworks for effective multilevel governance that support transformation in the era of urbanization.

2.4. Wildfires

2.4.1. Societal relevance

The global increase in wildfires is the fourth illustration of a typical Anthropocene challenge that we explore in this article. Of course, wildfires have always been a normal and even valuable ingredient of ecosystem functioning, and the significance of fire in global biogeochemical cycles dates back to the pre-Quaternary (Scott, 2000; Whitlock et al., 2007; Nelson and Pierce, 2010). However, over the last century we have witnessed frequent, widespread and intense wildfires that far exceeded ecological and land use benefits and caused large damages such as human and animal mortality, loss of property, and negative consequences on long-term land productivity, fresh water supply, and climate. Fire in the Anthropocene has thus shifted dramatically, from an ecological phenomenon driven by natural factors to a spatially and temporally variable hazard strongly associated with humans (Whitlock et al., 2007; Dube, 2009; Bowman et al., 2009). Fire incidents range from small to medium-scale fires to very large and destructive events, the so-called 'mega-fires'. Such fires are now perceived largely negatively, and hence fire-restriction policies prevail globally, even though land-use practices that incorporate fire are still wide-spread (Xanthopoulos, 2004).

2.4.2. Distribution, scale and interdependence

The global problem of increasing wildfires shows high variability in occurrence, intensity and effects. Fire intensity with regional variability increased already before the Holocene, driven by changes in global climate and growing human modification of the landscape through fire (Bird and Cali, 1998; Carcaillet et al., 2007; Daniels et al., 2005; Genries et al., 2009; Gill et al., 2009; Marlon et al., 2006, 2008, 2009; Millspaugh et al., 2000; Nelson and Pierce, 2010; Pausas and Keeley, 2009; Power et al., 2008; Roebroeks and Villa, 2011; Rolland, 2004; Thevenon et al., 2004). Yet fires increased dramatically in the Holocene under the Neolithic Revolution, marking the begin of novel, complex relationships among fire, human activity, and vegetation (Whitlock et al., 2007; Dube, 2009).

It is estimated that in 2001–2004, each year 2.97–3.74 million km^2 land are burned (Giglio et al., 2006). Humans account for 90% of ignitions in all biomes of the world, due to a combination of fire policies, land use practices, and other human actions (Dube, 2013). Yet the impact is not the same all over the world. The tropical and boreal regions are the most frequently affected (Chuvieco et al., 2008), and about 30–50% of the total annual biomass burned globally is traced to Africa (Goldammer and de Ronde, 2004). Humans have altered the number, location, timing and intervals of ignitions. Also seasonality and timing of fire has shifted globally to dry-season burning and within a diurnal range of early to late afternoon, giving rise to highly destructive fires (Evett et al., 2007; Giglio, 2007). By fragmenting, depleting or maintaining exceptionally high fuel loads, humans influence the ability of fires to ignite and spread as well as fire intensity. At the same time, the use of fire continues to be an important tool in local food production practices supporting the livelihood of rural societies (e.g. Bird et al., 2008; Lavorel et al., 2007).

The increase in frequency and intensity of wildfires has far-reaching local, regional, and partially even global consequences. Once lit and left to spread, wildfires release stored energy from soil and vegetation, along with evaporating moisture and unleashing large quantities of greenhouse gases, volatile organic compounds, black and organic carbon and mineral ash. The impacts are often far beyond the site of the fire, and include air pollution, ocean acidification and deposits of black carbon soot, which lead to rapid melting of snow, glaciers and sea ice (McConnell et al., 2007). Frequent hot fires further the loss of biodiversity and contribute to land degradation and sedimentation of water bodies with implications on fresh water supply and fisheries downstream. Land degradation and fire reinforce each other, with the former supporting fast growing fire-prone species that burn easily over the dry season and then leave the land exposed to further degradation (Dube, 2007; Lavorel et al., 2007). Together with land pressures such as overgrazing and drought, fires also reduce carbon sequestration by terrestrial ecosystems, thus enhancing global warming (McConnell et al., 2007; Chuvieco et al., 2008). Considering these teleconnections of the effects of fire, current estimates of damage by fires may underestimate their multiple consequences, including social ones. For example, frequent small fires in Africa are rarely noticed, yet play a role in widespread poverty on the continent.

2.4.3. Governance in the Anthropocene

For much of the fire-prone regions of the world, such as the tropics and Mediterranean, governance and management approaches fall essentially into two categories: local fire practices that are driven by subsistence livelihood activities, and the national to global fire suppression approaches that have hardly any consideration for ecological needs for fire, disregard local fire uses, and take merely a reactive approach to hazards and disasters (Julio-Alvear, 2004; Xanthopoulos, 2004). Catastrophic fires during extreme dry weather in the USA, Europe, Australia and other industrialized countries are linked to a strong inclination towards fire suppression. The prevalence of such suppression practices can partially be explained by history in these less fire-prone temperate regions. It also relates to economic interests such as the timber industry, and perceptions that stem from longer periods of urbanization and years of witnessing the consequences of destruction of natural systems (Xanthopoulos, 2004; Chuvieco et al., 2008). Many fire-prone developing countries, however, do not fare well by adapting a fire management system that has been developed in less fire-prone temperate zones. Moreover, inefficient national governance in developing countries tends to disempower local resource management that often makes fire a necessary tool, giving rise to uncoordinated widespread burning (Dube, 2013).

The political challenge in the Anthropocene requires careful integration of local, regional and global governance that balances ecological requirements with the fire needs related to land use. Effective local fire management strategies are needed that consider simultaneously socio-economic factors, ecosystem requirements, and changes in climate and fire risk (Julio-Alvear, 2004; Xanthopoulos, 2004; Eriksen, 2007; Dube, 2013). Local fire management should also take into account fire-dependent production systems of indigenous and other traditional social groups, recognizing that small-scale subsistence-based anthropogenic fires reduce the risk of large-scale destructive fires, and could thus make a positive contribution to local fire policies (Bird et al., 2012; Eloy et al., 2015). This again requires a degree of decentralization of fire management so that key components of fire management – preparedness, prevention, suppression and rehabilitation – are incorporated within the ecological needs and local land use practices. At the regional level, a broader, often transnational strategy is needed to deal with exceptionally large fires, transboundary fires, and fires in protected areas. Moreover, given the teleconnections in fire, international – possibly even global – fire protocols will be essential to assess regional and global fire weather, the effects of burning on biodiversity and land degradation, as well as feedbacks on global warming.

The Anthropocene lens provides better understanding of the link between biophysical factors and the highly divergent socio-economic systems that drive fires. This analysis clearly shows the high variability in occurrence, intensity and effects of the global wildfire problem. Equally diverse are the capacity of societies to respond and recover from fire, with poorer communities generally being most severely affected by the spread of wildfire. This global diversity points, on the one hand, to the need for locally specific approaches to wildfire management. On the other hand, local governance requires global support and cooperation, in particular with a view to the poorest regions that are least able to cope with such challenges.

3. Conclusions

Taken together, the four issue domains that we have reviewed in this article – from the nitrogen cycle to ocean acidification, urbanization, and wildfires – at first appear vastly different. Yet there are also significant similarities. Importantly, all four issue domains exhibit key manifestations of the changed role of humankind in the planetary system, as it is captured in the notion of the Anthropocene. Each of the four domains displays different dimensions of the Anthropocene. Some are associated with the key drivers of global change, such as urbanization. Others relate more to intermediate processes, such as the nitrogen cycle, or on the overall effects of global change, such as ocean acidification. Nonetheless, all four issues are inevitably entangled in the complexities of the Anthropocene.

Moreover, our analysis of the four domains manifests the global links among these domains through numerous interdependencies and teleconnections. Urbanization, for instance, is both a driver of change as well as one of the prime sites where global change will affect the wellbeing of people. Urbanization drives intensification of food production and increased fire risk from commercialization of natural resources and tensions at the wildland–urban interface. Food production, in turn, is a major source of emissions through land degradation, fertilizer use, or fire, which eventually contributes to ocean acidification and climate change, with again a feedback loop on fires, food production, and use of nitrogen fertilizers.

All four issue domains also demonstrate the highly varied role of people in both causation and effect of global environmental changes. Novel teleconnections now link countries and communities in many ways. Local farmers are connected with global markets and fertilizer developments; the livelihood of local fishing communities depends on global issues such as climate change and ocean acidification; and urban areas across the world are connected through financial, technological and governance networks. The multiple connections of rural communities with often richer urban areas are in themselves interconnected across the globe. In sum, the Anthropocene is a global phenomenon that is marked by the new impact of humankind as a whole, yet – as illustrated by our analysis – there remain tremendous differences in both causation and impacts among societies and people in the Anthropocene.

The interdependencies, inequalities and disparities that we uncovered in exploring the four issue domains have important consequences for the governance challenge of the Anthropocene and the underlying need for fundamental changes in social values and development pathways.

First, the Anthropocene lens, in the contextualized and nuanced form that we propose, has major implications for the *appropriate levels of governance*. All issue domains that we analysed require effective local and national governance, from instilling more social and environmental development aspects into sectoral governance (e.g. related to fire management) towards better adaptation policies (e.g. related to fisheries that will increasingly be affected by ocean acidification). However, local and national governance alone will be inadequate for addressing Anthropocene challenges without strong coordination and support through global governance institutions and intergovernmental cooperation, given the high connectivity. While current research practice is still often marked by distinct communities of scholars who are studying local governance, and those who are studying global governance, much more integration of both strands of research is needed. This is, among others, a key concern for the leading research programmes in this field, notably the Earth System Governance Project that explicitly seeks to build bridges between different communities in the social sciences.

Second, the lens of the Anthropocene helps to focus attention on new functional and sectoral domains of governance. Our analysis has illustrated, for example, important interlinkages between urbanization, food production, wildfires, ocean acidification, coastal fisheries, and the emission of greenhouse gases leading to global warming. These multiple interdependencies emphasize, first, *novel needs of policy integration* at all levels, from local governance – for example in coastal regions – to a renewed attention for improved global policy integration. Our analysis also points to the *possible definition of new policy domains and governance issues*. For example, the distortion of the nitrogen cycle, with its local and global dimensions, might suggest the strengthening of local and global coordination and governance mechanisms that focus on this particular system, which has not been addressed as such before in political terms. Likewise, the issue of ocean acidification could be seen as calling for an integrated approach, at least with a view to research and the coordination of policy responses.

Third, the Anthropocene lens might suggest a *redefinition of existing governance systems* and policy domains. For example, while our analysis has emphasized the emergence of urban areas as key elements of the Anthropocene, most key political institutions, including the intergovernmental system, largely rely on the nation state as prime site of policy-making. The importance of urban areas, including their interdependencies and teleconnections, might suggest a strengthening of global alliances and networks of cities, in an effort to help address the negative impacts of urbanization and leverage the many advantages that urbanization might bring about. However, such strengthened focus on cities, as key governance sites in the Anthropocene, might also reinvigorate conflicts between urban and non-urban areas, from national to global levels. Hence, we suggest that there is a need to embed local and regional contextualized governance solutions within a planetary frame of reference and strengthened systems of earth system governance.

We conclude that the concept of the Anthropocene is useful in improving our understanding of social-ecological complexities and that it has important consequences for the governance of social-ecological systems. This is, however, only the case when the Anthropocene concept is downscaled and opened up to more diverse policy arenas and larger numbers of potentially influential stakeholders. Only such a contextualized, localized and social understanding of the Anthropocene, sensitive to global inequalities and disparities, can contribute to new insights into global and local interconnectivities and teleconnections between issues and system levels, and to novel ways of understanding the various intricacies of vulnerability. Only then will it have any analytical power, as well as any social and policy relevance. Our approach of down-scaling the Anthropocene thus contributes to a better analytical understanding; a more appropriate and complex normative understanding (making differences among humans visible, including pervasive inequalities); and novel directions for better governance, from local to global.

When understood in this way, the Anthropocene concept can provide a new frame for holistic analysis, while building on contextualized and localized data. In sum, the notion of the Anthropocene, in its contextualized and nuanced form, allows for novel ways of integrated analysis of issue-based problems in the context of a global understanding, in both academic and political terms.

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