

Speculative Political Ecologies: (re)imagining urban futures of climate extremes

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Abstract

What role can a speculative political ecology play in (re)imagining urban futures of climate extremes? In recent years, narratives of dystopian futures of climate extremes have proliferated in geosciences, and across the media and creative arts. These anxiety-fueled narratives often generate a sense of resignation and unavoidability, which contributes to foreclosing the possibility of radically different political projects. In this article, we argue that these narratives conceal the coproduction of nature and society and treat nature as the problem, thereby locking futures into dystopic configurations. Political ecology scholarship can contribute to generate a politics of possibility by reconceptualizing the relations that constitute urban futures under climate extremes as socionatural. This, we argue, calls for a more experimental political ecology and new forms of theorizing. To this aim, we develop a speculative political ecological approach grounded on a numerical model that examines the potential of transformative change in the aftermath of extreme flood events in a capitalist city. Analytically, this opens a unique possibility of exploring urban futures beyond current trajectories, and how these alternative futures might transform vulnerability and inequality across urban spaces. From a policy perspective, we lay the foundations for a new generation of models that apprehend the role of power and agency in shaping uneven urban futures of climate extremes.

Keywords: Speculative political ecologies, climate change, disasters, transformative change, urban futures

Résumé

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Quel rôle une écologie politique spéculative peut-elle jouer dans la (re)représentation des futurs urbains sous l'effet des extrêmes climatiques? Ces dernières années, les extrêmes climatiques sont apparus dans les géosciences, les médias et les arts créatifs. Ces récits anxiogènes génèrent souvent un sentiment de résignation et d'inévitabilité, ce qui contribue à exclure la possibilité de projets politiques radicalement différents. Dans cet article, nous soutenons que ces récits dissimulent la coproduction de la nature et de la société et traitent la nature comme un problème. Une écologie politique plus expérimentale et de nouvelles formes de théorisation peuvent ouvrir des espaces pour des futurs alternatifs, en reconceptualisant les relations socationnelles qui constituent les futurs urbains. Nous développons une approche spéculative d'écologie politique fondée sur un modèle numérique qui examine le potentiel de changement transformateur à la suite d'inondations extrêmes dans une ville capitaliste. Nous explorons la manière dont les alternatives pourraient transformer la vulnérabilité et l'inégalité dans les espaces urbains. D'un point de vue politique, nous posons les bases d'une nouvelle génération de modèles qui appréhendent le rôle du pouvoir et de l'agence dans l'élaboration d'avenirs urbains inégaux face aux extrêmes climatiques.

Mots-clés: Écologies politiques spéculatives, changement climatique, catastrophes, changement transformateur, avenirs urbains

Resumen

¿Qué papel puede desempeñar una ecología política especulativa a la hora de (re)imaginar futuros urbanos bajo condiciones climáticas extremas? En los últimos años, narrativas sobre futuros distópicos enmarcados en un contexto de extremos climáticos han proliferado en las geociencias, los medios de comunicación y las artes creativas. Estas narrativas, impulsadas por la ansiedad, a menudo generan un sentido de resignación, contribuyendo a cerrar la posibilidad de proyectos políticos más radicales. En este artículo sostenemos que estas narrativas ocultan la coproducción de naturaleza y sociedad. Una ecología política más experimental con nuevas formas de teorizar abre espacios para futuros alternativos, al reconceptualizar las relaciones socationnelles de la ciudad. Desarrollamos un enfoque de ecología política especulativa basado en un modelo numérico que examina el potencial de cambio transformador existente tras inundaciones extremas en una ciudad capitalista. Analíticamente, esto abre una posibilidad única de explorar futuros urbanos más allá de las trayectorias de desarrollo económico actuales y cómo futuros alternativos podrían transformar la vulnerabilidad y la desigualdad en espacios urbanos. Sentamos las bases para una nueva generación de modelos que comprendan el papel del poder y la agencia en la configuración de futuros urbanos desiguales bajo condiciones climáticas extremas.

Palabras clave: Ecologías políticas especulativas, cambio climático, desastres, cambio transformador, futuros urbanos

1. Introduction

This article explores the potential of a speculative political ecology that engages with and (re)imagines incumbent futures of anthropogenic climate change. Earth systems scientists have long warned that many regions will experience increased intensity and frequency of several categories of climate events under anthropogenic climate change (Balch *et al.*, 2020; Blöschl *et al.*, 2019; Mazzoleni *et al.*, 2021; Zhu *et al.*, 2021), fueling the "anthology of scary tales" and imaginations of incumbent gloomy futures (Buck, 2015, p. 370). Planetary thresholds of "Hothouse Earth" (Steffen *et al.*, 2018, p. 8252), climate tipping points (Lenton *et al.*, 2019), and planetary boundaries (Rockström *et al.*, 2009) have been recently popularized by the Netflix documentary *Breaking Boundaries* (Clay, 2021), featuring a dialogue between broadcaster and natural historian David Attenborough and scientist Johan Rockström. These same narratives are channeled into cli-fi movies (*Mad Max: Fury Road*, 2015; *Beasts of the Southern Wild*, 2012; *Waterworld*, 1995), novels (*Memory of Water*, 2014), apocalyptic scenarios of climate change (Boia, 2005) and journalistic accounts of the "inhabitable earth" (Wallace-Wells, 2019). As a result, dystopian and anxiety-fueled imaginaries of catastrophic, incumbent futures are proliferating and generating a diffused sense of panic or "androphobia", inevitability, and resignation (Buck, 2015; Robbins & Moore, 2013, p. 7). We argue that narratives of 'doomed' or 'locked-in' futures are based on a Western-centric notion of the separation of nature and society. This, in effect, forces us to take for granted the dystopian elements of the catastrophic futures that lean on us. 'Doomism' works by conceptualizing climate

change as an external threat and by concealing the socio-political production of these catastrophic futures, thereby excluding the possibility of systemic change and alternative urban futures. We propose that there is a need for political ecology scholarship to engage with these incumbent futures to resist doomist narratives and (re)imagine urban futures. Apprehending the power relations that produce 'doomed' or 'locked-in' futures, we argue, opens the possibility of changing these relations and responding to impending futures in a way that is not merely defensive.

While critique is, implicitly, oriented to the future, political ecology has developed retrospective analyses of the social construction of climate-related disasters and the uneven outcomes thereof (Ajibade & McBean, 2014; Bakker, 2000; Bullard & Wright, 2009; Collins, 2008, 2010; Grove *et al.*, 2020; Marks, 2015; Millington, 2018, 2021; Pelling, 1999; Ranganathan, 2015; Rusca *et al.*, 2021; Savelli *et al.*, 2021; Scheba & Millington, 2018). Urban futures and the possibilities of (re)imagining what is before us have been far less explored. Moreover, the exploration of radically different urban climate futures rests on an intellectual and ethical stance on the condition of its possibility. Thus, engaging with and reimagining urban futures calls for a more experimental approach to political ecology, new forms of theorizing, and the making of a politics of possibility to open spaces for alternative futures (Braun, 2015b, 2015a; Buck, 2015; Gibson-Graham, 2006). To this aim, we develop a speculative political ecological approach grounded on an idealized numerical model that examines the transformative potential of flood-related extremes in the capitalist city. The model takes past and present logics of racism, colonialism, and capitalism as the starting point. It considers a city that developed unevenly and generated differential vulnerability to climate extremes across intra-urban spaces, identities, and socio-economic groups. In this model, however, climate futures are not exhausted by this dystopian present and past. The transformative potential of climate extremes is explored by examining the ways in which rapid and disruptive changes caused by floods might change political alignment with the government and, in turn, policy responses and development trajectories of the city.

The purpose of the model is threefold. First, the model conceptualizes urban floods and their uneven outcomes as a coevolutionary relationship between socio-ecological flows. In this way, it redistributes agency between nature and society and repoliticizes the doomed or locked-in futures of climate extremes. Second, in doing so, the model brings to the fore the possibilities that are opened when political alignments are changed, thereby making the future potentially different to the dystopian projections expected under current development trajectories. Third, the model explores development trajectories under different scenarios of socio-political change and associated policies. In this way, we explore how different transformative policies reshape urban inequalities and vulnerability to climate extremes in the city. We proceed as follows. In Section 2, we explore the relationship between colonial legacies, racial capitalism, and climate extremes. We then consider the potential of transformative change in the aftermath of a disaster, drawing on transformative geographies and speculative thought. Section 3 introduces the model. We engage urban political ecology and critical disaster studies perspectives discussed in Section 2 to define the socioecological dynamics simulated by the model. Next, we translate these socioecological dynamics into a set of equations that govern the model's evolution. In Section 4, we discuss the results and the speculative potential of the model. We conclude by reflecting on the value of political ecology critique to develop plausible future scenarios and models, and on how speculative models might inform other futures.

2. The making of a politics of possibility: transformative and speculative geographies of climate extremes

In order to extend the possible, it is necessary to proclaim and desire the impossible. Action and strategy consist in making possible tomorrow what is impossible today. Henri Lefebvre (1976, p. 36)

Cultivating ourselves as thinking subjects within a politics of (economic) possibility has involved us with techniques of ontological reframing (to produce the ground of possibility), rereading (to uncover or excavate the possible), and creativity (to generate actual possibilities where none formerly existed). (Gibson-Graham, 2006, pp. xxviii-xxx)

It matters what stories make worlds, what worlds make stories (Haraway, 2016, p. 12)

What if the social sciences had cultivated, like their experimental sisters, the art of the thought experiment? (Stengers, 2018, p. 30)

Colonial legacies, racial capitalism, and the construction of disaster

Capitalism is argued to be the dominant form of socio-economic organization in cities across the globe (Brenner & Theodore, 2002a, 2002b; Peck, 2004; Peck & Brenner, 2010; Peck *et al.*, 2010; Peck *et al.*, 2013; Peck & Tickell, 2002), producing uneven development, inequality and vulnerability (Smith, 2010; Wisner *et al.*, 2004). Urban political ecology has conceptualized urban development processes through the lenses of flows of commodities, profit, and labor (Desfor & Keil, 2004; Gandy, 2002, 2005; Heynen, 2014; Kaika, 2005; Swyngedouw, 2004). On the one hand, urban flows are shaped by uneven power relations between workers and capitalist investors, mediated by government institutions and underpinned by a logic of capital accumulation. On the other, urban flows animate capitalist relationships, making them appear as if they were relatively stable.

A vast literature has shown the implications of these social and economic relations for the nature, scale, and distribution of risk and vulnerability to different hazards. Cities develop unevenly and generate urban spaces that are disproportionately exposed to hazards, with levels of vulnerability varying in critical ways across income groups, identities, intra-urban spaces, and neighborhoods (Arifeen & Eriksen, 2019; Bolin & Kurtz, 2018; Cutter *et al.* 2003; Mustafa, 2005; Sultana, 2021; Wisner *et al.*, 2004). Research has pointed to the impact of neoliberal processes on public disinvestment, the contraction of affordable housing, pro-business development strategies and the uneven distribution of infrastructure and basic services, all affecting the production and polarization of uneven vulnerability to hazards (Ajibade & McBean, 2014; Collins, 2008; Dodman *et al.*, 2017; Fothergill & Peek, 2004; Kaika, 2003; Kallis & Coccossis, 2003; Kates *et al.*, 2006; Millington, 2018; Pelling, 2003; Rusca *et al.*, 2022; Rusca *et al.*, 2023; Vitz, 2018; Wisner *et al.*, 2004). To illustrate, lower-income and minority groups often reside in areas that are more prone to flooding, own or rent housing facilities that cannot, in many cases, withstand hurricanes and floods, and are more exposed to toxic spills and health risks associated with these hazards (Collins, 2009; Dodman *et al.*, 2017; Fothergill & Peek, 2004; Maldonado *et al.*, 2016; Rusca *et al.*, 2021; Van Zandt *et al.*, 2012). Concurrently, the most vulnerable groups suffer greater (relative) economic losses and take significantly longer to recover from a disaster (Adger, 2010; Elliott & Pais, 2006; Harris *et al.*, 2017; Mustafa, 2005; Peacock *et al.*, 2014; Verchick, 2012). This is also because the dynamics of capital accumulation and marginalization are often reproduced in post-disaster trajectories, which entrench pre-disaster inequalities and differential vulnerability. The concept of disaster capitalism (see Klein, 2007) aptly illustrates the idea of post-disaster reconstruction being a profitable enterprise or as an (other) expression of "surplus absorption through urban transformation" that exacerbates differential vulnerability (Harvey, 2012, p. 16).

These uneven outcomes are often attributed to neoliberalism and austerity or, more broadly, to a system in which private property rights and growth are valued over any other collective and basic rights. However, political economy alone cannot fully explain environmental injustice and differential vulnerability across urban spaces (Pulido, 2017). As noted by Melamed (2015), capital needs to accumulate to be capital: the process of accumulation is generated by continuously reproducing and polarizing social difference and inequalities, also through the practice of racism. Thus, "racialization and capitalism are ultimately never separable from each other" (Melamed, 2015, p. 77). Racism is foundational to the processes of commodification of land and production of space, as well as to shaping labor arrangements (Pulido, 2017). The making of cities globally,

therefore, continues to be shaped by imperial roots and colonial legacies, ideologies of white supremacy, and different forms of racialized austerity, displacement, evictions, police violence, urban planning, and slum governance techniques that have often been overlooked in urban political ecology scholarship (Danewid, 2020; Gilmore, 2002; Heynen, 2016; Ranganathan & Bratman, 2021).

The "racialization of uneven urban environments" (Heynen, 2016, p. 840) has significant implications in the social construction of disasters. The racialized health inequalities revealed by the Covid-19 pandemic (Laster Pirtle, 2020; Liebman *et al.*, 2020), the fire at Grenfell in London (Danewid, 2020), and the disproportionate impact of urban floods and droughts on racial minorities (Bates & Green, 2018; Bullard & Wright, 2009; Maldonado *et al.*, 2016; Millington, 2018; Savelli *et al.*, 2021; Scheba & Millington, 2018) epitomize the relation between colonialism, capitalism, and the practice of racism in generating uneven exposure and vulnerability to, and differential recovery trajectories from, disasters. To illustrate, research on the recent drought in Cape Town (2015 - 2017) has shown how colonial and apartheid legacies and more recent neoliberal reforms continue to generate a segregated and highly unequal urban form, which in turn determined different degrees of vulnerability to the drought and its uneven outcomes. Black residents living in townships suffered disproportionately from the water rationing and conservation measures introduced in response to recent drought events and took significantly longer to recover (Enqvist & Ziervogel, 2019; Fallon, 2018; Maxmen, 2018; Savelli *et al.*, 2021; Scheba & Millington, 2018).

Similarly, Hurricane Katrina (2005) revealed the "uneven landscape of social reproduction in New Orleans" (Katz, 2008, p. 19). Class and racial segregation coalesced in generating highly uneven exposure and vulnerability to the destructive impacts of Hurricane Katrina (Bullard & Wright, 2009; Elliott & Pais, 2006; Finch *et al.*, 2010). A wide range of studies has shown that significantly more African American, low-income neighborhoods in the St. Bernard bowl area were flooded (Finch *et al.*, 2010; Jonkman *et al.*, 2018; Kates *et al.*, 2006) and more exposed to toxic spills (Godsil *et al.*, 2009). Here, lack of private transport and alternative shelter prevented residents from evacuating, and impacts were further exasperated by the prevalence of mobile and stick (wood frame) homes that are less resilient to flooding (Masozera *et al.*, 2007). Literature further suggests that a lack of political commitment prevented or slowed the recovery of minority and lower income groups. The response to Hurricane Katrina, often grounded on exceptionalism, violence and authoritarianism, has entrenched what Giroux (2006, p. 171) has termed a biopolitics of disposability, whereby racial minorities and low-income groups are portrayed as a burden to be dismissed by the state. African American workers were also four times more likely than white workers to lose their job (Elliott & Pais, 2006). They were, together with Hispanic residents, disproportionately affected by the erosion of worker's protection caused by the interruption of the Davis-Bacon Act and by the subjugation of low-wage workers in the aftermath of Hurricane Katrina (Button & Oliver-Smith, 2008; Keegan, 2020). These minorities also suffered greater relative economic losses and were faced with gentrification, closure of public schools, and discriminatory treatment of undocumented workers (Arena, 2011; Bullard & Wright, 2009; Button & Oliver-Smith, 2008; Klein, 2007; Schuller & Maldonado, 2016).

This succinct review importantly highlights that disasters are generated by human-environment relations. As aptly illustrated by Collard *et al.* (2018, p. 3), disasters are violent sociocultural and political economic issues to the fore – from colonialism and race, to growing patterns of inequality." The city can be seen as a coevolutionary relationship that generates social-environmental disasters that unevenly impact residents across urban spaces and identities. Importantly, these analyses serve to reconnect and redistribute agency across nature and society and to apprehend the pervasive power of capitalist imagination and practice. At the same time, they might perpetuate the discourse of capitalism as the only possible paradigm, thereby reinforcing the belief of the absence of viable alternatives to the free-market (Fisher, 2009; Gibson-Graham, 1996; Gibson-Graham, 2006; Harvey, 2012; Jameson, 2003; Lefebvre, 1976). As discussed below, "it matters which ideas we think other ideas with" (Haraway, 2016, p. 14). We thus turn to scholarship engaged with exploring openings for other, 'better' urban worlds with the aim extending what might be possible in post-disaster redevelopment.

Extending the possible: the transformative potential of disaster

The quotations with which we began this section, celebrate the power of imagination to transcend entrenched capitalist socio-ecological configurations and to experiment with and reimagine alternatives to current (urban) worlds. The "strategic hypothesis" put forward by Lefebvre (Lefebvre, 1976, p. 13), as illustrated in the first passage, is that the apparently impossible must not conceal the possible, which is always latent in the impossible. What appears as impossible depends on what is assumed to be static and untouchable. Capitalist ideology aims to naturalize the social relations it reproduces, but as these relations are revealed as mutable, the categories of the impossible and the possible are transformed and new forms of possible are actualized. Through a dialectical process that Pinder (2015, p. 28) describes as "reconstituting the possible", Lefebvre questions and ultimately inverts these categories of the (im)possible: what is truly impossible is to indefinitely abide by existing social-economic relations. At cognitive, political, and discursive levels, therefore, what was perceived to be impossible but in 'reality' was possible is recognized: it can be foreseen, considered, and becomes part of the political vocabulary. Imagination, therefore, is concrete in that it determines how we navigate the everyday. But it also enables collective political action (Purdy, 2015).

Feminist geographers Gibson-Graham (1996; 2006) have taken these ideas further. Their path-breaking work develops a clear stance of the possibility of postcapitalist worlds and outlines the contours of a transformative politics. Central to *The end of capitalism (as we knew it): A feminist critique of political economy* (1996), is the critique of "capitalocentric" representations of economic and social worlds that conceal non-market relations and portray capitalism as a stable, totalizing economic force, rather than as a contested space. Drawing on feminist economics, the authors de-center capitalism by shedding light on the multiple non-market relations that shape everyday life. *A postcapitalist politics* (2006), published a decade later, aims to generate an awakening to the multiple forms of economy and politics that are possible and, in some cases, actual. As argued by the authors, a politics of possibility is constructed by widening options of what is possible, rather than by attributing decisions to an abstract and somewhat predetermined global force. This does not mean denying the existence of durable structures of power, but actively working towards a language of possibility, developing capacities and a desire to generate alternatives, as well as a conscious and collective effort to transform economic realities by, for instance, promoting well-being and environmental sustainability. To this aim, in the quotation above, Gibson-Graham (2006) invoke a new ethics and habit of thinking that is ontologically focused on the emergent (rather than on a notion of stable capital), and on illuminating and creating a politics of possibility. Importantly, the authors recognize that thinking "political and economic possibility" can be challenging and uncomfortable, especially for those formed in a field grounded on critique (Gibson-Graham, 2006, p. 1). Changing the habit of thinking, therefore, requires cultivating new relations with the world and an ethical and affective disposition towards the possible.

The writings of Gibson-Graham (1996, 2006) have led to a proliferation of studies on alternative economics and have had significant influence on geographical scholarship. Several scholars have argued that capitalism never exists in isolation, subsuming alternative imaginaries of socio-ecological relations (Andueza, 2021; Braun, 2008; Castree, 1995; Gandy, 2005; Swyngedouw & Heynen, 2003) and have invoked "a recalibration and re-imagination of economic, political and social institutions beyond accumulation and growth" (Schmid & Smith, 2021, p. 254). This has significant implications on the conceptualization of disasters. Here too, solely focusing on neoliberal reforms and disaster capitalism in post-disaster redevelopment, without paying attention to the emergent and to contested spaces, reproduces capitalocentric discourses and forecloses alternatives to capitalism (Gibson-Graham, 1996, 2006). Disasters are disruptive phenomena that can generate heightened awareness of systemic contradictions of capitalist cities and exacerbate urban inequalities and uneven vulnerability to hazards. In this light, they can be conceptualized as 'critical junctures' or 'tipping points' that rupture existing socio-ecological configurations (Cretney, 2017; Gawronski & Olson, 2013; Pelling & Dill, 2010). The rupture of the status quo can both catalyze the emergence of new political paradigms or entrench reactionary politics and neoliberal logics (Cretney, 2019; Rusca *et al.*, 2021). It is precisely in the tensions and conflicts between these imaginaries that alternative urban development trajectories can emerge.

Identity transformations are one of the sites from which progressive development pathways can emerge (O'Brien & Sygna, 2013; Manuel-Navarrete & Pelling, 2015; Pelling, O'Brien, & Matyas, 2015). During crises, governments are often unable or unwilling to fulfill social contracts and to offer the type of support and generate the transformative change that citizens expect (Blackburn & Pelling, 2018). As a result, a crisis of recognition between citizens and the State may ensue, opening the possibility for questioning one's political identity (Grosz, 2001). Transgressions of normative expectations and socio-environmental disputes become sites for the emergence of new identities (Nightingale, 2006, 2011). This may lead to the renegotiation of social contracts and, in turn, the emergence of transformative development trajectories (Blackburn & Pelling, 2018; Donovan, 2017; Shaw, 2012).

For instance, in the aftermath of Hurricane Katrina, social and environmental justice movements challenged market and state forces that were attempting to capitalize on the disaster by unsettling housing and racial politics, and the notion of disaster as 'natural.' These movements drew attention to the racialized economic and political drivers of disaster and its uneven impacts, and they fought to remake collective and communal spaces in their city (Houston, 2013; Ishiwata, 2011; Luft, 2009). Similar dynamics and imaginaries emerged in Ōtautahi Christchurch, New Zealand, in the aftermath of the 2010 earthquake (Cretney, 2017, 2019). Despite the government's attempt to foreclose democratic spaces, over time community-led recovery initiatives generated a critical reflection on the city's identity. This, in turn, led to reframing disaster narratives and reimagining public spaces in a way that challenged the status quo. Extreme droughts have also generated new alliances across social movements promoting a new ethics and culture of water beyond its economic value in Spain and Catalonia (Albiac, *et al.*, 2006; Saurí, 2003), Ontario, Canada (Jaffee & Case, 2018) and São Paulo, Brazil (Cohen, 2016).

By challenging the notion of pre-constituted impossibility, the emerging alternatives of post-disaster described above make what is often framed as 'impossible' part of the political vocabulary (Lefebvre, 1976). Illuminating possibilities for change is an essential but not sufficient theoretical task for reimagining the climate futures before us. Examining past events allows to reflect on the development logics that shape current socioecological configurations and the possibilities for transformative change. Looking to alternative futures, however, also opens new questions. For instance, what alternative futures can be generated by transgressing current capitalist logics in post-disaster redevelopment? How would these alternatives reconfigure socioecological inequalities and vulnerabilities across the city? Being oriented to possible futures, these questions call for more speculative ways of theorizing. To this aim, we place transformative geographies into engagement with fields exploring fictional and speculative worlds to (re)imagine post-disaster redevelopment.

Reworlding climate futures: speculative fabulation and science fiction

Speculative worlds have been explored by a variety of scholars concerned with socionatural relations and climate change. The quotation above – "It matters what stories make worlds, what worlds make stories" – by feminist thinker Haraway (2016, p. 12) celebrates the power of everyday storytelling and speculative thought, which are central in her book *Staying with the Trouble* (2016). Here, reading and telling stories is a way to speculate about and transform the perceptions of what is possible. Haraway's (2016) political and ethical aspiration is making kin through complex knotting with all species and plants, becoming responsible for all beings and things at all temporal and geographical scales and in every place. Stories, as she suggests, can generate new meanings and, in turn, that sense of response-ability that can enable practices of multispecies recuperation.

As noted by Kohn (2018), although the 'trouble' in *Staying with the Trouble* is the Anthropocene, the book is not about the Anthropocene. Haraway aims at moving beyond two positions on the Anthropocene – the "comic faith in technofixes" and the "game over" approach – (Haraway, 2016, p. 3) – that might appear antithetical, but ultimately generate similar outcomes. Eschewing apocalyptic and hopeful techno-scientific imaginaries of the future, she proposes a third story. The story of the Chthulucene is creatively developed through "ongoing multispecies stories and practices of becoming-with in precarious times, in which the world is not finished and the sky has not fallen — yet" (Haraway, 2016, p. 55). Storytelling, she argues, is essential

to reimagine and collaboratively craft thriving worlds that today are only a fragile possibility. SFs – science fiction, speculative fabulation, string figures, speculative feminism, science fact so far – are crucial allies of this reworlding practice. In her story of the Chthulucene, science facts and science fiction do not only cohabit, but they are also symbiotic: "sf is storytelling and fact telling; it is the patterning of possible worlds and possible times, material-semiotic worlds, gone, here, and yet to come" (Haraway, 2016, p. 32). Thus, storytelling and stories are to be elevated to thinking practices and forms of theorizing, rather than a way of embellishing 'actual' thinking. Scientific 'facts' are not enough to repattern the worlds we live in (Haraway, 2018). Similarly, Stengers celebrates "the imaginative freedom of science fiction" to engage with questions that should belong to the realm of mainstream social sciences but that cannot be answered with conventional methods (Stengers, 2018, p. 28). The world, she argues, cannot be merely reduced to what conventional methods are able to capture. Speculative or thought experiments ("what if?") developed in science fiction can transcend the artificial boundary between what is often called proper science or mere speculation. Speculative or thought experiments do not generate new 'facts', validated so these can claim authority. Rather, they allow readers (and writers) to break away from "modernity's hidden agenda" by crafting stories that destabilize what are often perceived as stabilized narratives, and by generating new possibilities and worlds (Stengers, 2018, p. 2018).

Haraway and Stenger disrupt and transcend conventional Western thinking habits, moving towards new forms of sense-making in which scientific knowledge is a part of and compatible with speculative or utopic thinking and fabulation. Importantly, combining cultural experiences and histories with pluriverses, science fiction, spiraling time, time travel, polytemporality, and alternative realities has always been part of Native epistemologies (Dillon, 2012; Whyte, 2018). In Native communities' narratives, futurisms and alternative realities are infused with "responsibility-rooted strategies" to better worlds and futures (Medak-Saltzman, 2017, p. 139). Here, SF is an experiment to "recover the Native space of the past, to bring it to the attention of contemporary readers, and to build better futures" (Dillon, 2012, p. 4). Whyte (2017; 2018) refers to a dialogue with ancestors to both understand and find the agency to overcome current conditions of Indigenous people. He describes this practice as science (fiction) to reflect the combination of two elements: on the one hand, the fiction of "philosophizing counterfactually through narratives of spiral time", and on the other the science of Indigenous knowledge (Whyte, 2018, p. 230). This form of meaning-making also serves as a critique of dystopic narratives of the Anthropocene and climate change that overlook Native communities and cultures (Medak-Saltzman, 2017; Whyte, 2018, p. 230). Western-centric narratives of dystopic futures of climate extremes erase populations that have already experienced colonial violence, environmental apocalypse, and the destruction of their ways of life. For these populations, dystopian times are not incumbent but rather ongoing (Whyte, 2018). To be clear, Native science (fiction) too explores utopian and dystopian "what ifs", but as a way of overcoming dystopic presents rather than (only) avoiding incumbent apocalyptic futures (Medak-Saltzman, 2017, p. 143).

Speculative approaches to nature/society relations and climate change remain scant. However, recent work has leveraged storytelling and speculative experiments to extend the possible and to reworld the Anthropocene. To illustrate, the degrowth utopia postulated by Kallis & March (2015) aims to liberate readers from the determinism of capitalism and to foreground alternative futures. Because Degrowth is to a large extent an aspirational goal (rather than a spatialized reality), it cannot be examined with conventional methods. To overcome this impasse, the authors approached their analysis speculatively by engaging with Ursula Le Guin's (2015 [1974]) science fiction novel *The Dispossessed* – a "unique case of a territorialized degrowth" (Kallis & March, 2015, p. 361). Ultimately, this thought experiment served to ground and advance a radical theory of degrowth beyond what would have been achievable with conventional social science methods. In a similar vein, Collard and colleagues (2015) speculate about alternatives to neoliberal conservation through a manifesto inspired by Indigenous thought and peasant movements. Whilst departing from a critique of colonial and capitalist logics underpinning current socio-ecological configurations, the authors speculate about what a world grounded on pluriversality (rather than universality) and animal autonomy would look like. In this way, they sketch a hopeful trajectory for multispecies abundance. Last, existing experiments with alternative worlds have also been strategically mobilized to show that entrenched regimes can be challenged by new imaginaries in the making. Rather than reproducing ongoing and future apocalyptic imaginaries, Buck (2015) examined emerging

alternatives to capitalism as a way of telling a different story of the Anthropocene. This, she argues, requires reimagining humans beyond the "rapacious antagonist of the horror stories" by reclaiming gestures of care, sense of responsibility, and cooperation as part of human nature (Buck, 2015, p. 376). Similarly, for Harris (2023), storytelling is critical to address the cultural and political challenges brought about by climate change and other crises. Whilst in part already written, the story of climate change is still open ended and remains one of possibility. Thus, he notes echoing Haraway (2016), it matters what stories about climate change shape the imagination and actions of humans; it matters whether these stories will "enable or disable possibility" (Harris, 2023, p. 2).

To conclude this section, we argue that the speculative fabulations, science fiction and storytelling practices discussed here are powerful tools for making sense and responding to the climate (and other) crises. They allowed 'us' – the authors of this article – to recognize or recover the freedom and inspiration to make new connections and to imagine better futures. In a review of Haraway's *Staying with the Trouble*, Kenney (2017, p. 75) perfectly captures this idea: "...with her exuberant and omnivorous approach to feminist storytelling, Haraway gives us permission to follow our own curiosities and experiment with our own fables of response-ability." It is in this spirit that we have developed our thought experiment of modelling postcapitalist urban futures, as discussed below.

3. Methodology: a system dynamics model to (re)imagine urban futures

Modelling as a political practice: proliferating possibilities

Political ecologists have critiqued the knowledge models generate and the 'world-making' power they carry. First, models are seen as powerful producers of scientific concepts. They are well positioned to inform policy options that can reshape the social order, and that might be promoted as universal guiding principles (Bouleau, 2014). Moreover, it has been argued that models reproduce rather than challenge existing injustices and power structures (McLaren & Markusson, 2020). Rubiano Rivadeneira & Carton (2022), for instance, have raised concerns about the mainstream economic assumptions and (unexplored) ethical question of Integrated Assessment Models. These inform the IPCC's Assessments and climate policy and carry significant justice implications that are largely overlooked. Importantly, concerns about the ethical and political implications of the tool-model have been raised also from within the modelling community. Drawing on Actor-Network Theory and STS, for instance, Beck & Krueger (2016, p. 639) have argued that hydrological models can produce "authoritative representations of dominant perceptions of the world" and play an active role in stabilizing knowledge. Similarly, a recent article analyzing different models and their underlying assumptions demonstrates that research practices shape worlds by generating depoliticized explanations of hydrological phenomena (Krueger & Alba, 2022). In doing so, the authors note, models may pre-configure some future possibilities and foreclose others. Our thought experiment is grounded on this precise critical premise: recognizing that modelling is a world-making practice, we propose that they can play a role in (re)imagining urban worlds or, following Gibson-Graham (2006), in proliferating rather than foreclosing possibilities.

Modelling speculative thought

We conceptualize speculative political ecology as a thought experiment about other possible worlds. In our thought experiment, we model alternative futures of urban climate extremes, by speculating about the potential of transformative change in the aftermath of extreme flood events in an imaginary city. Conceptually, we do so by placing situated understandings of disasters into engagement with transformative geographies and speculative thought. Following Stengers (2018), we ask ourselves 'what if' extreme floods established some of the conditions of possibility for the restructuring of capitalist relationships – 'then what?' In this way, we aim to bring alternative visions of urban climate futures to life.

To address these 'what if – then what?', we developed a numerical model based on a system dynamics approach (Mazzoleni *et al.*, 2021) that examines the potential of transformative change in the aftermath of

extremes flood events. The model is inspired by a city governed by racial, colonial, and capitalist logics, and characterized by uneven development. Drawing on the urban political ecologies and critical disaster studies perspectives above, the model considers that floods may establish some of the conditions for transformative change. As flood-induced disasters exacerbate vulnerability and socio-political marginalization, the expectations of vulnerable residents in relation to well-being and economic development are also eroded. In the model, this flood-induced identity crisis is represented by the variable of (mis)alignment, which shows the extent to which neighborhoods in the city identify with and support the political orientation of the Government (Figure 1). The political configurations before the flood event are represented by an equal number of Misaligned, Aligned and Non-Aligned neighborhoods (Panel 1a). The model assumes that an extreme flood event – or a series of flood events – increase inequalities and vulnerability and, in turn, political misalignment. Panel 1b depicts a scenario in which the misaligned are strengthened (represented by the red color), thereby changing the development trajectory of the city. We are thus able to speculate about possible transformative trajectories in post-disaster redevelopment.

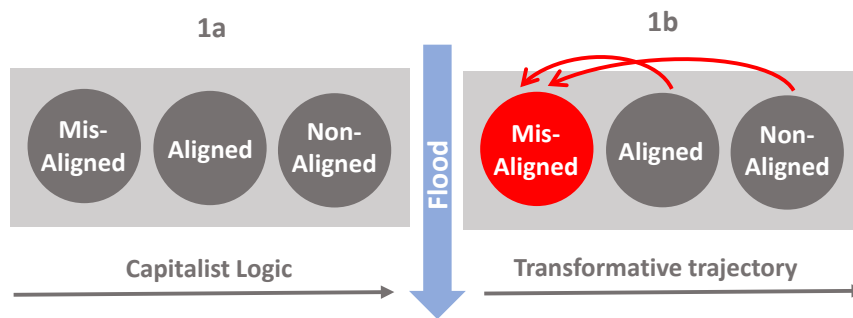


Figure 1: Simple schematic of transformative trajectories, shaped by the interplay between political misalignment and urban floods.

Model design

Our system dynamics model simulates key physical components of the flood events along with the infrastructural and socio-political processes of the capitalist city as numerical variables. It considers a hypothetical city composed of one-thousand neighborhoods. By building a series of equations linking together the variables in the model, one can represent the temporal evolutions (or 'dynamics') of both the physical and human processes shaping the capitalist city and its transformative potential. The value of each variable at a given point in time then reflects the results of these interactive dynamics.

Figure 2 illustrates the relationships between the hydrological, socio-economic, and socio-political variables, as well as the role and impact of different policy measures. The input is water levels. Flood level is calculated as the water level exceeding a given threshold, whilst flood intensity is calculated using the hydrology equation proposed in Di Baldassarre *et al.* (2015). The socio-economic characteristics of each neighborhood are represented by the Building Quality, Damaged Housing, Well-being, Unemployment and Cost/Income ratio. Well-being is a crucial variable of the model, as it summarizes several dimensions of flood impacts and directly influences the socio-political dimension of the model (Figure 2). It is analytically computed as indicated in Eq. 1. Values of the different socio-economic variables are randomly assigned to each neighborhood at the beginning of the model simulation. This leads to large differences across neighborhoods, which reflects the high level of inequality that characterize a capitalist city. *Affordable Housing*, *Social Protection*, *Flood Infrastructure* and *Building Back Better* represent the range of transformative policy options that go beyond a capitalist logic, and that can be enacted by the government.

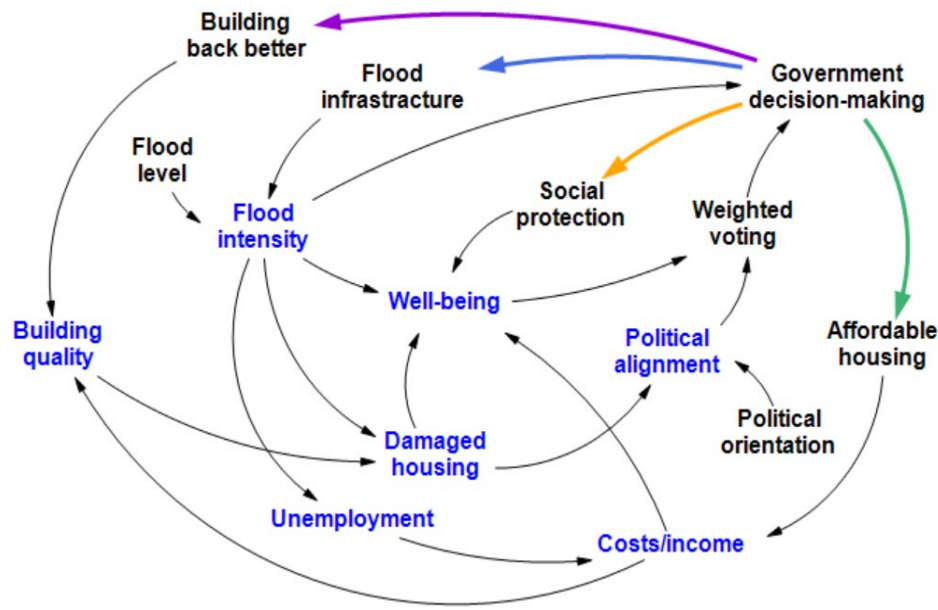


Figure 2: Causal loop of the proposed human-flood model. Blue text represents variables which can take different values in different neighborhoods, while black text refers to the variables representing the collective behavior of the city.

Socio-economic inequalities between neighborhoods, given by the random initialization of the model variables, imply that each one is differently affected by floods. Each experiences different changes in the aftermath of a flood event. To reflect these unequal experiences of floods, the model calculates the impacts of flood on each neighborhood independently. For instance, after a flood every neighborhood will have different levels of Building Quality, Damaged Housing, Well-being, Unemployment and Cost/Income ratio. Socio-economic changes are represented using normalized variables that can vary between 0 and 1. The variation of Well-being (W) in each neighborhood at time step t is calculated as:

$$\frac{dW^n}{dt} = \alpha_W^n(CI_M - CI_t^n)(1 - W_t^n) - D_t^n W_t^n + \eta SP_t W_t^n + (1 - \eta)SP_t(1 - W_t^n) \tag{1}$$

The subscript t indicates that a given variable is assessed at time step t , while the superscript n indicates that the variable refers to the neighborhood n . α_W is the annual increase in the well-being depending on the pre-existing socio-economic characteristics, CI is the cost/income ratio (a function of the unemployment level and quality of the housing), CI_M is the maximum value of the cost/income ratio, D is the damage to the housing (assessed as function between flood intensity and building quality), η is a pro-growth coefficient changing at each time step t , while SP is the social protection policy measure adopted by the government to reduce social inequalities, which we model as influencing the well-being of a given neighborhood. We thus assume that Well-being is inversely related to the cost/income ratio CI (first term on the right-hand side of the equation) and to damage D and positively related to *social protection* policies SP . However, the effect of SP is in turn inversely related to the pro-growth coefficient. The pro-growth coefficient is calculated based on the Political Alignment and well-being of all the neighborhoods. A value of η equal to 1 will result in pro-growth policies applied in all the neighborhoods, while when η is equal to 0 (no pro-growth policies adopted) the SP policies will be uniformly distributed among neighborhoods. The socio-political characteristics of each neighborhood are represented by the Political Alignment (PA), Political Orientation (PO), and weighted voting (see Figure 2).

Each neighborhood is characterized by a different PO, randomly assigned at the beginning of the model simulation. The socioeconomic changes that follow a flood event will reshape the socio-political characteristics of each neighborhood by modifying its PO, i.e., the tendency of a neighborhood to align or not with the current Government. The evolution of the PO of each neighborhood over time is assessed as:

$$\frac{dPO^n}{dt} = D_t^n(1 - PO_t^n) - \gamma PO_t^n \quad (2)$$

where γ is a Political Orientation decay rate. This decay rate embodies the assumption that the default behavior of each neighborhood is to gradually return to its initial PO. The higher the value of γ , the faster the neighborhood's PO will return to its initial value. The *Proportion of misaligned neighborhoods* (i.e., neighborhoods antagonistic toward development trajectory and government) and *Proportion of aligned neighborhoods* (i.e., neighborhoods supportive of development trajectory and government) are proxies for socio-political change. The political alignment, PA is assessed as:

$$\begin{cases} PA_t^n = +1 & \text{if } PO_t^n > +0.2 & \text{Aligned} \\ PA_t^n = -1 & \text{if } PO_t^n < -0.2 & \text{Misaligned} \end{cases} \quad (3)$$

If $-0.2 < PO < 0.2$, the neighborhood is non-aligned. The initial random assignment of the PO seeks to avoid "locking" the model into specific political configurations. To ensure the possibility of exploring different political scenarios, the city initially has the same number of Aligned, Misaligned and Non-aligned neighborhoods. The socio-economic changes that follow a flood event will reshape the agency of each neighborhood by modifying its PA. Once PA for each neighborhood is assessed, the weighted voting is calculated as a weighted average between PA and the well-being of each neighborhood. The weighted voting coefficient rescaled between 0 and 1 is the pro-growth coefficient η used in the decision-making process of the government. Values higher than 0.5 indicate the dominance of pro-growth policies driven by capitalistic logics, while values lower than 0.5 indicate that social policies are favored.

Changes in socio-political behavior will affect the government's policy priorities, enabling a range of future transformative options to take shape. Leveraging literature on flood responses (Kreibich *et al.*, 2015; Kundzewicz, *et al.*, 2018; Pelling *et al.*, 2015; Radonic *et al.*, 2020; and Rusca *et al.*, 2021), we have identified the following policy options, which we broadly term Social Policies (SP):

- *Flood infrastructure*: a structural measure aimed at reducing flood level and consequently flood intensity. Examples can include *levees*, retention basins, or reservoirs for flood control purposes.
- *Affordable housing*: a non-structural measure to increase the ratio between costs and income to boost the neighborhood investment in improving building quality.
- *Building back better*: a structural measure aimed at directly improving building quality.
- *Social protection*: a non-structural measure aimed at increasing the wellbeing of a given neighborhood.

In this study we implement only one of the four social policies at a time. We also assume that the capitalist city will resist change, attempting to maintain a pro-growth trajectory. This is reflected by the above-discussed political orientation decay rate γ . Therefore, these social policies are typically implemented in combination and competition with pro-growth ones. The pro-growth coefficient represents the degree to which Social Policies or pro-growth policies are prioritized. In turn, the pro-growth coefficient depends on the

weighted voting, determined by the political (mis)alignment and the Well-being of the neighborhoods. After a flood event, both the Political Alignment and the Well-being decrease, increasing the pressure for Social Policies. Specifically, high numbers of misaligned neighborhoods will lead to negative values of weighted voting and a consequent value of η close to zero. On the other hand, a high Political Alignment of the city will lead to prioritizing pro-growth policies that increase Cost/Income ratios for the aligned neighborhoods, thereby exacerbating the level of inequality across urban spaces. Finally, to assess the impacts of each scenario the model measures the standard deviation of Well-being of each neighborhood over time. The complete set of model equations is available in the Supplementary Information after the reference list.

The strength and the weakness of such types of models is that they sacrifice the detail of some individual components of the system being studied, to offer a heuristic picture of the behavior of the system as a whole. Thus, the insights they provide into complex systems necessarily imply some degree of reductionism, which blurs or elides sub-system dynamics. This is reflected in the selection of model variables through which the model seeks to describe system behavior (Figure 2). The choice of these variables is necessarily parsimonious: since values of these variables at each timestep are analytically computed by connecting them through equations, it would not make mathematical sense to duplicate these equations by explicitly modelling sets of closely correlated variables. Consequently, the effect of some variables and processes is implicitly or indirectly accounted for in other variables. Thus, elements that critical theory would treat as distinct and deserving of attention may in our model be incorporated within other variables.

Race is a case in point here. The effect of racial capitalism is implicit in the model, and racialized vulnerability is embedded in variables such as Housing quality, Well-being and Unemployment. If race were included as an explicit variable, for example as proportion of minority groups in a neighborhood, it would simply duplicate in terms of equations the information already provided by the other socio-economic variables. In other words, our model describes the orientation towards capitalist policies as premised on changes of wealth/vulnerability, while racial capitalism distributes these costs along racial lines. However, this does not mean that the results obtained from the model cannot be used to draw inferences about race. This analysis can be done by interpreting the outputs from the model through an urban political ecology and critical disaster studies lens. For instance, the model does not explicitly treat the way in which flood impacts and losses are distributed socio-spatially, beyond recognizing the uneven outcomes across neighborhoods. By combining insights from models and critical theory, it can be inferred that the modelled distribution of losses falls asymmetrically along racial, gendered, and socio-economic lines.

4. Model results: the transformative potential of climate-related disasters

200 years of flood events and political (mis)alignments

The model simulates the implementation of different combinations of pro-growth and social policies for 1,000 neighborhoods over several flood episodes over a period of 200 years (Figure 3). This long timescale allows us to study the impact of a single flood event, and the effects of consecutive floods and of protracted periods when no floods occur. Specifically, the results presented below focus on three interrelated aspects: a) the evolution of socio-economic status because of government policies; b) the effect of flood intensity and frequency over inequality and political alignment; and c) the effect of government policy on infrastructure and vulnerability.

Model results show different patterns of average Well-being and societal inequalities in response to the four social policies adopted by the government. In this study, social inequalities are a proxy of the spread of the Well-being across neighborhoods, i.e. higher inequality values represents higher variation of Well-being. Whilst *Building back better* and *Social protection* are effective in increasing the neighborhoods' Well-being, these policies maintain higher levels of inequalities, leaving the city highly fragmented. In particular, *Building back better* shows higher values of inequalities also when no severe flood events are experienced. This can be because it runs in combination with a higher coefficient of the pro-growth variable η and the consequent intensification

of the pro-growth strategies end up exacerbating inequalities. The *Social protection* policy increases inequalities even with low values of η (cf. Fig 3.b, c around the 100-year mark). This is because this policy targets the Well-being of the neighborhoods. An increase in Well-being reduces the proportion of Misaligned, thereby inducing an increase in the pro-growth variable, which ultimately causes a return to polarized inequalities in the city. In other words, the success of the policy in the short term leads to its long-term inefficacy because it enables a return to pro-growth measures.

The policy that is overall most effective at reducing inequalities is *Affordable housing* as it influences the Costs/Income ratio that, in turn, generates increases in both neighborhood Well-being and Building quality, regardless of the neighborhood's Well-being before the flooding. Thus, *Affordable housing* leads to a higher increase of Well-being in all neighborhoods and not only in the ones with already high Well-being, as in case of *Social protection* policy (i.e. high average Well-being and high inequalities). The former policy is in other words the most transformative mechanism within the model, although at different times during the simulated period other policies (such as *Flood infrastructure*) can temporarily lead to comparable inequality levels.

Our initial model assumption was that inequalities are influenced by flood intensity. However, Figure 3 shows that the frequency of the flood events also plays a significant role. We observe higher inequalities after the flood event occurring in year 100 (flood level of 15m), than after the event occurring in year 56 (flood level of 18.5 m). In fact, while the first severe flood event (year 56) led to an abrupt reduction of Well-being (Figure 4.b), the period without events between the year 75 and 90 led to a reduction in Misaligned (Figure 4.a), leading to an increase of both well-being (Figure 4.b) and pro-growth policies at different moments in time (η in Figure 3.c). As a result, the city experienced higher inequalities after the second flood event (year 100) than after the first (year 56), even though the former was of lower intensity.

This analysis also reveals the coevolutionary nature of the flood-social system. Whenever an extended period elapses without a flood event, the number of aligned neighborhoods tends to increase. Concurrently, pro-growth measures and capitalist development tend to be restored. In this period, capitalism returns the dominant form of socio-ecological organization that produces the city. One needs a succession of floods to maintain a sufficiently large portion of the neighborhoods as misaligned, pressuring the government into continuously promoting social policies. We also observe that following a large flood, subsequent floods mainly act to maintain the balance in favor of social policies, but do not lead to further large shifts in political alignment (Figure 4.a). In other words, when a series of floods occurs in close succession, it is the first event that provides the largest shock and acts as a driver of change.

Different policies produce uneven impacts across the built environment. This can be observed from the differential damage to housing when different policies are adopted (Figure 4.c). For example, implementing *flood infrastructure* measures – such as *levees* – leads to higher levels of damaged housing when flood infrastructure fails to protect neighborhoods from high flood level – such as when a *levee* is breached. This '*levee* effect' is a well-known unintended consequence due to the over-reliance of society on structural flood protection infrastructure which leads to an increase in vulnerability and consequent negative impacts (Collenteur, *et al.*, 2015). As a result, higher unemployment levels are experienced, resulting in low Well-being values compared to the other measures, and a strong political misalignment (Figure 4.a). Average values for unemployment levels show negligible variation among the different government policies (Figure 4.d). Similar inequality index values occur in cases where there are no actions or flood infrastructure measures.

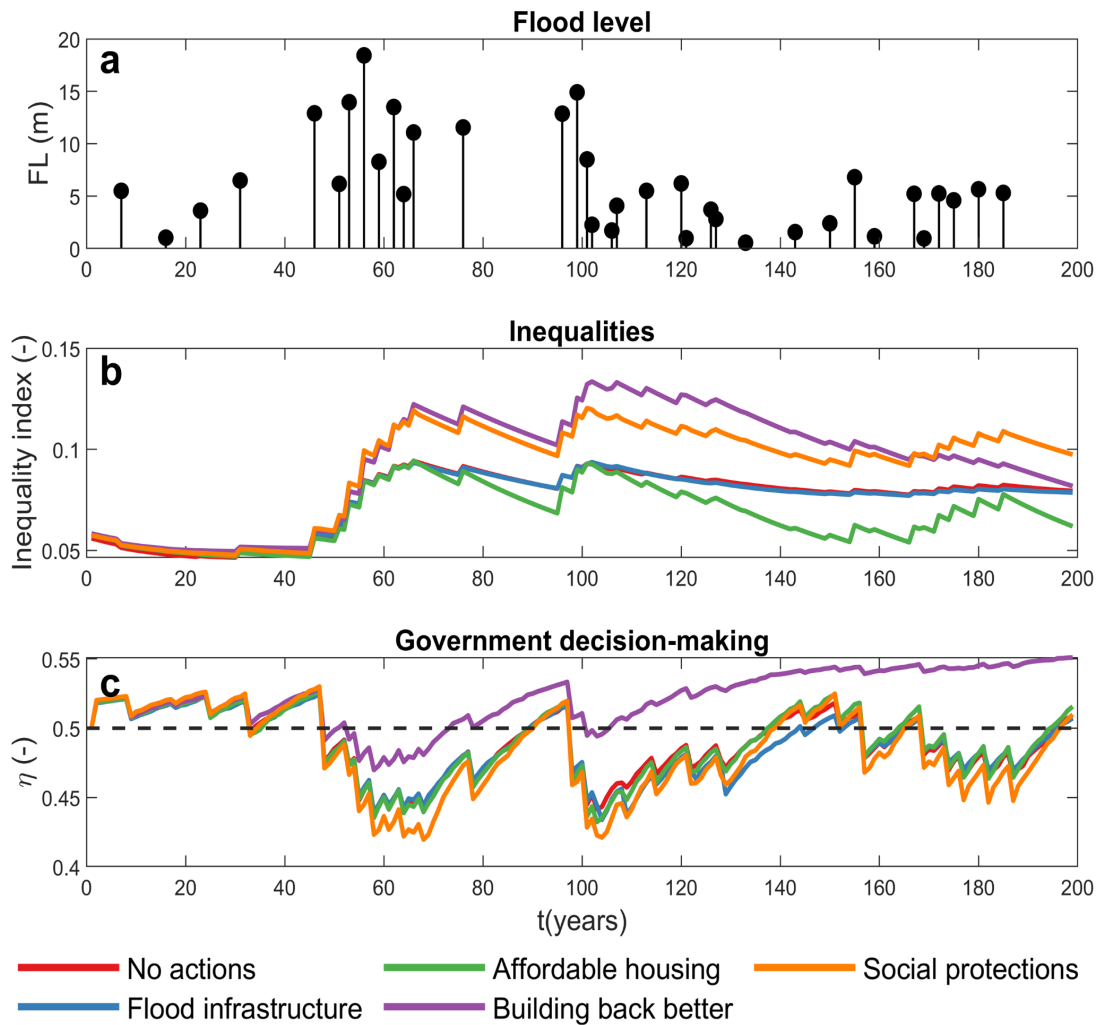


Figure 3: Model results representing the Flood level (a), Inequality index (b), and Government decision-making (c) over time for the different social policies.

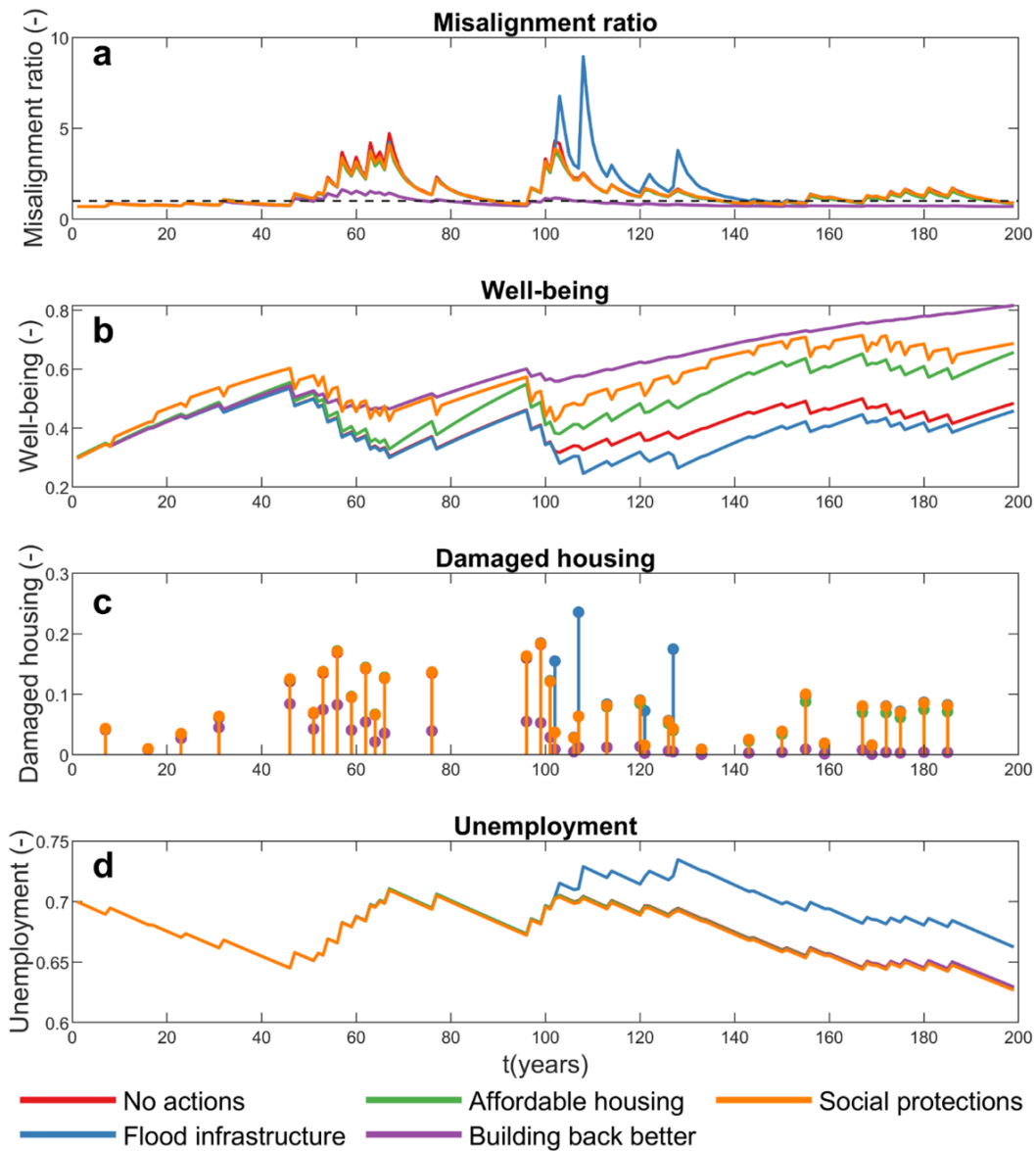


Figure 4: Model results showing the average values for the Misaligned ratio, expressed as the ratio between misaligned and aligned neighborhoods (a), Well-being (b), Damaged housing (c), and Unemployment (d) over time for the different social policies.

The speculative potential of the model

Overall, the model yielded mixed results in terms of its potential for reimagining urban futures under climate extremes. It did succeed in representing how human and non-human processes co-evolve and co-produce socio-ecological flows and urban transformation. It also effectively represents the movement across (mis)alignment through which neighborhoods become sites of political transformation, thereby apprehending

the transformative potential of the repolarization of identity on the urban landscape (O'Brien & Sygna, 2013; Manuel-Navarrete & Pelling, 2015; Pelling & Dill, 2010; Pelling *et al.*, 2015). On the other hand, modeled futures are susceptible to a return to capitalist logics. Thus, despite the emergence of alternative development trajectories, the city remains anchored in capitalist imaginaries (Brenner & Theodore, 2002a, 2002b; Peck, 2004; Peck *et al.*, 2010, 2010, 2013; Peck & Tickell, 2002). We asked ourselves: is this result to be attributed to our inability to imagine change outside this system? Are the changes envisioned by our model enough to reimagine urban futures? If not, what would it take for the model to envision a postcapitalist future?

A posteriori, we have identified two interrelated limitations in our attempt to model the postcapitalist city. A first concerns our own imagination in defining and mathematically developing the model's alternative trajectories. As discussed in Section 3, we take the capitalist city as a starting point. Moreover, our model assumptions postulate that exacerbating inequalities generate the conditions for transformative change. The implication of this assumption is that in the absence of floods, and following a period in which transformative policies (e.g. *Building back better*) reduce inequality in the city, there is a tendency to return to a capitalist logic. Whilst this design limitation might appear obvious in hindsight, in the process of designing the model our focus was on making room for transformative change, rather than considering its stability over time. As a result, the model accounts for transformative change that modulates vulnerability and inequalities *within* a capitalist city, rather than radical change that would set an entirely new baseline for the city. To be clear, these reflections on our experiment are as much part of the findings as the ones generated by the model itself. The process of speculation and the reflective exercise on the model work as a method to capture the potential and limitations of our ability to extend the possible, and to reconfigure urban futures under climate extremes. This is a way of theorizing that is more attuned to our subjectivities and identities, and the possibilities that these produce at a given time and place.

The second limitation of the model is that it does not adequately account for discursive practices. Whilst neighborhoods are confined to three choices (aligned, mis-aligned, and non-aligned), contemplating post-capitalistic imaginaries also requires creative discursive production that escapes capitalist imaginaries. We argue, therefore, following Gibson-Graham (2006), that the making of a politics of possibility requires more than 'just' disrupting capital imaginaries. It also requires making space and sustaining alternative economic and social relations. In relation to this, conceiving a radical socio-ecological change requires a vision of its spatial dimension, because all radical transformations must be grounded on "crystallization of multiple, intertwined geographical dimensions" (Brenner, 2009, p. 32). In contrast, in the current form, our model conceptualizes uneven urban development on a lumped spatial scale, rather than a distributed one. We thus conclude that a version of our model that spatializes relations, and connects them to creative discursive production, could advance a speculation beyond hegemonic imaginaries.

5. Conclusions

In this article, we considered the potential of a speculative political ecology that engages with and (re)imagines urban futures of climate extremes. By treating climate change as an external threat, doomist imaginaries of apocalyptic futures foreclose the possibility of transformative change. We have thus argued that political ecology can proliferate possibilities of radically different political projects and futures by reconceptualizing the relations that constitute urban futures of climate extremes as socionatural. This future-oriented and speculative exploration requires engaging with socionatural relations more experimentally. To this aim, we have developed a system dynamics model to support our thought experiment of alternative urban futures.

In concluding, we consider the value of political ecology critique to develop models of societal responses to future climate extremes, what these models can contribute to political ecology, and how speculative models might inform other futures. Concerning the first point, our thought experiment demonstrates that political ecology critique carries significant analytical value for developing plausible models of future societal responses to climate extremes. Conventional studies of societal responses to future climate events rely on numerical models, such as integrated assessment models, which incorporate mainstream economic assumptions. An

engagement with political ecology enables changing this perspective by developing models that account for how power relations, economic visions and differential agency shape the system and the uneven outcomes thereof. Models that – like ours – are grounded on the idea of the power-laden nature of socio-natural systems, logics of capital accumulation and the potential of the (re)politicization of identity are better placed to capture the interplay between social and the natural-physical processes. We thus see our thought experiment as a first building block for a new generation of models that are more attuned to social processes and justice concerns.

Moving to the second point, we see great potential of advancing political ecology perspectives and analyses by establishing interdisciplinary collaborations with modelers. The field of political ecology has largely focused on the critique of past and present socio-natural configurations at multiple scales and in different geographical contexts. Through this collaboration we were able to explore the value of that critique for future-oriented and speculative explorations of climate extremes. Our thought experiment also opened spaces for generating analytical possibilities beyond what is achievable within conventional political ecological approaches. The speculative approach developed here is an example of the ways in which system dynamics models can be creatively mobilized to sustain alternative and future-oriented political ecology analyses. We conclude that the exposure to fields that routinely explore future scenarios allows for potentialities latent in political ecology critique to emerge.

Concerning our last point, we suggest that if modeling is a worldmaking practice (Beck & Krueger, 2016; Bouleau, 2014; Krueger & Alba, 2022; Rubiano Rivadeneira & Carton, 2022), then speculative models might inform other futures. Our modelled observations about climate extremes and political change are speculative but plausible. The model, therefore, allows us to consider plausible future possibilities latent in current socio-natural configurations. It simultaneously constructs and delimits what is possible in the future, reducing its uncertainty by excluding some options whilst widening its possibilities by changing economic and political assumptions in the model. The model's numerical representations offer a unique possibility to explore urban futures beyond current trajectories, and to speculate on what actualizing alternative possibilities might entail. Ultimately, by making space for a different story of climate change and urban futures, the model challenges discourses of the unavoidability of capitalism, and it encourages us to change our thinking habits towards a politics of possibility, and to bring alternative futures to life.

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Supplementary Information

MODEL EQUATIONS

Here we report the equations used to represent the variables of the system dynamics model proposed in this study.

Flood level

$$FL_t^n = WL_t(\eta_t FI_t W_t^n + (1 - \eta_t) FI_t (1 - W_t^n)) \quad (S4)$$

Where η is pro-growth variable changing at each time step t , FI is the flood infrastructure measure adopted by the government, W is the well-being of the neighbour n , and WL is the water level.

Flood damage:

$$F_t^n = 1 - \exp\left(-\frac{FL_t^n}{\alpha_H^n}\right) \quad (S5)$$

where α_H indicates a relation between river level and relative damage (Penning-Rowsell *et al.*, 2006).

Percentage of the community unemployed:

$$\frac{dU_t^n}{dt} = -U_t^n \alpha_U^n + 0.04 F_t^n \quad (S6)$$

Where α_U is the annual ratio of unemployment due to external socio-economic factors in each community, while 0.04 is the maximum percentage of unemployment after a flood event.

Building quality:

$$\frac{dB_t^n}{dt} = -\alpha_B^n B_t^n + IV_t^n + \eta BB_t B_t^n + (1 - \eta) BB_t (1 - B_t^n) \quad (S7)$$

Where α_B is the annual reduction of building quality, BB is the *building back better* policy adopted by the government, and IV are the investments made by the neighbourhood to increase building quality based on the cost/income ratio:

$$\begin{cases} IV_t^n = \frac{(0.8B_1^n - 0.6B_t^n)(CI_M - CI_t^n)}{CI_M} & \text{if } B_t^n < 0.6 B_1^n \\ IV_t^n = 0 & \text{else} \end{cases} \quad (S8)$$

Where B_1^c is the initial building quality and CI_M is the maximum value of the cost-income ratio CI set equal to 2.

Damaged housing:

$$D_t^n = F_t^n(1 - B_t^n) \tag{S9}$$

Ratio between costs and income:

$$\frac{dCI^n}{dt} = \alpha_{CI}^n(1 - U_t^n)(CI_M - CI_t^n) + IV_t^n - \eta AH_t CI_t^n - (1 - \eta)AH_t(CI_M - CI_t^n) \tag{S10}$$

where α_{CI} is the annual increase in the ratio between costs and income, and AH is the affordable housing policy adopted by the government m value of CI (considered equal to 2 in this study).

Wealth of each community:

$$\frac{dW^n}{dt} = \alpha_W^n(CI_M - CI_t^n)(1 - W_t^n) - D_t^n W_t^n + \eta SP_t W_t^n + (1 - \eta)SP_t(1 - W_t^n) \tag{S11}$$

where α_W is the annual increase in the wealth of the neighbourhood

Political orientation:

$$\frac{dPO^n}{dt} = D_t^n(1 - PO_t^n) - \gamma PO_t^n \tag{S12}$$

Where γ is a political orientation decay rate assumed equal to 0.1

Political alignment:

$$\begin{cases} PA_t^n = +1 & \text{if } PO_t^n > +0.2 & \text{Aligned} \\ PA_t^n = -1 & \text{if } PO_t^n < -0.2 & \text{Misaligned} \\ PA_t^n = 0 & \text{else} & \text{Neutral} \end{cases} \tag{S13}$$

Weighted Voting system

$$WV_t = PA_t^n W_t^n$$

Government decision:

Flood infrastructures

$$FL_t \begin{cases} 1 & \text{if } FL_t^n = 0 \\ 2 & \text{if } FL_t^n > 0 \end{cases} \tag{S14}$$

Affordable housing

$$AH_t \begin{cases} 0 & \text{if } FL_t^n = 0 \\ 0.05 & \text{if } FL_t^n > 0 \end{cases} \tag{S15}$$

Social protection

$$SP_t \begin{cases} 0 & \text{if } FL_t^n = 0 \\ 0.05 & \text{if } FL_t^n > 0 \end{cases} \tag{S16}$$

Building back better

$$BB_t \begin{cases} 0 & \text{if } FL_t^n = 0 \\ 0.05 & \text{if } FL_t^n > 0 \end{cases} \tag{S17}$$

MODEL PARAMETERS

The following table summarizes the minimum and maximum values used to generate 1000 uniform values for each parameter representing the random socio-economic and socio-political values of the neighbourhood.

Parameter	Description	Min value	Max value
α_H	Relation between river level and relative damage	10	15
α_U	Annual ratio of unemployment	0.001	0.002
α_B	Annual reduction of building quality	0.001	0.005
α_{CI}	Annual increase in the ratio between costs and income	0.0008	0.001
α_W	annual increase in the wealth of the neighbourhood	0.008	0.01

INITIAL CONDITIONS

The following table summarizes the minimum and maximum values used to generate 1000 uniform initial values of the model variables

Variable	Description	Min value	Max value
F	Flood intensity	0	0
U	Unemployment	0.7	0.7
B	Building quality	0.6	1
D	Damage housing	0	0
CI	Cost-income ratio	0.4	1
W	Well-being	0.2	0.4
Po	Political orientation	-0.5	0.7