International Institute for Applied Systems Analysis
www.iiasa.ac.at

SOLUCIONES PRÁCTICAS
Tecnologías desafiando la pobreza

ZURICH

MANAGING EL NIÑO RISKS UNDER UNCERTAINTY IN PERU:

Learning from the past for a more disaster-resilient future

September 2017

Imprint

This report was written by Adam French* and Reinhard Mechler of the International Institute for Applied Systems Analysis (IIASA) with input from Emilie Etienne, Pedro Ferradas, Abel Cisneros, Miguel Arestegui, Orlando Chuquisengo, and Miluska Ordoñez of Soluciones Prácticas (Peru), Michael Szönyi of Zurich Insurance Group, and Adriana Keating of IIASA.

*Corresponding author: french@iiasa.ac.at

All photographs courtesy of Soluciones Prácticas ©

Design and Layout: Fanny Arnold

Acknowledgements

This report would not have been possible without the generous contribution of time and insights from a diverse group of interview respondents in Peru. Our sincere thanks go — in no particular order — to professionals from the National Institute for Civil Defence (INDECI); the National Center for the Estimation, Prevention, and Reduction of Disaster Risks (CENEPRED); the Ministry of the Environment (MINAM); the Ministry of Economy and Finance (MEF); the Ministry of Housing, Construction, and Sanitation (MVCS); the Ministry of Agriculture and Irrigation (MINAGRI); the National Water Authority (ANA); the National Service for Natural Protected Areas (SERNANP); the National Institute for Investigation of Glaciers and Mountain Ecosystems (INAIGEM), Desnivel Peru, UN Office for Disaster Risk Reduction (UNISDR), the Pontifical Catholic University of Peru (PUCP), the Municipality of Lurigancho-Chosica, the communities of Los Carrizales, Esteras, Angaraes, and Pariachi in the Municipality of Ate, and everyone else who contributed to this report.

Post Event Review Capability Reports

As part of Zurich's flood resilience program, the Post Event Review Capability (PERC) provides research and independent reviews of large flood events. It seeks to answer questions related to aspects of flood resilience, flood risk management and catastrophe intervention. It looks at what has worked well (identifying best practice) and opportunities for further improvements.
For further information see: https://www.zurich.com/en/corporate-responsibility/flood-resilience/learning-from-post-flood-events

Recommended citation: French, A. and Mechler, R. (2017). Managing El Niño Risks Under Uncertainty in Peru: Learning from the past for a more disaster-resilient future. Laxenburg, Austria: International Institute for Applied Systems Analysis.

Contents

Cover Photo: A "flood-risk zone" in Peru's Rimac River valley. Although typically characterized by extreme aridity, Peru's Pacific slope is one of the planet's most exposed and vulnerable regions to El Niño-triggered flooding and related disasters.

EXECUTIVE SUMMARY

Peru is a global hotspot for El Niño-related disaster risk, and recent severe El Niño events (1982-83, 1997-98, and 2017) have led to widespread loss of life and destruction of assets in this central Andean nation. While capacities to forecast and prepare for El Niño in Peru have improved markedly in recent decades, challenges linked to uncertainty and variability in hazard occurrence and exposure coupled with high levels of vulnerability in many sectors and regions of the country continue to produce substantial disaster risk.

Since 2015, these challenges have been highlighted by two distinct El Niño events. The first, which occurred from late-2015 through mid-2016, was one of the strongest global El Niño events ever recorded in terms of elevated sea-surface temperatures, with extreme impacts widely predicted across the Pacific Basin. In Peru, these forecasts led to unprecedented investments in diverse preparatory measures, but, contrary to expectations, the event never developed beyond moderate intensity in the country, and many experts considered it a "non-event". The second event — termed a "coastal El Niño" because its impacts were limited to coastal Peru and Ecuador — developed rapidly in January 2017, surprising forecasters, authorities, and the general public. Despite the extensive preparations just a year earlier, this 2017 event produced damages in Peru comparable to those of the 1982-83 and 1997-98 El Niño's, which are broadly seen as the most destructive El Niño events in the country's history.

This study was begun at the end of the 2015-16 El Niño in an effort to document and evaluate the disaster risk management (DRM) measures undertaken in preparation for the event, along with the broader historical and institutional context for El-Niño-related risks and DRM in Peru. During the course of the analysis, the unforeseen 2017 event occurred, providing additional opportunities to reflect on El Niño impacts and the effectiveness of earlier DRM measures and institutions. Grounded in the Post Event Review Capability (PERC) methodology but with a greater focus on institutional analysis and impacts across multiple events, this study is designed to provide detailed contextual information on the diverse and interacting drivers of El Niño-related risks in Peru as well as on important advances and constraints in the country's evolving DRM policies and practices. As such, the study provides a basis for understanding the underlying hazard, exposure, and vulnerabilities related to El Niño in Peru and the institutions in place to address them. Following the PERC methodology's emphasis on highlighting both challenges and best practices in disaster response from a non-biased and apolitical perspective, the report is targeted at fostering the consolidation and implementation of lessons learned. Additionally, the report provides useful background to complement a traditional PERC analysis of the 2017 event in Peru that is currently underway. The rest of this summary provides a brief overview of key findings and lessons presented in detail in the full report that follows.

Uncertainty and variability characterize El Niño

The El Niño phenomenon is a principal cause of global inter-annual climatic variability. While its development at the global scale can now be monitored and forecasted with far more precision than ever before, the regional to local-scale impacts of particular events remain impossible to predict. In 2015-16, for example, expert forecasts predicted high probabilities of a strong to extraordinary event in Peru, but the resulting El Niño was of only weak to moderate intensity. One year later, the development of localized El Niño conditions off the Peruvian coast was not predicted in advance by forecasters and led to an unforeseen coastal El Niño event that rapidly evolved into one of the most devastating disasters in the country's history.

Hazard, exposure, and vulnerability must all be addressed

Disaster risk is a combination of hazard, exposure, and the vulnerability of affected populations and assets. In the context of El Niño disasters in Peru, all of these components of risk require sustained attention to reduce future disaster impacts. Specifically, measures to better understand the variable hazards associated with El Niño and to address growing exposure (e.g. through more effective zoning regulations and relocation processes) should be coupled with efforts to identify and reduce the socio-economic drivers of vulnerability that affect much of the country's population and infrastructure.

A transition from emergency response to integrated DRM approaches is needed

DRM in Peru has long been dominated by a focus on emergency response. Currently a shift towards an integrated approach combining reactive, corrective, and prospective DRM measures is under way in the national institutional context, but much work remains in implementing this policy change in everyday practice. Progress in this transition has been greatest at the national level, and there is a pressing need to strengthen DRM capacities at regional and local levels of government. Concurrent to the development of DRM capacities across political levels, there is a need within broader society to promote greater understanding of disaster risk and the corrective and prospective measures designed to reduce it.

Institutional support, oversight, and accountability are critical to effective DRM implementation

With ongoing transformative changes to DRM policy and strategy in Peru, there is a critical need for intra- and inter-organizational support in the implementation of new DRM approaches, especially from national to sub-national levels. In light of substantial increases in DRM-related funding over recent years, there is also a pressing need to improve the abilities of governmental entities—especially at regional and local levels—to access and employ these funds effectively. Additionally, increased oversight and accountability around how such funds are used are needed at all governmental levels and particularly in the context of formally declared states of emergency when controls on public spending are relaxed.

DRM should be a key component of long-term development planning and resource governance

Peru has made substantial progress in establishing laws and policies for long-term development and resource governance, including integrated watershed management and landscape-level planning processes. While implementation of these policies remains a work-in-progress throughout the country, it is vital to build prospective and corrective DRM measures into these initiatives from the earliest stage possible. Rather than having separate entities working independently to implement these related policies, efforts should be made to create synergies between these processes through inter-sectoral and multi-level collaboration and through public-private-civil society partnerships.

The consolidation and implementation of lessons learned is urgent for risk reduction

Many of the insights generated by this analysis are neither new nor surprising in the context of contemporary Peru. In fact, many recommendations made in the wake of earlier El Niño disasters have not yet been implemented; and as a result, similar patterns of impacts continue to reoccur across multiple events. There is an urgent need to implement the lessons learned during prior disasters to reduce future risks and build disaster resilience. Peru's recent economic growth and social stability combined with its evolving DRM sector and the widespread impacts of the 2017 coastal El Niño event provide conditions to implement the costly and contentious—but ultimately more sustainable—corrective and prospective DRM measures long recommended.

INTRODUCTION

Peru is one of the planet's most vulnerable nations to the destructive impacts of the El Niño phenomenon. In the months preceding the onset of the widely forecasted and heavily publicized 2015-16 El Niño, the Peruvian government declared much of the country in a state of emergency and invested nearly $US 1.5 billion in risk-reduction, emergency-preparedness, and disaster-response activities. The 2015-16 event, however, never surpassed moderate intensity in Peru and caused relatively minor impacts. Then in January 2017, the rapid and unforeseen development of a "coastal El Niño"[1] brought heavy rainfall and widespread flooding to the country's Pacific slope. Despite the substantial preparations undertaken just a year earlier, this 2017 event exposed critical gaps in the nation's disaster-preparedness and response capacities, and, by late April, the event had produced damages comparable to the severe El Niño disasters of 1982-83 and 1997-98. The President of the 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," while the Minister of Defense, Jorge Nieto, suggested that Peru's "institutions had to work more closely together to attend to the population, and especially to its poorest members."[2]

In the context of Peru's recurrent and devastating El Niño events, this report analyzes the recent history of the phenomenon's impacts in Peru, along with the evolution of institutions and strategies for reducing the risks of such disasters. The study is particularly interested in the measures implemented prior to the 2015-16 El Niño, including how they were shaped by lessons from earlier events (especially the 1997-98 El Niño) and why they did not do more to reduce the impacts of the 2017 event.

The study has been conducted through a combination of desk-based research, institutional analysis, and key-informant interviews[3] and is informed by and structured around the Post Event Review Capability (PERC) methodology to disaster forensics (Keating et al. 2016; Venkateswaran et al. 2015). In contrast to prior PERC studies that analyzed discrete disaster events, this study examines recent El Niño events in Peru broadly (focusing especially on 1997-98 and 2015-16) and features more detailed analysis of the institutional context around DRM in the country, with attention to how recent post-event learning has influenced current DRM strategies. Additionally, this study adds a projective component to the existing PERC literature through the consideration of several scenarios to envision the potential outcomes of distinct DRM-development trajectories for the year 2030.

The report is structured in the following manner: the first section provides an overview of the physical context of El Niño-related risk and impacts in Peru, the second section introduces important sectoral vulnerabilities to these impacts, the third section discusses the evolving institutional context for DRM in Peru, the fourth section provides an overview of the principal measures taken in preparation for the 2015-16 El Niño, the fifth section offers key insights from the analysis into the effectiveness of these measures and related challenges to El-Niño DRM, the sixth section presents the forward-looking scenario-based component, and the final section highlights a set of recommendations for building resilience to future El Niño events and improving DRM effectiveness more generally in Peru.

1 The term "coastal El Niño" has been used by Peruvian experts and media because the sea-surface temperature changes that occurred with the 2017 phenomenon were localized to the coastal areas of Peru and Ecuador rather than extending across the central Pacific Ocean as is typical during a normal El Niño year.

2 See: http://larepublica.pe/politica/844962-fernando-zavala-sobre-huaicos-no-estabamos-preparados-para-estos-hechos and http://cdn8.larepublica.pe/politica/852500-jorge-nieto-nosotros-somos-el-desastre-la-hora-de-afrontar-las-emergencias

3 Specifically, the study entailed analysis of peer-reviewed and grey literature; formal laws, policies, plans and institutional frameworks; institutional websites; and media coverage of DRM activities and disaster events along with semi-structured and unstructured interviews of representatives of government agencies, the private sector, and NGOs and conversations with varied professionals, researchers, and citizens involved in Peru's DRM efforts.

1.

THE PHYSICAL CONTEXT OF EL NIÑO RISK IN PERU

The El Niño-Southern Oscillation (ENSO) is a coupled oceanic-atmospheric phenomenon in the tropical Pacific region 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 climatic variability (Cane 2005). 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 a strong decline in the upwelling of cold, nutrient-rich waters off the western coast of central South America, leading to warmer-than-average sea-surface and atmospheric temperatures in the region. These higher temperatures drive increased convection and heavy rains on the usually arid northern Peruvian coast (Figure 1). During some El Niño events, an intensification of the annual rainy season also occurs in the central highlands (e.g. 1997-98) and drought conditions may develop in the southern highlands (e.g. 1982-83) (CAF 2000).

Evidence of El Niño-related impacts in contemporary Peru dates back centuries, and of the dozens of documented events at least nine are described as being of *very strong* or *extraordinary* intensity[4] (Figure 2) (Quinn et al. 1987). During such events, the greatly enhanced precipitation regimes generate damages directly and through riverine flooding, landslides, and debris flows (known locally as *huaicos*) that are triggered in steep, unstable terrain. In the 1997-98 El Niño, for example, official reports indicate that intense rains, flooding, and *huaicos* accounted for 75% of the 1301 destructive events recorded (Table 1). These impacts have created significant challenges for Andean and coastal cultures in this region for millennia, and over the last two centuries, El Niño events have contributed to major upheavals in Peruvian economy and society, including catastrophic impacts on the guano industry, the anchovy fishery, and coastal and highland agriculture (Thorp and Bertram, 1978; Ferradas 2015). In recent decades, severe events in 1982-83 and 1997-98 have taken many lives and generated billions of dollars in damages (CAF 2000; Ferradas 2000).

Figure 1: Precipitation anomalies during January-March 1998. Data: SENAMHI.

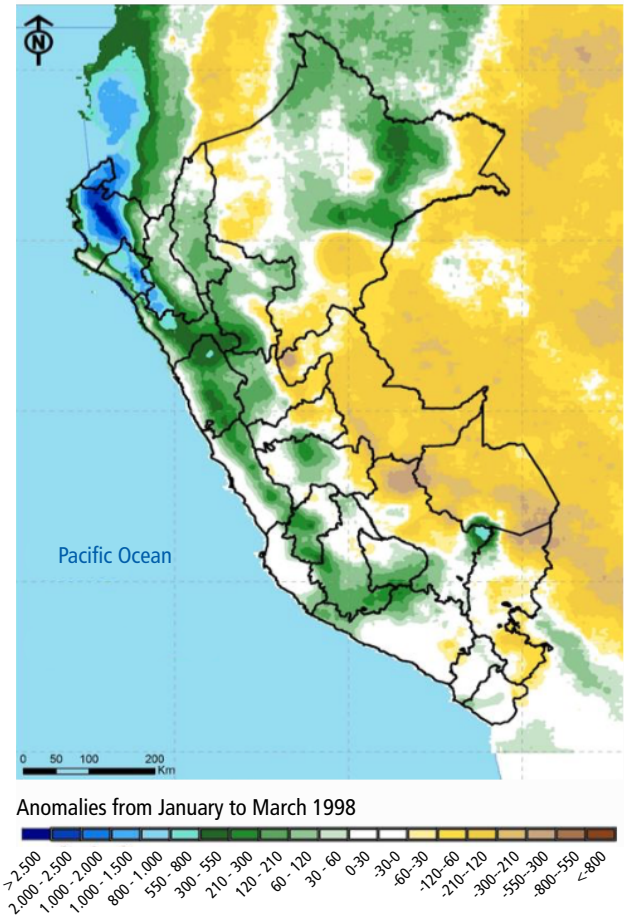
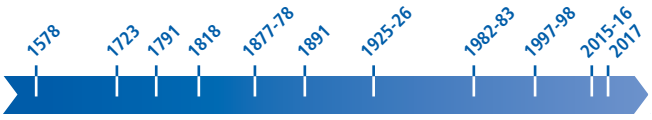


Figure 2: "Very stong" El Niño events documented in the historical record (Quinn et al. 1987; INDECI 2015, 2017).



4 The seminal review paper by Quinn et al. (1987) referenced here uses the description *very strong* for the highest intensity El Niño events documented. The Peruvian forecasting agency ENFEN uses the term *extraordinary*. In this report, this strongest category of events is referred to as *severe* or *extraordinary*.

Table 1: Reported disasters by type in the 1997-98 El Niño (Adapted from CAF 2000).

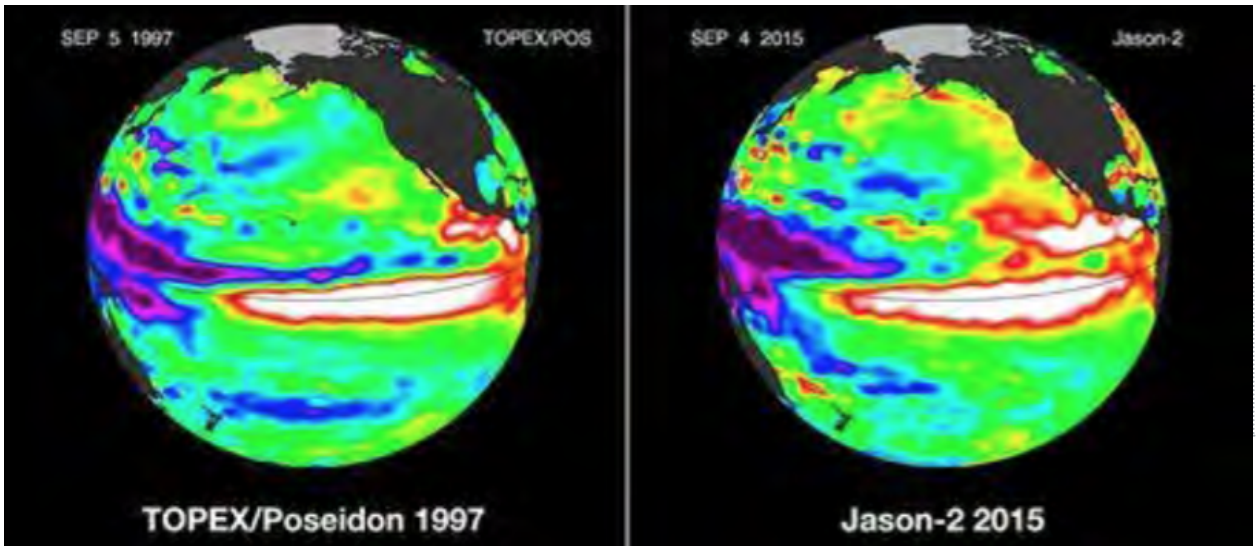
Type of Event	Frequency	% of total events reported	National departments most affected
Intense rains	444	34	Apurímac, Ayacucho, Piura, La Libertad, Lambayeque, Tumbes
Flooding	297	23	Ancash, Cuzco, Lambayeque, Lima, La Libertad, Piura, San Martín Tumbes, Ica
Huaicos	229	18	Ancash, Arequipa, Lima, La Libertad
Landslides	188	14	Ayacucho, Loreto, San Martín
Others (e.g. drought, extreme cold, wind and electrical storms)	143	11	
TOTAL	**1301**	**100**	

Peru's physical geography and hydrography contribute importantly to the damages that El Niño-related weather phenomena generate. Although Peru is a relatively water-rich country in general, the country's western slope is extremely arid, receiving less than 2% of the nation's total freshwater reserves while concentrating approximately 60% of the national population and 70% of the country's GDP production (Peru 2009). The hydrologic regime in this region is also highly seasonal, with surface-water flows in many westward-flowing rivers restricted to the tropical rainy season (~October-April). Additionally, many of these rivers and their tributaries feature steep gradients in their upper reaches along with high levels of bare ground or degraded vegetation cover and are thus especially prone to *huaicos* and flash flooding (Photo 1). Nevertheless, given the limited water resources available in the region, much human settlement has occurred adjacent to major water sources, often without attention to the flood hazards generated by relatively infrequent severe El Niño events.

While El Niño events in Peru are recurrent, the timing and intensity of specific events remain impossible to predict precisely, and the spatial distribution of impacts is highly variable between events. Although the accuracy of ENSO forecasting has improved considerably over recent decades (Chen et al. 2004), continued uncertainty regarding the intensity and distribution of effects poses substantial challenges to preparedness. In light of these challenges, the impacts of prior events have been used to guide preparatory measures, but this approach is only partially effective. For example, risk reduction measures undertaken for the 1997-98 El Niño based on impact patterns from the 1982-83 event did not include preparations for the ensuing catastrophic flooding on the central coast but did lead to measures for managing drought impacts that never developed in the southern highlands (CAF 2000). In 2015-16, expectations of an El Niño of similar intensity to that of 1997-98 (Figure 3) led to extensive preparations, but the severe event never developed in Peru. Most problematically, unlike the true warm phase of ENSO, which can now be detected and monitored several months in advance, the coastal El Niño phenomenon (like that which devastated Peru in 2017) comes with little to no forewarning, surprising forecasters, authorities, and the general public alike.

Photo 1: Arid riverbeds and steep, unstable hillsides may rapidly flood and erode with even small amounts of localized rainfall.

Figure 3: Sea-surface height (SSH) anomalies from the El Niño events in 1997 and 2015 indicating their similar evolution by early September of each year (Courtesy NASA/JPL-Caltech).



El Niño Forecasting and Risk Assessment

In order to support improved ENSO analysis and forecasting, Peru established the Multisectoral Committee for the National Study of El Niño (ENFEN)[5] in 1977. Currently, ENFEN brings together experts from the National Geophysical Institute (IGP), the National Meteorology and Hydrology Service (SENAMHI), the National Water Authority (ANA), the National Maritime Institute (IMARPE), the Navy, and the National Institute of Civil Defense (INDECI). ENFEN publishes monthly analyses of ENSO conditions and indicators (e.g. sea-surface and air temperatures and wind anomalies)[6], which help to inform the government's preparation and response strategies for particular El Niño events.

In parallel to ENFEN's continuous ENSO monitoring, INDECI has in recent years prepared *risk scenarios* for individual ENSO events and annual rainy seasons (e.g. INDECI 2015). These scenarios are based on the combination of a range of geographic, meteorological, and demographic data (see Box 1) and are designed to help pinpoint and prepare for disaster impacts before they develop.

Ongoing efforts to estimate El Niño hazard exposure in Peru underscore the potential for severe events to impact a large proportion of the national territory as well as the substantial uncertainty that remains around the distribution of impacts from individual events. Notably, the methodology employed in these risk scenarios entails little consideration of localized levels of vulnerability and resilience to hazards, which in turn reflects the dearth of detailed information on these factors in much of the country (INDECI 2015). Together, such information gaps, high levels of exposure, and the pervasive uncertainty around El Niño all highlight the critical need to incorporate DRM activities that build resilience to flooding and other El Niño impacts into the country's long-term planning and development policies.

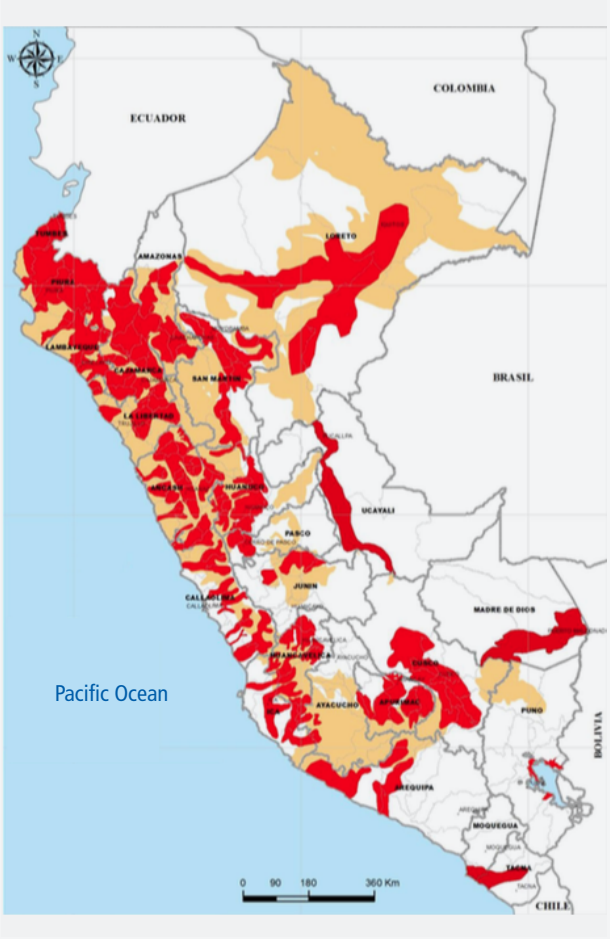
An additional challenge to managing El Niño-related risks in Peru is the uncertainty around the relationship between El Niño and global climate change. The occurrence of several severe El Niño events in Peru since 1982-83 (including the 2017 coastal El Niño) is suggestive of an intensification of the phenomenon under a warming climate, and recent research corroborates this perspective (Wang et al. 2017). Nevertheless, there is still no clear consensus among the scientific community regarding this intensification, and the nature of the relationship continues to be a focus of inquiry (Takahashi and Dewitte 2016). Similarly, efforts to model changes in seasonal precipitation levels at regional scales in Peru under projected future climate change are inconclusive (Burek et al. 2016). This uncertainty further underscores the need for broad-reaching DRM strategies that support adaptive management capacities and resilience to a range of impacts and conditions.

5 See: Ministerial Resolution # 120-77-PM/ONAJ (June 7, 1977), Supreme Resolution # 053-97-PE (Sep. 12 1997), and Ministerial Resolution # 761-97-PE (Nov. 26, 1997).

6 See: http://www.senamhi.gob.pe/?p=0812

Estimating Exposure to the Impacts of El Niño in 2015-16

Figure 4: Predicted hazard zones in an extraordinary El Niño event (beige areas) and priority zones for preparedness and response activities (red areas) (Courtesy INDECI).



hazard zones

priority zones

To provide exposure estimates for the 2015-16 El Niño, INDECI combined precipitation records and emergency statistics from the 1997-98 El Niño with broader impact data on specific hydro-meteorological events registered between 2003-2015 in the National Information System for Prevention and Attention to Disasters (SINPAD).[7] On the basis of this analysis, INDECI determined that an area of approximately 671,946 km^2 (~52% of the national territory) was exposed to potential effects from an extraordinary El Niño event in 2015-16 (Figure 4, areas in beige). By combining these results with census-based demographic data, INDECI estimated a total exposed population of more than 11.8 million.

To support the targeting of DRM activities, INDECI then identified priority areas with a high probability of impact by delineating zones based on: 1) frequency of reported impacts during the 1997-98 El Niño, 2) reported emergencies to the SINPAD between 2003 and 2015, 3) population density, and 4) geographic criteria including the topography of watersheds and flood plains (Figure 4, areas in red). Under these additional criteria, it was estimated that a population of almost 9.4 million—nearly a third of the total population—was at high risk from an extraordinary El Niño event in 2015-16. Based on this same analysis, exposure estimates were provided for the housing, transportation, education, and heath sectors (Table 2) (INDECI 2015).

7 See: http://sinpad.indeci.gob.pe/sinpadweb/

Table 2: Estimates for sectoral exposure to an extraordinary El Niño in 2015-16 (INDECI 2015).

	Population	Housing	Transportation	Education	Health
Exposure by sector	9.4 million	2.4 million homes	19,600 kms. of improved roads	39,000 schools	6,000 health facilities

2.

SOCIO-ECONOMIC IMPACTS AND SECTORAL VULNERABILITIES TO EL NIÑO IN PERU

Residents of Peru's Pacific slope have long settled in close proximity to the seasonal streams and few perennial rivers that flow from the Andes across the coastal plain. Given the region's desertic conditions, these populations have constructed and relied upon extensive water transfer, irrigation, and transportation works to support settlement, agriculture, and, more recently, industrial development. While El Niño-related hazards have long impacted these settlements and infrastructure works, prospective measures to address this recurrent but infrequent phenomenon remain incipient. This section examines the historic impacts and vulnerabilities of socio-economic sectors commonly affected by El Niño, focusing on sectors critical to the broadest portion of society (i.e. housing, water and sanitation, transportation, education, and health). The analysis highlights recurrent impacts across multiple El Niño events and suggests that many sectoral vulnerabilities have not been significantly reduced over the last several decades — while some have likely grown worse (Table 3).

Table 3: Sectoral Damages for recent El Niño events. Data: CEPAL, CAF, INDECI.

Sector	1982-83	1997-98	2017 (preliminary figures)
Population	• 512 deaths • 1,304 injuries • 1.27 million affected	• 366 deaths • 1,053 injuries • 531,104 affected	• 114 deaths • 414 injuries • 1.08 million affected
Transport Network	• 2,600 km. of improved roads damaged • 51 bridges destroyed	• 3,136 km. of improved roads damaged • 370 bridges destroyed	• 6,614 km. of improved roads damaged • 326 bridges destroyed
Housing	• 98,000 homes destroyed • 111,000 homes damaged	• 48,563 homes destroyed • 108,000 homes damaged	• 41,632 homes destroyed or uninhabitable • 242,433 homes damaged
Education	• 875 schools damaged	• 2,873 schools damaged	• 2,150 schools damaged
Health	• 260 health posts damaged	• 580 health posts damaged	• 726 health posts damaged
Total Monetary Losses US$	**3.28 billion** (1998 $)	**3.5 billion** (1998 $)	**Estimated ~6-9 billion** (2017 $)

Housing Sector

Many of Peru's cities and peri-urban spaces have been settled through rapid migration from rural areas and unplanned processes of urbanization. While early waves of migration in the middle of the 20th century settled extensive areas of undeveloped land adjoining Lima and a few of the country's other largest cities, recent decades have seen continuing housing demand coupled with a lack of zoning controls drive the creation of new settlements (*asentamientos humanos*) in increasingly hazardous spaces (Seminario and Ruiz 2008). Much of this settlement has occurred along periodically flooded and erodible reaches of watercourses (*quebradas*) and on unstable hillsides featuring high levels of exposure to *huaicos*, especially under the heavy rainfall characteristic of severe El Niño events (Photo 2).

The establishment of *asentamientos humanos* in these hazard-prone areas is frequently orchestrated by land traffickers who identify vacant spaces and plan their coordinated "invasion" by multiple households (Calderon et al. 2015; Seminario and Ruiz 2008). Despite the illegality of such processes, municipal governments and other groups tasked with property titling often support these occupations — be it unwittingly or for political or material gain — through the granting of formal land titles (Calderon et al. 2015). In some cases, existing legislation (e.g. Law Nº 28687 and Law Nº 29090) has even streamlined formal titling processes for residents occupying hazardous spaces (UN 2014; Calderon et al. 2015).

Photo 2: Demand for inexpensive housing near urban areas drives households to occupy hazardous spaces like this *huaico*-prone valley outside Lima.

In addition to the location of settlements, the materials used and processes by which many homes are constructed contribute to their vulnerability to El Niño impacts. Woven fiber (*esteras*) and cane reinforced with stucco (*quincha*) are common low-cost materials in coastal areas while adobe is common in both the highlands and the coastal desert. These locally sourced materials are especially prevalent in many rural areas and in the early stages of establishment of *asentamientos humanos*, while simple brick and mortar construction is frequently used as homes are improved and made more permanent (Photo 3). In Peru in general, an estimated 80% of homes are self-constructed with little formal oversight regarding design specifications or compliance with building codes (Calderon et al. 2015).

In many areas the exposure and vulnerability of settlements is recognized but has gone unaddressed. For example, in parts of Piura, Sullana, and Lambayeque that were impacted by flooding during the 1997-98 El Niño, urban plans identifying physical risks and vulnerabilities existed prior to the event but their recommendations had not been implemented (CAF 2000). Similarly, investigations by the National Institute for Urban Development (INADUR) undertaken in 1997 found that in northern cities impacted by the 1982-83 El Niño event, recommendations for risk reduction after that event had not been followed (CAF 2000). As a result, the 1997-98 El Niño impacted many of the same areas heavily damaged in 1982-83. A similar pattern is currently re-emerging in areas that were impacted by the 1997-98 event and again by the 2017 event.[8]

Photo 3: Typical brick and mortar construction in the Rimac River valley.

8 See: http://www.laindustria.pe/detallenoticias.php?codarticulo=5797

Water and Sanitation Sector

Potable water and sanitation systems are one of the infrastructural elements most frequently and severely impacted by El Niño-related flooding. While the coverage of these systems has expanded markedly over the last several decades, especially in urban contexts, the access of the poorest sectors of the population to improved water and sanitation infrastructure often remains precarious. Moreover, existing systems have often been constructed in ways that leave them vulnerable to flooding impacts (Photo 4) (CAF 2000). By design, intake and treatment infrastructure for potable water 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 under watercourses where it is vulnerable to high flows.[9] Increased turbidity due to heavy sediment loads transported by *huaicos* and by rivers at flood stage also impact water quality and damage infrastructure.[10] Surface-water drainage networks and sanitation systems — where they exist at all — are also frequently overwhelmed by heavy runoff and suffer from a lack of regular maintenance, which predisposes them to clogging and overflow. While substantial funding was directed to water and sanitation service providers for the implementation of corrective measures and preparedness activities in the months prior to forecasted El Niño events (e.g. 1997-98 and 2015-16), there is a need to shift from these short-term interventions towards the development of less vulnerable infrastructure and continuous maintenance regimes (cf. CAF 2000).

Photo 4: Water and sewage lines exposed by flash-flooding-induced erosion in early 2017.

9 Examples include the collapse in the 1997-98 event of the Simon-Rodriguez Bridge over the Chira River that destroyed the pipe transporting potable water to Talara and damage in 2017 to the canal infrastructure of the CHAVIMOCHIC irrigation project that supplies water to Trujillo.

10 In 2017, high turbidity in the Rimac River led to several days of water cuts throughout the capital city of Lima: http://larepublica.pe/impresa/sociedad/858023-trabajadores-de-sedapal-intensifican-labores-de-limpieza-del-rio-rimac

Flooding impacts on the water and sanitation sectors also contribute to a range of secondary impacts. These include interruptions in the provision of potable water that increase the consumption of contaminated water and the prevalence of waterborne illnesses: for example, confirmed cases of cholera (41,717) in 1998 were 1000% greater than in the two years prior (CAF 2000). Similarly, the failure of drainage and sewage systems often leads to contaminated standing water that pollutes pristine water sources and creates breeding grounds for mosquitoes and diseases like leptospirosis. As a result, after major flooding events, outbreaks of water and vector-borne diseases including malaria and dengue[11] have occurred along with increased prevalence of skin, eye, and respiratory infections.

Transportation Sector

Peru's road network has expanded substantially over recent decades, greatly increasing connectivity across the country's varied and rugged topography. Much of this transportation network, however, traverses steep and unstable terrain or runs in close parallel to watercourses and is extremely vulnerable to the impacts of severe El Niño events and heavy rainfall in general (Photo 5). In the 1997-98 event, for example, more than 3,100 kilometers of improved roadways were damaged and 370 bridges collapsed in the country, and the reconstruction and rehabilitation of this infrastructure cost an estimated US$686 million (CAF 2000). Damages in the transportation sector also frequently compound impacts in other sectors due to problems of isolated populations and difficulties in delivering critical and time-sensitive goods and services.

Photo 5: Railway and road damage from erosion along the Rimac River in 2017.

11 Since 2016, the mosquito-borne Zika virus has also emerged as a concern, especially in northern Peru.

Preparations in the transport sector for recent El Niño events have focused on short-term interventions such as clearing streambeds and drains upstream of and adjacent to bridges and roadways and establishing protective infrastructure in critical areas. While these measures have mitigated impacts in select locations, the need to expand such efforts and undertake them more consistently is pressing. Additionally, since at least the 1982-83 El Niño event, recommendations have been made regarding the modification of design criteria for hazard-prone transport infrastructure to accommodate the precipitation and discharge levels of severe El Niño events rather than lower intensity flood events (e.g. with recurrence intervals of 25-50 years) but have gone unheeded (CAF 2000).

Health Sector

Despite being a critical component of the nation's disaster-response system, health-sector infrastructure is often located in hazard-prone locations, and direct and indirect impacts on health facilities may have broad-reaching effects on local abilities to respond during and after disasters. During prior El Niño events severe rainfall, flooding, and *huaicos* have damaged health posts and hospitals, although these facilities have often continued to function in at least basic capacities (CAF 2000). In the 1997-98 event, for example, an estimated 580 health facilities at the national level were significantly impacted or destroyed, and preliminary reports from the 2017 event suggest that more than 700 health facilities were damaged (INDECI 2017). While access to health care facilities at the national level has improved in recent decades, it remains difficult in many rural and remote areas and, during disaster events, is further complicated by damages to transport infrastructure. Limited staff and equipment in existing facilities also lead to challenges in responding simultaneously to disaster impacts and the ordinary healthcare demands of the population (CAF 2000).

Education Sector

In recent decades, the number of educational facilities in Peru has grown substantially, yet much of this infrastructure has been constructed to specifications or with materials vulnerable to intense rainfall and flooding (e.g. low-quality roofing materials) or in hazard-prone locations (CAF 2000). During the 1997-98 El Niño, for example, a reported 2,873 educational facilities were damaged, 5% of which required complete relocation due to the unsuitability of their locations. Despite such shortcomings, during El Niño events and other disasters these facilities have frequently served as shelters for displaced populations. While such shelters are critical, the reliance on educational facilities for this service has led to the deterioration of infrastructure and educational materials as well as extended breaks in instruction (CAF 2000). Preliminary figures from the 2017 event indicate that more than 2150 schools were impacted, with more than 150 facilities destroyed or left unusable, and in many parts of the country extended recesses in instruction occurred due to weather-related hazards and infrastructural damages (INDECI 2017).[12]

12 See: http://elcomercio.pe/lima/nino-costero-300-mil-escolares-podran-iniciar-clases-411697

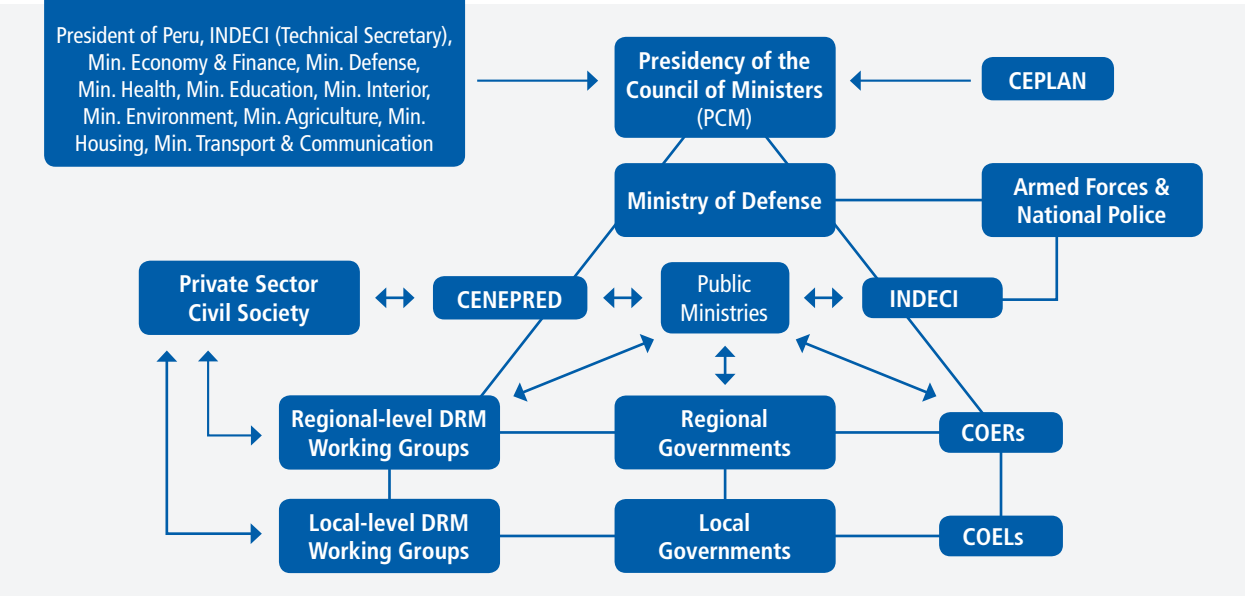
3.

PERU'S EVOLVING INSTITUTIONAL CONTEXT FOR DISASTER RISK MANAGEMENT

Despite Peru's long history of El Niño and other disasters (Carey 2010; Ferradas 2015; Seiner 2001), institutional development for DRM in the country remained incipient through the 20th century, with efforts focused largely on emergency response to individual events. By late 2010, however, an integrated vision of DRM was explicitly designated a priority in the national policy agenda (Acuerdo Nacional Nº 32), and by early 2011, Law Nº 29664 was passed to found the National System for Disaster Risk Management (SINAGERD), which provides the formal institutional structure for an integrated DRM strategy combining prospective, corrective, and reactive DRM measures.

To advance this integrated strategy, SINAGERD incorporates diverse actors from across governmental levels and sectors (Figure 5). At the head of the system is the Presidency of the Council of Ministers (PCM) with a key role in directing, supervising, and coordinating national DRM actions. Beneath the PCM, two national-level organizations within the Ministry of Defense are tasked with directing the technical aspects of DRM policy and managing related informational resources. One of these organizations is INDECI, which continues its role overseeing activities related to disaster preparation, response, and rehabilitation. Reflecting the country's longstanding focus on reactive disaster 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). To complement INDECI, the National Center for the Estimation, Prevention, and Reduction of Disaster Risks (CENEPRED) oversees prospective and corrective DRM measures as well as reconstruction processes. Established in 2011, CENEPRED is a centralized institution based in Lima, with a mandate to coordinate with regional and local-level

Figure 5: Institutional map showing key actors in the National System for Disaster Risk Management (SINAGERD).



governments through formal DRM working groups (discussed in further detail below). Originally ascribed to the PCM, CENEPRED was incorporated into the Ministry of Defense in early 2017 in an effort to improve the efficiency of SINAGERD.

SINAGERD also incorporates two high-level advisory bodies to the PCM. The National Council for Disaster Risk Management (CONAGERD) serves as the highest-level political decision maker and strategist in SINAGERD, and is composed of the President of the Republic (who presides over the council), ministers from nine different ministries (see Figure 5), and a representative of INDECI, who serves as the Technical Secretary. Notably, there is no permanent representative of sub-national governments or of the private sector or civil society on CONAGERD, though the law stipulates that additional participants may be convened to the council as necessary. The National Center for Strategic Planning (CEPLAN) also coordinates directly with the PCM in order to incorporate DRM priorities into the Strategic Plan for National Development.

Adding further complexity to the governance of SINAGERD is the fact that much of the DRM agenda's implementation has historically been and remains in the hands of various public ministries (e.g. Ministry of Agriculture; Ministry of Housing, Construction, and Sanitation; Ministry of Education; and Ministry of Health). These ministries have their own internal governing structures and institutional cultures that add to the challenges in coordination and integration in the DRM sector. While inter-ministerial groups such as the PCM and CONAGERD provide formal spaces for integration in high-level planning, achieving coordination in the day-to-day activities of these large siloed bureaucracies remains complex and incomplete. Of the varied ministries involved, the Ministry of Economy and Finance (MEF) plays a particularly critical role in DRM strategy through its control of fiscal mechanisms and spending oversight.

Despite the centralized character of much of SINAGERD, under the system's subsidiarity principle, regional and local-level governments are designated as the principal executors of DRM activities. Under this principle, decisions should be made at the lowest level possible and national-level intervention should occur only when the capacities of subnational-level actors are surpassed. DRM responsibilities should be organized at subnational levels by working groups (*grupos de trabajo*) and centers of emergency operations (COERs and COELs) organized at both regional and municipal scales. These groups are tasked with the evaluation of disaster risks and social vulnerabilities and with the development of formal plans to reduce or respond to these risks.[13]

Additional groups incorporated in SINAGERD by law include the Armed Forces and National Police, who play key roles in disaster preparedness and response activities. The law also explicitly includes the "participation of private entities and civil society," including universities, diverse corporate sectors, NGOs, and volunteer organizations like the Red Cross.

Policies and funding supporting DRM in Peru

Peru's first National Disaster Risk Management Plan 2014-2021 (PLANAGERD) provides clear guidelines and indicators for the implementation of the country's DRM strategy, and a variety of additional laws and policies support the plan's objectives. Some of the most important—if insufficiently implemented—supporting legislation includes policies targeted at landscape-level planning and zoning to prevent and reduce settlement and infrastructure construction in hazardous areas. For example, the National Water Authority is responsible for delineating buffer zones (*faja marginal*) around riverbeds and other watercourses, which are some of the foremost hazard zones in the country (see Box 2). Landscape-scale planning and zoning processes (*ordenamiento territorial*) have also been formally established, with oversight divided between the Ministry of the Environment and the Ministry of Housing: the former is tasked with facilitating processes of territory-wide "ecological and economic zoning" while the latter focuses on organizing development processes in urban contexts. Notably, however, neither of these ministries currently enforces binding zoning regulations. Numerous respondents highlighted this lack of effective zoning policy and the continued occupation of hazardous areas across the national territory as a central challenge to DRM implementation.

To begin to address the extensive settlement of risk-prone spaces, the Ministry of Housing has recently modified legislation governing property formalization to prohibit the issuing of titles in zones of immitigable risk. In 2012 Peruvian policymakers also passed Law Nº 29869 governing the relocation of populations inhabiting zones of immitigable risks.[14] This legislation establishes the formal process through which the analysis and determination of such risks and

13 DRM working groups have been established in all 26 regional governments while their creation at lower levels is less developed. Respondents insisted, however, that the formal establishment of these working groups does not ensure effectiveness or even sustained action on their part, and it was suggested that national-level institutions could do more to support the continued actions of sub-national working groups.

14 Article 4 of Law Nº 29869 defines zones of immitigable risk as "zones where there is the probability that the population or its livelihoods will suffer damages or losses due to the impacts of a hazard, and where the implementation of mitigation measures results in greater cost or complexity than relocating the respective households or infrastructure."

Box 2

Collaborating to create room for the Rimac River in Ate

Most of the time, the middle reaches of Peru's Rimac River watershed are difficult to imagine as a flood-risk hotspot. Located in the arid transition zone between the desert metropolis of Lima (pop. ~11 million) and the foothills of the western Andes, the municipalities of Ate, Chaclacayo, and Lurigancho-Chosica have grown from lightly populated agricultural and recreational spaces bordering the river into a bustling urban corridor. This transformation has been driven by extensive settlement of the Rimac River valley and the steep, rocky canyons (known as *quebradas*) nearby. Yet despite the region's desert façade, this zone is vulnerable to riverine flooding and streambed erosion in the main Rimac valley as well as to debris flows caused by flash flooding (known as *huaicos*) within and below the adjacent *quebradas*. These hazards, which strike during some El Niño years and annual rainy seasons, imperil local residents and their assets and disrupt critical transportation routes.

Flood risks in the middle Rimac basin are tied to the region's geophysical conditions and hydrologic processes, but this is only part of the story. Risks in this region are also closely linked to a history of settling in hazard-prone spaces. These occupation patterns underscore how a lack of land-use planning, zoning, and enforcement coupled with limited public awareness of hazards can lead to rapid growth in disaster risk. In this context, the National Water Authority (ANA) is currently working to disseminate and retroactively enforce the *faja marginal* (a buffer zone around the river corridor where settlement is prohibited) along hazard-prone stretches of the Rimac. Yet, despite the risks local populations face, this process has often been met with resistance from residents concerned with losing access to the lands they inhabit.

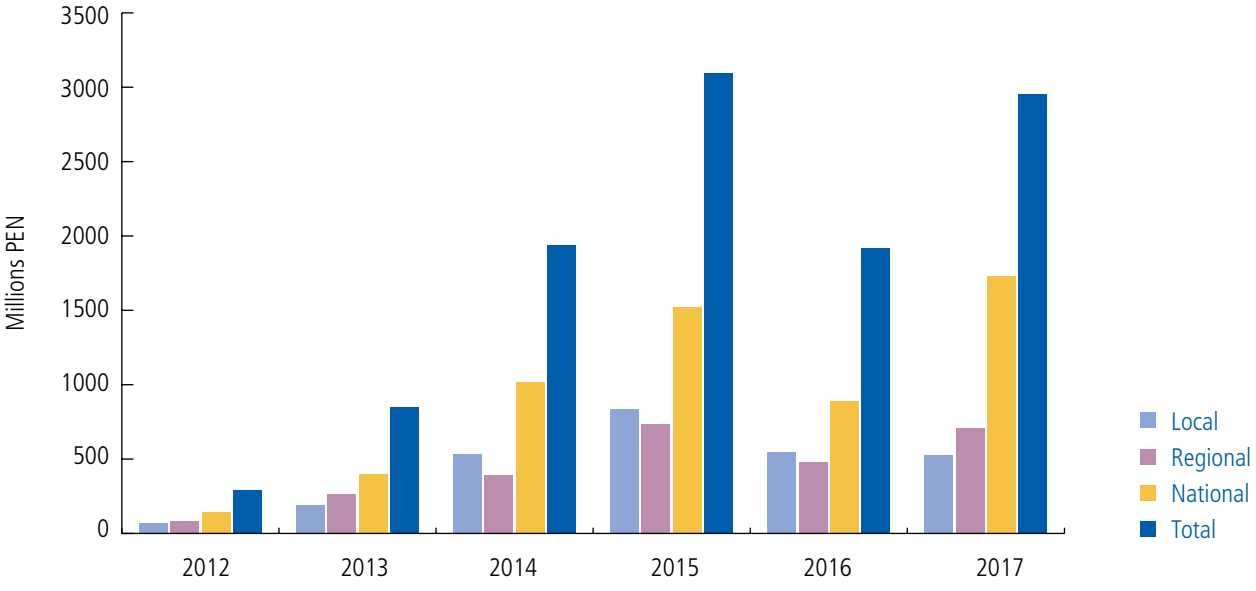
Fears of displacement and a refusal to recognize the *faja marginal* in one part of Ate, however, have recently given way to improved cooperation between residents and ANA. In this area, locals who have long lived next to the river—in some cases for four decades—but lack formal titles for their lands are designing plans for alternative uses for the river's buffer zone, including public green spaces and a walking boulevard. By respecting the *faja marginal* in this way, these residents hope to avoid encroachment on the flood zone while improving their communal space and receiving support for the formal titling of their lands from ANA and other government institutions.

subsequent voluntary or involuntary relocation should occur, dividing key responsibilities between relevant local and regional governments, CENEPRED, INDECI, and the Ministry of Housing. Despite these advances, the laws have yet seen little implementation and the definition of what constitutes immitigable risk remains contentious in many settings, while the conditions of relocation and the politics surrounding them are also complex and conflicted (see Box 3). However, in the wake of the 2017 coastal El Niño, relocation has been stressed by authorities and DRM experts as a necessary component of the reconstruction process, thus the relocation law and related legislation are likely to receive further tests in the near future.

To support the implementation of PLANAGERD and related policies, a variety of funds for financing DRM measures have been established. These mechanisms are overseen by the PCM and the Ministry of Economy and Finance (MEF) and include one-time allocations for specific initiatives; annually reoccurring budget lines and special incentive programs designed to fund prospective and corrective measures at all levels of government (e.g. PP 0068); funds from mining-sector taxes to be used for relocation; and contingency funds and a fiscal stabilization fund for preparation, response, rehabilitation, and reconstruction activities related to specific disaster events (UN 2014). Yet despite substantial increases in DRM funding in recent years (Figure 6), a principal concern of national-level authorities and DRM practitioners is the lack of capacity at regional and local levels to effectively access and use such resources. According to respondents, this inability to take full advantage of DRM-specific financing is grounded in factors including a continued lack of awareness of the funding's availability and purpose and limited technical capacities at subnational levels for accessing public budget programs. Both of these factors are made worse by problems of frequent staff turnover at lower governmental levels and an entrenched vision of DRM as emergency response rather than prospective and corrective long-term planning. Additionally, multiple respondents underscored problems of inefficient and corrupt uses of DRM funding, particularly under formal declarations of emergency, when oversight and auditing of public spending are less stringent.

To summarize, the evolving policies and institutional and financial context supporting DRM in Peru illustrate a transition away from a system focused solely on emergency response towards a more integrated approach. Nevertheless, many authorities and practitioners stress that substantial gaps still exist between the DRM policies enshrined in law and the grounded practices of the varied groups tasked with their implementation (cf. UN 2014). In this context of gradual transformation, the El Niño events of 2015-16 and 2017 provide concrete circumstances in which to examine the country's existing DRM practices and their outcomes. The following sections of the report turn to a discussion of the measures taken in preparation for the highly publicized 2015-16 event and provide preliminary reflections on how these measures influenced the outcomes of the 2017 event.

Figure 6: Funding for DRM measures to different levels of government under the Budget Program PP0068 in millions of Peruvian Soles (PEN) (2017 amounts are preliminary). Source: MEF.



Box 3

Risk-reducing infrastructure versus relocation: seeking long-term DRM solutions in Chosica

In the Municipality of Lurigancho-Chosica, located in the Rimac River valley outside Lima, government authorities declared a neighborhood at the base of the Carosio *quebrada* as a zone of immitigable risk and mandated the relocation of numerous households after *huaicos* in late March 2015 killed at least 7 people and displaced dozens of families. Yet most of the population refused the order, preferring to stay in their homes and face the *huaico* risk rather than accept the conditions of the relocation process offered by the government.

Given the unwillingness of the population to be relocated and the forecast for a severe El Niño event in 2015-16, the National Water Authority (within the Ministry of Agriculture) sponsored the installation of numerous geodynamic barriers capable of arresting the solid material entrained by *huaicos* in the steep valleys above the community in Carosio and neighboring *quebradas*. These barriers, which cost about one million soles each (~US$330,000), initially drew harsh criticism from some local residents and politicians who found them excessively costly in comparison to the typical cement and rock retaining walls that had been periodically constructed and subsequently destroyed by earlier *huaicos*.

Given the lack of substantial El Niño impacts in central Peru in 2015-16, none of these geodynamic barriers were tested that first year, and some of the structures suffered from the theft of components over the following year. Nevertheless, with the heavy rainfall and numerous *huaicos* that struck the region in early 2017, the barriers' value was illustrated as they filled with material that would have otherwise flowed downstream into neighborhoods, damaging homes, blocking roadways, and perhaps taking additional lives. Once their effectiveness had been proven, neighboring areas where they had not been installed began to request them, and in mid-2017, the viability of a more extensive implementation of the infrastructure was being evaluated.

As these geodynamic barriers proved in 2017, effective DRM infrastructure can play an important role in protecting populations and assets from foreseeable hazards. However, where future hazards might overwhelm such infrastructure due to changes in intensity or a lack of ongoing maintenance, such infrastructure may also generate greater risks over the long-term if it creates a sense of security that leads to further settlement or asset build-up in hazard-prone

spaces. As a result of this potential, careful analysis of the long-term efficacy of investing in protective infrastructure versus implementing other forms of corrective or prospective DRM—such as hazard zoning or relocation—is necessary. In the wake of the 2017 coastal El Niño, such analysis should be undertaken in Chosica and neighboring communities to determine where geodynamic barriers are an appropriate long-term DRM solution and where risks are such that acceptable relocation strategies should instead be prioritized and negotiated with local populations.

4.

PREPARATIONS FOR THE 2015-16 EL NIÑO IN PERU

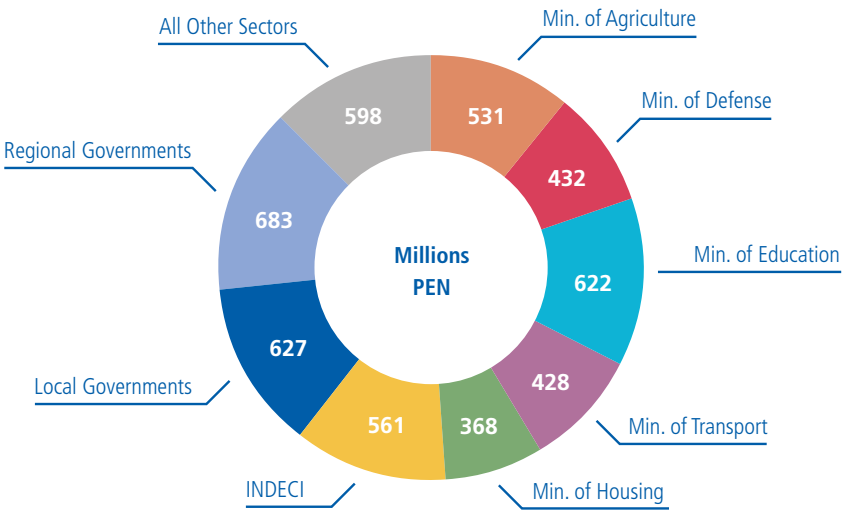
By mid-2015, Peru's ENFEN and other El Niño forecasters worldwide began to warn of a significant global El Niño event for the upcoming austral summer. These forecasts triggered Peru's central government to proactively declare parts of 14 regions in a state of emergency in early July due to the event's potential impacts during the upcoming rainy season. Over the next several months, additional declarations would bring a total of 89 % of all municipalities in the country under a state of emergency, and by late August it was suggested that the intensity of the event could rival those of 1982-83 and 1997-98 (INDECI 2015).

In early September a "Decree of Urgency" (D.U. Nº 004-2015) granted authority to redistribute annual budget allocations and implement additional financial mechanisms to support further preparedness activities throughout the country. This decree also created the National Council for Management of El Niño Risk (CONAGER-FEN), consisting of nine ministers and presided over by the Minister of Agriculture, to serve as the chief decision-making and policy-coordinating entity during the 2015-16 event.

In October, CONAGER-FEN released a detailed plan (CONAGER-FEN 2015) outlining the principal actions to be taken across governmental sectors and geographic regions in preparation for the event, with a total budget allocation of more than 4.85 billion soles (~US$ 1.5 billion) (Figure 7).

This substantial funding included existing allocations from 2014 and 2015 for risk reduction and preparedness activities relevant to El Niño, as well as additional support for emergency response and rehabilitation. As had been the case in the 1997-98 El Niño event, the predominant preparedness activities involved using heavy machinery to clear debris and channelize flows in or beside river courses or irrigation canals, along with the reinforcement and construction of protective infrastructure in some risk-prone watersheds (Photo 6). These activities were led in rural and peri-urban areas by the Ministry of Agriculture and regional governments, while in urban settings the Ministry of Housing typically oversaw them.

Figure 7: Budget allocations across government sectors for DRM measures related to the 2015-16 El Niño. Total budget allocation exceeded 4.85 billion Peruvian Soles (PEN) (~US$1.5 billion) (CONAGER-FEN 2015).



The importance of these watershed- and infrastructure-focused measures is understandable in contexts where development in and adjacent to flood-prone watercourses is common. Nevertheless, the prevalence of these activities in the portfolio of short-term preparatory strategies for two consecutive El Niño events suggests that previous lessons regarding the need for more consistent and routine maintenance of river courses and infrastructure coupled with more restrictive zoning policies are yet to be taken up by authorities. Questions also arise as to the long-term benefits of spending large sums on *ad hoc* river clearing, channelization, and protective works that may create an unwarranted sense of security in vulnerable populations. Additionally, respondents underscored that these watershed-focused activities—especially stream clearing, widening, and channelization efforts—were highly susceptible to corruption due to the difficulties in verifying factors such as the length of time worked, the amount of fuel used by heavy machinery, and the extent of riverbed treated. Such problems were reportedly made worse under the declarations of emergency when spending controls were relaxed and the use of third-party operators in some cases led to significantly elevated costs for contracting heavy machinery and labor.

The Ministries of Housing, Health, Education, and Transport also all received substantial funding for protection, repairs, and improvements to infrastructure vulnerable to heavy rains, flooding, and landslides (e.g. potable water and sanitation systems, schools, health posts and hospitals, and roads and bridges). Yet, as in the case of the watershed-level interventions discussed above, respondents suggested that these infrastructure improvements would have been more effective had they been undertaken on a routine basis instead of in the months immediately preceding the forecasted event. Moreover, the vulnerability of much of this infrastructure had been underscored during earlier flooding events, and explicit recommendations to address these problems after prior El Niño events were not implemented (CAF 2000).

Photo 6: Ongoing efforts to open the channel of the Rimac River as flooding impacts intensified during early 2017.

In complement to watershed and infrastructure-focused activities, authorities and civil society organizations at the national, regional, and local levels undertook diverse activities to support preparedness for the general public and for entities responsible for disaster response. Much of this action entailed material preparations, for example the stockpiling of food, 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 their network of storage facilities for emergency supplies, while the Ministry of Housing used its recently established system of *tambos* (facilities in rural areas where a range of government services are concentrated) to stockpile supplies for rapid distribution to populations at risk of isolation from more centralized service provision.

Recognizing the critical importance of maintaining access to potable water, the Ministry of Housing also provided financing and loans totaling nearly US$ 20 million to local water systems 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). Additionally, the Ministry of Housing supplied eight portable water treatment systems along with cistern trucks to the departments of Tumbes, Piura, Lambayeque, and Amazonas — areas that suffered potable water shortages and related disease outbreaks during the 1997-98 event — as well as five portable drain-cleaning systems (hydro-jets) for select water and sewage providers (MVCS 2016).

In addition to supplies and equipment, mobile infrastructure including modular buildings to provide 500 temporary residences and 2000 temporary classrooms were acquired by the Ministries of Housing and Education respectively and distributed to vulnerable regions. The Ministry of Transport meanwhile acquired numerous temporary bridges (e.g. Bailey style, Photo 7) up to 60 meters in length and 151 new pieces of heavy machinery (i.e. dump trucks, front-end loaders, backhoes, etc.) for distribution to vulnerable

Photo 7: A Bailey bridge established in the wake of the 2017 coastal El Niño.

regions. This heavy machinery complemented similar equipment owned by the Ministries of Agriculture and Housing as well as by regional governments, but due to high demand in the period prior to the onset of the rainy season third-party providers were still relied upon in some settings. Notably, while an emphasis was placed on insuring sufficient distribution of such equipment, respondents described coordination problems that in some cases led machinery to stand idle due to a lack of allocated funds for fuel supplies.

Substantial efforts were also undertaken across sectors and governmental levels to prepare populations to effectively respond to disaster once it hit. These interventions were diverse, and targeted a wide range of authorities and citizens. One area of focus was in training emergency-response and search and rescue brigades. Such training was undertaken by INDECI and its decentralized COERs and COELs, the Volunteer Firefighters Association, diverse Ministries (especially the Ministry of the Interior via the national police and the Ministry of Defense via the armed forces), and a range of NGOs working directly with civil society. In some instances, this training was coupled with the creation or dissemination of strategies and contingency plans for specific groups and sectors. CENEPRED, for example, worked closely with the disaster-risk working groups in 14 priority regions to build teams, develop technical capacities, and formulate DRM plans.

Several additional strategies were used to build public awareness of physical risks and appropriate responses. For example, with support from the National Water Authority, both INDECI and CENEPRED worked to map high-risk zones and evacuation routes, with the resulting maps hosted on online platforms open to the public.[15] Many groups contributed to preparations for a series of drills and simulations of disaster and emergency response in the months prior to the rainy season, and in some settings Early Warning Systems (EWS) were developed or implemented through the monitoring of meteorological and hydrologic conditions (e.g. by monitoring river levels at points upstream of vulnerable population centers or infrastructure). Additionally, training activities were undertaken by INDECI and some NGOs to prepare local authorities and civilians to complete the formal documentation of the post-disaster Evaluation of Damages and Analysis of Necessities (EDAN), which is a critical step in the dispersal of governmental aid through registration in the National Information System for Response and Rehabilitation (SINPAD).

15 See: http://sinadeci.indeci.gob.pe/VisorEvacuacion/index.html and http://sigrid.cenepred.gob.pe/sigrid/

5.

KEY INSIGHTS: EVALUATING RECENT EL NIÑO-RELATED DISASTER RISK MANAGEMENT IN PERU

Despite the widely publicized forecasts and extensive preparations for a severe event, the 2015-16 El Niño produced much less significant impacts than expected in Peru. The impacts reported included minor flooding in Piura and Tumbes and localized drought impacts on agricultural production in the south of the country. While some public authorities pointed to the role that preparedness and corrective measures had played in minimizing impacts, many experts considered the 2015-16 El Niño a "non-event" due to its weak to moderate intensity. In light of the lack of impacts, evaluation of the effectiveness of the varied measures taken in preparation for the event is difficult. Nevertheless, interviews with diverse public authorities involved in or peripheral to El Niño-related DRM activities in 2015-16 provide grounded perspectives on the effects of these measures as well as on the recent institutional developments in Peru's DRM sector and what might be learned going forward. Additionally, the catastrophic impacts of the 2017 coastal El Niño provide opportunities to consider the effectiveness of measures undertaken the year before. While a detailed consideration of the 2017 event is beyond the scope of this report, reflections based on media and governmental coverage of the event and conversations with DRM experts are offered where relevant. A forthcoming PERC report focused specifically on the impacts of the 2017 El Niño in Peru will expand considerably on the preliminary reflections regarding that event contained here.

1) The challenges of uncertainty and variability for forecasting and preparedness

The ability to forecast El Niño-related dynamics at the global scale has improved markedly, but precise prediction of event intensity and impacts at regional to local scales remains a significant challenge. The impacts of prior El Niño events can help target and structure DRM activities, but variability between events should be expected.

Throughout the early stages of its development, the 2015-16 El Niño event showed close alignment with conditions during 1997-98, and experts around the globe — including from Peru's ENFEN — warned of an event of potentially severe intensity. While damages in some regions (e.g. southern California) were substantial, the fact that the event was not stronger in Peru contradicted the forecasts of ENFEN and other experts. Given the status of El Niño indicators in mid-late 2015, our respondents concurred that utmost precaution was warranted on the part of ENFEN, and it was broadly perceived that the group had acted effectively in forecasting the event. One year later ENFEN's forecasting efforts were called into question again as the 2017 coastal El Niño event rapidly developed with no forewarning. Here again, the group's assessments — based in continuous monitoring of standard El Niño indicators — were in-line with those of other international experts, none of whom predicted the event beforehand.[16]

Rather than scientific error, the challenges in accurately forecasting the events of 2015-16 and 2017 are indicative of the complexity and uncertainty inherent to El Niño events, and especially to the infrequent and little-understood coastal El Niño phenomenon unique to the Peruvian and Ecuadorian coastline. This uncertainty underscores the critical need for development of prospective DRM measures that work towards building long-term resilience rather than a continued dependence on short-term corrective and preparatory strategies. Moreover, "no regrets" solutions that contribute directly to national development goals regardless of disaster occurrence should be a priority. Such prospective and resilience-

16 In their report issued on January 16, 2017, ENFEN concluded that the probability of a weak coastal El Niño was 30%, while that of a moderate to extraordinary coastal event was only 1%. That same day, rainfall in the foothills outside of Lima produced a series of *huaicos* in the Rimac River Valley that damaged homes and blocked roads. While such events occur in some El Niño years, they are also common during the annual rainy season and were not considered indicative of the developing coastal El Niño. One week later, however, ENFEN issued an update reporting that sea-surface temperatures off the northern Peruvian coast were rising rapidly and producing conditions conducive to a weak coastal El Niño that would continue to be monitored closely. By the first week of February, as intense rainfall in the north of the country began to generate widespread flooding, ENFEN issued a full alert for the coastal El Niño. For further detail regarding these reports see: http://www.senamhi.gob.pe/?p=0812

focused approaches would also help to confront the high variability in the spatial and temporal distribution of impacts between different El Niño events that can make relying on past events — and especially single events — as guides for preparedness inefficient and potentially misleading.

2) The need for inter-sectoral and multi-level institutional coordination for integrated DRM

The institutional context for DRM in Peru is shifting from a model focused largely on disaster response to an approach integrating corrective, prospective, and reactive measures and capacities across sectors and levels of government and society. This shift is well supported by formal laws and policies, yet significant implementation challenges in practice remain, particularly at subnational scales. Further incorporation of DRM planning into existing processes of watershed management and landscape planning is also needed.

The 2015-16 El Niño — and to a greater extent the 2017 event — have provided opportunities to observe the evolving institutional context for DRM in Peru in action. According to respondents, the forecasting of the 2015-16 event served as an important catalyst for enhanced coordination across the various components of SINAGERD. For example, preparation for the 2015-16 event reportedly helped divide and clarify some roles and responsibilities for the three principal DRM organizations at the national scale — the PCM, CENEPRED, and INDECI — whose roles had been redefined or created over the few years prior to the event and who experience some overlap in activities and authority. Similarly, the designation of the national council to oversee the preparation and response strategy (CONAGER-FEN) worked to bring diverse governmental ministries, with often distinct and at times competing objectives, together in a collaborative forum. However, as the threat from the 2015-16 event declined, CONAGER-FEN was dissolved; a decision that some respondents suggested was counterproductive to maintaining institutional capacities for responding to the recurrent threat of El Niño. This dissolution does raise concerns about institutional continuity and preparedness under conditions of surprise, as highlighted by the challenges in responding to the 2017 event. In light of the difficulties in 2017, it remains to be seen whether the permanent National Council of SINAGERD (CONAGERD) can fulfill the El Niño-specific advisory role of the *ad-hoc* CONAGER-FEN.

The extensive DRM investments and activities in preparation for the 2015-16 event also tested institutional linkages and functions across the different levels of government, from national to regional to local scales. According to respondents, the process underscored that multi-level coordination and lower-level capacities remain the weakest aspects of SINAGERD and the country's evolving DRM efforts. These weaknesses reflect a historic concentration of resources and expertise for DRM at the level of the central government, and they are compounded by the relatively recent redesign of SINAGERD — a process initially and, to a large degree, still centered at the national level. While substantial efforts were undertaken to train and prepare lower-level authorities in DRM-related processes in the months leading up to the 2015-16 rainy season (e.g. in the creation of emergency plans and the management of various DRM information platforms), only a relatively small percentage of all subnational governments could be included in these activities. To be effective at scale, such capacity building requires widespread and sustained action and engagement across governmental levels as well as ongoing dissemination amongst personnel at lower levels. According to respondents, these activities remain significantly constrained by the frequent turnover in professional staff, especially at lower levels of government, and by the fact that DRM remains a peripheral and reactive activity in many contexts without adequate and permanently allocated staff resources.[17]

A final observation related to improving inter-sectoral and multi-level DRM coordination concerns the need for greater inclusion of DRM policy and planning in ongoing processes of integrated water resource management at the watershed scale (via watershed councils) and in landscape-level planning and zoning processes (*ordenamiento territorial*). This suggestion was emphasized in the wake of the 1997-98 El Niño (CAF 2000), and since then formal multi-sectoral processes have been developed in both areas, with the former led by watershed councils assisted by the National Water Authority and the latter overseen by the Ministry of Environment in conjunction with regional governments. These evolving processes are currently being conducted in diverse settings; and while they include varying degrees of attention to disaster risks and DRM, there remains significant potential to more explicitly and systematically incorporate risk assessments and DRM strategies into long-range planning and decision-making, especially at the watershed scale.

17 While multiple respondents mentioned these issues at lower levels, it is important to note that our interviews were focused primarily with national-level authorities and actors. Additional interviews with a range of sub-national authorities would be useful in broadening the perspectives included in the study and examining whether subnational authorities view these problems in the same way as their national-level counterparts.

3) The importance of capacity and oversight for DRM investments and implementation

Funding for DRM activities in Peru has grown substantially over recent years, and financial mechanisms are in place to support the transition to a more integrated and prospective DRM approach. Despite such advances, there is currently limited capacity, especially in regional and local governments, for accessing these DRM-targeted funds and executing DRM projects. Additionally, it is important to address the problems of inefficient expenditure and corruption that worsen under conditions of formally declared "emergency," when DRM funds are subject to less stringent oversight and accountability in spending. Increased funding of DRM measures through standard budgeting procedures along with enhanced oversight of the use of emergency funds should improve efficiency and transparency.

Funding for DRM-related measures has increased dramatically since the creation of SINAGERD in 2011. For example, in the flagship budget program for DRM (PP 0068), apportioned funds increased from 62 million soles in 2011 to more than 3 billion soles in 2015. Despite such prodigious growth in spending on DRM, multiple respondents identified a lack of capacity on the part of authorities to effectively access these funds and execute projects as an ongoing limitation, especially at subnational levels.

While funding for DRM interventions is principally directed by the MEF and the PCM, the sweeping "emergency" declarations in mid-2015 relaxed controls on the dispersal and monitoring of public funds. According to a number of our respondents, this created conditions for widespread inefficiencies in spending as well as outright corruption. Notably, as the impacts of the 2017 coastal El Niño began to accumulate, Peruvian President Pedro Kuczynski resisted a universal declaration of "emergency" out of an explicit effort to avoid fomenting corruption at levels of local government through less-controlled government spending.[18] Reflecting on these issues, representatives from the MEF acknowledged that some inefficiency in spending had undoubtedly occurred with the disbursements of 2015, but that such problems were typical for short-term contracting, especially under significant time constraints. Respondents also affirmed that corruption, especially at regional and local levels, is a pervasive problem extending well beyond the DRM sector, and that sustained efforts by public authorities at all levels are required to address it. Within the DRM sector specifically, respondents underscored the need for increased oversight of government spending as part of SINAGERD's development, as well as for a greater focus on prospective DRM measures undertaken over the long-term through programs like PP 0068 in lieu of *ad-hoc* measures.

4) Fomenting a culture of disaster preparedness and decentralized disaster response

Although much DRM practice in Peru remains grounded in a long-standing focus on response to individual disasters, there is a transition underway to a more integrated and comprehensive DRM approach. Currently, much of the progress in this area has been focused in the state institutions directly involved in DRM activities, most notably at the national level and to a lesser degree in subnational institutions. Widespread dissemination of these approaches in ways that achieve changes in the broader institutional and cultural context of the country will require the ongoing commitment of financial and human resources and extensive outreach and communication across levels and sectors of the state bureaucracy as well as between government and society.

In the past, DRM in Peru has been viewed principally as the purview of the police, armed forces, and civil defense groups acting in response to particular disasters. The creation of SINAGERD in 2011 marks an important step in the transition to a more integrated vision of DRM incorporating broader society. Respondents noted that moving from this policy vision to widespread implementation is a long-term process, however, that remains incipient in most governmental sectors and segments of society. While activities related to preparation for the 2015-16 El Niño (e.g. citizens learning about early warning systems, evacuation routes, and basic first aid through workshops and drills or local governments learning how to use DRM-information platforms) provided significant opportunities for outreach and capacity building in disaster preparedness and response, it was noted that to have long-term effects, these activities must be seen as part of a continuous process of DRM that extends beyond the threat of a single forecasted disaster into a culture of risk awareness and readiness.

Respondents also emphasized that to be effective at the institutional level, the work of SINAGERD must extend beyond the central institutions tasked with DRM into the full range of government

18 See: http://larepublica.pe/politica/858074-ppk-declarar-todo-el-peru-en-emergencia-es-abrirle-la-puerta-la-corrupcion-video

sectors and their quotidian activities—a process that will take time and involve incremental change in entrenched institutional cultures. Meanwhile at local levels, DRM activities must be seen as relevant and worthwhile for authorities and citizens rather than as an additional bureaucratic burden imposed by central authorities. While some concern was expressed that the lack of severe impacts from the highly publicized 2015-16 El Niño might have negative effects on overall willingness to prepare for disasters in the future, the impacts of the unforeseen 2017 event have likely reinforced the importance of such preparation in many contexts, underscoring the fact that disaster may strike at any time.

5) From "emergency" response to long-term resilience through corrective and prospective DRM

Despite the country's long history of disaster response coupled with sustained growth and stability in the national economy over recent years, the disaster-risk context in Peru has improved little for much of the population. This lack of progress on risk reduction is often linked to continued high levels of exposure and vulnerability, both for populations and infrastructure. In this context, integrating long-term corrective and prospective DRM actions into ongoing development planning and resource management processes is critical for future risk reduction.

Prior El Niño events have highlighted the exposure of much of the national territory and population, as well as the underlying vulnerabilities of many households and infrastructure developments that increase disaster risks. Yet despite such lessons, planning and preparation for El Niño events in Peru have continued to be characterized by short-term measures conducted only once events have been forecasted. For example, a substantial component of the DRM measures in both the 1997-98 and 2015-16 events focused on preparing watercourses and infrastructure for the impacts of heavy rainfall and flooding in the months immediately prior to the event's predicted onset. During the 2015-16 El Niño, such interventions may have served to mitigate the event's limited impacts. However, under the much stronger impacts of the 2017 event, significant injury and loss of life and severe infrastructure impacts—including to housing, potable water and sewer systems, roads, bridges, schools, and health facilities—occurred on a scale comparable to that of both the 1982-83 and 1997-98 events. These impacts raise doubts over the degree to which learning occurred and was implemented after these earlier events and highlights the lack of durability of the preparedness measures undertaken in 2015-16.

Rehabilitation and reconstruction after the 2017 coastal El Niño provide an opportunity to systematically address these issues, and debates at the national level regarding reconstruction have focused on the need for long-term corrective and prospective DRM measures, especially regarding relocating populations and assets located in zones of immitigable risk, with concomitant development of effective zoning regulations to avoid future occupation of these spaces. Additionally, the need to construct more disaster-resilient infrastructure to accommodate the precipitation and discharge levels of severe El Niño events is once again being stressed. In light of the required shifts in DRM and development strategy, authorities have officially labeled the process as "reconstruction with changes," but building back in ways that ensure that the same exposure problems and patterns of vulnerability are not re-created will be an expensive and complicated long-term endeavor, with issues around relocation being especially contentious.

Despite such challenges, the legal and policy context in Peru for comprehensive DRM approaches has improved markedly. In particular, DRM has begun to be incorporated into landscape and watershed-scale planning processes and some progress has been made in establishing laws regulating zones of high and immitigable risk. Respondents noted, however, that in most contexts these laws have not yet been implemented effectively due to factors including limited institutional capacities and resources, the lack of political will, corruption, and resistance from residents. As one interviewee said, "the policies are very good on paper but no one follows them." Such obstacles emphasize that not only will the development of long-term corrective and prospective DRM measures be extremely costly and logistically complex, but they will also confront difficult underlying institutional, political, and social challenges. Overcoming such obstacles requires more than engineering expertise and financial resources, including sustained awareness and capacity building and a commitment to institutional and socio-cultural transformation spanning all levels of government and society.

6.

FROM RETROSPECTION TO FORESIGHT: PROJECTING FUTURE RISKS USING SCENARIO ANALYSIS

The insights of this analysis show that while DRM is seeing heightened attention in Peru, more comprehensive steps still must be taken to reduce hazards and vulnerabilities significantly in the longer term. The challenge in this context is large, however, given existing trends, continued uncertainty, and the potential contributions of socio-economic and climatic change to risk and vulnerability (Table 4). This forward-looking section aligns findings from our PERC-based assessment with a scenario approach for considering risk and resilience around future El Niño events in Peru. As a guiding question we ask: given existing and evolving risk drivers, how might different DRM strategies influence the evolution of El Niño impacts over the short to medium-term horizon (up to 2030) as compared to today? What additionally can be undertaken to comprehensively reduce risk and build resilience?

The discussion builds on scenario analysis (see Box 4) for scoping the space of future pathways, building on past insight derived from PERC analysis, as well as a comprehensive perspective on risk. The risk discussion identifies key risk drivers organized into hazard, exposure, and vulnerability as well as risk actions for tackling those drivers (Figure 8).

Table 4: Trends in risk factors and DRM strategies over the last several decades in Peru.

Risk Factors	Trends	Evidence	References
Hazard		• Hazards generally increasing (climate change, extreme weather, glacier-loss) • ENSO uncertain under climate change • "Coastal El Niño" poorly understood	Field et al. 2014; Magrin et al. 2014
Exposure		• Exposure continues to grow with largely unregulated development, especially in urban and peri-urban contexts	Seminario & Ruiz 2008; UN 2014
Vulnerability		• Vulnerability is highly uneven across social groups, but continues to increase for many, especially the poorest segments of society	CAF 2000; Calderon et al. 2015
Risk reduction measures Corrective and preparedness		• Corrective and preparedness measures substantially increase around forecasted El Niño events then stagnate post-event	CAF 2000; UN 2014
Prospective		• Prospective measures are recent and incipient	

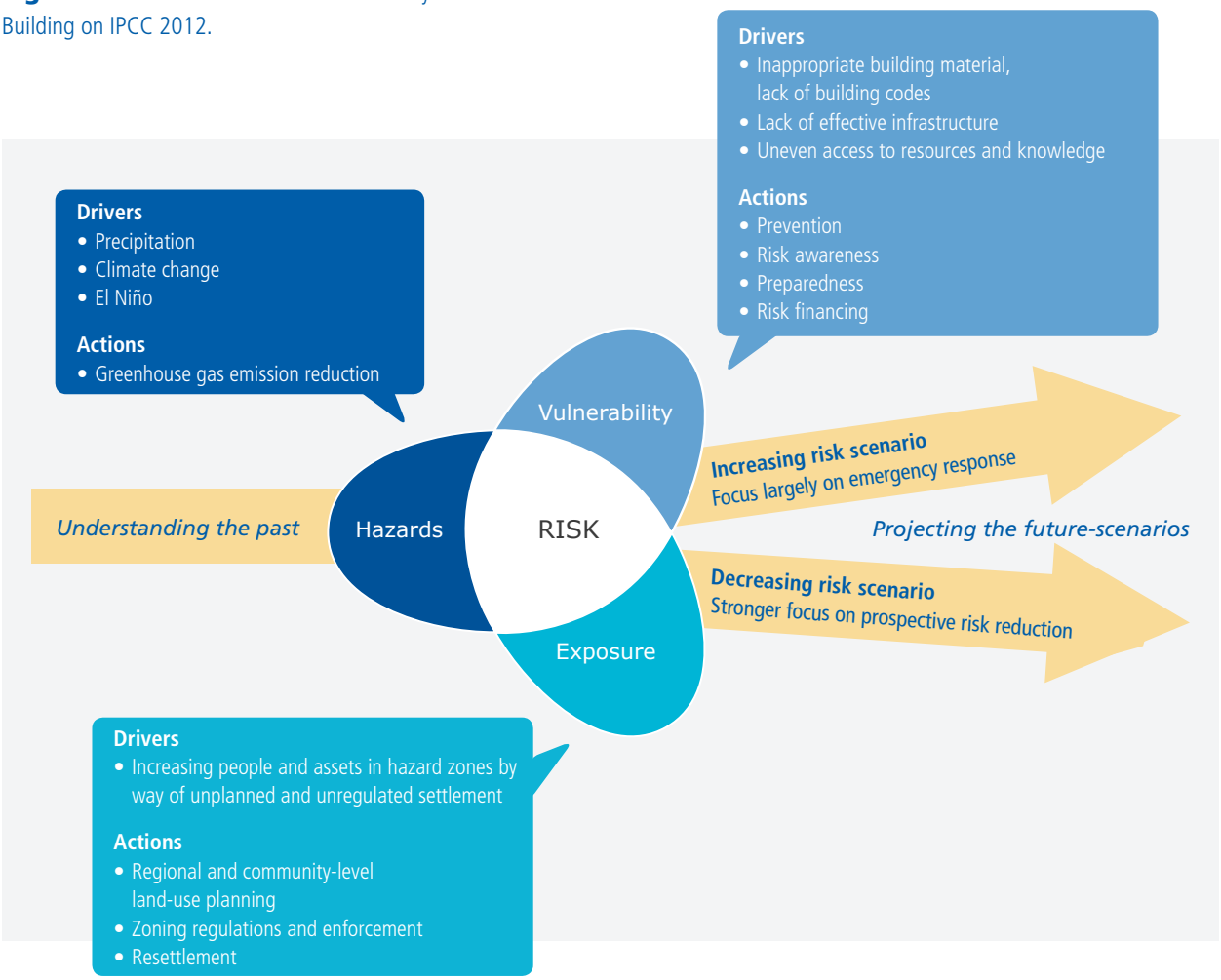
Box 4

Scenario-based approaches - key aspects

Scenario analysis is a technique and structured process, often used in systems analysis, for qualitatively or quantitatively projecting key variables of interest (in this case disaster risk and resilience) as a function of their drivers based on shared narratives (stories) about future socio-economic development and other inputs (Notten et al. 2003). Scenarios link narratives and models, and can be derived by experts in top-down fashion (e.g. IPCC's climate scenarios) or bottom-up as part of a participatory process as often used by NGOs and community-based organizations.

Scenario analysis has been widely used for global, collective problems associated with high uncertainty (e.g., climate change) as well as applied in local-participatory context to explore solutions to contested local problems (e.g. siting of waste dumps). Building on the PERC-retrospective analysis presented, the following discussion presents an approach for qualitatively and quantitatively projecting future flood risks including its drivers.

Figure 8: Risk framework and scenario analysis. Building on IPCC 2012.



Risk scenarios and projections: narratives to numbers

Drawing upon our analysis of historical and contemporary DRM trends and institutional development in Peru, we propose three scenarios depicting different potential DRM pathways for the near to medium-term future.

Scenario 1: *Ad hoc* response

The first of these scenarios generally reflects the approach taken to DRM in Peru over the last few decades and before recent attempts to create a more integrated approach via the creation of SINAGERD in 2011. DRM actions in this scenario are dominated by short-term preparedness measures undertaken on an *ad-hoc* basis in the context of pending (i.e. forecasted) or recent disaster. Such measures feature several characteristics that help to explain their prevalence in the past as well as their potential to continue to dominate DRM approaches in the future. First, these strategies feature lower initial financial and broader transaction costs, as they do not require the development and maintenance of a substantial institutional framework and bureaucracy explicitly for DRM. Instead they rely heavily on existing national-level ministries and the national police and armed forces to respond to disasters as they arise. Such response strategies have historically been orchestrated at the national-level and, if effective, can generate substantial political capital for public authorities. This approach also has relatively low potential for generating social conflict around contested processes like zoning and relocation. The principal downside to this approach is that severe disasters often overwhelm short-term capacities to correct risk-producing conditions and prepare for and respond to disaster impacts as they strike. These shortcomings can thus contribute to very high levels of losses and damages and significant long-term social upheaval.

Scenario 2: Engineered safety

The second scenario focuses on a trajectory characterized by an expanded focus on advanced planning for long-term corrective measures, particularly through the design and implementation of physical infrastructure projects (e.g. permanently channelized rivers, levee systems, retaining walls, geodynamic barriers, etc.). This approach requires substantial upfront investment in these infrastructural developments as well as in long-run maintenance costs. In a setting where short-term electoral cycles bear importantly on political decision-making, the often-lengthy periods required for construction and proof of worth of such projects may undermine their political feasibility. Such projects are also typically orchestrated by central governments, often with financial assistance from large multi-lateral lenders (e.g. World Bank) that can help defray the initial financial impacts of development at the cost of long-term indebtedness. While such developments may generate some conflict over localized displacements or other impacts, they generally are not overly conflict prone. One considerable drawback, in addition to the overall cost and ongoing maintenance requirements of infrastructure projects, is that they may lead to increasing settlement or use of "protected" but ultimately hazard-prone zones (i.e. through the "levee effect"), such that eventual infrastructure failure would be more catastrophic than prior to development. Concerns of catastrophic failure are particularly acute in contexts where long-run maintenance may be difficult to complete or where hazards are becoming more extreme.

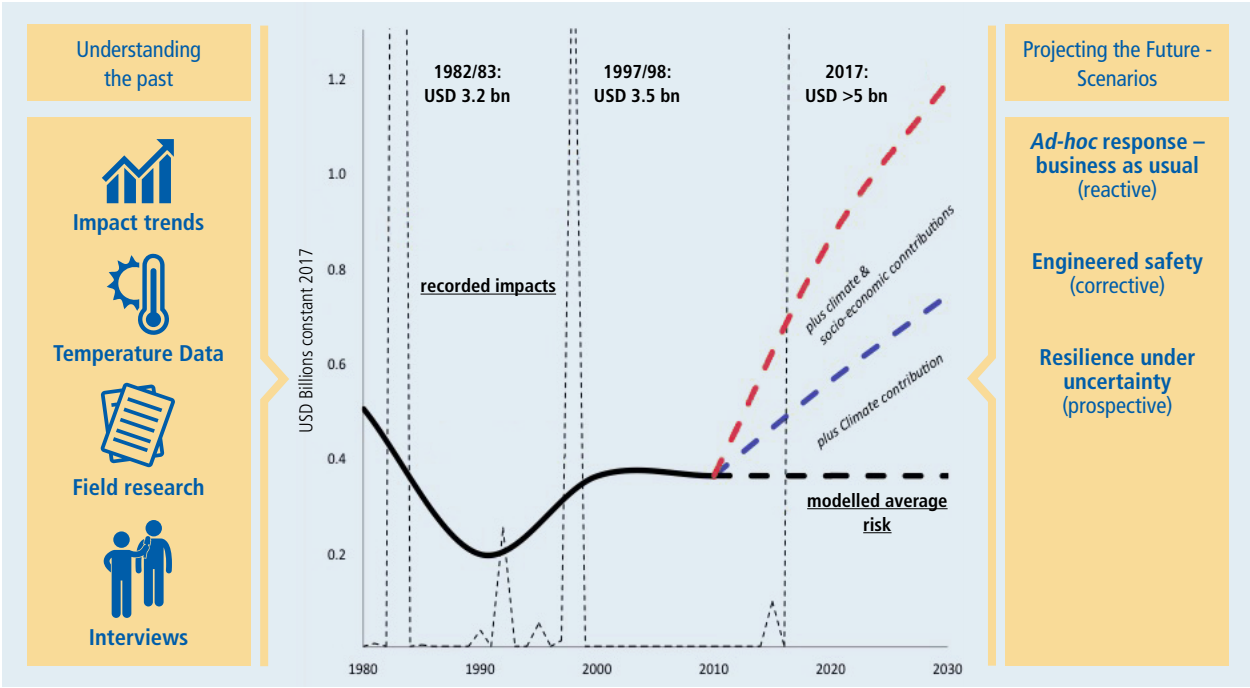
Scenario 3: Resilience under uncertainty

The third scenario reflects the effective implementation of an integrative and multi-level DRM approach — similar to that envisioned in the recent Peruvian legislation establishing the SINAGERD and PLANAGERD — coupled with an aggressive commitment to prospective DRM through enforcement of hazard-zoning regulations and related relocation processes. This approach features substantial upfront and ongoing financial and institutional costs for organizational development and implementation and capacity building across governmental sectors and levels as well as for the broad spectrum of DRM measures entailed. While national-level authorities may still be charged with strategic direction and supervision of the overarching DRM system, this approach requires effective and sustained action at all levels of government and the material resources and professional capacities to support such action. The implementation of the approach's zoning and relocation requirements,

particularly in a context like Peru where occupation of risk-prone spaces is pervasive, is likely to generate substantial levels of social conflict and resistance. Effective implementation of such an approach thus requires strong political commitment, dedicated resources over the long-term, and a comprehensive transformation of the culture around DRM in government and broader society. While the initial costs of this approach are likely to be the highest of the three scenarios (this approach, in fact, demands some of the same measures encompassed by the other strategies), over the long term this strategy should significantly lessen the impacts of El Niño and other disasters on Peruvian society.

Figure 9 shows the large variability in observed flood losses in Peru with the recent severe ENSO events producing massive impacts, while other flooding led to small losses only. Modeled average risk over the future is projected to decrease, particularly with an approach building on *ad-hoc* response. Engineered safety emphasizing further corrective, largely physical, risk reduction will help to arrest increases in risk. Yet, more is needed and a resilience-focused strategy proposing broad-based resilience building across financial, human, social, natural as well as physical capital will be an even more promising future pathway with substantial benefits.

Figure 9: Loss trends based on projective forensic analysis. Data: Losses-CRED 2017; Flood risk-Winsemius et al. 2013.



7.

RECOMMENDATIONS

In light of the analysis presented above and drawing especially upon the insights provided by our interview respondents, we offer the following policy-targeted recommendations:

- Given the recurrent and unpredictable nature of ENSO in Peru, it is important to move beyond an "emergency" mindset and disaster response approach towards transformative DRM measures that combine long-term prospective and corrective strategies.
- The stochastic recurrence of El Niño highlights the importance of continuity in the institutional arrangements for directing and implementing DRM activities related to the phenomenon. While ENFEN plays an important role in event forecasting, a permanent multi-sectoral and multi-level council or working group could serve a critical role as a coordinating body within the nation's institutional structure for risk management (SINAGERD).
- Institutional capacities for integrated risk management are needed across all levels of government. Given the key role of regional and local governments as the principal implementers of DRM actions, the building of such capacities at these levels should be prioritized through the development of permanent resource allocations and programs that work not only to prepare competent professionals but also to keep them in their posts in order to address problems of frequent staff turnover and a lack of institutional memory.
- Representation of local and regional governments in the National Risk Management Council (CONAGERD) would strengthen the role of these governmental levels in strategic DRM planning and decision-making.
- Increased funding for DRM at the national level supports the development of *ex ante* risk-management strategies throughout the country. In order to capitalize on the potential of this funding, efforts are required to enhance the capacities of regional and local-level governments in accessing funds and directing spending towards long-term prospective and corrective DRM strategies.
- Increased monitoring and evaluation of how funds—especially those dispersed under formal declarations of emergency—are used for DRM activities will help to improve transparency and accountability and is likely to lead to improved DRM outcomes. To the extent possible, funding for DRM actions should be distributed via regular budgetary programs rather than under emergency and *ad-hoc* circumstances.
- Prospective and corrective measures should be worked into long-term development planning and implemented continuously, rather than on an *ad-hoc* basis once disasters are imminent.
- Peru has made substantial progress in establishing basic legislation and policies that support prospective risk management in hazard-prone settings—e.g. in watercourses and zones of immitigable risk—as well as related policies for integrated watershed management and landscape-level planning. Rather than having separate ministries work independently to implement each of these sets of related regulations, efforts should be made to promote inter-sectoral collaboration and create synergies between these efforts.
- The potential to replicate and expand DRM infrastructure that has proven to be effective in trial settings (e.g. geodynamic barriers) should be evaluated. Nevertheless, protective infrastructure creation should not be prioritized in cases where it has significant potential to create greater risk over the long-term.
- The impacts of repeated severe El Niño events suggest that in some cases relocation of at-risk populations and infrastructure is likely the most effective and sustainable option for long-term risk reduction. The extensive damage resulting from the 2017

event along with the current public awareness of hazard exposures and underlying vulnerabilities may be effective incentives for promoting relocation.

- While relocation is an important strategy in some settings, avoiding the continued or recurrent settlement of high-risk spaces through the establishment and enforcement of effective zoning regulations is paramount.
- The effective implementation of hazard-zoning policies and relocation processes may involve complex cultural, socio-economic, and political dynamics that require careful analysis, public consultation, and negotiation. These processes should be facilitated by professionals experienced in conflict management and negotiation.
- There is a strong need for the increased involvement of civil-society actors in DRM planning and action, including from grassroots and non-governmental organizations, universities, and the private sector.
- Given similar patterns of impacts over the last several severe El Niño events in Peru, there is a clear and urgent need to increase learning from past events. A shortage of analysis and recommendations is not the problem: with past events, recommendations for specific disaster risk-reduction measures have been made. Nevertheless, effective strategies for both the dissemination and implementation of recommendations are critical.

References

Burek, P., Satoh, Y. and Wada, Y., 2016. Flood Resilience Peru: Flood hazard assessment, climate change, and El Niño influence on flooding, a first approach. International Institute for Applied Systems Analysis, Laxenburg, Austria.

CAF, 2000. El Fenómeno El Niño 1997-1998: Memoria, Retos y Soluciones. Corporación Andina de Fomento.

Calderon, J., Quispe, J., Lucci, P. and Lenhardt, A., 2015. On the Path to Progress: Improving living conditions in Peru's slum settlements, Overseas Development Institute, London.

Cane, M., 2005. The evolution of El Niño, past and future. *Earth and Planetary Science Letters*, 230(3-4), 227-240.

Carey, M., 2010. In the Shadow of Melting Glaciers: Climate Change and Andean Society. Oxford University Press, New York.

Chen, D., Cane, M.A., Kaplan, A., Zebiak, S.E. and Huang, D., 2004. Predictability of El Niño over the past 148 years. *Nature*, 428(6984), 733-736.

CONAGER-FEN, 2015. Plan de Acciones Multisectoriales ante Probable Ocurrencia del Fenómeno El Niño y Temporada de Lluvias 2015-2016. Consejo Nacional de Gestión del Riesgo del Fenómeno El Niño, Lima.

CRED, 2017. EM-DAT: International Disaster Database, Centre for Research on the Epidemiology of Disasters. Universite Catholique de Louvain, Belgium.

Ferradas, P., 2000. Las aguas del cielo y de la tierra. Lima, Perú: PREDES.

Ferradas, P., 2015. La memoria es también porvenir. Historia mundial de los desastres. Lima, Perú: Soluciones Prácticas.

Field, C.B. et al. 2014. Technical summary. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA: 35-94.

INDECI, 2015. Probable Escenario de Riesgo Ante La Ocurrencia del Fenómeno El Niño Extraordinario y Lluvias Intensas 2015-2016. Instituto Nacional de Defensa Civil, Lima, Perú.

INDECI, 2017. Resumen Situación a Nivel Nacional: Evaluación de Daños. Instituto Nacional de Defensa Civil, Lima, Perú.

IPCC, 2012. Managing the risks of extreme events and disasters to advance climate change adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change. Cambridge University Press.

Keating, A., Venkateswaran, K., Szoenyi, M., MacClune, K. and Mechler, R., 2016. From event analysis to global lessons: disaster forensics for building resilience. *Natural Hazards and Earth System Sciences*, 16(7), 1603-1616.

Magrin, G.O. et al. 2014. Central and South America. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1499-1566.

MVCS, 2016. Gestión de Riesgos 2011-2016 (Report). Ministerio de Vivienda, Construcción, y Saneamiento. Lima, Perú.

Notten, P., Rotmans, J., van Asselt, M., Rothman, D., 2003. An updated scenario typology, *Futures*, 35(5): 423-443.

Peru, 2009. Política y Estrategia Nacional de Recursos Hídricos del Perú. Autoridad Nacional del Agua, Lima, Perú.

Quinn, W.H., Neal, V.T. and Antunez De Mayolo, S.E., 1987. El Niño occurrences over the past four and a half centuries. *Journal of Geophysical Research*: 92(C13), 14449-14461.

Seiner, L., 2001. El fenómeno El Niño en el Perú: reflexiones desde la historia. *Debate Agrario*, 33.

Seminario, P. and Ruiz, M., 2008. Discusión y alternativas de las politícas de vivienda en el Perú. Pontificia Universidad Cátolica del Perú, Lima.

Takahashi, K. and Dewitte, B., 2016. Strong and moderate nonlinear El Niño regimes. *Climate Dynamics*, 46(5-6), 1627-1645.

Thorp, R. and Bertram, G., 1978. Peru, 1890-1977: growth and policy in an open economy. Columbia University Press, New York.

UN, 2014. Análisis de la Implementacién de la Gestión de Riesgo de Desastres en el Peru, Misión de Naciones Unidas, Lima, Perú.

Venkateswaran, K., MacClune, K., Keating, A. and Szoenyi, M., 2015. The PERC Manual: Learning from disasters to build resilience, Zurich Insurance Company Ltd., Zurich, Switzerland.

Wang, G., Cai, W., Gan, B., Wu, L., Santoso, A., Lin, X., Chen, Z. and McPhaden, M, 2017. Continued increase of extreme El Niño frequency long after 1.5 degree C warming stabilization. *Nature Climate Change*, 7, 568-573.

Winsemius , H., Van Beek , L., Jongman, B., Ward, P., Bouwman, A.,2013. A framework for global river flood risk assessments. *Hydrological Earth System Sciences*, 17: 1871–1892.

IIASA
International Institute for Applied Systems Analysis

Schlossplatz 1, 2361 Laxenburg, Austria
Tel: +43 (0)2236 807 0
Fax: +43 (0) 2236 71 313
E-mail: info@iiasa.ac.at
Web: www.iiasa.ac.at

Founded in 1972, IIASA is an international scientific institute that conducts policy-oriented research into problems that are too large or too complex to be solved by a single country or academic discipline. Problems such as climate change, energy security, population aging, and sustainable development, which have a global reach and can be resolved only by international cooperation.
IIASA has a demonstrated track record of delivering global, regional, and national impact through conducting excellent interdisciplinary research into real-world problems, often in collaboration with large international research networks, and working with policymakers to identify and assess possible solutions based on the results of that research. Funded by prestigious research funding agencies in Africa, the Americas, Asia, Europe, and Oceania, IIASA is independent and unconstrained by political or national self-interest.

About the Zurich FLOOD RESILIENCE ALLIANCE

An increase in severe flooding around the world has focused greater attention on finding practical ways to address flood risk management. In response, Zurich Insurance Group launched a global flood resilience programme in 2013. The programme aims to advance knowledge, develop robust expertise and design strategies that can be implemented to help communities in developed and developing countries strengthen their resilience to flood risk. To achieve these objectives, Zurich has entered into a multi-year alliance with the International Federation of Red Cross and Red Crescent Societies, the International Institute for Applied Systems Analysis (IIASA), the Wharton Business School's Risk Management and Decision Processes Center (Wharton) and the international development non-governmental organization Practical Action. The alliance builds on the complementary strengths of these institutions. It brings an interdisciplinary approach to flood research, community-based programmes and risk expertise with the aim of creating a comprehensive framework that will help to promote community flood resilience. It seeks to improve the public dialogue around flood resilience, while measuring the success of our efforts and demonstrating the benefits of pre-event risk reduction, as opposed to post-event disaster relief. For further information see floodresilience.net.

International Institute for Applied Systems Analysis
IIASA www.iiasa.ac.at

SOLUCIONES PRÁCTICAS
Tecnologías desafiando la pobreza

ZURICH