Journal Pre-proof

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PII: S2212-4209(19)30230-4

DOI: https://doi.org/10.1016/j.ijdrr.2020.101539

Reference: IJDRR 101539

To appear in: *International Journal of Disaster Risk Reduction*

Received Date: 24 February 2019

Revised Date: 30 January 2020

Accepted Date: 18 February 2020

Please cite this article as: A. French, R. Mechler, M. Arestegui, K. MacClune, A. Cisneros, Root causes of recurrent catastrophe: The political ecology of El Niño-related disasters in Peru, *International Journal of Disaster Risk Reduction* (2020), doi: https://doi.org/10.1016/j.ijdrr.2020.101539.

Root Causes of Recurrent Catastrophe:
The Political Ecology of El Niño-related Disasters in Peru

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The authors acknowledge support for this research from the Zurich Flood Resilience Alliance Program.

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Abstract

Peru has experienced a long history of disasters linked to the El Niño-Southern Oscillation (ENSO), including during the global El Niño events of 1982-83 and 1997-98. This history has contributed to progress in ENSO forecasting and preparation, as well as broader development of the country's disaster risk management (DRM) capacities. Despite such advances, in early 2017 Peru was devastated by a localized "coastal El Niño" event. This study examines why the 2017 event proved so catastrophic, especially given Peru's substantial preparations for the 2015-16 global El Niño a year earlier. To address this question, the analysis applies a disaster forensics approach grounded in the interdisciplinary lens of political ecology. Drawing upon historical and institutional analysis and stakeholder interviews, the study describes how the geophysical characteristics of El Niño events interact with the extensive exposure and vulnerability of Peru's population and infrastructure to produce high levels of disaster risk. The study then examines the contemporary institutional context for DRM in Peru and describes recent measures to address El Niño-related risks specifically. While acknowledging challenges to DRM linked to El Nino's geophysical attributes, the analysis locates crucial root causes of Peru's recent El Niño disasters in socio-political and institutional characteristics—including centralization, sectoral division, and corruption—and describes how these factors undermine efforts to develop more integrated and robust DRM capacities. The analysis concludes with recommendations for conducting forensic studies of the political ecology of disaster in other contexts.

Keywords: disaster risk management (DRM); disaster forensics; El Niño–Southern Oscillation (ENSO); coastal El Niño; Peru; political ecology

1. Introduction

In January 2017, Peruvian society was caught off-guard by the rapid development of a "coastal El Niño" event that brought heavy rainfall and widespread flooding to the northern and central reaches of the country's Pacific slope. By late April, this unforeseen event would become the country's worst disaster in two decades, affecting more than 1.7 million people and leading to billions of dollars in damages and more than 130 casualties (INDECI 2017). Soon after the event's impacts began, the President of Peru's Council of Ministers, Fernando Zavala, described the situation as "anomalous" and stated that "definitively, we are not prepared as a country for this type of event" (República, 2017a)[1].

History, however, shows that while "coastal El Niño" events are comparatively rare, catastrophic disasters linked to the El Niño-Southern Oscillation (ENSO) are a recurrent feature of Peru's past (e.g. Seiner, 2001). Most recently, El Niño disasters of a similar severity to the 2017 event impacted the country in 1982-83 and in 1997-98. Since the 1997-98 event, Peru has substantially improved its El Niño monitoring and forecasting capabilities and has expanded the resources dedicated to disaster risk management (DRM) in efforts to address risks linked to El Niño as well as the country's high levels of seismic activity, recurrent droughts, and other hazard-producing phenomena (JICA, 2014). As a result, Peru's risk governance policies and institutional frameworks are currently well aligned with international recommendations for DRM, including those of the United Nations' Sendai Framework for Disaster Risk Reduction 2015-2030 (UN, 2015).

In this context of increased governmental action and expenditure in the DRM sector and improved capacities for confronting recurrent El Niño events specifically, this article examines why the 2017 event proved so destructive for Peru. To explore this question, we couple a stakeholder-focused, disaster-forensics approach with the critical historical and institutional lens of political ecology. Rejecting the idea of "natural" disasters, this political ecological approach locates the root causes of environmental change and disaster risks in political, economic, and cultural dynamics that link societies and the biophysical world across geographic and temporal scales (e.g. Blakie 1985; Watts 1983a). We apply this analytical perspective to the interacting components of El Niño-related disaster risk (i.e. hazard, exposure, and vulnerability), and to the contemporary institutional arrangements for risk reduction and DRM in Peru. Our analysis suggests that, while the 2017 event was anomalous in some ways (Rodríguez-Morata et al., 2018), the critical drivers of the ensuing disaster were underlying problems of exposure, vulnerability, and ineffective institutions that have persisted—and in some cases worsened—in Peru over recent decades despite widespread awareness of their contributions to disaster risk. Specifically, we underscore how enduring political centralization, sectoral divisions, and

[1] All translations by authors.

widespread corruption have allowed, and in some cases facilitated, the growth of exposure and vulnerability that undermines the nation's ongoing efforts to improve DRM capacities. We also highlight the substantial implementation gap between Peru's DRM policies and institutional framework and the systems that exist on the ground.

The article is developed in the following manner. Section 2 provides a brief discussion of theoretical and conceptual perspectives on disaster risk, political ecology, and forensic approaches to the study of disasters, and then outlines the methodological approach and data used in the article. Section 3 examines El Niño-related hazards, exposure, and vulnerability on Peru's Pacific slope, and Section 4 describes the institutional structure and recent innovations of Peru's evolving DRM system. Section 5 outlines the principal measures taken to prepare for the forecasted 2015-16 El Niño and surveys the characteristics and impacts of the unexpected 2017 event. Section 6 then provides a discussion of our key findings, and the concluding section reviews several lessons from the Peru case relevant to forensic investigation of disaster risk in other settings.

2. Interrogating the Interacting Drivers of Disaster

2.1 Political Ecologies of Disaster Risk

Nearly three decades of focus on disaster risk reduction (DRR) led by the United Nations has catalyzed significant national-level political commitment and institutional innovation centered on DRR. Nevertheless, disaster losses in economic terms continue to increase at the global scale, averaging US$ 250-300 billion annually by 2015 (UNISDR, 2015). And while some countries have seen promising declines in disaster-related mortality, these gains remain highly uneven with both mortality and economic losses resulting from high-frequency, lower-severity disasters (i.e. extensive risks[2]) continuing to increase in low- and middle-income countries (UNISDR, 2015). Making this situation worse, the effects of climate change are

[2] "Extensive risks are those that are most closely associated with underlying drivers, such as environmental degradation, social and economic inequality, poorly planned and managed urban development and weak or ineffective governance" (Oliver-Smith et al., 2016, 5).

expected to contribute to rising disaster impacts and losses in many settings in the future (IPCC, 2012).

In response to the pervasive challenges disasters continue to pose to livelihoods and economies around the globe, the *Sendai Framework for Disaster Risk Reduction 2015-2030* establishes a set of guiding priorities to reduce disaster risk while better integrating disaster resilience into mainstream development (UN, 2015). These priorities are: 1) understanding disaster risk, 2) strengthening disaster risk governance to manage disaster risk, 3) investing in disaster risk reduction for resilience, and 4) enhancing disaster preparedness for effective response and to "build back better" in recovery, rehabilitation, and reconstruction (UN 2015). The Framework's first priority, understanding disaster risk, is inarguably the foundation upon which the remaining priorities must be developed, and thus crucial to the entire process of risk reduction.

While seemingly straightforward, understanding the major drivers of disaster risk in specific contexts is complex and has led to enduring critiques of mainstream DRM perspectives that view disasters primarily as an outcome of extreme geophysical phenomena exogenous to the social-ecological systems in which they occur (Hewitt, 1983; Oliver-Smith and Hoffman, 1999). Political ecological perspectives in particular have emphasized the fallacy of the idea of "natural" disasters, instead underscoring the role of power-laden and uneven social relations and their interplay with the natural components of systems (Watts, 1983b; Blaikie et al., 1994). Work in many contexts has built on these perspectives to show how disaster risk is an outcome of geophysical phenomena and associated hazards interacting with social, cultural, political, and economic factors that produce differential levels of exposure, vulnerability, and resilience to these hazards (e.g. Pulwarty and Riebsame, 1997; Pelling, 1999; Wisner et al., 2004; Oliver-Smith, 2004; Ribot, 2014).

Although political ecology and other interdisciplinary approaches[3] have contributed to increased recognition of the diverse drivers of disaster risk in mainstream DRR planning and development (UN, 2005; UN, 2015), experts continue to note that "geophysical and geotechnical understanding is rarely brought together with social profiles of risk and response" and "the separate and interactive roles of natural and human drivers [of disaster risk] are still not adequately understood" (IRDR, 2011, 12-13). In light of this ongoing challenge to understanding the interacting components of disaster risk, the development and application of inter- and trans-disciplinary approaches grounded in the socio-environmental dynamics of specific empirical contexts remain crucial to advancing effective risk analysis and management (Oliver-Smith et al., 2016).

2.2 Disaster Forensics

Disaster forensics has emerged as one such integrated approach to systems-focused disaster risk analysis. The forensics approach[4], as outlined by the Forensics Investigations of Disasters (FORIN) research project, aims at understanding "the middle ground between the geophysical 'trigger' events and the response" in order to identify factors influencing "major policy choices" for risk reduction as well as "the many everyday incremental decisions and social and cultural practices, beliefs and perceptions that shape the resilience and vulnerability of communities" (IRDR, 2011, 8). Rather than focusing exclusively on the dynamics of individual disaster events and response efforts (although this is an important analytical component of the research process), disaster forensics is concerned with identifying the root causes of disaster risk and response capacity in specific settings over time. To examine these long-term drivers, the FORIN project proposes a systems-focused, interdisciplinary approach that integrates physical science perspectives on triggering events and environmental conditions with social science perspectives on factors including institutional and organizational features, political economic structures, and governance arrangements (Oliver-Smith et al., 2016). Notably, forensics research as envisioned by the FORIN project also entails careful attention to distributional issues and

[3] For example, the "climate affairs" approach advocates careful attention to the interplay of social and natural dynamics and has been applied to analyzing El Niño impacts both in Peru and more broadly (e.g. Glantz, 2003; Ramírez 2019).
[4] Proponents of the approach use the word *forensic* to "signify systematic, probing, and dispassionate investigations, rather than suggest links with morbidity, post-mortems, or criminal detective work" (IRDR 2011, 8).

inequalities in access to both material and immaterial resources, including decision-making capacities and the broader power dynamics in which such capacities are embedded (Oliver-Smith et al., 2016).

The FORIN project's disaster-forensics approach has given rise to and influenced a variety of systems- and event-focused disaster analyses and frameworks in recent years (e.g. Fraser et al., 2016; Masys, 2016; Schröter et al., 2018). The emphasis of these studies ranges widely as does the degree to which each adheres to the FORIN approach and methods. Here, we engage in greater detail with one such framework and application, the Post Event Review Capability (PERC) developed by the Zurich Flood Resilience Alliance (Venkateswaran et al., 2015). In brief, PERC is a systematic framework for disaster-event analysis that examines how a specific hazard event produces a disaster by evaluating "successes and failures in the management of disaster risk prior to the event, disaster response and post-disaster recovery" and "identifies future opportunities for intervention/action that could reduce the risk posed by the occurrence of similar, future hazard events" (Venkateswaran et al., 2015, 4). PERC analyses rely heavily on semi-structured interviews with DRM experts and stakeholders affected by the disaster *in situ*, who are typically identified through snowball sampling methods. Approximately a dozen PERC analyses have been undertaken to date, and a meta-analysis covering seven of these studies provides an overview of crosscutting themes and lessons (Keating et al., 2016)[5].

The following analysis of El Niño-related disasters in Peru takes the PERC methodology as a point of departure but incorporates a detailed historical and political ecological perspective on the creation of vulnerability and on processes of policy formation and institution building. In this way, our analysis is closely aligned with the focus on root causes proposed by the FORIN project, and underscores the need for thorough empirical attention to the diverse and interacting drivers of disaster risk.

2.3 Methods and Data

[5] See: <https://www.zurich.com/en/corporate-responsibility/flood-resilience/learning-from-post-flood-events>

This analysis, which expands upon findings from two recent studies of El Niño-related impacts in Peru (French and Mechler, 2017; Venkateswaran et al., 2017), is based on a combination of desk-based research and interview-focused fieldwork. The desk-based component entailed the collection and analysis of formal laws, policies, plans and institutional frameworks; information on institutional websites; press coverage of DRM activities and disaster events; meteorological and hydrological data; and peer-reviewed and gray literature. The field component included semi-structured and unstructured interviews, site visits, and field evaluations with government, private-sector, and NGO officials involved in DRM at local, regional, and national levels in Peru; interviews and informal conversations with professionals, researchers, and citizens involved in varied aspects of DRM in Peru, and interviews with stakeholders directly impacted by El Niño-related hazards in 1982-83, 1997-98, and 2017 in the regions of Piura, La Libertad, Ancash, and Lima.

3. Key Components of El Niño-related Risk in Peru: Hazards, Exposure, and Vulnerability

3.1 El Niño and Related Hazards in Peru

The El Niño-Southern Oscillation (ENSO) is a coupled oceanic-atmospheric phenomenon in the tropical Pacific that produces variations in wind patterns, sea-surface temperatures, and precipitation levels over an approximately 2-7 year timescale and is credited with being the planet's strongest source of inter-annual climate variability (Cane, 2005; McPhaden et al., 2006). ENSO is best-known for the effects of its warm phase, El Niño, which is characterized by a weakening of the easterly trade winds and warmer than normal sea-surface temperatures (SST) in the central to eastern reaches of the equatorial Pacific along with an associated decline in the upwelling of cold, nutrient-rich waters off the western coast of central South America (Quinn et al., 1987; Trenberth, 1997). These anomalously warm SSTs off the northern and central Peruvian coast often—but not always—drive enhanced convection that produces heavy rains and flooding in this usually arid region, while also displacing the vast anchovy schools that are the cornerstone of the region's fishery (Caviedes, 2001; McPhaden et al., 2006). Additionally, during some El Niño years an intensification of the annual rainy season occurs in Peru's central highlands and along parts of the southern coast while drought conditions may develop in the southern highlands (Vuille et al., 2008).

Archaeological and historical evidence illustrates how these El Niño-related phenomena have affected Andean and coastal cultures in this region for centuries, if not millennia (Orlove et al., 2000; Caviedes, 2001; Seiner, 2001; Dillehay and Kolata, 2004). The heavy precipitation characteristic of severe El Niño years is particularly destructive on the Pacific slope through a combination of the direct impacts of rainfall on vulnerable infrastructure, riverine flooding, and debris flows (known locally as *huaicos*) that are triggered by flash flooding in steep, unstable terrain. In the 1997-98 El Niño, for example, intense rains (34%), flooding (23%), and huaicos (18%) accounted for 75% of the 1301 total emergency events reported (CAF, 2000). While the entirety of the Pacific slope may be impacted by these phenomena, intense rains and flooding are typically most severe in the northern departments of Tumbes, Piura, and Lambayeque, while huaico impacts are most prevalent in the steeper terrain of the central and southern departments of La Libertad, Ancash, Lima, and Arequipa (INDECI, 2015).

Although El Niño events are recurrent and forecasting capabilities have improved considerably over the last several decades (Chen et al., 2004), the onset, duration, and intensity of specific events remain impossible to predict precisely (Glantz, 2015) and the spatial and temporal variability of impacts between different events is high (Cane, 2005; Takahashi and Dewitte, 2016). For example, in Peru the 1982-83 and 1997-98 events differed substantially in their impacts, with only the former causing severe drought in the southern highlands and only the latter causing heavy rains and flooding on the central coast (CAF, 2000; Velasco-Zapata and Broad, 2001). More recently, the 2015-16 El Niño, which featured positive Oceanic Niño Index (ONI)[6] values slightly stronger than the 1997-98 event, was predicted to bring severe impacts to Peru, but instead produced relatively moderate effects in only a few regions of the country (INDECI, 2015; Ramírez and Briones, 2017). This variability and uncertainty inherent to El

[6] The Oceanic Niño Index (ONI) tracks 3-month average sea surface temperatures (SST) in the east-central Pacific Ocean between 120°-170° W longitude (the Niño 3.4 region). To calculate ONI, the average SST in the Niño 3.4 region is calculated and then averaged with the values from the previous and following months. The resulting three-month average is then compared to a 30-year average and the observed difference between these values is the ONI value for a specific 3-month period; when the index is +0.5°C or higher, El Niño conditions exist (Dahlman, 2009). As occurred in 2017, the ONI index is not always a reliable predictor of El Niño-like conditions in coastal Peru, leading Peruvians to develop their own "Coastal El Niño Index" (Ramirez and Briones, 2017).

Niño creates significant challenges for forecasting, public communication of risks, and the disaster readiness of policymakers, risk managers, and broader society (Glantz, 2015).

Even less predictable than global ENSO dynamics are those of the so-called "coastal El Niño" phenomena (*El Niño costero*), including the localized events of 1925 and 2017 that occurred during seasons when ONI values were near neutral (Rocha, 2011; Takahashi and Martínez, 2019; Ramírez and Briones, 2017; Rodríguez-Morata et al., 2019). The 2017 event specifically featured rapid warming of SSTs off the northern-central Peruvian coast in late December and early January, reaching a peak of 5-6°C above average in some locations at the end of January (ENFEN, 2017; Garreaud, 2018). This rapid warming and the associated onset of extreme precipitation in the absence of anomalously high ONI values surprised both Peruvian and international forecasters, as well as emergency response systems. Post-event analysis of rainfall levels between January and March 2017 illustrate that precipitation "exceeded the 90th percentile of available records (1981-2017) over much of the northern and central coasts of Peru, the Andean region, and Amazonia" and were comparable only to 1982-83 and 1997-98 (Rodríguez-Morata et al., 2019, 5605). The event was especially unusual as it occurred in the year following a very strong global El Niño (Rodríguez-Morata et al., 2019), and explanations of its causes are still emerging (Garreaud, 2018; cf. Takahashi and Martínez, 2019).

The influence of climate change on the frequency and intensity of future El Niño events creates additional uncertainty for DRM. Despite sustained scientific inquiry, little consensus has emerged over how global warming will affect the diverse oceanic and atmospheric conditions that drive ENSO, and whether climate change will ultimately enhance or dampen the phenomenon and its impacts (Collins et al., 2010). Recent research with grave implications for disaster risk, however, predicts a doubling in the frequency of extreme El Niño events globally under even 1.5°C of warming, with this increased prevalence continuing for up to a century after the stabilization of global mean temperature (Cai et al., 2014; Wang et al., 2017). With regards to event intensity, analysis of precipitation levels in Peru during early 2017 indicates that rainfall amounts "unprecedented (i.e. 100th [percentile])" in the observational record (1981-2017) occurred at 16 gauge stations on the country's north coast and west Andean slope during January, February, and March (Rodríguez-Morata et al., 2019, 5611). Relatedly, respondents in our study from the regions of Lima and La Libertad (Central Andes) described the occurrence of unusually intense, short-duration rainfall events (i.e. over hourly time frames) that contributed to some of the worst huaico and flash-flooding impacts in these areas. While such limited observations should not be interpreted as indicative of trends, they do highlight the importance of continued investigation and analysis of event impacts at local scales. Moreover, regardless of continuing uncertainty about climate change's long-term influence on El Niño, recent events underscore the urgent need for permanent disaster readiness in regions like western Peru where events are recurrent—and may arrive without forewarning—and where exposure and vulnerability to El Niño-related hazards is pervasive.

3.2 Exposure to El Niño-Related Hazards on Peru's Pacific Slope

In late 2015, in the context of a developing El Niño with ONI values similar to those of 1997, Peru's National Institute of Civil Defense (INDECI) conducted an analysis of the country's El Niño-related hazard exposure. Using inputs including topographic and demographic data, reports of hydro-meteorological emergencies between 2003-15, and precipitation records and emergency statistics from the 1997-98 El Niño event, the analysis concluded that approximately 9.4 million residents (almost a third of the country's total population), 39,000 schools, 6,000 health facilities, and nearly 20,000 km of improved roads featured high levels of exposure to damage from a significant El Niño (INDECI, 2015).

Much of this exposure to El Niño-related hazards is concentrated on the country's Pacific slope, where rapid urban population growth and infrastructural expansion have occurred over the last several decades. This region's settlement patterns and the resulting hazard exposure are strongly influenced by both physical geography and hydrography. The Pacific slope consists of an arid coastal plain that receives negligible precipitation during most years and the adjoining steep western side of the Andean escarpment, which is characterized by a seasonal hydrologic regime with substantial precipitation and surface-water flows in most areas restricted to the tropical rainy season (~December-March) (ANA, 2015). The region is divided into 62 major watersheds, which contain numerous tributary catchments (known locally as *quebradas*). On average, Peru's Pacific slope receives only 1.8% of the nation's total freshwater reserves despite sustaining approximately 65% of the country's population and 80% of its annual economic production (ANA, 2015). There is thus high dependence on very limited water resources, and much settlement and infrastructure development is concentrated near major water sources (e.g. adjacent to river courses or in flood plains), often without attention to the periodic hazards generated by the low-probability, high-damage events of severe El Niño years (CAF, 2000; Velasco-Zapata and Broad, 2001).

Western Peru's geophysical characteristics, however, are but one of the factors contributing to its high levels of El Niño-related hazard exposure (Velasco-Zapata and Broad, 2001; Trigoso Rubio, 2007; Ramírez, 2019). Also crucial are the social and institutional conditions that have long supported settlement and development in hazard-prone areas despite the impacts of recurrent disasters. A fundamental element in this ongoing growth in exposure has been the rapid and often unplanned character of Peru's urbanization process: between 1950 and 2010 the percentage of the population living in urban areas increased from 41% to 77%, with roughly a third of the country's population now concentrated in the capital of Lima alone (Calderón et al., 2015). This process of rural to urban migration intensified in the 1980s and early 1990s in the midst of widespread violence linked to internal conflict and severe economic crisis, which constrained resources and policy focus for urban planning (Seminario and Ruiz, 2008). Additionally, neoliberal reforms in the 1990s facilitated the rise of export-oriented agricultural operations in several parts of the country's coastal plain, which led to the establishment of large-scale irrigation infrastructure and new residential areas, often in hazard-prone settings (Eguren, 2006).

With Peru's strong economic recovery in the early 21st century, growing urban economies have continued to drive high demand for residential and commercial real estate in increasingly densely populated areas. A lack of zoning measures and a generally permissive official stance on informal land occupation has allowed the development of numerous urban and peri-urban settlements (*asentamientos humanos*) in hazard-prone spaces, including along periodically flooded watercourses and huaico-exposed hillsides (Calderón et al., 2015; León Almenara, 2017; Seminario and Ruiz, 2008) (Figure 1). The settlement of these areas is frequently orchestrated by land-trafficking mafias who plan coordinated group "invasions" that are more difficult for authorities to control than isolated land occupations by individual households (Hawley et al., 2018; Seminario and Ruiz, 2008). Despite the illegality of these invasions, municipal governments and other authorities responsible for providing land titles and certificates of possession to homeowners often support such occupations through formal recognition of tenancy or ownership (Calderón, 2013). With this recognition, households can legally connect to public services and utilities (Calderón et al., 2015); and, as communities become permanently established and expand, public institutions such as schools and health centers may locate nearby. Moreover, once established, the relocation of even the most severely exposed communities has proven difficult for policymakers and risk managers (e.g. La República, 2016).

Figure 1: Peri-urban settlement in a huaico-exposed valley outside Lima, Peru. Credit: Soluciones Prácticas

3.3 Vulnerability to El Niño in Peru

In simple terms, vulnerability can be understood as susceptibility to harm from exposure to a specific hazard. While this broad definition may be adequate for describing the physical vulnerability of critical infrastructure, it does not sufficiently capture the complexity of social vulnerability. Overlapping with the concepts of resilience and adaptive capacity, social vulnerability has been defined in the context of natural hazards as “a measure of both the sensitivity of a population to natural hazards and its ability to respond to and recover from the impact of hazards” (Cutter and Finch, 2008, 2301). Social vulnerability is frequently associated with quantitative measures of poverty; yet, while poverty is closely linked to vulnerability in many contexts, it does not account for other important material and social relations that can significantly reduce or amplify both sensitivity to harm and response capacity (Turner, 2016). In this research, we conceive of social vulnerability in relational terms, recognizing how it is shaped by both material factors and the broader social structures and dynamics in which entities (e.g. individuals, households, communities) and their daily actions are embedded (Sen, 1981; Watts, 1983b; Bohle et al., 1994; Oliver-Smith, 2004). This perspective stresses the inherent heterogeneity of vulnerability among groups and populations, even at very fine scales (e.g. the household), as well as the importance of interdisciplinary approaches and detailed empiricism for analyzing the mutualistic and systemic character of vulnerability’s linked material and social drivers and outcomes (e.g. Mark et al., 2017).

3.3.1 Physical Vulnerability

Peru’s physical infrastructure in both urban and rural spaces has expanded substantially in recent decades (Webb, 2013), but the characteristics of much of this growth have made critical infrastructure highly vulnerable to the impacts of extreme El Niño events and other disasters (Table 1) (CAF, 2000; Caviedes, 2001; Velasco-Zapata and Broad, 2001). The majority of construction in the country occurs informally and without building codes or supervision, especially in the residential sector, where estimates suggest 70% of buildings are informal (La República, 2018a). Inexpensive, locally sourced building materials such as adobe brick, woven fiber (*esteras*), and cane reinforced with stucco (*quincha)* are common in rural areas and *asentamientos humanos* (Trigoso Rubio, 2007; Calderón et al., 2015). These materials are highly susceptible to damage from heavy rainfall and flooding; but, given the typical aridity of western Peru, even improved homes may not be built to withstand such impacts. Structural damages have also plagued facilities providing critical public services, including health posts and schools, where service interruption can generate important indirect effects (CAF, 2000; Ramírez, 2019).

	1982-83	1997-98	2017
Population	512 deaths, 1,304 injuries, 1.27 million affected	366 deaths, 1,040 injuries, 531,104 affected	138 deaths, 459 injuries, 1.45 million affected
Transportation	2,600 km. of highway damaged, 47 bridges destroyed	3,136 km. of highway damaged, 370 bridges destroyed	13,311 km. of highway damaged, 449 bridges destroyed
Housing	98,000 homes destroyed, 111,000 homes damaged	42,342 homes destroyed, 108,000 homes damaged	63,802 homes destroyed, 350,181 homes damaged
Education	875 schools damaged	956 schools damaged	2870 schools damaged
Health	260 health posts damaged	580 health posts damaged	934 health posts damaged
Total Monetary Losses US$	3.28 billion (1998)	3.5 billion (1998)	3.1 billion (2017)

Table 1: Recorded El Niño-related impacts to Peru's population and infrastructure in the events of 1982-83, 1997-98, and 2017 (INDECI, 2016; INDECI, 2017).

Water and sanitation networks are also extremely vulnerable in many contexts. Intake and treatment infrastructure for both irrigation and potable water systems must often be located in flood-exposed watercourses, and water-transport infrastructure (e.g. canals, aqueducts, and pipes) frequently traverses steep, erosion-prone hillsides or may be located on bridges or in watercourses where it is vulnerable to high flows (CAF, 2000; Ferradas, 2000). In the 2017 event, potable water provision was interrupted for days at a time in many locations, including in the major urban centers of Lima and Trujillo (La República, 2017b). Surface-water drainage networks and sanitation systems—where they exist at all— often suffer from a lack of regular maintenance, which predisposes them to clogging and overflow during periods of heavy runoff (MVCS, 2016). Compounding direct damages to infrastructure, flooding impacts on the water and sanitation sectors contribute to a range of secondary impacts linked to contaminated drinking water supplies, standing water, and mud and dust that remain after flood waters have receded. These include outbreaks of water- and mosquito-borne diseases including malaria, cholera, dengue, and leptospirosis along with increased prevalence of skin and eye infections, especially in children (CAF, 2000; Ferradas, 2000; Ramírez 2019).

Peru's road network, which has grown substantially over recent decades (Webb, 2013), is also highly vulnerable to El Niño-related hazards. Both asphalt and dirt roads in the Andean foothills and highlands traverse steep and unstable terrain and cross or run in close parallel to major watercourses. On the coastal plain, road and bridge infrastructure may be built to withstand the precipitation and stream-discharge levels associated with low-intensity flood events but has failed catastrophically under the conditions of more severe El Niño events (CAF, 2000; Velasco-Zapata and Broad, 2001). Damages in the transportation sector often compound impacts in other sectors due to problems of isolated populations and restricted access (CAF, 2000; Ferradas, 2000; Ramírez, 2019). In the 2017 event, at least 20% of the nation's principal highways suffered significant damages, and movement along the Pan-American highway and other major north-south connectors was interrupted in several locations due to bridge failures, complicating evacuations and relief efforts (La República, 2017c).

In many settings, the extreme vulnerability of critical infrastructure has long been recognized, and plans for improvements have been developed but not implemented. For example in the northern cities of Piura, Sullana, and Lambayeque, urban planning processes identifying physical risks and potential mitigation strategies were conducted after the 1982-83 El Niño event, but their recommendations were never implemented, leading many of the same areas to be heavily damaged in the 1997-98 event (CAF 2000; Velasco-Zapata and Broad, 2001)[7]. Similar patterns occurred in many regions affected by the 1997-98 event and again by the 2017 coastal El Niño. In the wake of the 2017 event, a nationally led reconstruction effort has developed plans for comprehensive risk-reduction activities, including basin-level drainage projects and the fortification and relocation of infrastructure located in high-risk zones (e.g. La República, 2018b). Nevertheless, effective implementation of such plans remains a long-term challenge as the government has struggled to meet even the basic needs of displaced populations more than a year after the triggering event (Peru, 2018).

[7] In some cases, infrastructure failures during extreme El Niño events have led to improvements. Velasco-Zapata and Broad (2001), for example, describe the effective redesign of the highway linking Piura and the port of Paita, which was submerged in the 1982-83 event and rerouted such that it was not impacted severely during the 1997-98 event.

3.3.2 Social Vulnerability

Supported by high levels of foreign investment and relatively stable prices for primary exports, Peru's economy has experienced impressive growth over recent years, with an average expansion of 6.5% between 2005-2012 (Mendoza Nava, 2015). This growth has generated both employment and substantial tax revenue and has contributed to increased public spending, infrastructure development, and service provision. For 2017, national figures for the percentage of the population experiencing monetary poverty was reported at 21.7%, showing a decline of more than 20 percentage points since 2007 (INEI, 2018). Non-economic indicators of wellbeing such as life expectancy, years of schooling, and access to piped water and sanitation have also improved over recent decades (Calderón et al., 2015), and Peru is now positioned in the United Nations Development Program's "high human development" category based on the multi-criteria Human Development Index (UNDP, 2016).

These improvements in composite measures of poverty and wellbeing hide high levels of inequality, however, including substantial differences in poverty rates between urban (15%) and rural (44%) areas, as well as the country's persistently high Gini coefficient (.43 in 2017 down from .50 in 2007) (INEI, 2018). Large differences in poverty levels and access to services also exist across racial and cultural divisions. For example, in 2016, native Spanish speakers experienced a much lower monetary poverty rate (17.8%) than native speakers of an indigenous language (32.6%) (INEI, 2017). Additionally, access to services such as safe drinking water, electricity, and sanitation infrastructure as well as public assistance programs is highly variable across the national territory and population (Mendoza Nava, 2015). While such access is markedly higher in urban than rural areas, many urban and peri-urban households—especially those without proof of property ownership—still lack basic services[8].

Increased financial resources and expanded infrastructure and services have improved the basic capacities of governments and many individuals to prepare for and respond to disasters, but social vulnerability continues to be exacerbated by a range of structural and institutional factors

[8] For example, an estimated 450,000 households in Metropolitan Lima live in districts where average water consumption is below the UN's 50 liter/day minimum requirement for human needs (Mendoza Nava, 2015).

(Trigoso Rubio, 2007). Equitable public access to effective and accountable democratic institutions remains a particularly critical challenge. This challenge was exacerbated by the structural adjustments and political strategies of President Alberto Fujimori's administration (1990-2000), which controlled hyperinflation and internal insurgency but was characterized by an extreme centralization of power in the executive branch and the stagnation or decline of institutional capacities at other state levels (Crabtree and Thomas, 1998; Velasco-Zapata and Broad, 2001). These characteristics built upon Peru's long history of political and economic centralization and undermined nascent efforts to build administrative and fiscal capacities at subnational levels (Gonzalez de Olarte, 2004). Since Fujimori's abrupt downfall in 2000 due to corruption and human rights abuses, Peru has renewed its decentralization process. Nevertheless, the creation of effective institutions at both national and subnational scales faces continued challenges amidst a proliferation of political parties and frequent administrative and policy changes and high staff turnover that undermine the consistent protocols, clearly delegated responsibilities, and intersectoral collaboration necessary for effective DRM initiatives (Velasco-Zapata and Broad, 2001; Crabtree, 2006; McNulty, 2011; UN, 2014).

The governance challenges related to a lack of effective and accountable institutions contribute to social vulnerability in diverse ways, including by undermining government's capacity to provide critical infrastructure and basic services, by creating uneven implementation of and access to state programs and resources, and by fostering conditions for corruption and diminishing trust in public institutions more broadly. Widespread corruption has proven particularly problematic in Peru, as bribery and illicit influence can be crucial to accessing basic services and fraudulent use of tax revenues and budget allocations for public works have undermined service delivery and development efforts in many contexts (e.g. Kaufmann et al., 2008; La República, 2017c; Nureña and Helfgott, 2019).

4. Peru's Institutional Context for Disaster Risk Management

Peru's history of disasters linked to geophysical phenomena (including El Niño events, earthquakes, and avalanches and glacier lake outburst floods) has made disaster risk reduction and disaster response a national priority in specific regions at various times during the nation's past (Oliver-Smith, 1986; Seiner, 2001; Carey, 2010). Nevertheless, sustained institutional development for DRM did not really begin until the early 2000s, with earlier efforts focused on emergency response to individual disasters (UN, 2014). The devastation caused by the 1997-98 El Niño, even after months of preparation[9], underscored the need for more comprehensive and effective DRM approaches. In 2005, in-line with the Hyogo Framework (UN, 2005) and with external funding and technical support, Peruvian policymakers began to debate institutional reforms that would expand and decentralize the country's National Civil Defense System (UN, 2014). In 2007, the urgent need for such reform was reiterated by challenges in responding to and recovering from the 7.9-magnitude Pisco earthquake (Elhawary and Castillo, 2008).

In 2010, Peru's National Accord (*Acuerdo Nacional*) focused its annual policy directive on the establishment of a more integrated and decentralized DRM policy[10]. In early 2011, this vision was formalized with the passage of Law N° 29664[11], which created the National System for Disaster Risk Management (SINAGERD) and shifted the country's DRM agenda towards more prospective and corrective measures. SINAGERD's creation also expanded the organizational structure for DRM, creating new state entities and formally incorporating diverse actors from across governmental levels and sectors (Figure 2).

Under the 2011 legislation, the Presidency of the Council of Ministers (PCM) heads SINAGERD's governing hierarchy, with support from an inter-ministerial, advisory council (CONAGERD) that includes the President of the Republic and nine principal ministries as well as the National Center for Strategic Planning (CEPLAN)[12]. Beneath the PCM, two organizations

[9] Forecasts for a strong El Niño permitted the investment of US$ 219 million in 700 mitigation projects. Most were short-term in nature and many of the recommendations stemming from the 1982-83 El Niño were not implemented (CAF 2000; Velasco-Zapata and Broad, 2001).
[10] The National Accord is a non-partisan, political advisory panel established in 2002 to support Peru's sustainable development and democratic governance through inclusive consultation and dialogue; for the text of the panel's directive on DRM see <https://acuerdonacional.pe/politicas-de-estado-del-acuerdo-nacional/politicas-de-estado%e2%80%8b/politicas-de-estado-castellano/iv-estado-eficiente-transparente-y-descentralizado/32-gestion-del-riesgo-de-desastres/>.
[11] For full text of the Law see < https://busquedas.elperuano.pe/normaslegales/ley-que-crea-el-sistema-nacional-de-gestion-del-riesgo-de-de-ley-n-29664-605077-1/>.
[12] Although not formally included in the structure outlined by Law N° 29664, several government agencies provide important climate assessment and weather monitoring and forecasting services relevant to El Niño preparation and response. These agencies include the National Geophysical Institute (IGP) and the National Meteorology and Hydrology Service (SENAMHI), both of which also participate in the Multisectoral Committee for the Study of El

within the Ministry of Defense—known by the acronyms INDECI and CENEPRED—are tasked with implementing the technical aspects of DRM policy. The National Institute for Civil Defense (INDECI) directs reactive measures including disaster preparation, response, and rehabilitation. Reflecting the country's longstanding focus on emergency response, INDECI has existed in the Peruvian bureaucracy for more than four decades and currently has a decentralized presence through offices in each of the country's 26 political regions and through a network of Regional and Local Emergency Operation Centers (COERs and COELs). In complement to INDECI, the National Center for Estimation, Prevention, and Reduction of Disaster Risks (CENEPRED) oversees prospective and corrective measures as well as processes of reconstruction. In contrast to the longstanding and decentralized character of INDECI, CENEPRED was established in 2011 with the creation of SINAGERD, and is a Lima-based institution with a mandate to coordinate with subnational governments through DRM working groups. While separate responsibilities are formally delimited for the PCM, CENEPRED, and INDECI, substantial overlaps in focus and challenges in coordination between these groups have led to critiques of a multi-headed system that has not yet achieved functional integration (UN, 2014). In an explicit effort to improve the efficiency of the system, the SINAGERD hierarchy was restructured in early 2017 through the dissolution of the DRM secretariat within the PCM (whose responsibilities were transferred to INDECI) and the consolidation of CENEPRED within the Ministry of Defense[13].

Niño (ENFEN) that provides permanent monitoring and monthly reports of ENSO indicators and conditions (French and Mechler, 2017).

[13] See Supreme Decree Nº 018-2017-PCM; full text available at <https://busquedas.elperuano.pe/normaslegales/decreto-supremo-que-aprueba-medidas-para-fortalecer-la-plani-decreto-supremo-n-018-2017-pcm-1486525-1/>.

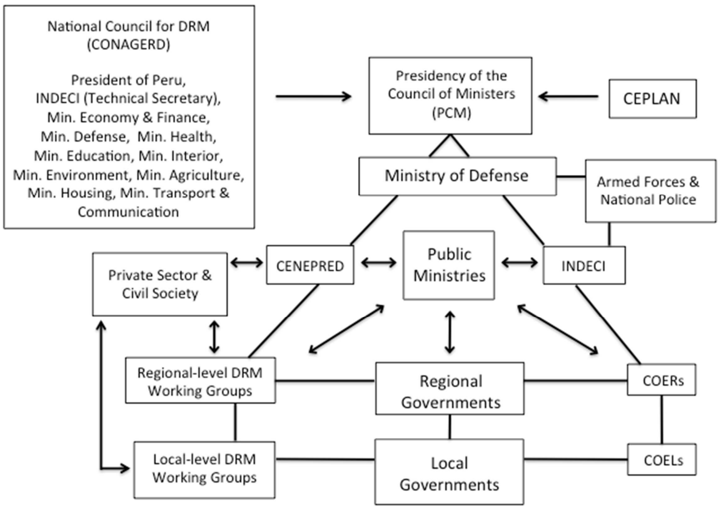

Figure 2: Institutional actors and structure of Peru's National System for Disaster Risk Management (SINAGERD).

The fact that many crucial DRM processes are tasked to specific governmental ministries rather than INDECI or CENEPRED adds further complexity to SINAGERD's functioning. These ministries feature their own internal governing structures and institutional cultures; and while high-level councils such as the PCM and CONAGERD support inter-ministerial integration, respondents emphasized that achieving coordination in the day-to-day activities of distinct sectoral bureaucracies remains complex and incomplete. One important example of these coordination challenges can be seen in the planning and zoning processes to prevent occupation of hazard zones. While the National Water Authority (located within the Ministry of Agriculture and Irrigation) is responsible for delineating buffer zones (*faja marginal)* around watercourses, which are some of the foremost hazard zones in the country, responsibility for landscape-scale planning and zoning processes (*ordenamiento territorial*) are divided between the Ministry of the Environment and the Ministry of Housing, with the former tasked with processes of territory-wide "ecological and economic zoning" in conjunction with regional governments and the latter focusing on development in urban contexts. Notably, each of these zoning processes remains disarticulated from the others and only partially implemented at the national scale. Relatedly, in

2012, Law N° 29869[14] was passed to regulate the relocation of populations inhabiting zones of immitigable risks. This legislation establishes the formal process through which the determination of immitigable risks and subsequent voluntary or involuntary relocation should occur, designating specific responsibilities to local and regional governments, to CENEPRED and INDECI, and to the Ministry of Housing. Since its passage, however, the law has seen little implementation and, in at least one setting, has been resisted by residents[15].

Despite SINAGERD's centralized hierarchy, the system is founded on a subsidiarity principle that considers regional and local governments as the principal executors of DRM activities. Accordingly, DRM decisions should be made at the lowest level possible, and national-level authorities should only intervene when capacities at local and regional levels are surpassed. Under the law, DRM working groups instituted by governments at regional and local levels are tasked with evaluating disaster risks and social vulnerabilities and developing strategies for their reduction, while emergency disaster response is directed by INDECI's decentralized COERs and COELs—together these subnational entities replace the Civil Defense Committees that existed prior to the 2011 legislation. Reiterating findings from earlier studies**,** many of our respondents underscored problems stemming from the fact that although the law recognizes and formalizes the crucial role of subnational actors in DRM, these groups remain insufficiently resourced and underdeveloped across the national territory (Velasco-Zapata and Broad, 2001; Elhawary and Castillo, 2008; UN, 2014).

Additional groups included formally in SINAGERD include the Armed Forces and National Police, who play key roles in disaster response. In very general terms, the law also formally includes the "participation of private entities and civil society" and mentions a range of examples including universities, the corporate sector, NGOs, and volunteer organizations like the Red Cross. In practice, these groups play important roles in many contexts, with diverse NGOs contributing to preparedness and response measures through local-level engagements, and the

[14] For full text of the law see <https://busquedas.elperuano.pe/normaslegales/ley-de-reasentamiento-poblacional-para-zonas-de-muy-alto-rie-ley-n-29869-794288-2/>
[15] In the Municipality of Chosica, authorities declared the neighborhood at the foot of the Carosio quebrada as a zone of immitigable risk, ordering the relocation of ~140 households. Most of the population refused to be relocated (La República, 2016), however, and preceding the 2015-16 El Niño the National Water Authority installed geodynamic barriers to mitigate *huaico* impacts in the area (ANA, 2016).

corporate sector investing substantially in disaster-risk reduction activities to protect assets prior to disasters as well as supporting response activities.

The Ministry of Economy and Finances (MEF) oversees varied fiscal mechanisms to support SINAGERD's DRM agenda. These include recurring annual budget allocations designed to fund prospective and corrective measures at all levels of government, funds obtained from taxes on mining-sector profits (*canon minero*) to be used for relocation of at-risk populations, and contingency funds, contingent credit lines, and a fiscal stabilization fund for expenses related to specific disaster events (Ferro, 2016). The most important DRM-specific financing mechanism is the budget program PP 068 for the Reduction of Vulnerability and Attention to Disaster Emergencies (PREVAED). This fund is available to national, regional, and local-level governments for a wide array of DRM measures. Although the resources available through PP 0068 have risen dramatically since the program's inception in 2011 (Ferro, 2016), many respondents emphasized the need to improve government capacities to access and implement activities under PP 0068 and related programs, especially at subnational levels.

The MEF may also redistribute budgetary allocations or mobilize a range of contingency funds to support short-term preparatory measures and disaster response. In past El Niño events and other disasters, these actions have often occurred under formal "declarations of emergency", which may predate the actual disaster event, as occurred in both 1997-98 and 2015-16. While emergency declarations function to expedite the provisioning of funds for disaster preparation and response, they also relax many formal controls and auditing procedures on the use of public funds. As a result, there is heightened potential under such conditions for the misuse of funds, and respondents across governmental levels emphasized the prevalence of ethically questionable practices and spending inefficiencies during these periods.

In summary, recent DRM efforts in Peru have been characterized by institutional development and restructuring coupled with increasing fiscal allocations. Broadly speaking, these developments are well aligned with leading DRM policy prescriptions at the international scale (e.g. the Hyogo and Sendai Frameworks). Yet, while guiding policies and the definition of key actors and roles are thoroughly articulated in legislation and institutional frameworks, substantial shortcomings in terms of actual organizational capacities continue to undermine the efficacy of Peru's DRM system. These shortcomings were underscored by the widespread devastation and difficulties in response during and after the 2017 coastal El Niño event, particularly given the significant preparations for a global El Niño event just a year earlier. To shed further light on the strategies and limitations of Peru's evolving DRM institutions, the following section examines preparations for the 2015-16 El Niño as well as the impacts of the 2017 coastal event.

5. Uncertainty and Surprise: the Challenges of El Niño in Peru during 2015-16 and 2017

5.1 Preparations for the 2015-16 El Niño

Forecasted months in advance and heavily publicized in local and international media, the 2015-16 global El Niño provided an opportunity for extensive coordination of DRM measures in Peru. In July 2015, ONI-based predictions of a potentially extreme El Niño later that year triggered Peru's central government to declare parts of 14 exposed regions under a state of emergency. Over the next several months, additional declarations of emergency would include 89% of all municipalities and 77% of all districts in the country, permitting the rapid dispersal of funding to these regions for preparatory measures (INDECI, 2016). An ad-hoc National Council for Management of El Niño Risk (CONAGER-FEN) was created to supervise preparation and response activities supported by fiscal allocations of ~US$ 1.5 billion (CONAGER-FEN, 2015).

To a great extent, Peru's preparations in 2015 replicated and extended the DRM strategies employed prior to the 1997-98 El Niño event (CAF, 2000; Velasco-Zapata and Broad, 2001). In particular, the Ministries of Agriculture and Housing along with regional governments were allocated major funding for clearing accumulated debris and opening channels in exposed watercourses and reinforcing protective structures such as levees and retaining walls. The Ministries of Housing, Health, Education, and Transport meanwhile received funding for repairs and improvements to vulnerable physical infrastructure (e.g. water and sanitation systems, schools, health posts and hospitals, and roads and bridges) (CONAGER-FEN, 2015). Given the vulnerability of many water and sanitation systems, the Ministry of Housing also provided financing and loans totaling almost US$ 20 million to local service providers for the relocation and reinforcement of treatment plants and other infrastructure, as well as the cleaning of sewage systems and storm-water drains (MVCS, 2016). With support from the private sector, the Ministry of Housing also supplied eight portable water treatment systems, five drain-cleaning systems, and cistern trucks to departments that had suffered potable water shortages and related disease outbreaks during the 1997-98 event (MVCS, 2016). In one high-profile example of new infrastructure development, the National Water Authority installed 22 steel geodynamic barriers in valleys outside Lima to protect populations exposed to huaicos (ANA, 2016) (Figure 3)[16].

Figure 3: Geodynamic barriers in the Carosio quebrada of Chosica, Peru. Credit: Soluciones Prácticas.

[16] These geodynamic barriers, which were not activated during 2015-16, became the focus of significant criticism from local officials and residents due to their high costs (~ US$ 330,000 each). During the 2017 event, however, many of the barriers were activated, capturing large debris and preventing *huaico*-related deaths in downstream communities. Authorities have since called for the expansion of this technology throughout the national territory. See previous note.

In complement to these environmental and infrastructure-focused measures, state authorities and civil society organizations at various levels undertook activities to support public preparedness and response. Much of this action involved material preparations, including stockpiling food, emergency kits, medicines, and other basic supplies in areas likely to be impacted. INDECI took a leading role in much of this work, coordinating with regional governments, and in some cases the private sector, to expand storage facilities for emergency supplies. Additionally, modular buildings to provide 500 temporary residences and 2000 temporary classrooms were acquired by the Ministries of Housing and Education respectively and distributed to exposed regions (MVCS, 2016). INDECI and CENEPRED, with support from the National Water Authority, also created maps of high-risk zones and evacuation routes that were hosted on open, online platforms[17]. Groups including INDECI, the Volunteer Firefighters Association, and various NGOs working directly with civil society organized response brigades, emergency drills and simulations, and trainings in the functioning of Early Warning Systems (EWS) and the processing of the post-disaster Evaluation of Damages and Analysis of Necessities (EDAN) forms, which are a critical step for the dispersal of governmental aid to affected populations.

In the end, while the 2015-16 El Niño event led to severe effects in some parts of the world, the impacts in Peru were far less than expected (Ramírez and Briones, 2017), underscoring the uncertainty and variability that challenges efforts to forecast and prepare for individual El Niño events (Glantz, 2015). As a result, it is difficult to evaluate directly the effectiveness of the preparations undertaken for the event in 2015 and early 2016. Moreover, it is uncertain how the much publicized forecasting and widespread anticipation of a severe event that never came to fruition may have impacted El Niño-related risk perceptions and future actions of both policymakers and the general public in Peru (cf. Glantz, 2015). The surprise coastal event of 2017, however, provided a test of the country’s readiness for a severe El Niño just a year after the extensive preparations of 2015-16.

[17] See <http://sinadeci.indeci.gob.pe/VisorEvacuacion/index.html> and <http://sigrid.cenepred.gob.pe/sigrid/>

5.2 Impacts of the 2017 Coastal El Niño

In stark contrast to the global El Niño of the year before, the localized event of 2017 developed rapidly and without forewarning in Peru (Ramírez and Briones, 2017). In late January, heavy rainfall first triggered multiple huaicos in valleys adjacent to Lima, followed by widespread flooding in the north of the country. On February 3, the national government declared a state of emergency in the northern departments of Piura, Tumbes, and Lambayeque due to flooding (La República, 2017e). Impacts worsened in northern and central Peru through April, with the most intense periods of rain and flooding in mid to late March in most areas. Many of the rivers that had been cleared and channelized a year earlier overflowed their banks or levees, flooding parts of major urban centers including Piura, Chiclayo, Tumbes, Trujillo, Chimbote, and Huarmey. Potable water, drainage, and sanitation systems in these and other cities were overwhelmed by water, debris, and related infrastructure failures leading to cascading impacts on the transportation, energy, education, health, and agriculture sectors (La República, 2017f).

According to respondents, emergency response efforts in many settings were hampered by coordination and communication problems between governmental sectors and across levels, including a lack of clarity around roles and responsibilities and inefficient and delayed dispersal of both emergency funds and relief supplies (Venkateswaran et al., 2017). As occurred in the response to the 1997-98 El Niño (Velasco-Zapata and Broad, 2001) and the 2007 Pisco earthquake (Elhawary and Castillo, 2008), national-level authorities often superseded their regional and local-level counterparts, generating inter-level conflict and redundancy in efforts. As the event worsened, the country's military forces were increasingly mobilized and relied upon for emergency relief, despite a lack of familiarity with local contexts and aid allocation (Venkateswaran et al., 2017). Broadly, the event underscored that many of SINAGERD's innovations, including the development of subnational DRM working groups, emergency contingency plans, and a multi-level system of articulated Emergency Operation Centers (i.e. COENS, COERS, COELS) were not yet fully implemented or operational (Peru, 2018).

As the event weakened by mid-late April, an estimated 1.5 million people had been affected, with direct economic losses estimated at approximately US$ 3.1 billion (Peru, 2018). By early May, the Ministry of Economy and Finances had approved $US 6.4 billion for reconstruction over the following three years (PCM, 2017). This process was formally titled "Reconstruction with Changes," to acknowledge the importance of avoiding the re-creation of vulnerabilities that have persisted since the El Niño disasters of 1982-83 and 1997-98. Reconstruction efforts, however, have been delayed and undermined by problems of inter-level governmental conflict and corruption (Peru, 2018), and in late 2019 authorities indicated that planned reconstruction and rehabilitation activities totaling more than $US 7.5 billion were roughly 40% complete and would still be underway by the end of 2021 (El Comercio, 2019).

6. Discussion

The coastal El Niño event of 2017 inarguably overwhelmed Peru's disaster-response systems, despite recent innovations in DRM policy and institutions as well as substantial investments in El Niño-focused risk reduction a year earlier. Our analysis of the event and the broader DRM context in Peru, however, underscores that the severity of this disaster should not be attributed to an anomalously extreme geophysical event. While the physical characteristics of the triggering event were important elements of the disaster and warrant careful analysis, we locate the principal root causes of the disaster in socio-cultural and political conditions that persist in Peru despite the nation's growing DRM emphasis. Acknowledging the role of institutional factors, Peru's Minister of Defense at the time of the event stated that the government itself was "the disaster" in reference to its shortcomings in emergency response (La República, 2017g). Rather than focusing on proximate causes such as inefficiencies in response and reconstruction efforts, however, we identify root causes as longer-term, structural factors that perpetuate outcomes such as limited emergency-response capacity, infrastructure failures, or "poverty" broadly defined. While these factors are too diverse to address comprehensively here, we focus our discussion on several aspects of Peru's contemporary socio-political and institutional context that contribute fundamentally to undermining urgently needed progress in disaster risk governance: high levels of centralization, lack of functional articulation between political sectors, and widespread corruption.

With the downfall of the Fujimori administration in 2000, Peru began a concerted process of rebuilding its democratic institutions at subnational levels (Crabtree, 2006; McNulty, 2011). Despite this ongoing effort, administrative authority and fiscal resources continue to be highly concentrated at the national level, reflecting the continuation of a longstanding domination of the nation's political and economic spheres by Lima-based authorities and institutions (Gonzalez de Olarte, 2004; McNulty, 2011). In the DRM sector, this centralization contributes to an enduring implementation gap between a policy framework premised on the subsidiarity principle and multi-level institutional structures and the reality of many subnational locales' lack of autonomy and incipient DRM capacities[18]. Similar implementation gaps exist across Peru's institutional landscape and can be attributed in part to the influence of internationally funded development processes that promote the "'implanting' [of] homogenous models of legislative and institutional systems" in diverse contexts where political will as well as capacities and dedicated resources for implementation are insufficient (Lavell and Maskrey, 2014, 11; French, 2016). Many of our respondents noted this implementation gap as a critical challenge, but explanations for its causes varied. Respondents working in national-level institutions, for example, frequently identified the limited capacities and frequent turnover in subnational governments as an obstacle to SINAGERD's implementation, while respondents at regional and local levels often stressed inadequate financial and technical support from national-level institutions as well as a lack of fiscal autonomy that undermined rapid and adaptive resource allocation, especially for emergency response (cf. Velasco-Zapata and Broad, 2001). Not surprisingly, respondents and analysts from civil-society organizations highlighted the combined effect of challenges at all levels of government as well as conditions unique to specific regional settings (UN, 2014). Examples from diverse contexts and sectors underscore the long-term character of decentralization initiatives and the crucial importance of devolving power and sharing resources in ways that enable independent and accountable democratic institutions at lower levels (e.g. Ribot, 2002). In Peru's DRM sector, the legislative and institutional architecture for such

[18] Evaluation of the current system suggests that subnational capacities are developing— for example, working groups have been established in all 26 regional governments although progress at municipal levels has been more gradual. Respondents were careful to clarify that the formal establishment of these working groups does not ensure effectiveness or even sustained action on their part. According to our evaluations, the central-level directors of SINAGERD (e.g. PCM, CENEPRED, and INDECI) could do more to orient the continued actions of these working groups after their initial formation (cf. UN 2014).

decentralization appears to be in place, but much work remains in building and empowering effective and robust institutions at subnational levels.

In addition to being highly centralized, Peru's governmental structure features numerous ministries with separate institutional bureaucracies whose policies and responsibilities often overlap without clearly defined processes for integration, prioritization, or the avoidance of redundancy. These conditions create a "state machine …[whose] core is afflicted with disorder and dispersion" and where "turf wars, conflict, and competition are the daily bread" between, and at times within, sectors (Velasco-Zapata and Broad, 2001, 187). In the context of the country's DRM agenda, our respondents stressed how a lack of cooperation and clarity over responsibilities between institutional "silos" significantly complicates intersectoral integration. While SINAGERD's formal hierarchy includes an inter-ministerial advisory council (CONAGERD), functional linkages between the nation's specialized DRM institutions and other sectors, especially at subnational scales, remain underdeveloped (UN, 2014). Consolidation of DRM-focused institutions within the Ministry of Defense in early 2017 was explicitly undertaken to improve the efficiency of SINAGERD and address the dispersion of responsibilities, but our respondents and other analyses have suggested that this reconfiguration overwhelmed INDECI's existing capacities and sowed confusion in the midst of the emerging coastal El Niño disaster (Peru, 2018).

Concurrent to more effective decentralization and intersectoral collaboration, our respondents stressed a need for a political and cultural shift towards treating DRM as a prospective endeavor with long-term social benefits rather than a discrete response to individual emergencies. Such a shift requires more thorough integration of DRM activities into the national development agenda as well as into policymakers' and residents' day-to-day decision-making. Currently, such change is forestalled by a prevailing focus on development initiatives that generate high-visibility outcomes over time horizons corresponding to electoral cycles (e.g. public infrastructure such as roads, plazas, and sports facilities) rather than long-term investments that offer less—or even undermine—political capital for elected officials (e.g. relocation of exposed populations and infrastructure). This challenge is not unique to Peru; as Lavell and Maskrey suggest, "very few politicians, nationally or locally, have won an election on a platform of reducing future disaster losses and risks" (2014, 10)[19]. Instead, our respondents noted that in some cases Peruvian elected officials have intentionally failed to enforce regulations that support DRM in order to cultivate political support, for example through the granting of certificates of property possession in hazard zones occupied by land invasions or through opposing state-led relocation of exposed populations. Moreover, there is currently little political incentive to dedicate resources to improve institutional capacities for prospective DRM. This situation is made worse by the tendency for newly elected governments to fill professional ranks with their own supporters, leading to frequent staff turnover that undermines the development of DRM expertise and institutional memory (Elhawary and Castillo, 2008; Peru, 2018).

A widespread lack of progress in implementing long-term, prospective DRM approaches was highlighted by both the preparations for the 2015-16 El Niño and the reconstruction efforts after the 2017 event. For example, in 2015-16, as in 1997-98, preparedness activities focused on urgently clearing watercourses and reinforcing exposed infrastructure (CAF, 2000; Velasco-Zapata and Broad, 2001; CONAGER-FEN, 2015). Yet in the years in between these events, little action was taken to reduce El-Niño related risks, and respondents suggested such measures would have been more effective had they been conducted on a routine basis rather than in the few months preceding the predicted onset of a severe event or once impacts had begun. Repeated damages to particular locations and critical infrastructure systems across multiple El Niño events also underscore how earlier lessons regarding the need for planning and zoning policies to reduce settlement and asset development in exposed areas have not yet been taken up in many contexts (Velasco-Zapata and Broad, 2001; Peru, 2018). The focus of the current reconstruction process on infrastructure repair and activities like river channelization continues to raise questions regarding the sustainability of such temporary measures versus long-term strategies including relocating exposed settlements and infrastructure. It is notable that this emphasis on short-term, infrastructure-focused responses over more transformative socio-cultural and institutional change has long prevailed in Peru, contributing to a persistent accumulation and expansion of disaster

[19]Although prospective DRM measures are not typically a political boon, there are cases of politicians using disaster response activities to generate popular support. Velasco-Zapata and Broad (2001), for example, emphasize how the Fujimori administration's preparation and response effort for the 1997-98 El Niño was highly personalized and tightly controlled by the executive branch in support of the administration's clientelist agenda.

risk in settings impacted by El Niño and other hazard-producing phenomena (Doughty, 1999; Velasco-Zapata and Broad, 2001; Peru, 2018).

In addition to the challenges outlined above, widespread political corruption remains one of the most significant and intractable issues currently undermining transparent and effective governance across political levels and sectors in Peru. Although corruption has long been endemic to Peruvian politics (Quiroz, 2013), its current extent has recently been highlighted by the country's involvement in the wide-reaching, international scandal "Operation Car Wash" (*Lava Jato*) and by the indictment and incarceration of numerous high-profile figures, including multiple former Presidents, regional governors, and members of Congress and the national judiciary (Durand, 2019; Nureña and Helfgott, 2019). The effects of corruption on the DRM sector can be seen in varied ways, including in the formal sanctioning of illegal land invasions in hazard-prone spaces and in the impacts of graft on infrastructure development and disaster-reduction activities. In numerous public-works and DRM projects, embezzlement and a lack of oversight and adherence to building standards have led to abandoned works in-progress or rapid deterioration and sudden failure of public infrastructure, including schools and hospitals, water and sanitation systems, and roads and bridges (e.g. La República, 2017d). Respondents also underscored the susceptibility of short-term, risk-reduction activities (such as watercourse clearing and channelization) to corrupt practices due to the difficulties in verifying factors such as the extent of area treated and the amount of time worked or fuel used by heavy machinery. Such problems reportedly worsen significantly under formal declarations of emergency when spending controls are relaxed and the contracting of third-party operators often leads to substantially elevated costs. Recognizing the prevalence of such practices, President Pedro Kuczynski resisted a nation-wide declaration of emergency in early 2017 explicitly to avoid "opening the door to corruption" (La República, 2017h). Although Operation Car Wash has provided an important impetus to confront and address Peru's deeply entrenched political corruption (Durand, 2019), the corruption crisis continues to undermine the "Reconstruction with Changes" process through questionable practices and distraction of resources and political focus from reconstruction activities (e.g. Urbina, 2018; La República, 2019).

7. Conclusion

Disasters linked to geophysical phenomena such as El Niño never merely result from exogenous "natural" hazards impacting society, but instead stem from root causes associated with both the hazard-producing phenomena and the socio-cultural contexts in which disasters occur. In this paper, we have argued that detailed forensic investigation of disaster events grounded in the interdisciplinary approach of political ecology is particularly well suited to understanding these complex and interacting root causes. To conclude, we offer several recommendations from our analysis of El Niño in Peru relevant to forensic investigations of disaster in other contexts.

First, we stress that addressing the complexity inherent to multi-level social and institutional systems requires stakeholder engagement and analysis across the various levels and sectors of government and society. As our interviews with Peruvian authorities and citizens highlighted, perceptions of the major challenges to DRM initiatives varied significantly across governmental levels and, to a lesser degree, between public sectors and geographic regions. Obtaining a broad sample of perspectives from these different sources is vital to understanding both intra-governmental and inter-cultural dynamics as well as the varied ways in which disaster risk is perceived and addressed by diverse stakeholders with highly variable levels of expertise, experience, and resource access.

A second recommendation concerns the need to examine formal laws and policies in conjunction with the realities of their implementation in varied contexts to understand how institutional development is operationalized on the ground. As the Peruvian case highlights, the implementation gap between the country's official DRM policies and quotidian practices remains substantial in many settings due to a combination of overarching and locally specific challenges. Such implementation gaps are common in contexts of both the Global North and South, and require thorough empirical investigation in complement to desk-based policy analyses.

Third, we highlight the important—and underexplored—role of political corruption in undermining efforts to reduce disaster risk and improve risk governance (Alexander and Davis, 2012). While political corruption is increasingly acknowledged as a pervasive problem at the global scale, its investigation remains both difficult and potentially dangerous in most contexts, and as a result, discussion of its influences are frequently omitted from otherwise detailed analyses. Although we have only broached the complexity of the topic here, we argue that a failure to address the influence of corruption as a root cause of disaster risk in a context like that of contemporary Peru leads to incomplete and potentially misleading explanations.

Last, we stress the need for detailed interdisciplinary analysis of the geophysical conditions and processes that interact with social root causes to shape disaster risks. In the Peruvian case, this includes considering how geographic and hydrographic factors contribute to high levels of exposure and interact with socio-cultural and political-economic conditions to accentuate vulnerability and resulting disaster risk for particular groups. Additionally, our research underscores the importance of the high levels of uncertainty around the dynamic and interacting physical drivers of the El Niño phenomenon and related hazards, as well as how these may evolve under climate change in the future. This uncertainty demands continued investigation of both global- and local-scale geophysical processes and their interactions with highly specific geographic and social contexts. Finally, communicating the complexity and uncertainty inherent to phenomena like El Niño to broader society through effective scientific interpretation and careful event forecasting remains a critical challenge in many contexts (Glantz, 2015; Ramírez and Briones, 2017).

Finally, taken together these recommendations suggest several characteristics crucial to robust forensic analysis of disasters. First, this approach requires thorough and sustained empirical engagement in affected contexts. Working across governmental levels and sectors and engaging with a diversity of stakeholders in multiple locations requires substantial time and significant financial and human resources. These demands underscore the value of partnering with local experts who have vital contextual understanding and personal and institutional networks that can facilitate detailed empirical research. Moreover, incorporating careful analysis of underlying—and often sensitive—political and cultural dynamics (e.g. intersectoral conflicts or corruption) in a forensic investigation will likely extend the time, in-depth contextual knowledge, and contacts and networks required. Attention to the interactions between complex geophysical and social processes also necessitates integrating varied disciplinary approaches and research capacities, which will often be most effectively achieved through collaboration. In light of these requirements, we suggest that forensic investigation of the root causes of disaster risk should be approached as a long-term interdisciplinary, empirical engagement. Perhaps most importantly, if such research efforts are to have meaningful influence on DRM institutions and decision-making, they will require significant investment in building dialogue and trust with policymakers and a wide range of stakeholders on the ground in disaster-stricken contexts.

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Declaration of interests

X The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: