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ADVANCED REVIEW

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Clouded skies: How digital technologies could reshape "Loss and Damage" from climate change

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Abstract

As dangerous climate change becomes more and more likely, a consensus has been reached on the importance of addressing Loss and Damage (L&D) residual to mitigation (i.e., preventing climate change) and adaptation (i.e., adjusting in order to avert adverse impacts). In spite of sharp divisions in terms of how to understand and operationalize L&D, most approaches draw on classic environmental governance, with discrete analogic interventions implemented by States and international actors. L&D is mainly envisioned as an "international court of climate justice" that identifies the culprits (emitters), quantifies harm, and compensates victims. While digital technologies and algorithmic governance have colonized many germane policy fields and virtually all economic sectors, in the L&D field a substantive discussion on the use of information and communication technologies, algorithms, and user-generated data has been conspicuously absent. By taking the prospect of a "digitalization" of L&D seriously, this advanced review identifies the seeds of emerging digitalized approaches to L&D through an overview of literature. We focus on examples in three key domains associated with L&D—insurance, disaster responses and risk management, and human displacement. These empirical cases are used to investigate the modes of governance that accompany the digital tools through which L&D could be implemented, and the profound changes in climate politics and justice that would accompany a digitalization/algorithmization of L&D.

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climate change, climate justice, digital governance, digital justice, disaster displacement, insurance, loss and damage

1 | INTRODUCTION

The impacts of climate change are becoming dramatically apparent. The new decade has been heralded by two catastrophic events associated with the Indian Ocean dipole: the unprecedented magnitude of the bushfires in Australia, and the devastating—yet quite underreported—floods in East Africa (Hirons & Turner, 2018; Ummenhofer et al., 2009). In the years to come we can expect such adverse impacts to escalate. In the absence of mitigation strategies at adequate scale and of massive investments in adaptation, what the UNFCCC calls "dangerous climate change" is set to materialize, posing an existential threat to many living beings and landscapes (IPCC, 2018). Contemplating mechanisms that address and compensate for the potentially massive harm that global warming is going to cause has become unavoidable. It is in this context that Loss and Damage (hereafter L&D), once a fringe issue for climate justice campaigners or bureaucrats, has emerged as a third pillar of climate policy (adding to mitigation and adaptation) and is widely recognized as a field of strategic future importance.

Yet most approaches to L&D have remained firmly anchored in the present—if not in the past. They envision solutions based on discrete decision-making and tools handled by multilateral institutions and actors of classic environmental governance (States, international organizations and institutions, private companies). Across the spectrum of positions on L&D, the keywords mobilized belong largely to a legal semantic field (e.g., liability, attribution, compensation), and L&D is often envisioned as being staged in an imagined "international court of climate justice"—which would identify climate wrongs and their perpetrators and compensate victims. Emerging forms of climate and environmental governance have largely been foreclosed from the domain of L&D. Crucially, the burgeoning trend towards a digitalization of mainstream environmental and climate governance (Bakker & Ritts, 2018; Chandler, 2018) seems to have affected L&D debates only very marginally.

In this advanced review, we highlight this "digital gap" in the L&D space. We explore how information and communication technologies (ICT), algorithms, user-generated data, and distributed technologies (DT)—increasingly central in a number of societal domains and economic sectors—could also become part of the implementation of L&D. We will start by introducing and conceptualizing the "digital gap" in current approaches to L&D, drawing on the growing scholarship that examines digital and algorithmic governance. We will then review interdisciplinary literatures that explore digitalized approaches in three crucial domains within the L&D policy field: insurances, disaster responses and risk management, and human displacement. For each domain, we will examine selected empirical cases. Building on these "seeds," the article concludes by articulating some future outlooks on digitalized L&D. As we will see, the digital might represent a vehicle for the mainstreaming—for better or worse—of L&D. To be clear, our point is *not* normative. We are not implying that digitalized approaches to L&D would be more equitable or desirable than the current ones. Rather, we bring under the spotlight a possible digital turn in L&D because this could lead to a number of diverging scenarios, with different outcomes in terms of who "pays the bill," how climate justice is understood and administered, and the forms of political mobilization and resistance accompanying the politics of L&D.

2 | SITUATING "CLASSIC" APPROACHES TO L&D

Avoiding dangerous climate change has been the mission of the United Nation Framework Convention on Climate Change (UNFCCC) since its establishment in 1992. Almost 30 years later, whether this will be achieved is highly uncertain. This was one of the key questions in the aftermath of the Paris Summit in 2015, and the outlook offered by the latest IPCC Special Report (2018) is quite bleak. Whereas some believe that limiting global warming below 2°C is still feasible (Geden, 2018), there is little doubt that insufficient steps have been taken so far if dangerous levels of warming are to be avoided (Anderson & Peters, 2016; IPCC, 2018; Smith et al., 2016; Xu & Ramanathan, 2017). Moreover, accumulated past emissions have locked in severe changes that will materialize regardless of present and future mitigation efforts (IPCC, 2013). Serious concerns exist also over the limits of and to adaptation, both in terms of feasibility and available resources (Klein et al., 2014; McNamara, Westoby, & Smithers, 2017; Ober & Sakdapolrak, 2019). The bottom line is that adaptation will inevitably reach its limits, that is, "points at which adaptation fails to protect things that stakeholders value" (Barnett et al., 2015, p. 5), and will not be successful for all people and all places (Tschakert et al., 2017). In other words, adaptation is not expected to fully prevent climate related-risks from reaching intolerable levels. It is in this context that L&D has emerged as a third pillar in the architecture of international climate governance (Klein et al., 2014). The Warsaw International Mechanism (WIM) was launched at COP18 in Doha in 2012 with the precise mandate to explore and promote measures addressing losses residual to mitigation (i.e., efforts to prevent climate change, such as emission reductions) and adaptation (i.e., measures adapting to climatic changes in order to avert adverse impacts), and that stretch beyond a "tolerable level" of risk. L&D was then included in a dedicated paragraph of the 2015 Paris Agreement (Mace & Verheyen, 2016). While there seem to be a vast consensus on the importance of understanding and addressing the irreversible L&D that vulnerable populations will suffer in the decades to come (Barnett, Tschakert, Head, & Adger, 2016), the policy space of L&D is still in the making. There are several conflicting interpretations on definitions, scope, and implementation (Calliari, 2016; Dow et al., 2013; Klein et al., 2014). How L&D can be made intelligible, measurable, and "actionable" in practice is still contested and unclear. Among the studies that classify the main approaches on the table in scholarly and policy debates (e.g., Calliari, 2016; Mace & Verheyen, 2016; McNamara & Jackson, 2019; Tschakert et al., 2017; Vanhala & Hestbaek, 2016), Boyd, James, Jones, Young, and Otto (2017) offer a comprehensive mapping that differentiates four distinctive but overlapping framings: *mitigation and adaptation*; *risk management*; *limits to adaptation*; *existential threat* (see Table 1 for an overview).

This table helps us understand how the complex politics of climate change that have animated arenas such as UNFCCC surface also when discussing L&D. The sharp contrasts on how to address uneven historical responsibilities complicate the debate on the nature and legal connotation of L&D, with fault lines often mirroring the "old" North–South divide (Boyd et al., 2017; Calliari, 2016; Roberts et al., 2017): since the idea of addressing permanent and irreversible L&D emerged in the 1990s, global south countries and climate justice advocacy organizations have argued for standalone and stronger conceptualizations of L&D, encountering the resistance of industrialized countries (contrast the *existential threat* and the *mitigation and adaptation* framings in Table 1). Indeed, southern countries have advocated for conceptualizations of L&D based on the understanding that climate change, as cumulative historical emissions are roughly proportional to wealth and are disproportionally concentrated in "industrialized" countries, constitutes a wrong which they have suffered. This wrong consists in permanent and/or irreversible harm (to lives, livelihoods, assets, landscapes, cultural values, etc.) in its most dramatic expression. Proposals have thus been made to build into L&D a legal *liability* for emitters, forcing them to compensate, proportionally to their responsibility (read emissions) for losses and damages in which vulnerable population will incur because of climate change (Gsottbauer, Gampfer, Bernold, & Delas, 2018). Governments and actors from the global North have been extremely reluctant to sanction a principle of legal responsibility, preferring to locate L&D in the spaces of adaptation (see the *mitigation and adaptation* and *limits to adaptation* framing), risk management, and climate finance (see the '*risk management*' framing), and often advocating for an integration with the international development field (Boyd et al., 2017; Calliari, 2016). Indeed, the

TABLE 1 Key framings of L&D, own elaboration based on Boyd et al. (2017) and other sources (Calliari, 2016; Gewirtzman et al., 2018; Mace & Verheyen, 2016; McNamara & Jackson, 2019; Roberts & Huq, 2015; Roberts & Pelling, 2018; Tschakert et al., 2017; Vanhala & Hestbaek, 2016)

Framing	Key proponents	Type of implementation
"Existential": emphasizes the extreme threats climate change poses to lives, livelihoods, culture in the global South, highlighting the possibility of loss of lives, livelihoods, landscapes, and cultures (NELD)	Global South block; G-77; Alliance of Small Island States (AOSIS); climate justice campaigners	Strong implementations of L&D with standalone mechanisms; compensation for L&D of vulnerable populations; legal liability for heavy emitters
"Mitigation and adaptation": situates L&D in the spaces of adaptation, risk management and international development. L&D is not recognized as intrinsically distinct from *mitigation and adaptation*	Governments and actors from the global North	No need for additional mechanisms, as averting adverse impacts of climate change is UNFCCC's very mission
"Limits to adaptation": focuses on the conditions at which the impacts of climate change exceed adaptive capacity	Climate adaptation academic and policy community; development practitioners	Identify and target conditions at which impacts exceed adaptive capacities; vulnerability reduction and livelihood support policies at micro-level to expand adaptive capacities, thus minimizing residual harm
"Risk management": suggests to "climate proof" risk management in order to avoid catastrophic and ungoverned L&D	Insurance and reinsurance business sector; some members of the disaster risk reduction community	Extension of risk transfer (e.g., insurance schemes, financial tools such as catastrophe bond), risk retention (e.g., social safety nets), and improved risk assessment through prediction tools

position of L&D in policy architecture remains contested. For instance, while the establishment of the WIM could be seen as a victory for vulnerable countries advocating for an ad hoc mechanism, the WIM was in effect placed under the Cancun adaptation framework, thus making it a de facto subcategory of adaptation, rather than a fully standalone pillar/mechanism, as advocated by the developing countries bloc (Roberts et al., 2017). These are only some of the many unresolved issues. The fate of L&D and its positioning in the context of climate policy, the shape it might take, and so on are all very open questions (Mace & Verheyen, 2016; McNamara & Jackson, 2019).

3 | A "DIGITAL GAP" IN L&D DEBATES?

Defining what "the digital" means can seem redundant, considering the degree to which digital technologies have become omnipresent in our lives. Radical improvements in a series of key devices and infrastructures (including sensors and processor capacity, faster communications networks, mobile, and portable devices), have made internet, smart phones, big data, algorithms, artificial intelligence, and machine learning key elements of most dimensions of human life. Following current geographical scholarship (for an overview, see Ash, Kitchin, & Leszczynski, 2016), we employ a broad definition of the digital, one that comprises the several layers of the "stacks" (Bratton, 2015) that form contemporary societal infrastructure and political economy. These layers include "material technologies characterized by binary computing architectures; the genre of socio-techno-cultural productions, artefacts, and orderings of everyday life that result from our spatial engagement with digital mediums; and the logics that both structure these ordering practices as well as their effects [; …] digital discourses which actively promote, enable, secure, and materially sustain the increasing reach of digital technologies" (Ash et al., 2016, p. 26). In other words, we refer to digital technologies as constituted by bits, machines, human practices, affects, and meanings, all inextricably intertwined in what can be referred to as socio-technical assemblages. Seen as more than machines and bits, digital technologies appear as instruments for government: they are not limited to the execution of "dull" technical operations dictated by a human operator, but open up entirely new fields of visibility to government. Crucially, what is at stake is a "shift not only from 'government to governance', but also from 'manual to automated' governance" (Bakker & Ritts, 2018, p. 208), as such technologies allow for the administration of rights, duties, and resources through algorithms. An example is the proliferation of preemptive security strategies and measures based on the analysis of big data sets by self-learning algorithms. The fact that decisions are taken by an algorithm highlights the ethical and political dimensions of such practices (Amoore, 2016; Aradau & Blanke, 2015; Pazaitis, De Filippi, & Kostakis, 2017; Sabel & Victor, 2017; Surminski & Lopez, 2015). Importantly, digital technologies and the ontologies and politics that accompany them are emerging as key to the affirmation of new forms of control and administration, but could also open up for experiments and "hacks" (Aradau & Blanke, 2015; Bratton, 2015; Chandler, 2018; Rothe, 2017).

Such transformations have already reshaped important policy fields. As mentioned, the granularity of analysis based on algorithms and big data is changing the way in which security is understood and threats identified and tackled (Aradau & Blanke, 2016). Distributed and mobile technologies are also transforming humanitarian aid (Duffield, 2016; Meier, 2015; United Nations, 2013) and refugees support (Maitland, 2018), while complex technological systems are reshaping borders (Tazzioli, 2018). Social media and distributed platforms have had deep impacts on the formation of public opinions and their circulations, on activism as well as electoral processes—in the last instance on political subjectivities and regimes (Baack, 2015; Dean, 2009; Elwood & Leszczynski, 2012; Luque-Ayala & Neves Maia, 2018). The proliferation of the digital and of "algorithmic governance" (Leszczynski, 2016) has also transformed urban space, its governance and political economy, as well as the way in which these spaces are produced, contested, and reinvented (Graham & Marvin, 2001; Kitchin & Perng, 2016; Marvin, Luque-Ayala, & McFarlane, 2016; Rose, 2017).

Coming closer to L&D, the digital turn has introduced ruptures in the established modalities of environmental governance. New frontiers are opened by the exponential growth in the resolution and quantity of available data, due to massive improvements in geospatial data collection and availability, but also to the new and more capillary data sources offered by the proliferation of sensing devices and the "internet of things". These technologies (often referred to as "Smart Earth" tools) are transforming the ways in which environmental issues are rendered intelligible and understood, recasting the actors and subjectivities involved, reshuffling and at times revolutionizing the spaces of environmental discourse (Bakker & Ritts, 2018; Chandler, 2018). The digitalization and exponential growth of mapping and sensing (Gabrys, 2016; Rothe, 2017) is reshaping sectors such as conservation (Arts, van der Wal, & Adams, 2015) and waste reduction (Koomey, Scott Matthews, & Williams, 2013). The governance of the complex political economy surrounding carbon has been also colonized by digital technologies and algorithms, while digital forms of activism are appearing in the context of climate change movements (Howson, Oakes, Baynham-Herd, & Swords, 2019; McLean & Fuller, 2016).

How have these new technologies entered the L&D debate? Surprisingly, very little. In spite of the important differences sketched out in Section 2, most approaches to L&D have been molded in line with modernist models of international policy-making and environmental politics, often embodying technocratic top-down visions (McNamara & Jackson, 2019). They have largely remained disconnected from new forms of (environmental) governance, not least those powered by digital technologies. This "digital gap" is evident in the definition of the problem, the actors involved, and the solutions envisioned. Building on a top-down, linear understanding of causality, current approaches strive to identify and circumscribe in a discrete manner biophysical changes, their impacts and human causes. Furthermore, current L&D discourses interpellate the usual suspects of classic environmental governance. While the IPCC provides "the evidence," the UNFCCC constitutes a legal and institutional framework, around which orbit a series of actors such as the World Bank and other financial institutions, the international development and humanitarian sectors, the private sector, "local communities." Most current framings privilege analogue manual mechanisms maneuvered by discrete human agencies. The central position of legal systems is emblematic. As L&D has been advocated as (or feared to become) an instrument to offset and compensate for major structural inequalities (in terms of responsibility, exposure, and adaptation capacities) linked to climate change (Roberts & Huq, 2015), it is often imagined to be administrated by an "international court of climate justice," which would adjudicate compensation and resolve litigation. Such a vision is strongly advocated for by the *existential* framing, while vehemently opposed by the *mitigation and adaptation* approach. Discrete human agency is central also in other approaches to L&D, such as the vulnerability and poverty reduction at the national and local level (to be fostered via development interventions) championed by the "limits to adaptation" and 'mitigation and adaptation' frames. The same applies for relocation programs for communities displaced by the most severe impacts of climate change (McNamara, Bronen, Fernando, & Klepp, 2018). The *risk management* approach puts great faith in markets and financial tools, such as "catastrophe bonds" or insurance schemes (see Gewirtzman et al., 2018 for an overview), as well as in better warning and information systems (Roberts & Pelling, 2018; Warner et al., 2012). But in spite of the differences (normative, epistemological, institutional), these approaches share a similar modernist horizon.

If L&D is to become substantive part of future climate policy, it is very unlikely it will be shaped against these "old" governance paradigms. If L&D is to become a structured policy field in the coming decade, it is likely it will do so in ways that go beyond the discrete epistemology of modern policy-making and classic approaches to climate justice, not least to comprise the big epistemological and policy changes entailed by the digital turn. Put emphatically, it seems more likely that climate justice (or what will be left of the idea) is going to be administered by an algorithm than by a courtroom judge. This is an analytic rather than normative point: we are not suggesting that approaches to L&D going beyond modernist models would be "better" or more equitable than those currently envisioned. We are rather attempting to map the field of possibility within which several alternative trajectories for addressing L&D could be traced in the years to come, sketching out their diverging implications on the contours of climate politics and justice.

4 | L&D AND (DIGITAL) JUSTICE

The prospect of a digital turn makes questions of justice—pivotal in "classic" L&D debates (see Section 2)—even more pressing, and requires the development of analytical frameworks able to critically investigate the peculiar justice ramifications of digital technologies. Therefore, we suggest reading both the empirical cases and the future scenarios (see in particular Section 6.4) examined by this article through the overarching concept of "digital justice." McLean and Mackenzie define it "as attempts to achieve just outcomes and processes through digital interventions and in digital spaces [...]. Digital injustices emerge when digital processes and spaces are not inclusive in terms of recognising and including diverse stakeholders, and ultimately do not produce equitable distribution of the costs and benefits of those processes" (McLean & Mackenzie, 2019, p. 292). In line with classic definitions of environmental justice (e.g., Holifield, Chakraborty, & Walker, 2018; Schlosberg, 2013; Walker, 2012), digital justice points at questions of distribution (of risks, burdens, benefits), the recognition of the different stakeholders and communities involved, as well as participation in decision-making and in the definitions of policies (McLean & Mackenzie, 2019). As we will see, all of these aspects are crucial when envisioning the possible implications of a digital turn in L&D. This useful but rather abstract framework has been articulated to explore a number of real-world challenges. To begin with, a well-established literature investigates the so-called "digital divide"—that is the unequal access to digital infrastructure and technology (first level divide) and know-how and skills (second level divide)—and its impacts across different groups (Dé, Pal, Sethi, Reddy, & Chitre, 2018; Ragnedda & Muschert, 2013; van Deursen & van Dijk, 2018; van Dijk, 2006). More recently, scholars have started advocating for a stronger and more sophisticated critical approach to the digital, one able to investigate how the usage of digital technologies can interact with and reshape power relations between a community and its broader context, as well as within the community itself, for instance along gender lines (Stephens, 2013). The impacts of digital technologies on rural and indigenous peoples, and marginalized groups in the global South, the ones most directly concerned with L&D, remain under-studied (Dé et al., 2018; Young, 2019).

The concept of "data colonialism" (e.g., Couldry & Mejias, 2018; Thatcher, O'Sullivan, & Mahmoudi, 2016) has been coined to stigmatize the forms of appropriation and dispossession that digitalization can foster, in particular in contexts characterized by exploitative processes of capital accumulation based on unequal power relations within and among countries. Along similar lines and applying elements of decolonial studies to local contexts, other authors have applied sophisticated critical approaches to appreciate the impacts of the digital on indigenous communities. Such studies highlight the complex ways (including but also beyond the digital divide) in which digital tools transform, erode, or empower knowledge systems of groups at the fringes of globalized Western culture and capital (Young, 2019, 2020; Young & Gilmore, 2017). These perspectives offer important tools to investigate the seeds of a digitalized L&D and to explore the different outcomes such a turn might have.

5 | SEEDS OF DIGITALIZED L&D?

The digital has the potential to bring about profound changes in the way L&D is conceived and implemented, potentially contributing to overcome some of the obstacles that still hamper the affirmation of L&D in international climate policy. Such obstacles seem unsurmountable by modernist forms of government implemented through analogue tools (for a more detail discussion, see Section 6). Against this background, we set out to explore modes of governing L&D beyond modernist paradigms and how they might become part of the climate change policy landscape in the near future. In order to highlight such potentiality, in the next sections we explore literature investigating the first implementations of digitalized approaches in the three most representative fields in the L&D debates: insurances, disaster responses and risk management, and displacement. For each, we also examine significant recent empirical cases. While the use of digital technologies, distributed sensing, algorithms, and big data in the following proto-examples were not explicitly designed to address L&D, we venture into exploring their potential impact also in that policy space.

5.1 | Insurances

Insurances are a key mechanism through which the implementation and funding of L&D has been envisioned (Gewirtzman et al., 2018; Mace & Verheyen, 2016; O'Hare, White, & Connelly, 2016), particularly within the *risk management* framing (see Section 2). The approaches the WIM Executive Committee has proposed (for a review, see Gewirtzman et al., 2018) boil down to insurance schemes subsidized with voluntary contributions, such as catastrophe risk insurance, contingency finance, climate-themed bonds, and catastrophe bonds. Such instruments are becoming increasingly popular in the whole field of disaster risk financing, and they have been heralded as the most promising solutions to the impasse of climate finance. Such instruments—all still at an inaugural stage of implementation—take various forms, from the macro-level of multi-country catastrophe risk insurance instrument, such as the pioneering Caribbean Catastrophe Risk Insurance Facility (CCRIF), to the level of microinsurance. A clear example of this is the recent G7 Initiative on ClimateRisk Insurance (InsuResilience), which has the ambitious goal of increasing access to direct or indirect climate insurance coverage for up to 400 million of the most vulnerable people in developing countries by 2020 (InsuResilience 2017). Yet, few studies have so far addressed the role that microinsurances can play in meeting preventative and curative targets of the WIM and the Paris Agreement (Linnerooth-Bayer, Surminski, Bouwer, Noy, & Mechler, 2019), and have focused on their role in providing post-disaster relief and reconstruction.

In this section, we focus on weather Index-based insurance (WIB) schemes, as they are often portrayed as the long awaited solution to one of the crucial conundrums in the development sector: How to make smallholder farmers (who make up the bulk of the global poor and of the climate-vulnerable) insurable? Global institutions like the World Bank have strenuously advocated for such risk transfer mechanisms as a vehicle for the introduction of "climate smart agriculture" in the global South (World Bank, 2007, 2015). In a nutshell, WIB schemes use an index composed of rainfall patterns, temperatures, and other indicators that are considered as proxy for risk and "translate" extreme weather fluctuations into crop failure and yield losses. The set parameters will indicate the probability of crop failure in a given territory, and payments are made to all policy holders residing there, irrespective of their individual losses. Proponents of WIB usually highlight the following three main advantages against traditional crop insurance schemes (Taylor, 2016, p. 248): They avoid the laborious process of detailing compensation on an individual basis; the objectification of risk ensures that "moral hazards" are kept to a minimum, as payment is not tied to individual losses (hence the farmers would not gain anything in allowing their crop to fail); they also circumvent the adverse selection problem, whereby those who are facing the biggest risk are more likely to get an insurance. As individual losses are no longer tied to payments, the differential in risks is no longer a stronger incentive. This would help also in keeping the premium affordable, another well-known dilemma faced by those trying to insure the global poor (Banerjee & Duflo, 2011). WIB schemes are proto-examples because of their rather limited diffusion—they still cover a tiny minority of smallholder farmers and in financial terms represent a minuscule proportion of the insurance and re-insurance market. Moreover, WIB schemes do not yet factor in the attribution of weather impacts to climate change, as no mechanism of attribution has reached a degree of maturity sufficient for the insurance sector to include it in its standard operations.

Digital technologies have great potential to contribute to overcoming several yet unresolved issues for WIB. For instance, "crowd-sensing" could address a key technical pitfall: WIB insurance schemes require a dense network of weather stations, which are often absent in the "majority world." In recent years, experimental WIB schemes have started employing big data and ICTs more heavily. A pioneering example is the WINnERS project. To overcome the usual hurdles to the implementation of WIB schemes, WINnERS has brought together farmers and global agricultural buyer corporations to improve resilience to climate variability and change, and thus co-reduce the risks involved for all the actors in the chain of production (Chavez, Conway, Ghil, & Sadler, 2015). The project is in the implementation phase, and so far 50,000 farmers have been insured in Tanzania, and a second-phase pilot scheme is being implemented in Mozambique. The WINnERS team designed a suit of algorithms, on which they built a dynamic index that links local meteorological records, user-generated weather observations, farmer's reports on farming practices and crop yield losses, as well as global market prices data (Biffis & Chavez, 2017). The assessment of risk underlying the scheme is thereby more dynamic, updated, and refined (thus, more reliable), which in turn allows to effectively extend the field of insurability on populations and activities uninsurable by traditional schemes. WINnERS claims to add a further "winner" to the entrepreneurial logic of risk mitigation and microinsurances: not only the (re)insurance market and smallholder farmers shall benefit from the scheme, but also global agricultural buyers. The potential of the innovations exemplified by the WINnERS project for the funding and implementation of L&D is apparent, and yet almost completely ignored by the literature that is concerned with the deployment of mechanisms to fund L&D. Again, we encounter the highlighted tendency to foreclose the potential game-changing impact of big data and algorithmic governance in the L&D-related policy landscape.

WIB schemes also raise major concerns. Because of the endemic exclusion from technology suffered by social groups and territories (Lai, Chib, & Ling, 2018), combined with the uneven geographies of access to microinsurance, a proliferation of digitalized schemes could exacerbate inequalities and vulnerability, rather than mitigating them. Overall, insurance schemes function in opposition to the deployment of rights-based universal social protection and have thus regressive social effects (Johnson, 2013; Peterson, 2012). At a macro-level, scholars have highlighted the "convergence between the rubrics of financial inclusion and risk management" (Taylor, 2016, p. 241). An expression of which is arguably the merging of the development and climate agendas under the common imperative of building the "resilience" of the global poor (Felli, 2016). The development of microinsurances implies that insurance takers participate more fully than before in market-based exchanges and thus in value-producing activities. It has been documented that such a compulsion can push towards more commodifiable crops and an intensification and mechanization of production. These profound changes to production practices have led to cycles of debt, increased environmental degradation, and for some participants to the exclusion from the schemes. In more abstract terms, microinsurance mechanisms can be seen as one of the many devices though which risk is managed within neoliberal relations. The key argument here is that the construction of risk as a "way of ordering reality, thus rendering it into a calculable form" (Dean, 1998) is complicit with a naturalization of risk that obliterates root-causes of poverty and vulnerability. WIB schemes render a complex issue such as climate change into a calculable and manageable risk, and foreclose questions on how risk is produced and displaced unevenly between social groups (Taylor, 2016). At the individual level, insurance and insurability can be seen as devices through which neoliberal subjects are supposed to negotiate their exposure to contingency (Baldwin, 2016).

These concerns should raise caution with regard to the emancipatory potential of WIB schemes. However, with an imaginative spirit, digitalized WIB schemes and microinsurance could also be envisioned as a vehicle for new ways to claim for compensation. Going back to the framings presented in Table 1, WIB schemes and micro-insurances seem to naturally belong to the *risk management* framework. Yet, they could as well be a way to implement the idea of responsibility and compensation in a "soft" (not through a direct legal liability) and tunable way (countries could decide the amount of funding they contribute with). This would bring WIB schemes closer to the *existential* framing of L&D, and potentially open up new spaces of negotiation that go well beyond the hegemonic framing of voluntary contributions and externalizations of the burden and costs on the "resilient-to-be" subjects.

5.2 | Disaster responses

Climate change will intensify hazards by increasing the frequency and severity of extreme events such as droughts, heatwaves, hurricanes, and so on. It will also—directly and indirectly—affect the factors shaping risk and vulnerability, such as availability of resources to cope with extreme events. In the context of climate policy, increasing emphasis has been devoted to disaster preparedness and responses, as well as on the links with adaptation and mitigation (IPCC, 2012). UNFCCC's decisions and processes also recognize the importance of the matter. The preamble of the final decision taken at COP 21 in Paris stresses the synergies that should be searched with other relevant international frameworks, such as "the 2030 Agenda for Sustainable Development [… and] the Sendai Framework for Disaster Risk Reduction" (UNFCCC, 2015). While the relevance of the question for the *risk management* framing of L&D is obvious, all other framings also engage with disasters, although from their own angle. For instance, the *existential* framing puts responsibility and compensation at center stage, stressing that channeling funds to those exposed to disasters and compensating them for the losses and damage they incur is a matter of justice.

While not always explicitly addressing L&D, a growing number of projects incorporate "Smart Earth" technologies—ICT, remote sensing, big data and social media—with the aim of designing more dynamic, responsive and accountable risk management and response strategies. Thanks to the exponential growth of sensing capacities, data available, and big data analysis techniques (see Section 4) the "digital" is opening up new territories for foreseeing, understanding, and visualizing disasters, for (ac)counting the damage caused, as well as for reparation and recovery in the aftermath. Indeed, in debates on disaster preparedness and responses, digital governance, and technological innovations are hot topics fuelling hopes as well as concerns among key actors (ITU-D, 2019; UNISDR, 2015). An interdisciplinary body of literature investigates the prospects and limitations of digital applications in the various phases of the "disaster management cycle"—namely *mitigation* (minimizing the effects of disasters), *preparedness*, *responses* (immediate measures during a crisis to protect lives and property), *recovery* (efforts to recover in the aftermath of a disaster) (Qadir et al., 2016; Tim, Pan, Ractham, & Kaewkitipong, 2017; Yu, Yang, & Li, 2018).

Satellite imagery, remote sensing, and geospatial information are among the key sources of data on which such initiatives build (Qadir et al., 2016). For instance, several Southeast Asian countries are developing online databases to collect data on the impacts, in terms of damage and losses, of both severe and small and recurring disasters. In particular, Cambodia's National Committee for Disaster Management has established an online information system called the Cambodia Disaster Loss and Damage Information System (CamDi), to systematically collect, store, and analyze L&D deriving from disaster events, including small-scale events (ADB, 2018). Such attempts are still hampered by a number of constraints—including maintenance cost, cross-sectoral coordination, and lack of data. Nonetheless, they emerged in a specific context whereby governments and actors in the global South (and/or aligning with the interests that can be broadly ascribed to the South bloc in the L&D discourse) are starting to see digitalization's disruptive power (e.g., in the negotiations) that could generate new ways of responding to emerging situations.

Less traditional sources of data are gaining traction in digital application for disaster risk management. Now popular terms such as crowdsourcing, citizen science, and volunteered geographic information describe applications where citizens or users are themselves producing or sharing data (Crampton et al., 2013; Goodchild & Glennon, 2010). Citizens are thereby emphatically described as "becoming sensors," contributing the compilation of information and data, which is then gathered and analyzed by a variety of platforms. Ground-breaking projects explored in the literature include the initiatives launched in the aftermath of the 2010 Haiti earthquake, which saw the Haitian government, UN as well as U.S. aid and relief agencies draw heavily on user generated data to coordinate relief efforts, target resource allocation, and support particularly vulnerable and exposed groups (ITU-D, 2019; Yates & Paquette, 2010). The landslides monitoring project recently implemented in the Three Gorges Dam region in China, which combines "traditional" remote sensing techniques with the user-generated data to monitor landslides (Li, Cheng, Cheng, & Mei, 2019), is another notable example.

Moving on to another source of data, Louis, Thiagarajan, and Shahedur (2016) and Tim et al. (2017) provide an overview of the increasing usage of social media and microblogging in disaster risk management. While noting the relative lack of studies on these emerging applications, such reviews illustrate how social media and microblogging can represent extremely versatile tools for DRM. They can indeed represent valuable additional sources of information in the initial phases of crisis situations, when situational awareness and information are vital to inform decisions and to help affected individuals make sense of events; they can contribute maintaining social connections and facilitate emotional recovery, and also facilitate efforts for disaster recovery, for instance by fostering engagement, mobilizing resources and donations, and recruiting volunteers (Louis et al., 2016; Wang, Amati, & Thomalla, 2012). The usage of social media still represents a challenge for many relief organizations, for which it can be difficult to gather the necessary technical know-how, fully understand the usage of such tools, as well as strategically plan and allocate resources for less-traditional crisis management tools (Louis et al., 2016). A relatively widely known case is PetaJakarta (Turpin, 2013), a disaster risk management project based in Jakarta that offered real-time mapping and flood alerts by elaborating user-generated Twitter feeds. The success of the project led to its out-scaling into PetaBencana, which covers a vaster area of Indonesia beyond Jakarta's boundaries. The platform collects flooding reports from citizens in the spot (via a Twitter hashtag and with pictures attached), validates them through advanced algorithms, and then in real time makes such reports available (via a mapping visualization tool and social media feeds) to the public. A less acclaimed but interesting initiative is My Coast, a platform coordinating a series of regional and national projects with the aim to gather, consolidate, map and visualize user-generated reports on storms and related damages, tides, coastal erosion, as well as adaptation projects. While not in real-time, MyCoast is a proto-example of how "crowdsourcing" could be mobilized to document L&D linked to climate change, in order to facilitate citizens' responses, policy measures, and potentially also compensation.

A recurring theme in the studies mentioned above, which is of great relevance for L&D, is the potential of digital tools to contribute to overcoming the limitation of top-down disaster risk management and response strategies. A key aim of crowdsourced and social media-based tools is indeed to enhance data collection and processing by adding new sources "on the ground" and thereby tackling the difficulties encountered by early warning systems in reaching the "last mile." As users/citizens can also participate in the assessment of data and interventions, crowdsourcing is often heralded as enhancing the inclusivity, transparency, and accountability of the data that informs disaster risk management initiatives (Georgiadou, Lungo, & Richter, 2014; Goodchild & Glennon, 2010). A number of case studies investigate less standard and more subtle dimensions and impacts of social media platforms and crowdsourcing in disaster situations. For instance, exploring engagements with social networks in the aftermath of the Ya'an earthquake, which hit China in 2013, Wang develops a theoretically informed analysis of the modalities and motivations behind citizens' participation to disaster-related sites on social networks (Wang et al., 2012). The study highlights the autonomous and spontaneous character of engagement with social media sites, but stresses the role of emergency managers and relief organization in facilitating such engagement (e.g., by creating specific sites or providing there more information), as well as in fostering and coordinating substantive engagement in the aftermath.

Several studies highlight the limitations of top-down and command-and-control attempts to foster digital engagement and participation by emergency managers and relief organizations. For instance, Tim et al. (2017) stress how official relief organizations had renegotiate their role and modus operandi when mobilizing crowdsourcing in the aftermath of the 2011 Thailand flooding. According to several studies by Palen and colleagues, command-and-control approaches struggle to adapt to the burgeoning data-generation and engagement by the public, as public and private organizations often aim to "harness" social media engagement and align them to their usual operation modalities, rather than the opposite; according to these authors, one of the implications of increased digital engagement is going to be a growing role of grassroot initiatives and improvization in disaster risk management and responses (Palen, Hiltz, & Liu, 2007; Palen & Liu, 2007). Palen and colleagues provide examples of innovative grassroots initiatives that emerged in occasion of the 2003 San Bernardino wildfires, of Hurricane Katrina in 2005, as well as in anticipation of a possible avian flu pandemic. In these occasions, several web forums (such as Katrina.com and Hurricane Information Maps and FluWiki) were spontaneous, citizen-led efforts to gather, share, and discuss information, and in some cases mobilize responses (Palen et al., 2007). In this respect, OccupySandy (OS) is an interesting and quite unique case, one mobilizing more the climate justice lexicon of the *existential* framing than the more technocratic visions often informing similar projects. OS is a grassroots, self-organized relief platform started in the New York area in 2012 in the aftermath of Hurricane Sandy. Relying on a bottom-up usage of social media, DTs, and crowdsourcing, OS aided tens of thousands of citizens that official relief organizations struggled to reach (Dawson, 2017). Since this event, OS has evolved into a platform coordinating self-organized initiatives that target socioecological vulnerabilities in the Northeastern United States.

Another area in which we can expect to see innovations is that of DT-based platforms. DTs and blockchain have attracted significant attention in other fields (such as humanitarianism, conservation, refugee support), but no projects have been launched in the field of L&D and few exist that explicitly refer to climate change. DT technologies could be employed in the accounting of L&D, in distributed systems that would not require a centralized authority to detect, verify, and store information. More experimental applications could also see the creation of blockchain-based organizations (in jargon, decentralized autonomous organization) that function though DT-based contracts, rules, and automated actions (De Filippi & Hassan, 2016; Swan, 2015). In the L&D case, and here we are in the realm of possible scenarios, these could for instance pool labor and resources in anticipation or in response to a "climate shock," facilitate citizen-led recording and validation of the losses, and thereby lead to P2P or at least more horizontal mechanisms of compensation and support for those exposed.

5.3 | Disaster displacement

While policy debates on L&D have largely ignored digital approaches, those have crept into one of the most visual, emblematic, and controversial dimensions of L&D: human displacement. Remote sensing, big data analysis, and mobile technologies are expected to revolutionize the ways in which displacement and mobility are tracked, governed, and addressed.

Displacement has been one of the most dramatic and powerful representations (in particular, within the *existential* framing) of the irreversible harm that global warming could cause, as displacement configures the loss of whole "lifeworlds"—a village made inhabitable by desertification, a settlement or even a whole country submerged by rising seas. The most cited examples are low-lying Pacific islands threatened by sea level rise, Sub-Saharan Africa, and big deltas areas such as coastal Bangladesh (for critical accounts on each case, see Farbotko, 2010; Carr, 2005; Paprocki, 2018). Policy, media, and academic debates have flourished around the various ways in which climate change could influence human migration (for an overview, see Ransan-Cooper, Farbotko, McNamara, Thornton, & Chevalier, 2015; Baldwin & Bettini, 2017; Methmann & Oels, 2015). Several forms of mobility—such as circular labor migration as adaptation strategy (cf. Bettini, 2014; Felli, 2013; Turhan, Zografos, & Kallis, 2015), planned relocation (McNamara, Bronen, Fernando, & Klepp, 2016; Mortreux et al., 2018), and international displacement (McAdam, 2016)—have been narrated within often overlapping humanitarian (cf. Oels, 2010), developmental (cf. Bettini & Gioli, 2016) or security (cf. Boas, 2015; Telford, 2018) registers. In the UNFCCC context, human migration has increasingly been discussed under the L&D pillar (Gemenne & Brücker, 2015; Stabinsky & Hoffmaister, 2015; Warner, 2012). Human mobility was initially mentioned in the 2010 Cancun Adaptation Framework (par. 14(f) UNFCCC, 2010). Fast-forward to the 2015 Paris summit, and the Decision adopted by the COP urges parties "to develop recommendations for integrated approaches to avert, minimize and address displacement related to the adverse impacts of climate change" (UNFCCC, 2015). Although much less ambitious than the creation of a "Displacement Coordination Facility" that many hoped for (Wentz & Burger, 2015), the Decision entailed couching displacement and mobility within the L&D chapter of the UNFCCC.

The WIM itself recognizes significant gaps in knowledge on the impacts of slow-onset and extreme weather events on migration and displacement. Direct links between L&D and displacement are also captured by the concept of non-economic loss and damage (NELD), which identifies secondary and tertiary impacts in social systems, including the loss of livelihoods, homelands, cultures, landscapes, identity, and agency (Fankhauser, Dietz, & Gradwell, 2014; Gewirtzman et al., 2018; Morrissey & Oliver-Smith, 2013). Displacement can be both cause and symptom of NELD. Current approaches to evaluation of displacement in the NELD context revolve around the number of people displaced as a proxy to infer the scale of the loss (for a classification, see Serdeczny, Bauer, & Huq, 2017; Serdeczny, Waters, & Chan, 2016). More broadly, there has been a quest for quantitative projections providing evidence on the magnitude of the phenomenon. A proliferating set of interdisciplinary methodologies try to model the complex relationship between climate change and human mobility (Piguet, 2010). Migration data are notoriously hard to collect and monitor, being spatially and temporally coarse. As the causal links between climate and migration are complex, socially mediated and multicausal (Black et al., 2011; Geddes, Adger, Arnell, Black, & Thomas, 2012; ch. 12 in IPCC, 2014; Nicholson, 2014; Suhrke, 1994), the urge to quantify current and future flows has led to extremely problematic and often simplistic projections, supported by very thin scientific evidence (cf. Foresight, 2011; Gemenne, 2011; IPCC, 2014; Jakobeit & Methmann, 2012). In spite of these problems, being able to detect early signs of displacement and understanding better the complex interaction of factors and processes on the ground remains a priority for policy.

It is precisely here that "the digital" comes onto the scene, and quite forcefully. In the last decade or so, a number of projects have pioneered the use of big data (obtained in particular from mobile phones) to understand at a finer resolution the links between disasters and environmental stressors and various forms of mobility. The field has seen the emergence of numerous projects and has undergone a rapid evolution (Blumenstock, 2012; Boas, 2017; ITU-D, 2019; Martin & Singh, 2018; Taylor, 2015). This is hardly surprising, when considering that ramified technological assemblages have reshaped how borders are imagined, visualized, and enforced (Baird, 2017; Squire, 2014; Tazzioli, 2018), and ICTs have been advocated also to support migrants and refugees (e.g., Maitland, 2018).

The use mobile phone user data to model and track mobility is a powerful and controversial method. In a nutshell: each time a subscriber calls with his/her mobile, a call detail record is generated. Such record gives information on the timestamp of the call, the phone number, and the mobile tower used to route the call (Boas, 2017; Lu et al., 2016; Martin & Singh, 2018). A seminal study was conducted by Blumenstock, whose analysis of 1.5 million mobile phone users in Rwanda over 4 years revealed mobility patterns of a subtler nature (in particular, concerning circular and temporal migration) that would escape traditional methods such as ad hoc surveys and government census (Blumenstock, 2012). Another study by Lu and colleagues mapped mobility patterns before, during, and after the earthquake that devastated Haiti in January 2010. In collaboration with Digicel (Haiti's largest mobile operator), the study analyzed data from 1.9 million users, offering an understanding of various forms of mobility at a resolution unattainable with other means (Lu, Bengtsson, & Holme, 2012). Since then, a new wave of projects and studies have developed second generation approaches to measure mobility combining phone records and GIS location data (for details, see Williams, Thomas, Dunbar, Eagle, & Dobra, 2015). Examples include the work by Andrade, Layedra, Vaca, and Cruz (2019), who investigated the effects of an earthquake that hit Ecuador in 2016, by analyzing call detail records of 11 million Telefonica subscribers. Several studied have traced mobility patterns related to environmental shocks. For instance, Isaacman and colleagues used anonymized mobile phone records to model the effects of a prolonged drought that hit La Guajira, Colombia, in 2014 (Isaacman, Frias-Martinez, & Frias-Martinez, 2018). Yabe and Ukkusuri have elaborated a model based on heterogeneous social media data to model disaster displacement, validating the model with Twitter data relating to the 2012 Hurricane Sandy (Yabe & Ukkusuri, 2019).

In the next part of this section, we will delve into a very illustrative case, exploring the application of such technologies in Bangladesh, a country particularly interesting for the role it has assumed in the global imaginary as a "hot-spot" of vulnerability to climate change. The haunting image of a country underwater has triggered research on displacement, with Bangladesh being the top country after the United States in terms of number of scholarly studies devoted to the issue of "environmental migration" (Piguet, Kaenzig, & Guélat, 2018). The narrative of "the most vulnerable country in the world" has been adopted by the government and a number of stakeholders in the country, leading to what has been defined an "adaptation regime"—that is, "a socially and historically specific configuration of power that governs the landscape of possible intervention in the face of climate change" (Paprocki, 2018, p. 3). This is particularly relevant in order to analyze the ways in which discourse(s) on L&D and the role of technology therein have been leveraged by stakeholders in the global South. Bangladesh has acted as a global leader on climate finance and L&D, regionally as well as in global negotiations at the UNFCCC. Indeed, the Bangladesh Ministry of Disaster Management and Relief recently supported a pilot project on disaster displacement jointly developed by five organizations (the International Centre for Climate Change and Development, Flowminder, Grameenphone, Telenor Research, and United Nations University). The project built a dataset of anonymized "call detail records" of 6 million users of the largest mobile network operator in Bangladesh over 3 months and 2 years respectively. The data were collected during Cyclone Mahasen, which struck Bangladesh in May 2013. Big data analysis techniques were employed to understand short- and medium-term mobility responses during and after extreme weather events (Boas, 2017; Lu et al., 2016). Given the success of the pilot, the Government of Bangladesh has also initiated a dialogue with national research entities and the two largest network operator companies in order to institutionalize the practice of using the data for DRR purposes.

It is clear that it is premature to assess the impacts of these innovations, in Bangladesh and more in general. While a general consensus exists on the broader need to examine how ICT shape human mobility in the context of environmental change, the Bangladesh case study is still one of the very few examples of such an application. This proto-example however rather indicates the need for careful research (for an ongoing project, see Boas, 2017) and close scrutiny. The import of such designs is still to be understood, as are the technical challenges (e.g., in terms of data reliance) and the dangers (e.g., in terms of privacy and/or migrants' rights) entailed. The still-in-the-making literature on the usage of mobile data for tracking mobility indeed highlights a number of technical, ethical and political concerns, of which

Taylor (2015) and Blumenstock (2012) provide comprehensive overviews. As succinctly put by Taylor (2015), data can be both misunderstood and misused. One first set of issues derive from the fact that most projects and experiments in fact address "inferred mobility" (Blumenstock, 2012), extrapolated from data collected by mobile towers rather than actual position of devices. This creates a number of apparently simple but far from trivial problems, summarized by Taylor (2015). First, there are issues of numerical accuracy: when large crowds concentrate in remote areas with few antennas (which can easily happen for instance when people flee for some reason), the antennas' capacity to receive users can be exceeded, making large number of users invisible. There are then issues with multiple identities, as methods for inferring mobility have to assume that one mobile/sim corresponds to one individual person. That is not always the case, as people can have multiple sim cards, or a sim card can be used by multiple users. There are also challenges of location accuracy: quite obviously, to be able to mirror a user' movement, the phone has to be active and charged, thus is the phone is off (e.g., out of battery) or with not credit, the users become (temporarily) invisible. In many cases, there are different degrees of access to be considered: call data (which many projects use) do not account provide a continuous signal as more rarely used real-time SIM location (Blumenstock, 2012; Taylor, 2015).

Such challenges are not merely technical. In fact, they lead to a number of ethical and political questions on the usage of mobile data to track mobility, in particular in middle- and low-income countries. Taylor incisively notes that the usage of mobile data "is a balancing act between uncovering and obscuring specificity. Each of these two conflicting processes, however, has its problems: the data may be non-specific in ways the researcher does not understand due to cultural or geographic distance, and the necessary qualitative information is not easily accessible to researchers who are not social scientists." (Taylor, 2015, pp. 327–328). The creation of new fields of visibility is directly linked to identification and intervention, with major ethical and political issues on multiple scales. Translating this in practice: the increased spatial and temporal resolution of mobile data and the potential of big data analysis can definitively contribute to the understanding of mobility responses to both slow and rapid onset impacts of climate change, but the intrusive character of such methods raises concerns. For instance, there are substantial issues linked to anonymity: users can be identified even in spite of anonymization—either because of the possibility of reidentification of individuals (e.g., with triangulation with other datasets) or group visibility and identification at aggregate level. Even when not retraceable to individual users, even group identification can be problematic. For instance, while mobile data is used in anonymized form, it could allow for a fine tracking of the mobility patterns of specific groups, which could increase the surveillance on migrants by border agencies and other actors interested in controlling and curbing mobility. Also the reverse—what we could call invisibility—is a conundrum: if (maybe even for ethical reasons) the data and mobility of a user group are not captured, their (im)mobility is not recorded, which in turn could undermine the possibility to get their rights—for example to refuge or compensation—recognized (Taylor, 2015).

The case of Bangladesh, on which this section has focused, is illustrative of these serious challenges. Bangladesh lies in a complex borderland (Cons, 2018), where tracking mobilities in relation to natural hazards could easily serve hidden agendas around controlling population movements along, for instance, ethnic and religious lines. In an even more dystopian but far from unthinkable scenario, individual responses to an extreme event or even a stressor could be monitored and sanctioned or rewarded on the basis of their adherence to established guidelines and codes of conduct. The adapted/resilient subject would get a reward, while those who do not comply would be penalized. Also the prospect of big data powered anticipatory measures—for instance, deciding who and when is allowed to move in response to a stressor—present concerning implications (more on this in Section 6).

6 | FUTURE OUTLOOKS

While they have colonized almost all aspects of human life, digital technologies have until now been conspicuous by their absence in discussions around L&D. So far, potential digital approaches to L&D have only been implemented at the margins, in pilot projects or in niche sectors, often experimental, not yet viable for any impact evaluation or large-scale roll-out (see Section 5). However, this tendency is worth interrogating, not least because, while some of the hype might evaporate as the aura of novelty fades away, the digital turn is here to stay and is generating new modes of governance and participation that raise a number of technical, analytical, and normative questions (see Section 4).

In this section we take seriously the consequences that digitalizing L&D might entail. The legal and policy indeterminacy of L&D coupled with the broad boundaries of our definition of the "digital" make the following attempt to sketch future tentative outlooks of the digitalization of L&D both heuristic and speculative. The key questions (and future outlooks) remain uncertain and open, hence we limit ourselves to the identification of two problem-fields: do our proto-examples contain the seeds of new approaches, able to overcome the obstacles faced by modernist framings of L&D? How do they align with the modes of governances and political subjectivities that are emerging in contemporary political ontologies?

6.1 | Overcoming obstacles to identification, attribution and adjudication

Digital technologies could revolutionize the way in which climate impacts are made intelligible, measurable, and actionable, providing a substantial contribution to overcoming a series of hindrances to the implementation of L&D. Most current analogic approaches entail the following steps: a discrete identification of individual damages or losses; their attribution to climate change; and their compensation based on a human-operated assessment. This creates a series of technical challenges regarding identification, attribution, and adjudication. To begin with, the *identification* and attribution of L&D is an even bigger challenge than the quantification of emissions and mitigation targets (already extremely controversial, see the negotiations on the Kyoto Protocol and subsequent agreements). In that case, some of the technical difficulties were bypassed by the mere fact that a number was put on the emission target (Surminski & Lopez, 2015). For instance, in the case of the 1.5 or 2°C targets, the major difficulties in linking emissions, temperature levels, and impacts (Guivarch & Hallegatte, 2013; Randalls, 2010; Xu & Ramanathan, 2017) have been partially overcome by the "political investiture" the target has received. While this could theoretically also happen for L&D, it presents several additional layers of complexity, as L&D refers to downstream impacts rather emissions. A discrete detection of losses linked to extremely diffused impacts of climate change becomes practically unfeasible. Moreover, while attribution science had made huge steps forward (Otto, 2016; Stott et al., 2015; Trenberth, Fasullo, & Shepherd, 2015), none of the existing methods for attributing an individual "impact" to climate change is mature enough to be the basis to sanction liability or compensation in a legal court (Huggel, Wallimann-Helmer, Stone, & Cramer, 2016; Lusk, 2017; Mace & Verheyen, 2016; Parker et al., 2015; Surminski & Lopez, 2015). Big data, remote sensing, user generated data, smart meters, and mobile data promise to offer the possibility to detect and register the myriad smaller, diffused and fractional impacts of climate change, thus opening up fields of visibility entirely unknown to previous technologies and paradigm (Amoore, 2016). This potential is clear in all three dimensions considered in Section 5.

Difficulties around *identification* and *attribution* in turn complicate *adjudication*, which, to various degrees, is required by all framings of L&D. The idea of establishing a legal liability relies upon the establishment of some sort of "international court of climate justice." Such juridical authority seems hardly a solution to the impasse of L&D, given the sheer number of cases, and the mediation of climate impacts (Lees, 2017; Wrathall et al., 2015). Less radical proposals, for example, vulnerability reduction plans, or insurance schemes still require some form of adjudication or litigation, with similar problems. Even in this case, digital technologies could have a huge role: current algorithms based on machine learning and artificial intelligence can automatize decisions and reduce the need for human interventions. The new WIB schemes in Section 5.1 are a proto-example of possible developments. WIB insurance schemes comprise elaborate attempts to identify the causal links between weather phenomena, commodity markets, and farmers' crops and livelihoods, thereby making intelligible and governable forms of L&D otherwise too complicate and costly to address. The implementation of indexes through algorithms and user-generated data allows for a handling of weather signals that approaches real-time and could allow for very rapid responses not only to single weather events, but also to the combination of these, of specific individual choices by farmers (which contribute determining expected yields), and changes in markets. We can see here hints to an approach to (or mode of governance of) rural vulnerability based not on planning and preemptive initiatives, but on adaptive responses and reactions.

6.2 | Political feasibility—mainstreaming L&D though datafication?

Current difficulties in identification, attribution, and adjudication also impact L&D's *political feasibility*. As discussed in Section 2, most of the tools envisioned are analogic instruments based on discrete decision-making—all variations of the same modernist mode of governance (Bodansky et al., 2018; Ciplet, Roberts, & Khan, 2015; Lövbrand, Stripple, & Wiman, 2009; Stripple, 2005). The meager progress in climate action raises serious doubts over the possibility for these modes of environmental governance to bring about substantial change and mobilize enough political will to address the monumental challenge of L&D. Put it bluntly, if we are to take the idea of L&D seriously, it would entail either preempting the occurrence of damages and losses (thus mitigating global warming and/or financing "limits to adaptation") or compensating for the harm caused. Both options would in effect entail huge financial transfers from emitters to those vulnerable, either by taking on the costs necessary to achieve de-carbonization, or via direct transfers. Considering the inaction and lack of substantial commitments—the Paris Agreement being the latest debacle, the institutions and mechanisms of traditional multilateral environmental policy seem unlikely to be able to mobilize the resources that would be needed to implement any substantive L&D, at least in the forms it has been conceived thus far (Roberts et al., 2017). And indeed, in international negotiations, L&D were included only in very watered-down and ambiguous formulations, not least because of vetoes posed by key actors such as the United States or EU (Mace & Verheyen, 2016).

Without fetishizing digital technologies in their ability to generate more willingness to pay for the impacts of climate change, a digitalization of L&D could introduce a new political and economic "normal," leading to a mainstreaming and broader implementation of L&D. The shift towards digital technologies and algorithms would open up the L&D policy field to the extraction, elaboration, and commercialization of growing amounts of *data*, which is one of the most lively sectors fuelling contemporary capital accumulation. The success of business models profiting from the extraction and appropriation of data has been so remarkable (and disruptive) that it is often read as symptomatic of no less than the rise of a new phase of capital accumulation, what some refer to as "platform capitalism" (for a discussion, see Langley & Leyshon, 2017; Pasquale, 2016; Srnicek, 2017). By opening L&D into a field generating sensitive data, digital technologies might entail a political economic recasting of L&D, from representing a potential and very costly liability to a field of capital accumulation. Given the success of platform capitalism and data extraction in a number of economic sectors, this is a scenario worth taking into serious consideration, one that might prove instrumental in attracting resources to the L&D field and contribute to its affirmation. Put bluntly, while it seems unrealistic that the global North and new heavy emitters such as China will accept the liability to compensate for the harm caused by their emissions, a less unlikely situation would be one in which L&D was conceptualized and addressed via protocols that generate data and transferred resources through digitalized, diffused, microexchanges. It is left to be seen to whose advantage such a shift would be, and whether it would enable to address the injustices linked to L&D and climate change.

6.3 | Capitalizing on climate disasters?

A scenario in which climate vulnerability and more specifically L&D became a frontier for the generation, elaboration, and capitalization of data is indeed troubling, not least for those concerned with justice considerations. Here the notion of "data colonialism" introduced in Section 4 is highly relevant, as the implementation of digital projects could be driven by a thirst to get access to new forms of data produced by vulnerable communities. The appropriation of such data by powerful actors makes L&D into a potential frontier for what has been called a data-driven "accumulation by dispossession" (Thatcher et al., 2016). Here the case of smallholder farmers in the case of WIB insurance is exemplary of such risks, and the question of insurability introduced in Section 5.1 comes again to the fore. Digital tools could facilitate a rapid penetration of finance capital into climate vulnerability, which would very rapidly become at once a frontier for capital accumulation and a technique for the government of "surplus" populations. The production of marginalized populations and the privatization of their government (generating extremely profitable economic sectors) have been documented as the combined effects of financialization in a number of cases. Examples include: unemployment, pauperization, and social stigma in United Kingdom (Tyler, 2013); the illegalization of migration and the creation of segmented labor markets (De Genova, 2016; Mezzadra & Neilson, 2013); pauperization, social insecurity, and privatized penitentiary systems (Wacquant, 2009a, 2009b). The proliferation of digital forms of control could favor such developments also in the name of L&D and in the field of climate policy, with effects far from emancipatory.

6.4 | Bits of value and justice

In line with the critical approach sketched in Section 4, it is imperative to consider the justice implications of the digital in a number of domains and scales. As the case studies hint, very different outcomes are conceivable in this respect.

The dominant framework for articulating climate justice concerns in relation to L&D remains that of an "international court of climate justice." Efforts in this direction entail introducing a principle of liability, making those responsible for the harms caused by climate change responsible to compensate for the hardships and losses individuals or groups suffer. Such approaches require the collection of data documenting L&D associated with climate change. New modalities of data collection (e.g., crowdsourced or mobile phone-powered) do not necessarily imply a move beyond a legalistic approach (the "court paradigm"), but they could be leveraged to provide foundational evidence supporting legal cases. The efforts of Bangladesh to pioneer digitalized approaches (see the proto-example on disaster displacement) could be also read as an attempt to strengthen the case for liability by "digitalizing" it.

Contrarily to what the persistence of digital divides along a "North–South" line might suggest, the expansion of the digital could also undermine the global North's dominance in L&D policy arenas, rather than only reaffirming its current dominance. Albeit at a very initial stage, countries from the global South have started countering framings originating in the global North from "below," also by spearheading innovative initiatives that could (potentially) support claims for reparative, if not political, justice. While the Cambodian initiative (see Section 5.2) is at an embryonic stage, the case of Bangladesh is paradigmatic here (see Section 5.3). Decades of investments in "big-D" development, the large scale piloting (and failure) of microfinance, and the current "adaptation regime" have turned the country into a real-world laboratory for testing technologies and modes of governance promoted by international actors (Cons, 2018; Paprocki, 2018), and yet endorsed and manipulated at various scales by national policy makers and interest groups. Thanks to this process, Bangladesh has acquired an international status as a country at the forefront of climate adaptation in terms of both imaginaries and practice. It is not by chance that Bangladesh has a leading role in negotiating the "existential threat" framing of L&D in international fora, and is also promoting national-level efforts such as the idea to allocate reserve fund of the adaptation budget towards setting up a national loss and damage mechanism (Huq, 2018).

The mechanisms commonly suggested for the enforcement of responsibility for harm and the related transferal of resources raise concerns though. Since the outset of the L&D debate, insurance mechanisms have been the privileged option in order to "finance" compensation and reparation (Warner et al., 2012). This approach could allow parties and policy makers to provide fund while avoiding a direct assumption of responsibility. As put by Lees (2017), "states could be required to contribute to an insurance pool on the basis of their gross domestic product or similar, rather than relying on their previous emissions on the basis of historical responsibility, or their ongoing emitting activities" (Lees, 2017, p. 65). Still, a mere bypassing of direct climate responsibility allocation does not adequately answer questions of justice and liability at the very core of the L&D discourse. The digital divide and uneven (targeted?) access to technology (Lai et al., 2018) could add further layers of concern. The capillarity and deep penetration of digital tools could directly transfer broader unequal power relations onto the micro scale. Moreover, the changes in practices, values and knowledges entailed by digitalization intersect with and can reshape contextual power relations. For instance, going back to the case of new generation WIB schemes, the ways in which smart technologies and the production of data influence the behavior and agency of smallholder farmers deserves closer scrutiny, not least because of the power the big economic actors involved (re-insurers, global food chain suppliers) have to control such digitalized practices and design them to their advantage. In the case of Bangladesh, the traceability of population movements in response (also) to weather events could enable the government to enhance control of and restrictions on the mobility of certain groups, for instance along the lines of ethnicity and economic status. Conversely, the tracking of human mobility as well as web platforms (e.g., social media) could also inform migration decisions as well as heighten the role of social networks supporting migrants (on this see e.g., Boas, 2019).

7 | CONCLUSION: A DIGITAL PANOPTICON OR A TROJAN HORSE?

The digital and L&D are both here to stay. Bar a collapse of the whole world infrastructure—ICT, algorithms and AI will continue increasing their presence. While not necessarily under the name of L&D, the disruptive impacts of climate change will be a constant, and one way or another will be part of the "new norm" in the decades to come. By pointing to the "digital gap" that affects current approaches to L&D, we have tried to sketch some possible outlooks on how L&D could be framed and implemented once it moves on from modern paradigms of environmental governance. While we are aware of the risk of overemphasizing the potential novelty contained by the seeds explored here, the practices discussed do indeed hint at more experimental and "disruptive" approaches to L&D. New approaches could generate new practices and positions or, emphatically put, new realities. Quite obviously, new does not mean better or fairer, as a digitalization of L&D could lead to far from emancipatory or just solutions.

For instance, the ultimate goal of the monitoring of mobile data to grasp disaster displacement—on which the next wave of initiatives in Bangladesh seem to focus (see Section 5.3), is not just a clearer understanding of the causal links between cyclones or flooding and population movements, but also the real time detection of these signals and movements. In this, the next generation of algorithms can be expected to have a massive role and impact, as they could "learn to read" signals of an impending mass displacement and ignite responses to it—for example, increased transports, the mobilization of disaster relief, or increased police control. Whether this would entail saving lives and/or the enforcement of a capillary surveillance network and/or the eradication of old vulnerabilities via smart, bottom up adaptation strategies (in this, saving many lives) is still an open question. Seeds of such radical reconfiguring practices—albeit not necessarily in a desirable direction—can also be seen in WIB. While this might be a rather dystopian scenario, it is not unconceivable to foresee the emersion of "smart" monitoring devices that orient farmers' conduct (e.g., via water price variation) towards practices and responses deemed to be "resilient." The capillary sensing and targeted instant feedback enabled by digital technology can make an automated process rewarding or punishing.

Signs of experimental reconfiguration—and disruptive power—can definitively be seen in OS, which bypassed the racial and class barriers that led official relief operations to isolate and make invisible the condition, needs and agency of less affluent areas and groups (see Section 5.2). More speculatively, digital approaches (e.g., blockchain-based platforms) could become a "Trojan horse" highjacking the immobility of climate policy, by documenting with crowdsourced data the manifold losses produced by the impacts of climate change (and thereby forcing an implementation of climate liability from below) and/or by enabling grassroots, decentralized and cooperative adaptation strategies.

It is thus clear that the digital could lead in very different directions, different forms of governance, political subjectivities and in the last instance (in)justices. Will the digital make possible a hacking of the (rather immobile) climate policy machinery, or will it lead to a further financialization of climate disasters? It is too early to answer such questions. What is certain is that when searching for emancipatory approaches to loss (that neither repress its presence nor displace it onto someone else, elsewhere), the role of digital technologies and the possibilities they entail should be brought into the picture.

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CONFLICT OF INTEREST

The authors have declared no conflicts of interest for this article.

AUTHOR CONTRIBUTIONS

Giovanni Bettini: Conceptualization; writing-original draft; writing-review and editing. **Giovanna Gioli:** Conceptualization; writing-original draft; writing-review and editing. **Romain Felli:** Conceptualization; writing-original draft; writing-review and editing.

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ENDNOTES

[1]For instance, in their recent comprehensive review of literature on L&D published in this journal, McNamara and Jackson show that "mobility, post-disaster aid and disaster risk reduction, as well as risk-based insurance emerge as key themes"(2019, pp. 9–10).

[2]Formed in 2007, the CCRIF draws upon a regional fund jointly financed by Caribbean governments, allowing the CCRIF to respond promptly to hurricanes and earthquakes and limit their economic impacts by providing financial liquidity for participants (Gewirtzman et al., 2018).

[3]https://www.insuresilience.org.

[4]WINnERs stands for "Weather Index-based weather-driven Risk Services." It is a EU-funded project (Climate KIC Innovation Scheme) led by Imperial College London.

[5]https://mycoast.org.

[6]Symptomatic of the proliferation and mainstreaming of "smart" approaches to mobility is the widespread roll-out of such technologies as part of several countries' (e.g., South Korea, China, Italy) strategies to curb the spread of the Corona Virus.

[7]For a further articulation of this point, see Chandler's (2018) comparison between "modernist" and "sensing" modes of governance.

[8]The very architecture of the Paris Agreement signals a partial overcoming of multilateralism, with the emergence of hybrid forms of governance that rely on different actors, mechanisms and conceptualizations of justice/equality. Exemplary in this respect is the replacement of the system of mandatory negotiated emission reductions on which the Kyoto Protocol was built with a "flexible" system of voluntary pledges for emission reductions; of significance is also the growing centrality of cities and other non-state actors in the context of so-called polycentric forms of governance (Bulkeley, 2014; Jordan et al., 2015; Kuyper, Linnér, & Schroeder, 2018).

[9]For instance, in Ashgar Leghari v. Federation of Pakistan, a Pakistani farmer sued his government for failing to comply with Pakistan's Climate Change Policy. The court found in favor of Leghari, holding that Pakistan is "a victim of climate change and requires immediate remedial adaptation measures to cope with the disruptive climatic patterns." (Ashgar Leghari v. Fed'n of Pakistan, (2015) W.P. No. 25501/2015 (Pak.)).

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