Disaster Studies and Management

Michael H. Glantz *Editor*

El Niño Ready Nations and Disaster Risk Reduction

19 Countries in Perspective

Springer

Disaster Studies and Management

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This book series aims to further academic scholarship and discourse in the rapidly emerging discipline of disaster studies – encompassing both theoretical and practical concerns in the interface between disasters, their conception, their management and their relationship with various aspects of governance. The series will cover diverse perspectives and approaches, reflected in case studies and narratives from different parts of the world.

The series addresses the growing need to bring together the wealth of dialogue and experiences in disaster research and disaster management. It seeks to enhance the knowledge base explicating the complex relationship between shifting socio-economic situations, unplanned urbanization, environmental degradation, climate variability and change, geological hazards and the threat of epidemics. The series adopts both a comparative and a critical perspective influencing the contemporary discourse around disasters, development and the use of appropriate technologies to foster safety, security and sustainability of the planet.

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- contributes to developing theoretical rigour, linking the fields of disasters, development and climate change adaptation
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✓ Disaster risk reduction, disasters and development
✓ Critical review of evolution of DM practices in diverse contexts
✓ Disasters and media, crisis communication, disasters in a hyper-mediated world
✓ Narrative analysis, ethnography and anthropology in disaster studies
✓ Education, capacity building in DM
✓ Climate change adaptation, extreme weather events and disasters
✓ Cascading disasters or complex emergencies
✓ Disasters and confiict, involuntary displacement, migration and disasters
✓ Local and cultural knowledge for disaster preparedness and response
✓ Critical refiections/analysis on DM as an emerging profession
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✓ Accountability, entitlements and ethics in DM
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✓ Globalisation, role of UN and international organizations in DM
✓ Technological approaches to DM, assessments and mapping
✓ Health, public health and hospital preparedness (water, sanitation, epidemics)
✓ DM as pluralist practice: Lessons learnt (pre and post disasters, before and after studies)
✓ Disaster "recovery" practices (economy, habitats, land use, housing, livelihoods, religious and cultural practices)
✓ Disasters, exclusion (special groups- caste, class, elderly, disabled, tourists, etc.)
✓ Data needs and decision making tools in DM, GIS—based approaches to DM
✓ Disaster logistics and supply chain management

Taken two years after the Indian Ocean Tsunami of 2004, the cover picture represents the sheer grit of Nicobari tribals, a fiercely independent community of Chaura, a low lying, tiny island in the Andaman and Nicobar Islands of India. Even as the administration evacuated them to temporary shelters on Teressa island for an indefinite period of time, the tribals, tired of waiting for government promises, built their own boats and moved back to their islands. An embarrassed administration was then forced to take note and provide livelihood and other forms of support.

More information about this series at https://link.springer.com/bookseries/13839

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Recognizing that each researcher today in every field is, in essence, standing on the shoulders of their predecessors and contemporaries, I can only draw attention to a few notable individuals here. They represent a larger army of my mentors and colleagues: Peter E. O. Usher (retired, UNEP), J. Dana Thompson (Oceanographer and Co-author of the first book (1981) focused on El Niño), Harry Van Loon (retired, NCAR scientist who introduced me to El Niño in mid-1970s), Jim O'Brien (FSU Oceanographer, an El Niño mentor), Walter Orr Roberts (Founder and Director of UCAR/NCAR for his trust, counsel and his support for my very first study of the value of a long range forecast for the West Africa Sahel), Bernard Haurwitz (former director of NCAR's Advanced Study Program, who provide advice to me on how to survive as a social scientist is a sea of physical science), and to my many colleagues since the early 1970s who guided me and contributed to my research and understanding about El Niño Southern Oscillation (ENSO), starting out with a focus on coastal upwelling. I would be *remiss if I did not mention my mother and brother Ronnie, who sent me any article they came across in the newspapers on El Niño. There are so many more I would like to thank for their support during my ENSO-related research career but it would take many more pages.*

Foreword

Recognizing the "Blind Spots":
Eliminating Inertia in El Niño Preparedness and Response

Over the course of the 2015–2016 El Niño event, the lives of over 60 million people in at least 40 countries around the world were affected by floods, droughts, storms, wildfires, frosts, and diseases. As bad as these impacts were, however, they could have been much worse had communities and countries not prepared to varying degrees for the event, taking mitigative and sometimes even preventive actions that likely saved countless lives and livelihoods.

This positive outcome was by no means arbitrary. In truth, it was the result of years of incremental advances in El Niño research and observation by the physical and social sciences in terms of monitoring, modeling, forecasting, and assessing sea surface temperature anomalies in the Central Pacific. By the time of the formation of the 2015–2016 event, the lessons of these advances had for several years already been incorporated into regularly held regional climate outlook forums from which were developed improved strategies and tactics for responding to future events. Over the decades, socio-economic and environmental awareness had also been raised and communications had been improved based on the lessons of previous, often less effectively planned for events.

Advances in planning and response capacities are known to come about on a regular basis through just such a combination of research and practice. Though praiseworthy, the regularity of these advances suggests that concerning "blind spots" remain in what is known about the El Niño phenomenon and how to respond to them. One such "blind spot," for example, is the tendency to attribute all hydrometeorological hazard impacts that occur over the course of an event to the event, even though the scientific basis for such attribution may often be lacking. Despite definite advances, risk continues to reside within such "blind spots."

What is clear at this point is that El Niño is an aperiodic recurring phenomenon resulting from air-sea interactions across the tropical Pacific Ocean. One concerning and often unattended to outcome of this known aperiodicity is that decision-makers who may have experienced one significant El Niño are likely to have left their jobs before another major event has formed, which means that undocumented or anecdotal references to specific El Niño-related experiences are lost to future responders. This all-too-common situation brings to light another “blind spot” in planning for El Niño events, one that reveals how inadequate documentation of impacts, actions, experiences, and lessons learned from the past limits what strategies and tactics will be available for responding in the future.

This is especially true with regard to forecasting El Niño events and their teleconnected impacts. Although numerous uncertainties regarding each specific event’s formation remain, what is clear now is that the formation of an El Niño event tends to increase the predictability of climate-related meteorological hazards like droughts and floods. Knowledge of this correlation between El Niño and extreme climate, water, and weather events should be valued as “usable” science that enables decision-makers to increase preparedness, readiness, and response efforts in order to reduce exposure and protect lives and livelihoods.

Compared to past El Niños, for example, during the 2015–2016 event disaster managers along with other decision-makers in climate-sensitive sectors across the world were acutely aware of the El Niño’s characteristics and its likely course. The more attentive public was also aware. This general awareness was partially a result of media, including social networks, being particularly active in disseminating timely information to communities known to be at-risk. Early government actions such as strategic planning and preparedness in addition to timely tactical readiness and response also critically helped reduce loss of life and mitigate socio-economic impacts, especially in El Niño “hotspot” countries.

Despite a number of other remaining “blind spots,” the overall response to the 2015–2016 event, which turned out to be one of the strongest since 1950, was no less creditable in comparison to past events. In fact, the overall response to the 2015–2016 event continued a positive trend that began in earnest after 1997–1998’s devastating “El Niño of the Century,” when public awareness of specific impacts associated with El Niño steadily began to rise across the globe.

Notwithstanding this encouraging trend, in many cases, the probability of impacts of El Niño is still inadequately understood, which has often led to poor communication even in those hotspot areas like the Philippines, South Africa, and Ecuador where likely impacts from events of different intensities are actually quite well known. What this concerning “blind spot” suggests is that the uncertainties surrounding El Niño forecasts, including the projections of regional climate outlook forums, need to be better communicated to the potential users of such information if greater overall confidence in forecasts and the agencies that produce them is to be achieved.

Finally achieving greater overall confidence among general forecast users, however, first requires institutional trust from government and community leaders. This is especially true when it comes to the reliability of those projections needed to guide decisions just prior to and during hazard events. In reality, however, lack of trust can in many cases be a byproduct of poor communication, so perpetuating a cycle that creates and then falls back on a status quo of government inaction. Regrettably, such status inertia often leads to real-world consequences such as ongoing social vulnerability, especially among those populations most in need of good governance and clear communication.

But action taken toward establishing greater trust in the reliability of projections can create its own set of "blind spots," especially because of the reality that two El Niño events, even two events with remarkably similar characteristics, will most often lead to quite different impacts and outcomes. In this way projection is inherently risky, which is why decision-makers need not only provide accurate forecast products but also alert potential users to the known limitations of the projections used to create those products. What needs to be communicated, that is, is how such limitations are inherent to but do not invalidate the usability of the science involved in creating the forecast products that when trusted as both useful and reliable almost certainly save countless lives and livelihoods during disaster events.

It is in this way that investigations into how weather and climate vary during the life cycle of an El Niño are critical to understanding risk for each event. Doing so should enable social actors—from policy-makers to community members—to incorporate understandings of vulnerability, exposure, and capacity into their active planning and response mechanisms. Such incorporations should, regardless of the distinct signatures that different El Niño events present in various locations across the world, result in more effective strategies and tactics that reduce vulnerability and harm for all members of a society. These incorporations should eliminate even more of the "blind spots" that continue to limit the effectiveness of our planning and response to the next, ever-looming El Niño event.

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Preface

The following volume primarily examines the impacts on known hotspots of the El Niño of 2015–2016. As the twenty-first century's first very strong event, we now know just how devastating it turned out to be. In fact, the 2015–2016 event has been found to have been the third most intense El Niño since 1950, strong enough to rival the 1997–1998 event, which was then dubbed "the El Niño of the Century."

Since the time of that very strong, late twentieth-century event, every El Niño that has followed has been compared to it. Like this, the 1997–1998 event has come to serve as the *de facto* baseline standard for forecasting the likely consequences and impacts of any newly forming event (e.g., Staupe-Delgado et al. 2018). Before then, however, the "go-to" El Niño for baseline comparisons had been the strong event of 1982–1983. Historical baselining of El Niño events really started with the 1972–1973 event, however, since before the late 1960s few people outside Peru and Ecuador, save for a small vanguard of international researchers, paid much attention to the phenomenon or its potential consequences.

Though scientific uncertainties continue to surround the El Niño phenomenon, what must be understood is that much has changed since that 1997–1998 very strong event. Since that time, ENSO researchers as well as societies at risk have benefitted from 20 more years of subsequent research, observation, and experience of the phenomenon. For this among other reasons, an argument can be made that the 2015–2016 strong event should be recognized as the new baseline for comparison with regard to forecasting the likely consequences and impacts of any newly forming event. The case studies comprising this volume not only examine various impact hotspots around the world, but taken together also constitute a claim for shifting to this latest very strong event as a new *de facto* baseline forecasting standard. This prologue briefly makes the case for this claim.

Reporting on the El Niño event of 2018–2019 and its foreseeable impacts, various articles cited the 2015–2016 El Niño for comparative purposes. In doing so, reporters sought to give the public a glimpse of what they might expect in the coming months as a result of the newly forming event.

Initially treated with some concern, as are all such forecasts, it was soon noted, however, that the 2018–2019 event would be relatively weak. Becker (2019), for instance, wrote of the graph in Fig. 1 that "The purple line is noticeably flat, without

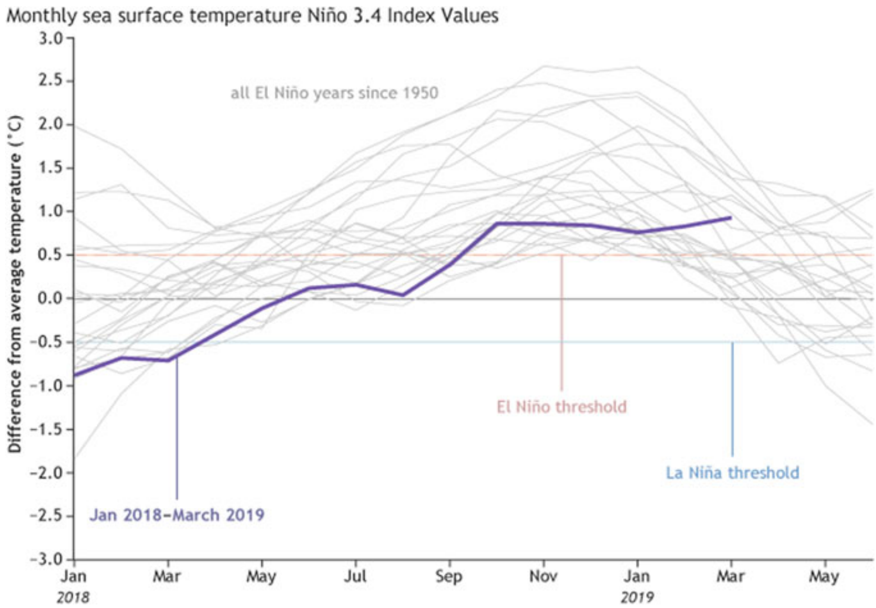

Fig. 1 Monthly sea surface temperature in the Niño 3.4 region of the tropical Pacific for 2018–19 (purple line) and all other El Niño years since 1950. Climate.gov graph based on ERSSTv5 temperature data. (http://NOAA.climate.gov)

the gradual increase, peak, and decline that so many other El Niño events have exhibited. This flatness isn't unusual behavior for a weak El Niño, however, as other events, including 1977–1978, 1978–1979, and 2004–2005, show." Nevertheless, forecasts of weak events can still have tremendous value in reminding at-risk end users of foreseeable impacts. In this way, forecasts of El Niño (both strong and weak) can stimulate tactical responses that enable societies to get ready and plan accordingly.

Only after the notable 1972–1973 El Niño, which saw the collapse of the Peruvian fisheries that had worldwide economic implications (Vondruska 1981), did event forecasts really start to have substantial awareness-raising consequences. Following on from this event, forecasts tended to generate headlines in the media, with articles and advisories that would compare a newly forecasted event's potential impacts to the impacts of previous very strong events. This tendency to compare newly forecasted El Niño events with past events especially became common for those El Niños that formed after the 1982–1983 very strong event, and then again for those that formed after the 1997–1998 very strong event.

This pattern of "forecasting by analogy" (Glantz 1988) remained consistent with estimates for the strong El Niño that was predicted to form in 2015; still, by mid-2016, the international meteorological research community jointly acknowledged that the 2015–2016 El Niño had become one of the three strongest El Niño events since 1950. Its intensity was already understood as being at least as strong as the very strong events that had preceded it and to which it had originally been compared in speculating on the likely extent of its impacts (Fig. 2).

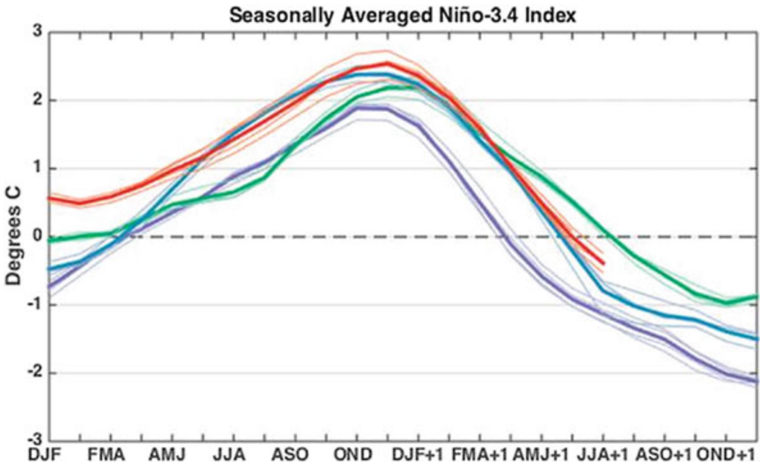

Fig. 2 Evolution of seasonal (3 month) averaged values of the Niño-3.4 SST indices during 2015-16 (red), 1997-98 (blue), 1982-83 (green), and 1972-73 (purple). Bull. Amer. Meteor. Soc. 2017;98(7):1363–1382. doi: https://doi.org/10.1175/BAMS-D-16-0009.1

Continuing with this forecasting trend, the UN Food and Agriculture Organization (FAO 2018), concerned about an emerging El Niño in 2018, noted the relevant particulars of the 2015–2016 event in order to create a forecast of the potential impacts for which at-risk societies might prepare. In particular, its projection stated that “the impact of El Niño on agriculture and food security can be severe. For example, the 2015/16 El Niño—one of the strongest on record—affected over 60 million people worldwide [and] resulted in 23 countries appealing for international humanitarian assistance worth over USD 5 billion.” It then added, “In view of the potential impact of the 2018/19 El Niño on food security and agriculture, high-risk countries… should be prioritized for further monitoring, analysis and early action.”

The FAO report also notably commented on a lesson learned: “In the immediate aftermath of the severe 2015/16 El Niño episode, the humanitarian and development community identified the need for a framework to guide the monitoring of El Niño/La Niña events and the initiation of early actions to mitigate their impacts.” Leahy (2018: 4) offered a similar comparison in a National Geographic article, stating: “The most recent El Niño event ended in 2016, and it was associated with catastrophic coral bleaching on the Great Barrier Reef, severe droughts in Africa, South America and parts of the Pacific and southeast Asia, and wildfires in Indonesia and Canada. *While the current El Niño* [2018] *is not expected to be as severe, it could still bring dangerous weather to vulnerable areas around the world*, scientists warn” (emphasis added).

Uruguay’s Merco Press (2018) also referenced the last very strong event, reporting on WMO’s 2018–2019 El Niño forecast as follows: “There’s a 70 percent chance of a recurrence of the El Niño weather event before the end of this year, according to the World Meteorological Organization. The last El Niño occurred in 2015–2016 and impacted weather patterns around the world, but researchers say they are not expecting this new one to be as intense as 2015–2016."

What this brief review of articles on the 2018 El Niño suggests is that: (1) people usually refer to the last notably severe El Niño event with regard to impacts when a new event is on the horizon and (2) the 2015–2016 very strong El Niño may have already become the twenty-first century's "go-to" standard for contemporary researchers for comparing and evaluating an event's socio-economic and environmental impacts. To be sure, as we move deeper into the twenty-first century, few media sources will continue referring to El Niño events that took place in the 1990s for comparative analysis—those previous events are increasingly considered passé ("so last century"), and we are smarter today (or at least we think we are) than they were 20 years ago.

The first very strong event of the first two decades of the twenty-first century was the 2015–2016 event. What this means, in essence, is that its forecast was important not only to its users but also for strategic as well as tactical decision-making for ongoing disaster risk reduction efforts. Given its intensity and impacts, consequently, the 2015–2016 event should replace the 1997–1998 event as the *de facto* analogue for El Niño comparison—until, that is, another extraordinarily strong El Niño comes along.

Boulder, Colorado, USA Michael H. Glantz

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We would like to use this opportunity to thank each author and his/her team for their contribution to our El Niño publication. In a very difficult year, while operating under pandemic-imposed restrictions in their own respective countries and workplaces, they worked to produce their contributions in a timely and efficient way. Special appreciation goes to our copy editor, Gregory E. Pierce, and to Robert Jay Ross who managed the entire publication process and acted as liaison with Doris Bleier, our Springer Nature Editor.

The Springer Nature Editor and staff deserve special mention as well for their understanding of the difficult conditions our contributors faced from 20 different countries in order to meet publication deadlines under COVID-19 lockdown as well as lockout conditions that the Springer Editor and staff also had to endure at their end of the publication process. We would be remiss if we failed to thank our anonymous reviewers who provided useful insightful comments.

It is the right place and very important to acknowledge the families of the contributors. They supported the researchers during this project. I know, as an example, that my wife and my CCB associates had to deal with a fair amount of a researcher's "mentally away time" (distractions), as we collectively focused on completing this El Niño Ready Nations and Disaster Risk Reduction manuscript.

A very special thanks to Marc Daniels. When the University closed in March 2020, because of the COVID-19 pandemic, CCB's workspace shifted to outdoor coffee shops. As fall weather approached Marc generously offered CCB a weatherproof environment during Winter and Spring that enabled us to meet deadlines—something we could not have done without Marc's support and generosity.

Finally, we sincerely appreciate the constant support for our El Niño Ready Nations Project of the USAID's Office of Foreign Disaster Assistance and of the NOAA's National Weather Service's International Office.

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Notes on the Text

For the most part, the El Niño hotspot countries studied for the 2015–2016 El Niño event are the same as those that were studied for a 1997–1998 UNEP-sponsored, 16-country report entitled *Once Burned, Twice Shy?: Lessons Learned from the 1997–1998 El Niño* (Glantz 2001). Notably, several of the country-study authors for that 2001 report also undertook leading roles in completing the studies that comprise this USAID/OFDA-sponsored report on the 2015–2016 very strong event.

A notable difference between the two publications is that the majority of the cases included in this volume were a part of the respective country authors' multidisciplinary research activities that were undertaken *during* the 2015–2016 event—in essence, in real time. In preparing their different studies for this volume, they have all updated their work with further information about the El Niño's consequences and impacts in each of their specific regions of focus. Additionally, three new country cases—The Maldives, Myanmar, and Timor-Leste—have also been added.

Finally, it is important to clear up an issue related to how the *2015–2016* El Niño has frequently been referred to as the *2014–2016* El Niño. This time-based discrepancy has been a source of confusion to those, mainly non-experts, who are not so familiar with this particular El Niño event. To be understood is that authors from various countries in a handful of the following chapters have identified the start of the event as 2014, while others have referred to 2015 as the year it formed. In a few cases, both start dates are, perhaps even more confusingly, used within the same chapter.

The reason for these discrepancies is summarized by Glantz (2015) as follows:

> The major . . . El Niño that was expected by several scientific organizations did not materialize when or as expected [in 2014]. That is understandable, given the complexities associated with the numerous oscillations in the global atmosphere and the world's oceans that impinge on the behavior and impacts of the ENSO 'cycle' . . . Although some forecasters admitted that the forecast was 'a flop', others did not give up on the possibility that an El Niño could occur by the end of 2014. But, if such an event were to occur, would it be a different one than the one that had been forecast earlier in the year? This suggests that forecasting El Niño's onset is still experimental and not operational. Forecasting its onset (as a specific event) should be separated from forecasting its behavior (as a process) and impacts once the onset has been assured.

To wit, after a few months of articles about favorable SST conditions in the Niño 3.4 region, researchers estimated a very high probability of a strong event forming in early 2014. They based this belief on several factors, including that a strong event was "due" since one had not formed in a decade and that signals from the Oceanic Niño Index (ONI) indicated the likelihood of an El Niño forming. As sometimes happens, however, sea surface temperatures in the Niño 3.4 region of ONI abruptly returned to average. Although the springtime failure of the inchoate 2014 El Niño to form was cursorily reported on, its collapse was soon overshadowed by nascent indicators of the formation of what turned out to be the 2015–2016 event, conditions for which were first detected by the end of 2014. The 2015–2016 event would become one of the three strongest events since at least 1950. For an update on the ONI, see Glantz and Ramirez (2020).

DRM and DRR

The concepts of Disaster Risk Reduction (DRR) and Disaster Risk Management (DRM) are often used interchangeably. They have two words in common, disaster and risk, and while the concepts overlap, they are not the same. The UNISDR (2015) noted that "while the terms are often used interchangeably,

> DRM can be thought of as the implementation of DRR, since it describes the actions that aim to achieve the objective of reducing risk.

As such, we tend to have a DRR policy and strategy and DRM plans and projects. However, you may see both terms being used.

Stated in another way, UNDRR (2020) wrote that "Disaster risk management is the application of disaster risk reduction policies and strategies to prevent new disaster risk, reduce existing disaster risk and manage residual risk, contributing to the strengthening of resilience and reduction of disaster losses…". Stated yet another way (MG2564A, 2018),

> Disaster Risk Reduction (DRR) and Disaster Risk Management (DRM) are both essential to minimizing adverse effects from disasters. DRR is a systematic approach to identifying, assessing and reducing the risks of disaster, while DRM involves the application of these DRR policies and strategies in order to prevent new disaster risks, reduce existing disaster risks, and manage residual risks.

When undertaking the task to compile a set of country studies, we (editor and contributors) agreed on the process: authors would consider a few common questions and were allowed to write about issues of great concern in their countries. The chapters that follow are focused on DRR with DRM appearing in name or deed throughout the various contributions.

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Contents

Introduction

Michael H. Glantz

Abstract Even if they cannot readily recall its exact definition or its particular historical impacts, governments, media outlets, communities, and weather-sensitive economic sectors are for the most part aware of El Niño as a potential threat to society. The quasi-periodic oceanic extreme is no longer the unexplained phenomenon that it was as recently as the late 1960s, when it was first determined to be a tropical Pacific Ocean basin-wide event (Bjerknes 1969).

Since that time, El Niño has come to be commonly viewed as another expression of climate variability on a sub-decadal scale, much as is the flow of the seasons at the annual scale. As with seasonal flows, El Niño, though more irregular in its timing, provides close observers who have been forewarned about its aperiodic onset and likely impacts with a degree of forecast reliability. To be sure, El Niño today almost invariably appears in media headlines as a red flag in countries at risk of the hydrometeorological hazards each event is known to produce. At this point, social media is also abuzz with concern when an El Niño forms, especially with regard to its impacts.

El Niños always yield new social and physical scientific research findings that provide insights for policymakers. They also tend to expose societal strengths and weaknesses and afford lessons for decision makers on how better to prepare for and respond to future event forecasts, impacts, and recovery efforts. Additionally, being adequately prepared for the extremes of the El Niño Southern Oscillation (ENSO), which are marked by anomalously warm or cold sea surface temperatures (SSTs) in the tropical Pacific, will benefit societal coping capabilities within a warming global climate, especially in terms of the variability and extremes that are predicted to accompany an altered climate regime.

Keywords ENSO · Climate change · Readiness · Forecasting · Impacts · El Nino

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1 Introduction to El Niño

The principle intent of this introduction is to briefly explain how El Niño events have recurring, aperiodic influences—some positive, some negative—on human activities and the ecological processes on which societies depend. A second intent of highlighting the El Niño phenomenon in the introduction is to provide social actors, from local communities and national governments to regional intergovernmental organizations, a capabilities testing ground for developing or enhancing mechanisms that might better enable them to cope with what consequences will likely arise from the often subtle impacts—creeping environmental changes that are long-term, incremental, *and* cumulative—of global warming.

Readiness, here, is key. Working within a framework of readiness better enables social actors to evaluate their strengths, weaknesses, and opportunities to respond to the respective threats with which they are likely to contend. But a framework of readiness not only enables social actors to respond more effectively to threats. It also forces them at least once every two to seven years (4.5 years on average) to reevaluate the very notion of effectiveness in rethinking what strategies and tactics they have adopted for coping with what are at this point the ultimately foreseeable climate, water, and weather-related hazards they are likely to face related to the formation of an El Niño event.

2 El Niño and Its Effects

El Niño is part of a quasi-periodic cycle of air-sea interactions, the El Niño Southern Oscillation (ENSO), across the tropical Pacific Ocean. ENSO consists of three phases—El Niño (the anomalously warm phase), La Niña (the anomalously cold phase), and Neutral—determined by a 30-year variable average of sea surface temperatures (SSTs). Within this cycle, an El Niño event is determined to have started to form when SSTs in the central tropical Pacific Ocean region labeled the Niño 3.4 region with an increase of + 0.5 °C or more above average for three consecutive months (Fig. 1).

Each phase of ENSO is associated with its own set of foreseeable climate, water, and weather anomalies that manifest as regional "teleconnections" in numerous and diverse locations across the globe. These teleconnections are identified by forecasters and other close observers through geophysical processes, statistical analyses, and historical accounts of attributable impacts.

That said, it is important to note that there is not as yet a universally accepted means available to forecast the formation of an El Niño event. While NOAA favors monitoring SSTs in the Niño 3.4 region, Peru and Ecuador favor monitoring for SST anomalies in the Niño 1 + 2 region, which stretches along their respective coasts. Japan, in contrast, monitors SST anomalies in the Niño 3.0 regions, while Australia and New Zealand rely more heavily on sea level pressure shifts monitored by the

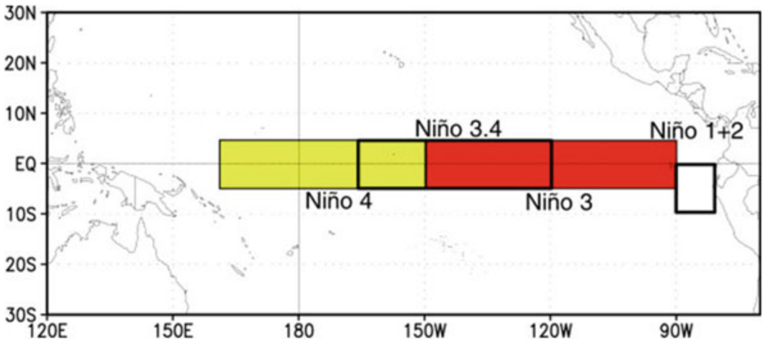


Fig. 1 El Niño regions in the Pacific Ocean (NOAA ND)

Southern Oscillation Index (SOI), which measures the seesaw-like sea-level pressure differences between Tahiti and Darwin, Australia.

Especially to be understood is that the common factor within these distinctive methods is how forecasting the formation of an event is often less about calculating statistical projections than about tracking variable tropical ocean temperatures. By all measures, accordingly, the 2015–2016 El Niño tracked as one of the strongest events since at least 1950. Figure 2 provides a typical image of a full-blown El Niño event based on the SST distribution in the tropical Pacific.

The El Niño extreme warm phase of the ENSO cycle results when certain changes in air-sea interactions (Fig. 3) lead to a weakening of westward winds along the

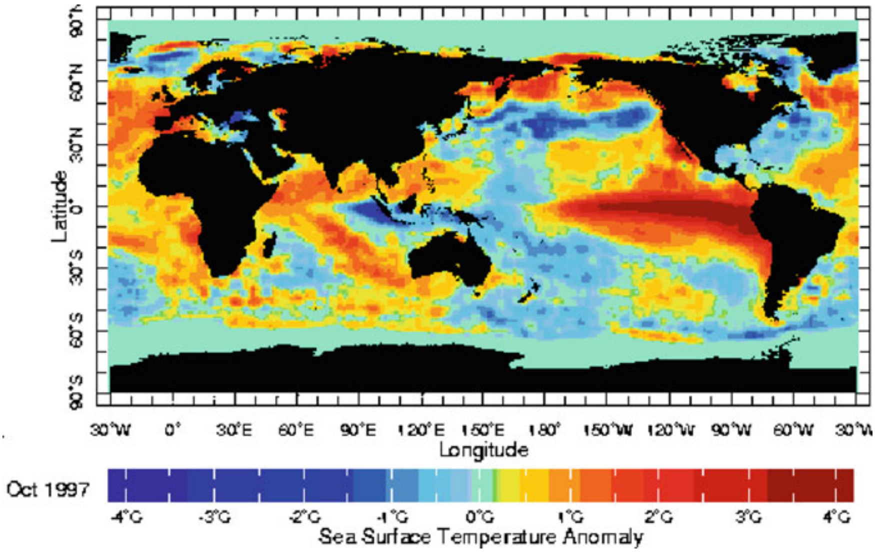


Fig. 2 El Niño Sea Surface Temperature (SST) anomalies (NOAA CPC)

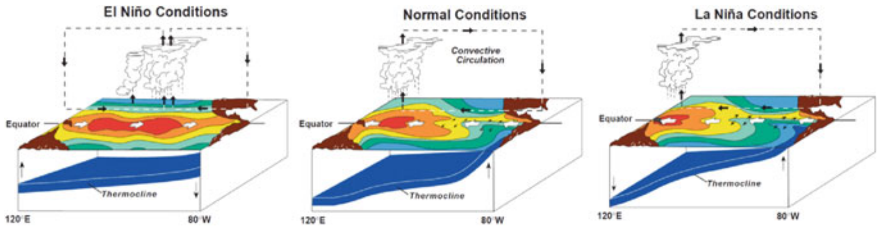


Fig. 3 Normal, El Niño and La Niña air-sea interactions in the Pacific Ocean (NOAA)

equator, which enables warm water from the western Pacific to shift eastward toward the relatively cooler waters of the central and eastern Pacific. The outcome of this shift is an El Niño.

Increased evaporation from these warmer central and eastern Pacific equatorial waters results in anomalous regional meteorological conditions that are associated around the globe with a number of adverse climate, water, and weather impacts. It is by these impacts that the societal and environmental upshots—sometimes positive but usually negative—of an extreme warming event can last for months to years after the event has dissipated and SSTs have either returned to a range within the neutral phase or have transitioned into the La Niña cold phase of the ENSO cycle.

The most concerning societal and environmental consequences of the meteorological conditions produced by an El Niño event tend to be droughts, floods, flash floods, heatwaves, and forest fires. Significantly, each of these upshots has its own secondary effects that tend to ripple even more deeply through societies and ecosystems. Effects such as food insecurity and forced migration, for example, can have devastating consequences, both spatially and temporally.

If any good news about El Niño's impacts is to be had it is that impacts can most often now be, if not averted altogether, then at least anticipated, planned for, and mitigated. Due to the level of predictability that has been achieved after decades of close monitoring of tropical SSTs, the distinctive hydrometeorological hazards an El Niño event will spawn are by now quite well-known for numerous locations across the globe.

This predictability being so, the warm extreme of the ENSO cycle has proven a good place to start developing approaches for hazard risk reduction (DRR), response, and recovery that can meet the specific needs of the various populations that will face the impacts of the hazard conditions resulting from such events. Such a starting place is especially appealing because it is at this point well-known that once an ENSO-related extreme event ends the next one will not be far behind. Like this, the El Niño phenomenon provides a distinct opportunity for governments to work to modernize their respective national meteorological and hydrological services (NMHSs). Utilizing the known recurrence of the phenomenon to their advantage provides governments with a foreseeable way to elicit cost-effective support from donor organizations that can be made to realize why incremental, phased approaches for NMHS modernization are important.

For example, scientists can explain to funding organizations that ENSO extreme events are always, once their warm or cold phases form and lock in, interannual calendar year events. In this way, organizations can be made to understand that an "El Niño year" is not the same as a calendar year. Instead, an El Niño year is said to start at the time when SST monitoring indicates that an event is forming, which begins in what researchers refer to as "year 0." The year ends when SSTs return to neutral or begin to transition toward cold phase values, which in both cases is referred to as "year + 1".

3 What El Niño Can Do: Mapping Global and Regional Hotspots

Without question, the El Niño story can be effectively presented through a set of user-friendly, captioned maps. Such maps serve to increase awareness within civil societies worldwide that El Niño is a naturally occurring, foreseeable disruption of the expected flow of the seasons and so is a threat to those numerous human activities that are dependent on that expected seasonal flow. In fact, compared to just a couple of decades ago a lot is now known about both the science and the impacts of El Niño events. That said, however, we do not yet know all we want to know about either.

Today, maps are available that identify foreseeable regional El Niño impacts around the globe. Many of these maps are variations of the one first produced by NOAA researchers (Ropelewski and Halpert 1987) that identifies, generally speaking, El Niño-related changes in precipitation and temperature for two key three-month periods (Fig. 4).

In a blog posted sixteen years later, (Glantz 2002) referred to, I first referred to the highlighted regions in Ropelewski and Halpert's map as "El Niño hotspots." Although the phrase was not picked up by researchers, I still believe that the term could be useful for enhancing general awareness within diverse societies around the world about the known dangers that the formation of an El Niño event tends to create. In this way, the term "hotspots" can refer to two distinct conditions, one positive and one negative. Positive hotspots indicate locations where opportunities for recreational or other enjoyable experiences have been enhanced by an event's formation, while negative hotspots refer to areas that are experiencing some sort of environmental or social trouble due to an event's formation. Such trouble can be anything from environmental stress leading to coral bleaching, forest fires, or biodiversity loss to social tensions from, for example, greater entrenchment at all scales of systemic inequalities to increased likelihoods of armed conflict, either within or between countries.

Although they can be positive, in using the term "hotspots," however, I do as a general rule mean to refer to locations and situations wherein the results of air-sea interactions in the tropical Pacific have already detrimentally affected human activities and the environment on which they depend in some way. In line with the

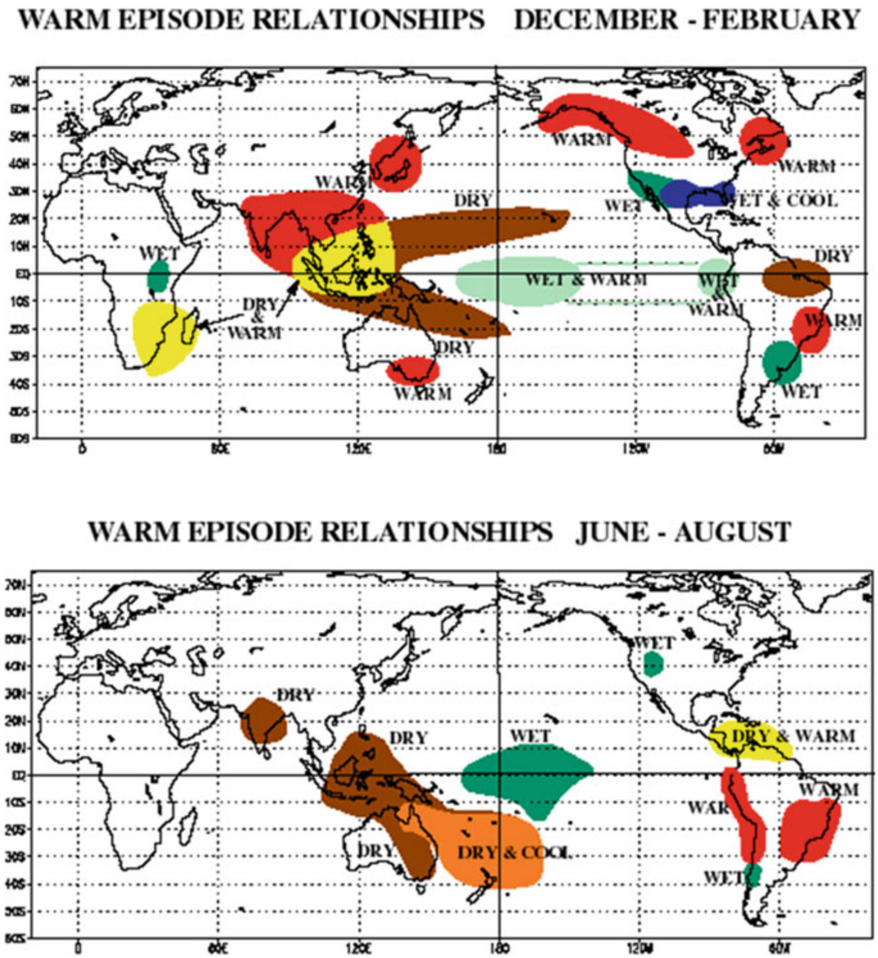


Fig. 4 Warm episode relationships for various months (Based on Ropelewski and Halpert 1987)

map in Fig. 4 therefore, El Niño hotspots are indicated by the regions in color that will—not would, as it is a matter not of *if* but of *when*—most likely be adversely affected by the aperiodic return of El Niño conditions. Hotspots, that is, nearly always refer to the negative social and environmental conditions that arise as an upshot of an event's formation.

Also noted in that same 2002 blog post in which I introduced the idea of "El Niño hotspots" is that relationships between the formation of an El Niño in the equatorial east and central Pacific and the impacts of that event at various distances across the globe are foreseeable. The impacts of El Niño events in areas far from the actual site of the anomalous SSTs are called "teleconnections." Enough is now known after decades of study and observation for researchers to credibly and reliably be able to advise policy and other decision makers on how best to prepare for and respond to the likelihood of teleconnected impacts. What this means is that, for example, while drought in the US is not assured every time an El Niño forms, the probability of drought certainly does increase during an event, so decisions involving both farmers' planting schedules and policymakers' agricultural strategies during El Niño years must consider this enhanced risk. The same is true in southern Africa, where drought can also be expected to occur *most of the time* when an El Niño that surpasses a certain threshold of intensity forms.

A partial list of such foreseeable impacts in some well-known El Niño hotspots includes:

- Drought in Zimbabwe, Mozambique, and South Africa
- Drought-related food shortages in Ethiopia
- Warm winters in the northern United States and southern Canada
- Heavy rains in southern California
- Fewer-than-average hurricanes in the tropical Atlantic
- Heavy rains in southern Ecuador and northern Peru
- Drought in the *Nordeste* (Northeastern) region of Brazil
- Flooding in southern Brazil
- Drought and fires in Indonesia
- Drought in the Philippines
- Droughts in various South Pacific island nations
- Drought in eastern Australia
- Coral bleaching worldwide
- Dengue outbreak in India

Important to understand here is that actions that a society needs to take to prevent, mitigate, or adapt to the worst impacts of an El Niño event are often those that would benefit its citizens even in normal times. Such actions include cleaning up dry river channels so torrential rainwater can pass to the sea; repairing leaky roofs or funding low-income housing; overhauling critical infrastructure like bridges, rail lines, and roads that are in poor condition, and the like.

Since their original publication in the mid-1980s, Ropelewski and Halpert's basic impacts maps have been modified to meet the more specific needs of a range of El Niño forecast users. These modified maps provide, for example, the months when anomalous regional precipitation changes have been observed, which has provided quite useful information about growing seasons to a range of users for crops that could be at risk during an El Niño (Fig. 5).

Figure 6 shows one such later Ropelewski and Halpert map that has been modified based on more recent climatological research to provide specific users with precipitation projections. Although a composite of impacts over the decades is very general, the map has proven no less useful to those in climate-sensitive socioeconomic sectors. Its usefulness stems from the fact that, although no single El Niño event will expose a given location with the full range of possible climate, water, and weather impacts, and an event's teleconnections will vary in intensity for any given event, knowing

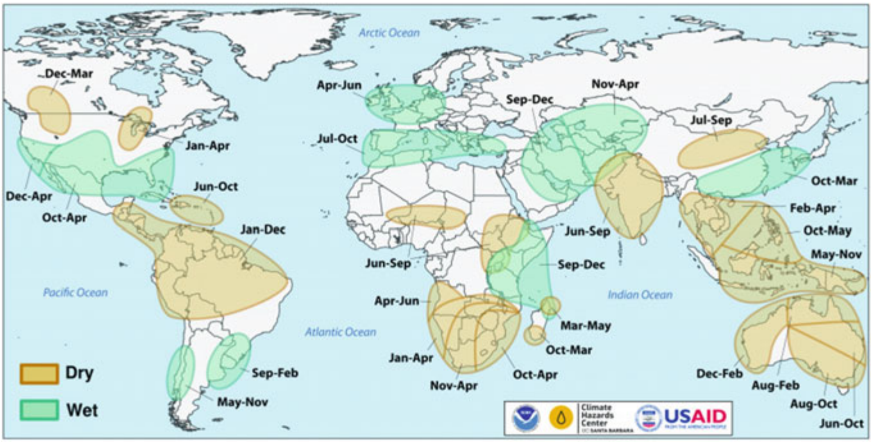


Fig. 5 Global map of El Niño impacts. (FEWS NET)

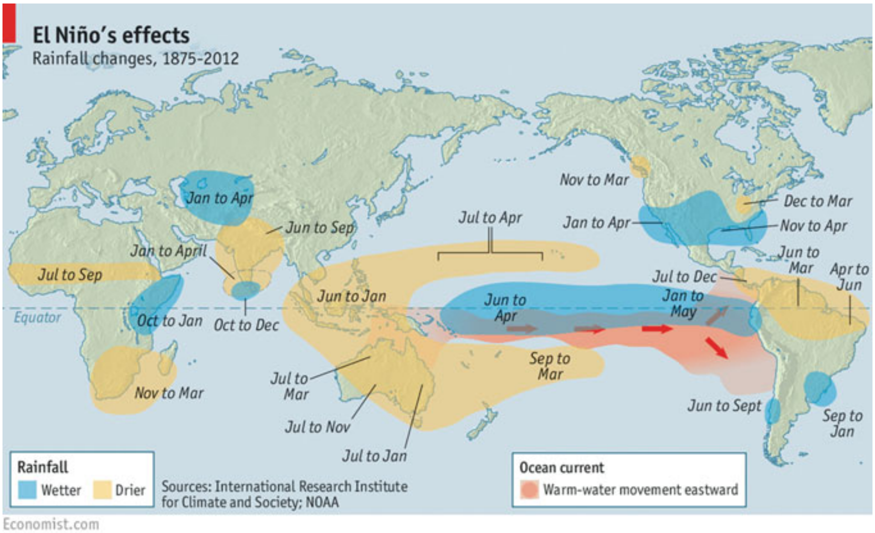


Fig. 6 El Niño impacts through rainfall changes from 1875 to 2012 (NOAA)

what impacts will likely be amplified during an El Niño still gives policymakers and the communities they serve an advantage when planning for an event.

Global impact maps have also been downscaled in order to identify or highlight El Niño's impacts for at-risk regions around the globe. Such maps—which are sometimes also in the form of charts, graphics, or photos—can provide more than a glimpse of desired information. To some, the information depicted is sufficient for their interests or needs, while for others the information can help raise awareness of,

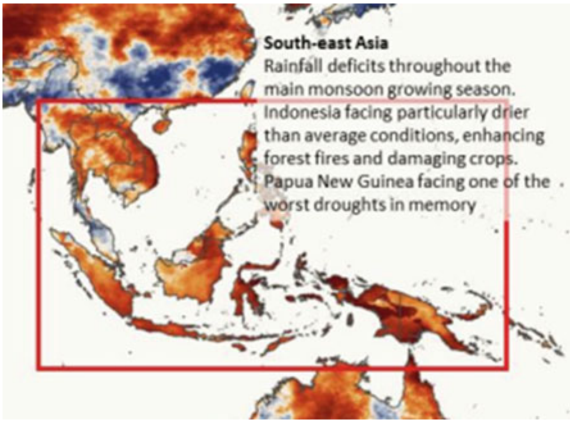


Fig. 7 Drought intensity map of Southeast Asia (WFP 2017)

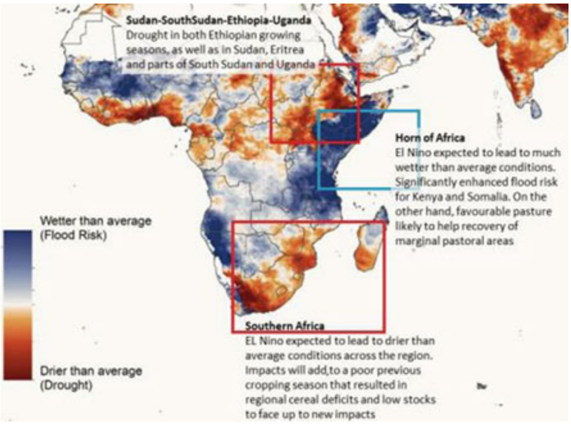


Fig. 8 Map of drought intensity on the continent of Africa (WFP 2017)

and even generate a stronger interest in, El Niño-related research. Figures 7, 8, 9, 10 and 11 are examples of regionally tailored El Niño impact maps.

Today, the growing number of research-based guesstimates about global warming's impacts on El Niños indicate that new maps may again be needed as the earth transitions into new conditions under a warming climate. Under such conditions, El Niño events are, as of some current projections, "anticipated" to become more intense as well as more frequent. Scientists also contend that the warming of the atmosphere and oceans will generate more intense local and regional hydrometeorological hazards, such as changes to seasonal rainfall patterns as currently represented in Fig. 5 (above). Furthermore, El Niño events are likely to be of greater spatial magnitude and of longer duration, with impacts appearing in new and unexpected locations. Given such likelihood, El Niño-related DRR merits greater visibility in political decision-making processes for better informed prevention, preparedness, and readiness activities. Updated maps of El Niño hotspots will be essential to help

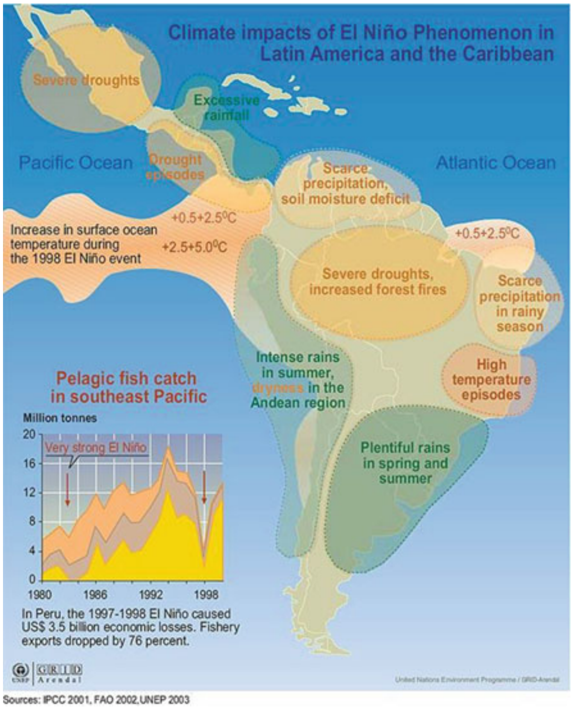


Fig. 9 Climate impacts of El Niño in Latin America and the Caribbean (Novikov 2005)

tell this emerging story, if sufficient planning is to be undertaken to meet the new challenges that such changes in global to local climate are expected to create.

4 Forecasting El Niño and What It Means to Be "El Niño Ready"

In the mid-1990s, I published a paper entitled "Forecasting El Niño: Science's Gift to the 21st Century" (Glantz 1994). My optimism, as implied by the title, was based on the then recent string of forecasting successes of the Cane-Zebiak model (Cane et al. 1986). First, the researchers had made public a projection that correctly identified the onset of the 1986–1987 El Niño event, a step that other modelers at the time had criticized as being premature because the forecast for the event was based only on an experimental model. A few years later, Cane et al. again went against the grain by contradicting the forecasts of other modeling groups that signaled the formation of an El Niño in 1990. Their model once again proved correct; no warm event developed in 1990. Cane and Zebiak then forecasted that an event would form in 1991, a projection based on outputs from their same model that once again proved

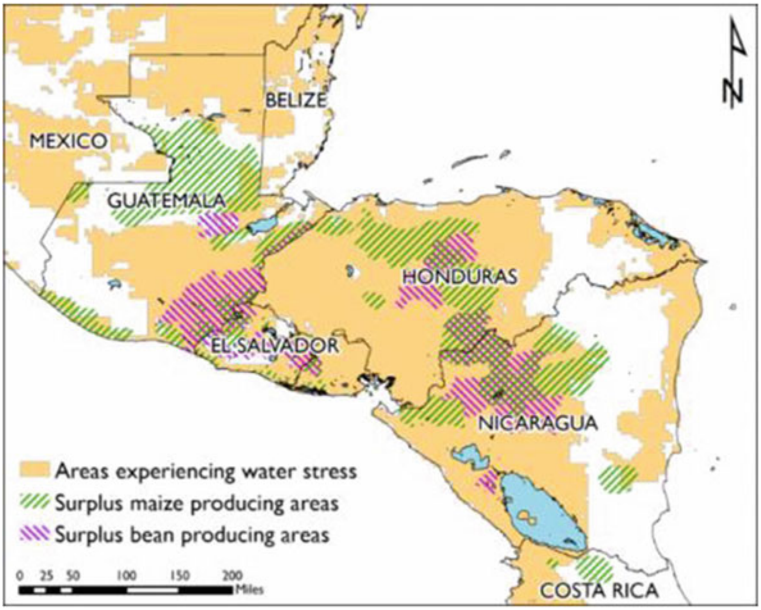


Fig. 10 Water stress in Central America (Robjhon and Thiaw 2014)

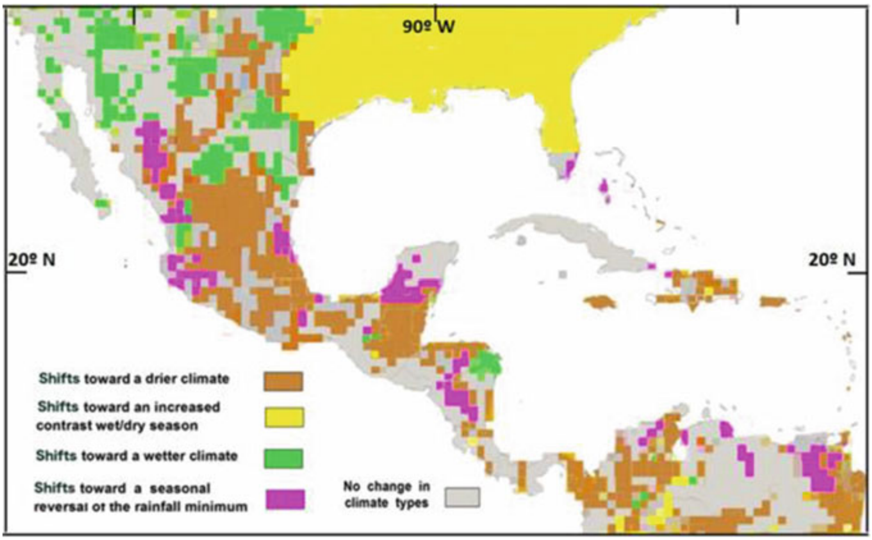


Fig. 11 Major climate shift types for rainfall regime in El Niño Year 0 based on five strong El Niños in the Central American and circum-Caribbean region. (Naranjo et al. 2018)

correct. My optimism based on this string of successes eventually proved premature, however, as their model, like all others at the time, failed to identify the formation of the unprecedentedly strong 1997–1998 event, which would later be dubbed, "The El Niño of the Century."

Recounting Cane and Zebiak's eventual "stumble" after their laudable string of successes is not meant to belittle their work. Instead, it is meant to highlight how forecasting the formation of an El Niño event with precision was then extremely difficult. Indeed, even today, two decades into the twenty-first century, doing so remains an intractable scientific challenge. Part of the challenge is finding better answers to some questions that have perhaps been too often taken for granted. Some of these questions are: What does it really mean to forecast El Niño? What is meant by a forecast in terms of the specific characteristics that signal the formation of an event? How are long-distance, teleconnected influences on regional to local climate conditions and on the intensity and frequency of extreme weather hazards to be tracked? What are the indirect societal consequences of teleconnected impacts like droughts, floods, heat, fires, and epidemics? How can the products of forecasts be tailored to maximize benefits for all potential end users?

El Niño readiness requires a more thorough examination of how answering such questions can enable societies to better prepare for the next inevitable event. To this end, I want here to propose that preparing effectively for future events can benefit from examining past El Niño projections according to three distinct groupings: *fore-casts*, *now-casts*, and *hind-casts*. A *fore-cast* is a projection about the formation of an event as well as how its phases are likely to change during ENSO's life cycle. Differently, a *now-cast* refers to updates in real time on the course of an El Niño once it has definitively locked in and will, invariably, run its course—peaking, decaying, and finally coming to an end, typically over a period of 9–18 months.

Finally, a *hind-cast* entails a comprehensive retrospective examination of an event after its geophysical processes have ended. It includes a final assessment of the direct and indirect impacts of El Niño on society and the environment, including information on a country's economic sectors and communities. UN agencies such as WMO, UNDP, FAO, WFP, ESCAP, and WHO, among a range of other organizations, all produced their own respective projections as well as hindcasts for the 2015–2016 El Niño (see, for example, WFP 2016).

These distinct groupings are helpful for thinking about readiness mainly because there is no general agreement on a definition of "readiness" in DRR. What this means is that each country, community, or socioeconomic sector determines not only when, but also how, it can be, should be, or wants to be hazard-ready.

Even so, the level of readiness that can be achieved in any given year will be influenced by various place- and time-specific conditions, some of which are controllable and others of which are not. Such influences might include, for example, decision makers' calculations about their jurisdiction's level of exposure to the threat of an El Niño, including costs of preparedness, availability of funding, and amount of leverageable political will.

What such calculations tend to mean is that, in reality, no society really knows how ready it has made itself until it has been tested by one or more of the climate, water, or weather-related hazards to which it is—often foreseeably—vulnerable. Readiness is, like this, always an exercise in an unending preparedness game, the winners of which tend to be those societies that successfully balance often competing variables, such as political will, resource (social, fiscal, and material) availability, and probabilistic calculation.

Preparedness over the long term, consequently, requires a multidimensional, strategic approach to coping—even with known recurring hazards—in a given area or country. In truth, if political will and sufficient funding were made available, a society could successfully mainstream its tactical responses into its sustainable development strategies. In the absence of sufficient resources or of proactive political will, however, governments, communities, socioeconomic sectors, and individuals must look for other ways to cope as best they can, which often means narrower shorter-term strategies that only enable tactical readiness on short notice, once the formation of an El Niño event has already been reliably forecasted. More often than not, this latter, unfortunately common, circumstance can lead to greater suffering and loss than need have been the case.

Planners' reliance on tactical aspects of readiness are often overly influenced by the scientific uncertainties that continue to surround El Niño. Unlike the flow of the seasons, El Niño is neither annual nor periodic, a reality that plays against the relatively short attention spans of policymakers and community members who often find it difficult to keep such an irregularly occurring threat, though a threat nonetheless, in mind.

Adding to the problem of the aperiodic nature of the phenomenon is the variance observed in the intensity of different events. Many people are relatively aware that the intensity of different El Niño events can range considerably from borderline weak, to weak, to moderate, to strong, to very strong. Beyond that general awareness, however, few people beyond highly specialized experts and attentive users know that NOAA's Oceanic Niño Index (ONI) is used to measure an El Niño's intensity and duration for the historical record. Null (2020) defined El Niño intensities in the following way: "weak (with a 0.5 ºC to 0.9 ºC SST anomaly), moderate (1.0 to 1.4 ºC), strong (1.5 to 1.9 ºC) and very strong ($\geq$ 2.0 ºC) events. For an SST warming in NIÑO 3.4 to be categorized as El Niño, it must have equaled or exceeded the + 0.5ºC threshold for at least 3 consecutive overlapping 3-month [running mean] periods" (see Fig. 12).

Further complicating the issue is that forecasts of El Niño's intensity have frequently been unreliable, with best estimates often being determined after an event has already locked in. Such short lead time reinforces the media's as well as the public's tendency to think back to the last notable event to understand what is likely happening during a current event. To counter this tendency, forecast users should be encouraged to consider the impacts of several past events, not just the latest or the strongest one, as no two events, or their impacts, are exactly alike. Understanding the impacts of several previous events could, for example, provide decision makers with a clearer understanding of the range of foreseeable impacts with which their societies might have to cope even as a new event forms and locks in.

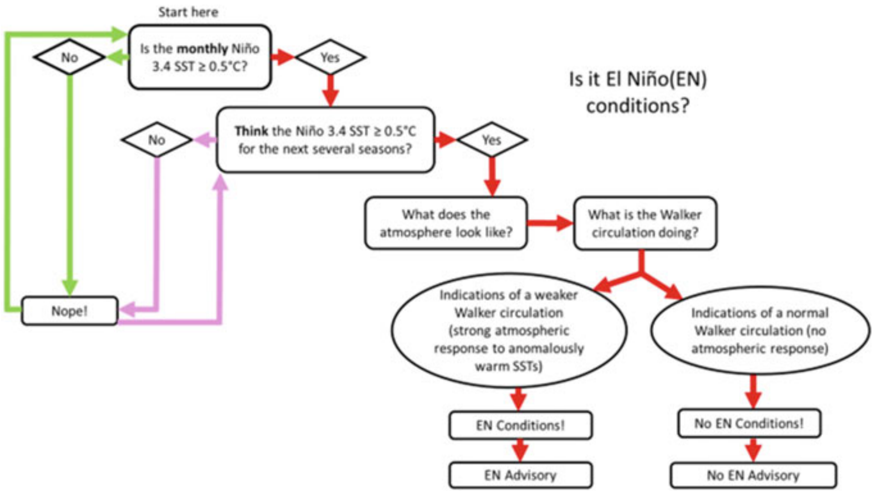


Fig. 12 Schematic from the ENSO Blog modified to provide more detail on decision making. Green and pink lines represent feedback loops, while red is the forecasting pathway in the decision tree. (Glantz and Ramirez 2020, based on Becker 2015)

5 Deconstructing Readiness

A question that merits more serious attention than it has often been given is "How important is it to be exactly right when a rough answer will do?" (Mathworks.com 2020). At the heart of the question is the notion of "fuzzy logic," which provides a useful way to approach concerns about the precision vs. the significance of information. Readiness can be thought of, like this, as just such a "fuzzy" concept. It is a concept that does not ring true when applied deterministically, as with the exclusive disjunction assumed of a yes–no question, but that requires gradated or intermediate possibilities (TutorialPoints 2014). It makes little sense to claim that a society is either ready or not to contend with the impacts of a known hazard like El Niño. In DRR, there are always "shades of readiness."

The reality of such shades reveals how fuzzy logic can be useful for decision makers to identify and communicate about distinct levels of DRR readiness in preparing for and subsequently coping with hydrometeorological hazards (Fig. 13). A part of this reality entails the ability to effectively communicate forecast probabilities in a way that the non-trained public can understand. Such distinct levels of DRR readiness might be better understood by the public, for example, as qualitative expressions that adverbially gradate those levels—hardly ready, relatively ready, almost ready, and absolutely ready.

On the other hand, a quantitative approach may be more useful for, say, ranking different nations' respective levels of readiness after a disaster event than it would have been for identifying what each nation's actual readiness level was before the event. Qualitative and quantitative expressions of readiness should be understood as

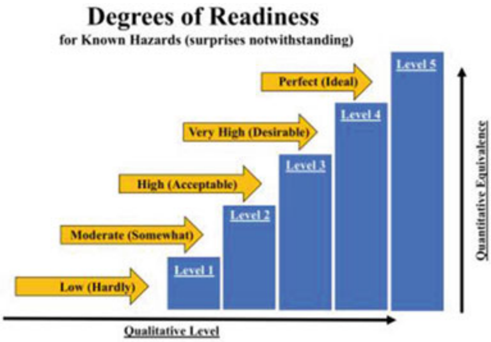


Fig. 13 Degrees of Readiness. As qualitative levels progress, the quantitative equivalence increases (Consortium for Capacity Building (CCB))

complementary indicators. Not understanding this complementary nature of qualitative and quantitative expressions leads to those situations to which René Dubos referred when he observed, "Sometimes the more measurable drives out the most important" (idlehearts.com ND). Sometimes, that is, the good enough is assuredly significant enough, as Fig. 14 *smashingly* suggests.

Perhaps, therefore, the question should really have always been, "Is 'good enough' in preparing for and coping with foreseeable climate, water, and weather-related hazards good enough?" In terms of El Niño readiness (e.g. Glantz et al. 2018), in other words, does Voltaire's famed adage really make the most sense—"Don't let the perfect be the enemy of the good"?

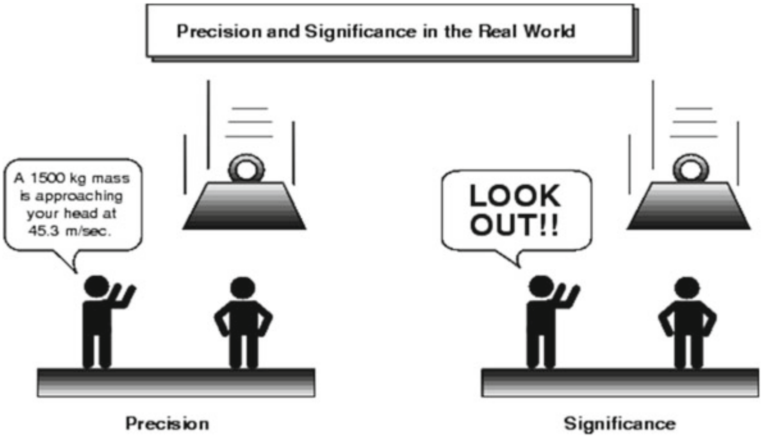


Fig. 14 Giving too much information can often confuse or even distract the intended user from the warning. Simple language is often needed to elicit the action intended. (Poynter 2015)

6 Limits to Readiness

Every country faces limits to becoming *perfectly* El Niño-ready, primarily because just about every El Niño has been accompanied by a surprise of some sort—in its timing, intensity, duration, characteristics, or societal and environmental impacts. Such surprises have often come several at a time.

There are a number of reasons why nations, industrialized and developing alike, might have difficulty becoming fully prepared for the adverse impacts of even known, recurring hydrometeorological hazards. Some of these reasons involve uncertainties about the science of forecasting El Niño. Such uncertainties can have to do, for example, with variant sea surface temperatures and sea-level pressures across the tropical Pacific, various oceanic and atmospheric oscillations, other physical interactions that can influence the behavior of an El Niño (Fig. 15), or the diverse strengths and distributions of an event's many teleconnections. Regardless, what is clear is that unresolved scientific uncertainties are not just trivial inconveniences; they markedly influence any nation's ability to ready itself.

Societal constraints on any nation's readiness will also likely always exist. For example, the formation of a weak event might be viewed by decision makers as of little concern, even though such events have been known to have outsized effects. To be sure, the historical record shows that even though an El Niño may have been relatively weak, its societal and ecological impacts proved to have been major and long-lasting. The 1972–1973 El Niño, as a case in point, despite its having been a *relatively weaker* event, saw Peru's lucrative anchoveta fishery collapse. The anchoveta was at the time an industrial catch that was processed into high-value fishmeal for export to the

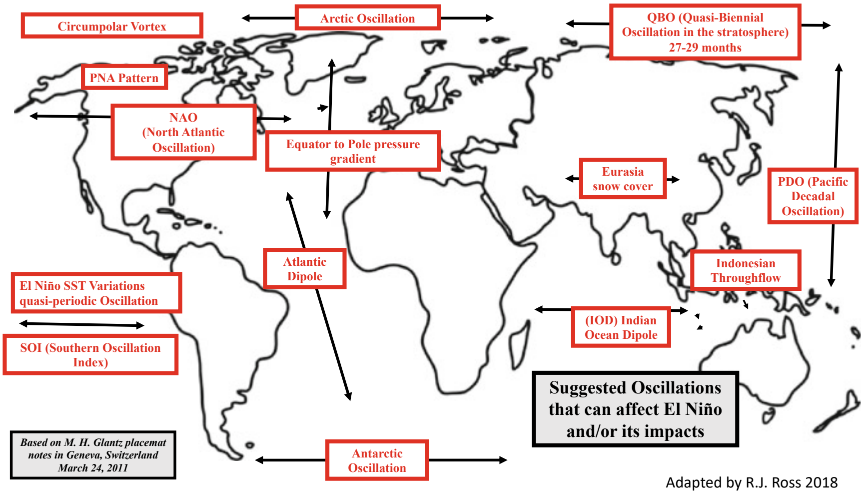


Fig. 15 Various oceanic and atmospheric oscillations around the globe that can influence the behavior of El Niño and the intensity and location of its teleconnected impacts. (Glantz 2011, adapted by Ross (2018))

global poultry industry, primarily to the U.S. The collapse of this Peruvian national industry, consequently, had an unanticipated, devastating impact that rippled across supply chains and destabilized agricultural markets both in Peru and across the globe (Vondruska 1981).

Importantly, the wording of forecast products and how such products are broadcast to the general public can also lead to constrained responses to El Niño events. What this means is that not only scientific uncertainties but also socio-political, psychological, cultural, and economic factors can become roadblocks to achieving effective responses to El Niño warnings. These roadblocks can combine in various, often unforeseeable ways to degrade even the most seemingly well-equipped and willing society's level of readiness.

7 Being Ready: The Who, the by When, and the to What Degree

Every climate, water, and weather-dependent activity is influenced to varying degrees by the strength of the correlations of El Niño's teleconnections to at-risk (or hotspot) regions (Fig. 16). Every nation is expected to protect its citizens from

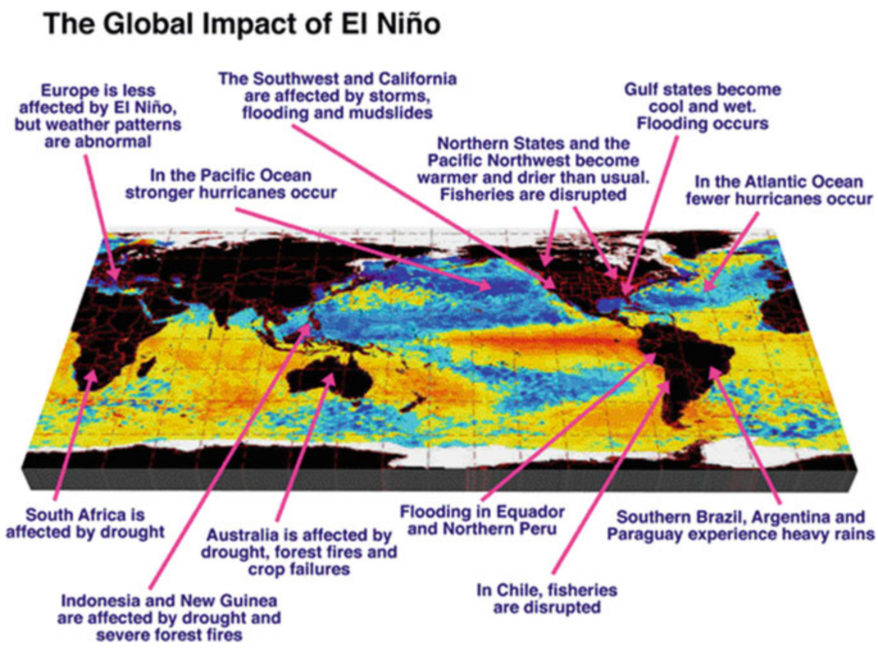


Fig. 16 Impacts in selected El Niño Hotspots. (TOPEX/Posiden Project NASA)

harm, including possible harms—even if unlikely in normal times—that arise from naturally occurring climate, water, and weather-related hazards.

The reality is, however, that many governments do not have the resources necessary to protect all individuals within their borders. Despite such limitation, all governments no less have a moral obligation, if not an ethical responsibility, to warn every citizen of impending, naturally occurring hydrometeorological threats. It is in this way that, as noted earlier, readiness must involve a mix of long-term strategic preparations and short-term tactical responses, depending on national-to-community level resources available for sustainable development and emergency response. The goal of protecting all citizens begins with investments in the ability to communicate with all citizens—by all possible means, technologically speaking, from the most basic to the most advanced.

In truth, however, El Niño forecasts as early warnings for hydrometeorological hazards are often quite imperfect. One problem is the probabilistic nature of forecasts: they cannot, rather fatefully, be verified until a forecasted event actually occurs. Nonetheless, despite this seemingly insurmountable reality, forecasts can still provide governments and at-risk communities with enough lead time to prepare adequately for foreseeable adverse impacts.

Still, even with adequate lead time, warning all at-risk communities in a timely manner can pose a number of often dogged challenges. For one, potentially affected groups are not likely to respond at the same time, in the same way, or with the same energy. The reality is that when first informed of a possible El Niño event forming in the tropical Pacific, not everyone or every economic sector feels the same urgency to know about or react to the forecast. While some people are naturally risk averse and take precautionary actions as early as possible, others are risk takers who tend to choose to wait as long as possible before responding to warnings. The lessons of past disasters show that there is also a third group of people that may not respond at all, even as consequential impacts begin to materialize all around them. This third group of actors tends to wait until follow-ups to initial warnings provide them with even greater certainty that they should act, often when it is already too late to do so.

Aside from countries and local communities, national meteorological and hydrological services (NMHSs) also have to think about El Niño readiness. Over the past few decades, a new generation of non-traditional NMHSs has been slowly emerging as a result of various WMO and World Bank initiatives to modernize such services worldwide. These initiatives have been designed to meet the demands of the increased burdens now facing many civil societies.

Instead of just "doing scientific research" for the sake of science advancement and issuing forecasts, twenty-first century NMHSs are expected—and often now required—to engage in a wide range of societal activities. A modernizing NMHS must develop working relationships with end users to assure that its forecasting products are being effectively received and correctly understood. In this way, NMHSs, as societal focal points for often dire hydrometeorological warnings, require sustained political, moral, and financial support so that they may continue this "refunctioning" process in order to become primarily public-facing services the products of which are broadly trusted by a range of users across various socioeconomic sectors.

8 Strategic and Tactical Responses

Strategic thinking and planning are imperative for protecting a society from the vagaries of climate, water, and weather hazards; despite appearing effective on paper and in PowerPoint presentations, however, strategy can never be sufficient without corresponding levels of tactical thought and practice. Strategic thinking envisions specific goals; tactical thinking and practice translate into actions that can achieve those goals. Strategy can be understood as what is to be done, while tactics are how what is to be done finally gets done.

For El Niño events, distinguishing the strategic from the tactical can contribute to long-term sustainable development prospects. Doing so indicates how tactical thinking and practice may prove even more important than strategic planning for protecting societies from unanticipated hydrometeorological harm. Unlike the long-term, often more abstract focus of much strategic thinking, tactical practices tend to provide short-term, often ad hoc, readiness responses to the immediate threats that arise with the forecast of an El Niño's formation (see Fig. 17). This is not to say that strategic and tactical planning are not complementary. To be sure, focusing exclusively on only one without the other would be like trying to make a sound by clapping with only one hand. But distinguishing the two is nonetheless helpful for understanding where each type of response provides opportunities to further improve sustainable development outcomes.

Especially to be understood is that both strategic and tactical capabilities are necessary for a government to adequately and effectively "get ready" for an El Niño. To develop only a strategic concept for DRR without developing a roadmap to meet that objective would likely lead to failure. Like this, strategic thinking about El Niño DRR in the long-term should be integrated as seamlessly as possible into planning for sustainable development as well as for more immediate post-disaster needs assessments (PDNA). What this means is that tactical DRR activities must always be undertaken with longer-term strategies for sustainability in mind. As such, sustainable development considerations must, in turn, always include hazard-related DRR in its planning. It is in this way that El Niño events provide decision makers with a means by which to bridge, or better yet blend, present-day disaster response and recovery practices with longer-term sustainable development goals.

Fig. 17 Strategy versus tactic approaches. (RallyPoint 2016)

	Strategy	Tactic
Definition	Larger, overall plan that can comprise several tactics.	Plans, tasks, or procedures that can be carried out; may be part of a larger strategy.
Perspective	Broad, "big picture".	Narrow, "close-up"
Time	Over time, long periods of time, future-oriented.	Soon or present
Example	Planning where to send the troops to win the war.	How soldiers should run in a zig-zag pattern to decrease the chance of being shot.

Reasons for governments to delay, shelve, or choose not to implement specific El Niño-related strategic responses can range from scientific uncertainty that surrounds ENSO to the possible fact that the impacts of previous events were not too disruptive of social functioning. Still another reason is that a government might lack the funds to engage fully in DRR activities. The truth is that El Niños are unique events that occur only intermittently, while limited available funds tend to be used for disbursal in the ever-present "now" to meet the current social needs of a specific constituency.

The unfortunate reality of this truth is only reinforced by the fact that longer-term strategic thinking, that which plans for abstract events that will often occur only years or decades in the future, does not fit well into that ever-present "now" timeframe to which even the most assiduous of policymakers are forced to attend because of the election cycle optics to which they are so often beholden. For example, policymakers in the U.S. must account every two, four, or six years for what they have done if they want to be afforded by voters another set term to try to do more. Election cycle optics, that is, tend to drive the short-term thinking of modern governance. What this means, basically, is that a government leader's perhaps genuine interest in pursuing long-term strategic planning constantly runs up against the unfortunate realities of funding availability and election cycle politics.

9 Using El Niño History and Science

The following graph (Fig. 18) is based on NOAA's Oceanic Niño Index, a key quantitative measure of changes in sea surface temperatures (SSTs) in the tropical Pacific's Niño 3.4 region. This graph really is worth a thousand words as it identifies ENSO's warm and cold extremes as well as the relative intensities of each. It also provides the grounds for historical comparisons of past, current, and eventually future El Niño episodes.

Although contemporary scientific understanding of the El Niño phenomenon is thought to have begun with a presentation at a Peruvian geography congress in 1891, not until the late 1960s was El Niño linked to sea level pressure changes (namely, the Southern Oscillation) across the tropical Pacific Ocean. With that mid-twentieth century finding, the "*fenomeno* El Niño" was elevated from being viewed as little more than a locally significant sea surface warming anomaly along the Peruvian-Ecuadorian coast with only regional impacts to a basin-wide phenomenon with worldwide, climate-related consequences.

Since the early 1890s, numerous El Niño events have occurred (and been studied), and enough scientific and environmental information has been gathered to enable political decision makers to take mitigative actions to minimize the foreseeable harms of the phenomenon on their societies (see FAQs, Glantz and Pierce 2020). To be able to do so wisely, however, decision makers need to know the history of El Niño in their respective countries and regions. History can provide a "heads up," that is, one that can perhaps provide the earliest of early warnings to better enable effective societal responses to El Niño-related hydrometeorological hazards. To this end, academic

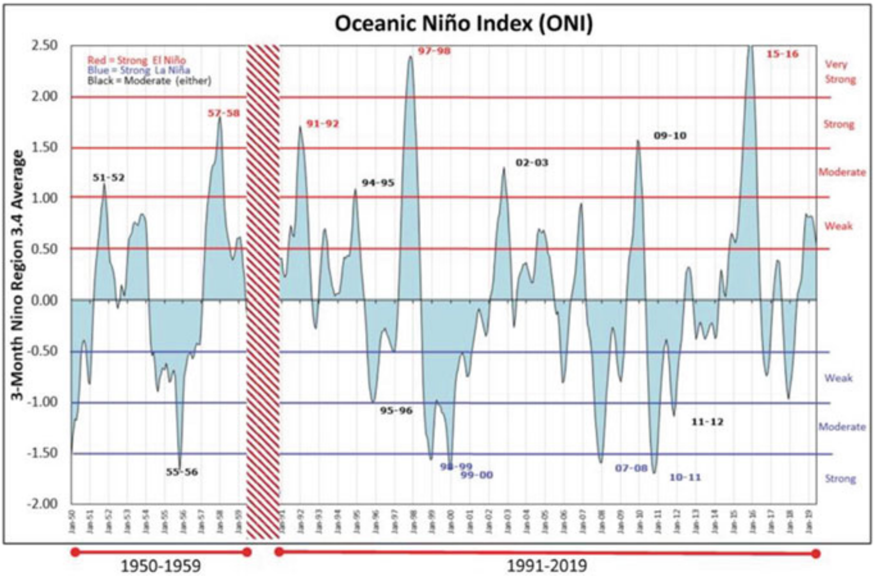


Fig. 18 3-Month Niño region 3.4 average. (Null 2020)

research in a number of physical and social science disciplines and the humanities continues today, often on a learning curve, as, for example, with regard to the possible influences of global warming on ENSO's extreme phases and how increasing economic inequality across many societies has increased overall risk to extreme events for the most vulnerable populations, including women, children, people with disabilities and the aged.

10 Climate Change and ENSO

A British Government Office for Science report succinctly captured what most scientists and IPCC reports (e.g., 2012) generally now believe:

> "Changes in climate due to global warming are widely expected in the coming decades. Rising temperatures will affect weather and precipitation patterns, sea levels may rise, and the average maximum wind speed of tropical cyclones is likely to increase. The expected increase in frequency of climate extremes will, in turn, increase hazard exposure and the risk of events such as droughts, flooding and storm surges affecting different regions in different ways. Although changes over the next three decades may only be small, the long-term trend towards more extreme events is important." (Beddington 2012: 2)

General warming of the earth's atmosphere has been shown to be enhanced during El Niño years. Researchers must, therefore, work to separate human-induced from El

Niño-caused contributions to increased global temperatures. At this point, considerable research-related *information* has been generated about the influence of El Niño warming in the tropical Pacific on global atmospheric temperature increases. But there remains considerable *speculation* about the influence of climate warming on the various characteristics and behaviors of ENSO's warm and cold extremes' teleconnections and impacts. Parsing the difference between what *information* has been generated and what *speculation* remains indicates just how extrapolation continues to drive a large part of our still-limited understanding. Guesstimation, that is, continues to fill in the many blanks that continue to perforate the comprehensiveness of our current empirical observations of the relationship between climate change and ENSO.

As Cho reports:

> "Scientists know that El Niño contributes to an increase in global temperatures. But do rising global and ocean temperatures, in turn, intensify El Niño? The science here is as yet inconclusive. One such study (Cai et al. 2014) suggests that super El Niño events could double in the future due to climate change. Using 20 climate models to examine possible changes in El Niño over the next 100 years, the scientists projected that extreme El Niño events could occur roughly every 10 years instead of every 20.
>
> Other climate models differ in their assessment of future El Niño events. Some suggest the ENSO cycle will become more intense, others say it will weaken, and some find there will be little change. According to Schmidt, 'There is a very large variation in ENSO statistics (frequency/magnitude) over time, and so detecting a shift due to climate change is very challenging. Models as a whole are all over the shop, and so it doesn't fill one with great confidence'." (2016: 4)

What this means, in essence, is that speculations about global warming and its effects on El Niño abound. That said, however, a review of the literature suggests that some consensus is beginning to emerge: El Niño events will become more intense as the atmosphere continues to warm due to human influences. As a result, the teleconnected impacts of El Niño events—droughts, floods, heatwaves, tropical storms, etc.—will also become more intense. Additionally, the very strong El Niño events that current records indicate recur more or less every 15 years may soon appear with greater frequency, forming perhaps every 10 years or so. As WMO has predicted that there will be little change in the overall frequency of events, weaker events will, logically, consequently likely be less common than they are today. Furthermore, heavier precipitation leading to greater overall risk from those hazards associated with inundation events (e.g., flooding, landslides, etc.) is likely to result from the increased frequency of strong events.

The important point to remember for each of these predictions is that consensus is always only educated conjecture; like forecasts, it comes wrapped not in a guarantee but in a probability. Even so, all but assured is that the changes in atmospheric composition that drive global warming could make El Niño events less predictable than they are today after over a century of focused research on and close observation of expected patterns under current climate conditions.

While considerable speculation continues to exist about just how such changes in atmospheric composition will manifest across the earth, many traditionally reticent,

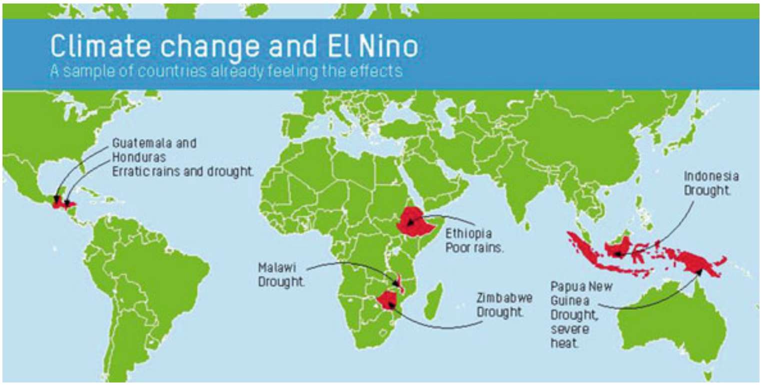


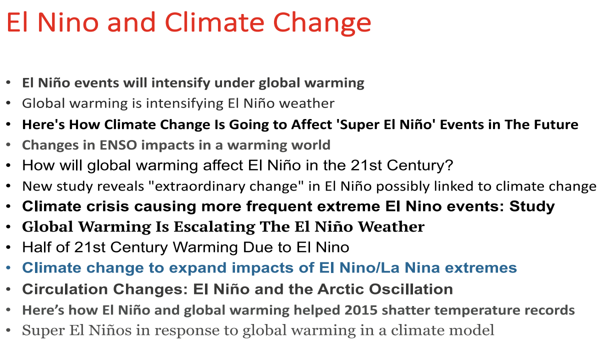
Fig. 19 "A sample of countries already feeling the effects" of global warming on El Niño impacts. (Magrath 2015)

that is, media-shy, researchers and organizations are now becoming less reluctant to attribute the impacts of such changes to global warming (Fig. 19).

A Munich Re report on the 2016 very strong El Niño, for example, contained the following statement on climate change impacts on the frequency of future events:

> "Strong El Niño events like that in 2015/16 may occur much more frequently this century than they did in the 20th century, if the observed pace of climate change continues (business-as-usual scenario). This is the conclusion of a study conducted by leading ENSO researchers (Cai et al. 2014). According to its projections, intensive El Niño events that occurred every 20 years, or less often, in the period 1891–1990, will be experienced twice as frequently in the period 1991–2090. The main reason for this is the relatively strong warming of the eastern equatorial Pacific that would occur with continued climate change." (2016)

Forecasts of such futures are now readily found on the Internet. Figure 20, for example, offers a randomly compiled list of El Niño-related climate change headlines from the Internet.


El Nino and Climate Change

- El Niño events will intensify under global warming
- Global warming is intensifying El Niño weather
- Here's How Climate Change Is Going to Affect 'Super El Niño' Events in The Future
- Changes in ENSO impacts in a warming world
- How will global warming affect El Niño in the 21st Century?
- New study reveals "extraordinary change" in El Niño possibly linked to climate change
- Climate crisis causing more frequent extreme El Nino events: Study
- Global Warming Is Escalating The El Niño Weather
- Half of 21st Century Warming Due to El Nino
- Climate change to expand impacts of El Nino/La Nina extremes
- Circulation Changes: El Niño and the Arctic Oscillation
- Here's how El Niño and global warming helped 2015 shatter temperature records
- Super El Niños in response to global warming in a climate model

Fig. 20 Headlines of internet articles from 2020 describing El Niño and its impacts

11 "Mostly El Niño": Uncertainty and Degrees of Attribution

"Mostly," unlike the certainty implied by the adverb "most," evokes nothing but the vagueness of mere likelihood. "Mostly," that is, does not mean that a foreseeable effect will definitely occur from a suspected, or sometimes even known, cause; instead, it means only that a qualitative likelihood of that foreseeable effect happening can be attributed to that cause. Basically, it's the difference between an effect "most" definitely being the result of some cause versus its only being most likely—or, that is, "mostly"—the result of that cause.

It is in this way that "mostly" can be useful for ascertaining whether, at least with some degree of certainty, the impacts of a specific (or seasonal) climate, water, or weather extreme event can be attributed to one of the phases of the ENSO aperiodic cycle. In a similar way, "mostly" can be useful for attributing the impacts of hydrometeorological extremes and anomalies to climate change.

Considering the complexity of the earth's interacting dynamic energy systems, it is understandable why the task of ascribing with any certainty what societal impacts are attributable to any particular El Niño remains problematic: Each stage in an event, from its initial formation to its final decay, will commingle with unique variations in other global oceanic and atmospheric perturbations to produce variations in just how any specific event's teleconnected impacts will affect different countries around the globe.

When it comes to attribution of impacts, that is, scientific uncertainties abound. What we do know beyond a doubt, however, is that when an El Niño event does begin to form, locks in, and runs its course over several months, the expected climate, water, and weather patterns that constitute the expected seasonal norms of the ENSO neutral phase in recognized El Niño "hotspots" will foreseeably be disrupted—a wet season in southern Africa will most likely turn dry, a growing season in Central America will most likely be plagued by drought, a dry season in the Yangtze River Basin will most likely become anomalously wet.

The ENSO research community has come to differentiate "flavors" of El Niño. This differentiation is based on the shifting locations of the anomalously warm sea surface temperatures in the tropical Pacific's Niño 3.4 region (L'Heureux 2014). Different locations have been found to lead to different types of El Niños, distinguished primarily by the differing strengths of particular events. Because the different strengths of El Niños lead to varying impacts, the notion of "flavors" can also be used for attribution of the most likely influences of an event's anomalous teleconnected impacts on specific areas across the world over the course of that event's lifespan.

With even the expected influences of global warming intensifying from year to year beyond what even the most forward-looking of scientists had predicted only a decade or two ago, perfectly forecasting the "flavors" of future El Niño's timing, intensity, and impacts with high confidence has become increasingly challenging. In other words, both the known and the yet-to-be-determined interactions between global warming and El Niño's air-sea interactions across the tropical Pacific have already increasingly muddled our still inadequate understandings of today's more or less accepted attributions of cause and effect. This muddle is only expected to increase in the near term as the abiding uncertainties inherent within these numerous interactions become more and more prevalent on an even warmer planet.

Still, despite this lack of certainty, forecasters need not despair. Lack of certainty does not eliminate flavors of likelihood. Regardless of what remains unknown or becomes increasingly muddled on a future warmer earth, El Niño-related impact attributions can yet be considered "mostly" accurate, especially with regard to tactical and strategic decision making. It's just like how from time-to-time warm spring-like weather conditions unexpectedly prevail during a winter season. Even at such anomalous times, the seasonal forecast is still said to have been correct, as even though there was a short period of warming the dominant conditions remained no less "mostly" winter-like.

In the same way, depending on the timings and intensities of El Niño events and the particular strengths of their respective teleconnections, one can argue that impacts during such events over decades can be used effectively to identify what might be thought of as an anomalous, seasons-long "El Niño climate." Just as a seasonal forecast might call for *mostly* winter-like conditions, that is, whatever weather anomalies might be produced during an El Niño event would be known to have some established, even if not definitive, causal link to that event.

Such weather anomalies would then be considered "mostly" attributable to the aperiodicity of the El Niño phenomenon's likely but still uncertain teleconnected impacts, a vagueness that the influence of climate change will likely only amplify as attributions into the future become ever increasingly more difficult to identify with any real confidence. See Epilogue for further discussion on climate change and ENSO.

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East Asia

China

China and the 2015–2016 El Niño

Ye Qian

Abstract El Niño events significantly affect China's social-economic-ecological system. By using its newly developed early warning information dissemination system, the China Meteorological Administration (CMA) successfully predicted the onset and development of the 2015-16 El Niño event and warnings were sent to decision makers in a timely manner. In this chapter, obstacles for improving meteorological service in China are identified. It is recommended that in order to reduce systematic financial risks to the economy, insurance and re-insurance companies should move forward to develop a disaster insurance mechanism as a relevant capital instrument for hedging massive contingent liabilities caused by hazards related to El Niño.

Keywords China · Impact of El Nino · Natural disaster · Risk Assessment · Insurance

1 Climate, Water, and Weather Setting

Because of its complex terrain, China is among the few countries in the world that suffers almost all types of natural disasters: floods, droughts, typhoons, snow and ice storms, landslides, mudslides, dust storms, forest fires, and pests. The crop-growing areas affected by various hydrometeorological hazards have collectively been as high as 50 million hectares, and the population affected by such major hazards as typhoons, droughts, heat waves, and sandstorms has reached upwards of 400 million people. From 1984 to 2014, hydrometeorological hazards annually caused an average of 4066 deaths and CNY192.2 billion (USD$30.5 billion) in damages, which translates to a yearly economic loss of 2 percent of China's GDP. The annual average loss ratio

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(direct economic losses/annual GDP) was halved from 2.08% (from 1984 to 2000) to 1.03% (from 2001 to 2014) thanks to improved disaster prevention and mitigation measures. At the time of the onset of the 2015 El Niño, however, China's average loss ratio still exceeded that of all other countries that are as seriously affected by hydrometeorological hazards (Qin Dahe 2015).

Because of its vast, complex geographical and climatic conditions, natural disasters occur frequently and exhibit significant regional characteristics, seasonality, and downstream (second-order) effects (Fig. 1) (Shi and Kasperson 2015). For example, regional severe drought occurs almost yearly, and the eastern coastal areas are also hit by an annual average of seven tropical cyclones. According to the UN report on extremes (IPCC SREX 2012), anthropogenic emissions of greenhouse gases are not only causing various manifestations of climate change, including higher global temperatures, warmer oceans, and higher sea levels, but are also producing more extreme and more variable weather events. Climate change is expected to continue to alter local to national, regional, and global patterns of precipitation, temperature, wind, and seasonality. In addition, extreme weather and climate events, such as heavy precipitation, heat waves, super cyclones, and El Niño/La Niña events will become more frequent, more intense, and longer lasting. Unlike human-induced global warming (a result of greenhouse gas emissions and tropical deforestation) as

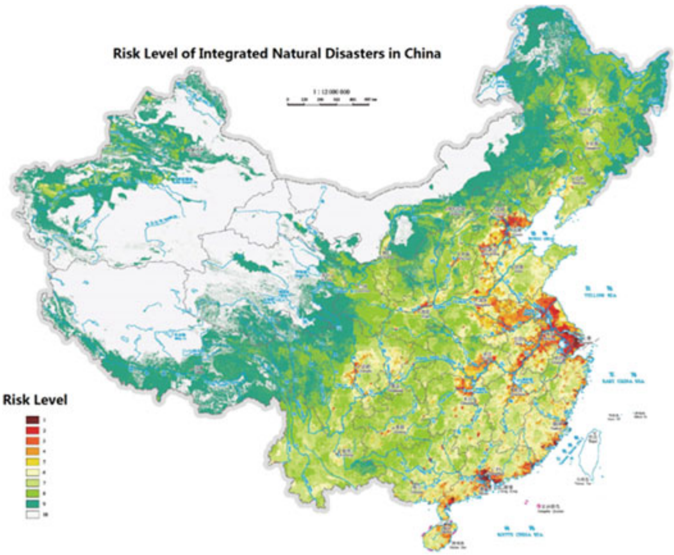

Fig. 1 Multi-hazard risk assessment aims to identify the total risk of various types of hazards in an area in a certain period of time. The TRI (Total Risk Index) and MhRI (Multi-hazard Risk Index) values of all 197 countries of the world are calculated at the county level and at per unit area, respectively. As an example, by MhRI, the top 1% countries with the highest expected annual affected population risk level are China and India at country unit. (Shi and Kasperson 2015) [Editor's Note: The sovereignty over several of the islands and atolls in the South China Sea is subjected to competing legal claims by various countries in the region.]

a long-term and cumulative phenomenon, extreme weather and climate events each year directly affect local to national societal and economic welfare worldwide.

2 Strength and Reliability of El Niño Teleconnections in China

China's climate is mainly dominated by the Asian monsoon. It has been observed that the East Asian summer monsoon has been changing gradually over the past 50 years. Through the mid-1980's and 1990s, the East Asian winter monsoon also weakened significantly because of global warming. The relationship between winter winds and the El Niño Southern Oscillation (ENSO) has also weakened, especially in the mid-1970s.

Moreover, different regional and global impacts on East Asian climate have been shown to accompany an eastern Pacific (EP) El Niño than a central Pacific (CP) one. Different impacts have also been observed for El Niños developing with the summer onset of monsoons than when those events decay by the end of summer in the following calendar year. For example, during an EP El Niño, there is a positive–negative–positive (+/ − / +) anomalous precipitation pattern over East Asia and the equatorial Pacific, whereas during a CP El Niño there is an anomalous − / + / − rainfall pattern.

The anomalous dry conditions over southeastern China and the northwestern Pacific during a CP El Niño are mainly due to the continuous anomalous sinking motion of the atmosphere over southeastern China as part of the anomalous Walker Circulation associated with a CP El Niño. During El Niño's developing phase in summer the impact of CP El Niño on East Asian climate is more significant than the influence of an EP El Niño. During the El Niño's decaying summer phase, however, the EP El Niño exerts a stronger influence on East Asia, probably due to the long-lasting anomalous warming over the tropical Indian Ocean accompanying the EP El Niño. Temperatures over portions of East Asia and the northwestern Pacific tend to be above normal during an EP El Niño but below normal from the developing autumn to the following spring during a CP El Niño (Yuan and Yang 2012).

3 Forecasting El Niño

Although Chinese scientists have studied El Niño's physical mechanisms for the past 30 or more years, only in 2006 were ENSO forecasts based on climate models first provided by research groups at the Chinese Academy of Sciences (CAS) as a consultancy to the National Climate Center (NCC) (Zheng et al. 2016). In the fall of 2012, the NCC, which is in the China Meteorological Administration (CMA), launched a project to develop the second generation of ENSO monitoring, analyzing, and forecasting systems to improve its operational capacity for ENSO. The new system (SEMAP 2.0) was tested from the spring of 2013, and its predictions were presented at NCC's annual spring consultancy workshop for preparing China's seasonal forecast and outlooks (Ren et al. 2016).

In March 2014, NCC issued a forecast in its ENSO Report stating that "the positive subsurface temperature anomalies increased rapidly across the central-eastern equatorial Pacific, and an El Niño event will develop during the summer." From March to June, NCC continued issuing its forecast of an upcoming and potentially strong El Niño event, referring to WMO's early warning and forecasts received and collated from other countries' national meteorological services, including those from the US, Japan, and the UK. In August 2014, the NCC downgraded its forecast to a weak El Niño. As the equatorial Pacific Ocean's sea surface temperatures (SSTs) began to heat up in October, however, NCC officially declared that a borderline weak El Niño had formed, having had in May passed a warming threshold. It was later found that the El Niño that appeared to be developing in early 2014 was hindered in the northern hemisphere (NH) summer.

The hindering of the emerging 2014 El Niño was largely attributed to a suppressed oceanic-atmospheric interaction caused by anomalous easterly winds (westward flowing) in the eastern equatorial Pacific. In determining this causal relation, Min et al. (2015) note that these winds were related to negative sea surface temperature anomalies (SSTAs) in the southeastern subtropical Pacific (SESP). The negative phase of the Inter-decadal Pacific Oscillation (IPO, also referred to as the PDO) had set up the foundation for the persistence of cooler SSTAs and enhanced trade winds in the SESP after the year 2000. As the recent PDO downward trend continued, the SSTAs in the SESP reached an extremely low value in the summer of 2014, which seriously obstructed the continued evolution of an El Niño event in 2014. More succinctly put, the SSTs had warmed early in 2014 but the atmosphere did not respond; hence, no El Niño developed. Later in 2014 SSTs again increased, and this increase did lead to an atmospheric response, an interaction that eventually led to the 2015–2016 El Niño, which is now widely considered to have been one of the three strongest events since at least 1950.

In the Spring of 2015, NCC issued its rainfall outlooks for the summer by mainly considering changes in the intensity and spatial pattern of El Niño events. Other factors—a warm tropical Indian Ocean (a phase of the Indian Ocean Dipole), the positive phase of the North Atlantic Oscillation, a normal amount of Arctic sea ice and an above normal amount of Antarctic sea ice, slightly more Tibetan Plateau snow with higher than normal temperatures—were also considered. NCC also claimed that it had accurately predicted that the 2015 East Asian summer monsoon would be weak with more precipitation in Southern China and less in Northern China. On June 7, 2016, NCC announced that "slightly negative SSTAs controlled the most eastern equatorial Pacific, while normal or slightly warm SSTs mainly remained in the central equatorial Pacific. All these signals indicate that the El Niño event of 2015/2016 ended in May 2016."

4 El Niño Analogue Years Noted

Historical data indicates that severe floods are very likely to occur in China's Yangtze River basin the year immediately following the onset year of an El Niño event. Comparing the most recent event's conditions with previous events, the 2015–16 El Niño can be said to have been similar to, though worse than, the 1997–1998 event in terms of its duration, intensity, and peak strength. The 1997–1998 event, however, is remembered as having produced the worst flooding in fifty years. In 1998, for example, the Yangtze River saw basin-wide flooding that caused significant loss of life, population displacement, and property damage (Li 1999; Ye and Glantz 2005).

5 Early Warning

An analysis of global climate observational data indicates that the 2015–2016 El Niño that was confirmed in spring 2015 rapidly gained strength over the summer months. Because of the stability of abnormally warm SSTs in the equatorial Pacific since Spring 2014 (Zhai et al. 2016), the event was also predicted to be among the longest recorded El Niños. Based on these indicators, forecasts were issued by the Chinese Meteorological Administration and warnings were sent to the central government as well as to various government agencies at different levels. The Chinese government then used its newly developed early-warning information dissemination system, which broadcasted warnings and updated the evolution of El Niño's life cycle and its foreseeable consequences in a prompt and timely manner through cell phones, TVs, radios, and disaster information service personnel (Fig. 2).

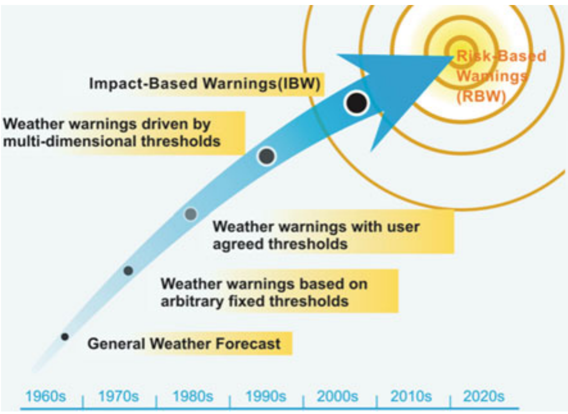

Fig. 2 Evolution in the development of China's Early Warning Systems (CMA 2015)

The government also used the Internet, SMS message, Mobile News, IM software, blogs, and other channels to provide early warning information to disaster-prone areas and to people in high-risk zones. In some areas, radio broadcasts and loudspeakers were used to spread timely early warning information to threatened people. Telecommunications and media relied on information from authorities to disseminate hydrometeorological hazard and early warning information, and to report on floods, droughts, and disaster situations as quickly and accurately as possible.

6 CMA's El Niño Information and Forecasts

As noted, China's meteorological services are mainly provided by the China Meteorological Administration (CMA). The National Climate Center of CMA is the government agency responsible for El Niño monitoring, prediction, and early warning (Jiao et al. 2015). CMA, in close cooperation with other government departments and agencies that work in disaster-related areas, established an emergency information release and dissemination system. CMA in 2015 had a meeting mechanism with focal points from 29 ministries or departments and dedicated lines to 17 ministries/provinces. Together, a joint dissemination system and a sharing and exchange mechanism for developing and disseminating meteorological early warning information was built. A meteorological-support system for major emergency relief was also in place among the ministries of land and resources, transportation, health, and public security.

7 First Observations of 2015–2016 El Niño

Supported by the Chinese Academy of Sciences (CAS), scientists from the Institute of Atmospheric Physics (IAP) developed the El Niño forecast system more than 20 years ago. It has also provided a consultancy to NCC since 2006. The IAP forecast system includes the main physical processes in and between the atmosphere and the oceans using the most advanced data assimilation methods to incorporate various atmospheric and oceanic observations in order to predict the formation as well as the stages of an El Niño's life cycle. The IAP predicted that the intensity of the 2015–2016 El Niño would be close to 2.3 °C in March 2015, which was quite close to observations of the actual event (Fig. 3).

The prediction was accepted by NCC in the spring of 2015. From March 2015 to January 2016, IAP's prediction results remained quite consistent, suggesting with more than a 90% probability that by mid-winter 2015 a strong El Niño event with a peak intensity close to 2.5 ºC would form (Fig. 4).

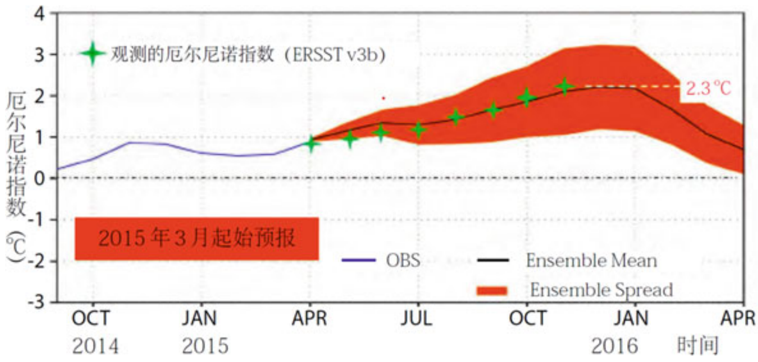

Fig. 3 IAP model predictions (in green) in March 2015 overlaid onto actual event (x-axis is time and y-axis is the El Niño intensity index) (Zheng et al. 2016)

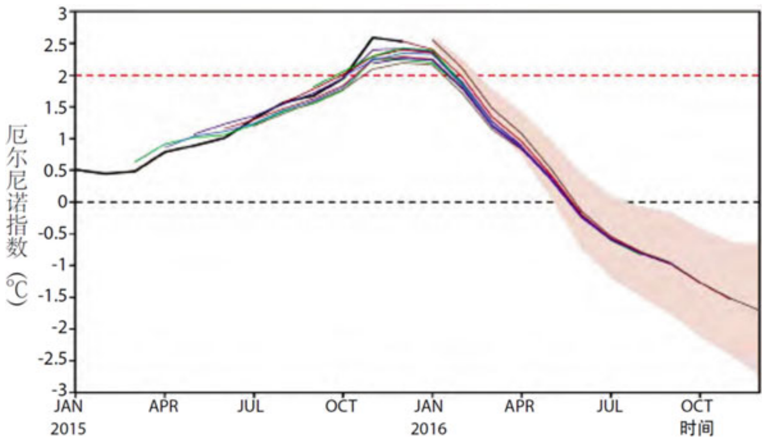

Fig. 4 IAP model predictions, March 2015–January 2016 (x-axis is time, y-axis is the El Niño intensity index) (Zheng et al. 2016)

8 Impacts Across China

The following excerpt from Ye (2017) explains the impacts across China due to various factors some of which are attributed to El Niño: “Due to the complexity of weather and climate systems over China, El Niño is but one of the major factors affecting their anomalous behavior. Many researchers have shown, for instance, that considerable heterogeneities exist in the responses of different parts of the country and of different socioeconomic sectors to El Niño-related hydrometeorological anomalies. During El Niño, for example, China’s urban areas are likely to suffer flooding and its agriculture, water conservancy, transportation, health, and energy industries are also likely to be affected. Generally, the observed impacts of El Niño on China's weather and climate have four main characteristics:

1. The number of tropical storms and typhoons in the Northwest Pacific. The number of landfalls on Chinese territory are less than in the ENSO neutral years that follow an El Niño;
2. In southern China, including the Yangtze River and southern regions, low temperatures and flooding tend to occur in the second calendar year (called "year + 1") of an El Niño. For example, 100-year floods occurred in 1931 and 1954, both of which are El Niño "year + 1." El Niño was also one of the most important factors during the 1998 Great Floods;
3. The occurrence of high temperatures and drought in the summer in northern China. During El Niño years, China's summer monsoon is usually weak. The monsoon rain belt stays to the south in central China or south of the Yangtze River. Northern China is prone to drought and high temperatures in summer. For example, drought and high temperatures in northern China were quite severe in 1997, which was an El Niño formation year;
4. Northern China is prone to warmer winters."

China experienced El Niño-like conditions starting in May 2014. Although a full-blown El Niño did not form then, a warmer winter and heavy rainfall were no less experienced. When an El Niño actually did form a year later, in 2015, six southern Chinese provinces witnessed rainfall amounts equal to their historical record. Consequences of such conditions were seen all over the country, from the landslide in Zhejiang Province to severe flooding in Hunan Province. To be sure, the 2015–2016 El Niño event played a significant role in weather and climate patterns across China, including a warm winter in the north that saw some of the highest November and December temperatures in the past several hundred years. Further influences include how most parts of Southern China measured more precipitation than normal, while most parts of the north experienced rainfall declines. According to incomplete statistics from the time, more than 20 million people and about 1.7 million hectares of crops were adversely affected across the country's 20 provinces (including autonomous regions and municipalities). Floods, as but one example, caused economic losses of about CYN35 billion.

In late fall 2015, precipitation was well above normal in southern China (such as in Guangxi, Hunan, and Jiangxi Provinces). The national average precipitation for this period was 50 percent more than normal and set new records. In the beginning of 2016, three consecutive cold fronts affected mid-eastern China. After late March 2016, Southern China suffered continuous floods. For example, in Guangzhou City the four-month cumulative rainfall was far more than for the same period in previous years (Figs. 5 and 6) and 2.84 times the average value for 2003–2015. Abnormal precipitation has a significant impact on the major river basins in China, so in 2016 NCC warned that of the ten major rivers, eight could expect between ~30 and 75% higher than normal precipitation.

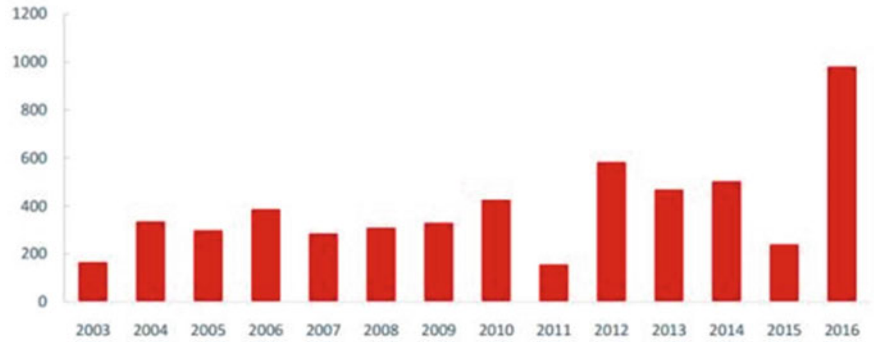

Fig. 5 Four-month (January to April) cumulative precipitation in Guangzhou City (NCC 2016)

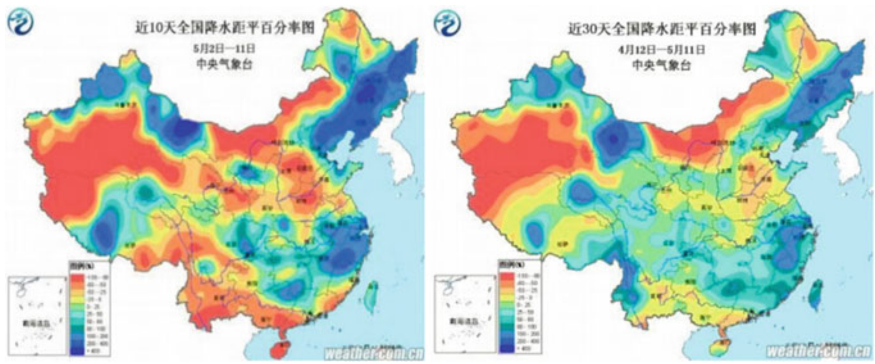

Fig. 6 National precipitation anomalies, May 2–11 and April 12–May 11, 2015 (NCC 2016)

9 Regional Impacts of El Niño

For a quite long time, Thailand, Vietnam, Laos, and Cambodia have been squabbling over dam construction and water usage along the Mekong River in China, an argument that grows more consequential when severe drought threatens rice yields across the Indochina Peninsula. The Mekong River originates in China and runs through Myanmar, Laos, Thailand, Cambodia, and finally Vietnam where it empties into the South China Sea. The stretch of the river within the Chinese border is known as the Lancang. China has a history of releasing surplus water from its dams, especially when water shortages downstream become dire. Due to the effects of El Niño, however, at the end of 2015 countries along the Lancang-Mekong River experienced droughts of varying degrees, and their peoples' lives and livelihoods were negatively affected. Requests from Vietnam and Cambodia were sent to the Chinese government to release water to help alleviate severe droughts. Initially set for March 15 to April 10, and later extended until the end of the low-water period, China agreed to discharge water in accordance with the situation in upstream areas and the actual demands of downstream countries.

10 Government and NMHS

In recent years, national meteorological and hydrological services (NMHS), including China's CMA and Ministry of Water Conservancy, have worked together to improve meteorological and hydrological information dissemination. For example, as of 2016 over 5000 weather forecasts were daily aired on local and national TV stations, China Weather (www.weather.com.cn/) had over 26 million visitors per day, the China Weather Channel was broadcast in upwards of 314 cities, and over 100 million people signed up for CMA SMS weather services. Furthermore, well over 88 million smartphone users installed the CMA meteorological service app, and an average of 50 million people a month called the CMA service phone number (dial 12,121). At that time, over 13 million people followed about 700 official CMA micro-blog/webchat accounts (Yu 2017).

In rural areas with less information infrastructure, CMA also expanded its dissemination network to include some 485,000 public radio speakers, 144,000 electronic display screens, and 78,000 weather information service stations. It also established eight ocean weather radio stations.

But dissemination is even more important when it comes to the government. The primary objective of an early warning system (EWS) is to enable the appropriate authorities to develop proactive, timely emergency preparedness and response measures to avoid or limit the impacts of extreme weather and climate hazards. To achieve this aim, a good understanding of lines of authority and decision-making processes is paramount. Additionally, all stakeholders must have a comprehensive understanding of hydrometeorological hazard risks and impacts. Emergency protocols and procedures need to be clearly developed from national to community levels with well-defined roles and responsibilities.

11 Inter-Agencies Involved with El Niño Forecasts and Impacts

After receiving the official prediction from the National Climate Center about the possible formation of an El Niño event in 2015, weather-sensitive sectors such as agriculture, water conservancy, and transportation, by consulting with CMA, conducted assessments on the potential impacts of El Niño and then actively carried out preparation and response plans accordingly. For example, in June 2015 the Ministry of Agriculture issued a "precautionary plan to respond and deal with the El Niño scientifically in order to reduce foreseeable harvest loss." It also issued in January 2016 a "precautionary plan to mitigate the impacts of El Niño in order to guarantee the harvest." Both plans required the entire agricultural sector to enact measures to reduce agricultural losses that might be triggered by El Niño.

In March 2016, the Ministry of Water Conservancy issued an order asking municipalities to accelerate the repair, maintenance, and construction of water management systems and underground pipes in city drainage systems to reduce urban flood risks. In April 2016, the National Flood and Drought Committee issued a special official warning jointly with the National Energy Bureau to provincial governments and their respective provincial offices advising dams and hydropower enterprises to pay attention to the safety of reservoirs and hydropower stations, not only to ensure that reservoirs did not collapse but also that they fulfilled their function in flood control.

Some provinces affected by the impact of the El Niño also issued precautionary plans to respond to potential risks. In April 2016, for example, the Department of Agriculture in Guangdong Province invited experts to develop a scientific, evidence-based precautionary plan to deal with El Niño-related hazards and disasters. The plan had a specific prevention focus and included technical measures for coping with disasters from cold weather and frosts in the spring as well as from typhoons, droughts, shortages of sunny days, and floods.

12 Media Coverage

For the 2015–2016 El Niño event, media in China started to pay attention in March 2014, when forecasts from NOAA and WMO about the formation of a potentially strong El Niño were first released. Since most media in China are under control of the government and all meteorological information including El Niño forecasts must be from a government agency like CMA, the media started to gather information from NCC about El Niño and its impacts. Unfortunately, because NCC is the only official resource in China, almost all of media articles presented readers with the same information. In some cases, the media began to question some of the government's wrong actions in either prevention or rescue when some officials tried to use El Niño as an excuse for certain problems in their jurisdictions.

13 Hurdles and Obstacles

In general, a major obstacle for improving meteorological services in China is the tight control of meteorological information, including observations, forecasts, and impact assessments, all of which are bound by the Law of Meteorology of China that was first established in 2000 and later modified in 2015. As a country with a vast territory that crosses a wide number of latitudes, the impacts of El Niño on different regions and different socioeconomic sectors vary significantly. To understand and then better deal with impacts requires huge investments and collaborative efforts among all stakeholders. The administrative structure was clearly not prepared, or suitable, for dealing efficiently with surprising extreme events such as the strong El Niño of 2015–2016, which lasted a long time and was unexpectedly intense. In late 2015, for example, CMA released an official statement to warn that the 2015–2016 El Niño-related floods in the Yangtze River basin were more serious than the Great 1998 Floods that affected the whole of central China. Although major hydrological infrastructures took immediate measures to prepare, many small to mid-size riverine areas still suffered greatly because of the lack of appropriate assessments and preparedness at those levels (Ye 2017).

14 El Niño-Related Surprises

The only surprise was when the forecast raised expectations in early 2014 of a Super El Niño that then "fizzled." Most of the time, however, the year following El Niño's formation—El Niño's "Year + 1"—tended to have the greatest impact on China, so the early 2014 false alarm did not cause any significant loss in the country.

15 Some Lessons Learned from El Niño Events

The lessons that follow were first identified in "Once Burned, Twice Shy" (Ye et al. 2001).

Lesson: Use existing social media to educate the general public and get more experts, officials from other agencies, and business managers involved to raise awareness of El Niño and its impacts on China.

Learning the lessons from the past, CMA started its education campaign in early spring of 2014 when WMO and NOAA issued their respective El Niño forecasts. In mid-June, the China Weather Channel, a media branch of CMA, produced a special program to discuss El Niño. Although NCC had not yet issued an official statement on the possible El Niño event, the experts they invited used WMO monthly bulletin and forecasts, which were based on more than 20 international models as well as their own research results, to inform the public of the science of El Niño and its impacts on both the world and China. Importantly, all of the experts emphasized the uncertainties associated with El Niños, the weakness in fully understanding their mechanisms, and making forecasts (China Weather TV 2014). Another program was made on December 10, 2014 once NCC finally issued its official statement that an El Niño had begun to form in October 2014.

CMA's efforts to educate the public deserve praise; however, because of government regulations on controlling weather information dissemination, it could only use its own channels such as China Weather TV, its own website, the Chinese Meteorological Newspaper, etc. to distribute its messages to the public. It is possible that more popular social media formats could actively be used, with scientists and professors from different disciplines expressing their views on El Niño. Moreover, experts from other agencies and business sectors could also be involved. Many governments control their weather and climate information, especially for hydrometeorological hazards, in order to avoid panic in civil society that could result from unofficial misinformation possibilities.

Lesson: Recognizing that natural disaster-related contingent liabilities that are largely ignored by financial entities presents systematic financial risks to the economy, insurance and re-insurance companies are now moving forward to work with the Chinese government to better use a disaster insurance mechanism as a relevant capital instrument for hedging the massive liabilities often caused by disasters such as those related to El Niño events (Ye 2017).

Impacts of El Niño in China are widely scattered. Because of large uncertainties in predicting the exact timing and scale of the impacts of an event, the government and most business sectors largely ignore the potential financial impacts of El Niño when assessing their financial and fiscal liabilities. Moreover, they do not set aside contingent capital to hedge against such liabilities. Massive contingent liabilities, particularly government fiscal liabilities, related to natural disasters including but not limited to El Niño are highly significant in the context of the Chinese economy and could expand exponentially in coverage and scale.

Currently, most companies do not use insurance to protect their assets and interests, and governments at all levels do not have sufficient fiscal funding to finance relief and reconstruction in the case of destructive natural disasters. When a severe disaster occurs, residents' financial risk can be converted into fiscal risk for the relevant government. Thus, fiscal risk has become the core issue of natural catastrophe risk. The lack of comprehensive insurance coverage clearly shows the vulnerability to hydrometeorological hazards of China's social wealth and economic prosperity. After a disaster, individuals, collectives, and the economy as a whole may suffer loss of income and assets. Debt can also increase to an extent that it drives up interest rates or even requires a state bailout. Governments at all levels would basically have to rely on fiscal measures such as reducing other spending, use of funds originally allocated to other budget items, transfer payments from higher government levels and the central government, increasing taxes, and raising debt to obtain unplanned funding for disaster relief, post-disaster repair and reconstruction, and post-disaster social assistance.

For these reasons, the use of commercial insurance to close gaps in the coverage of risks could be one of the potential measures to deal with impacts of extreme events such as a Super El Niño. Insurance companies continue to discuss with governments at different levels how to use an insurance mechanism as a potentially viable solution for the risks posed to public assets by natural hazards. The use of such a mechanism would enable central and local governments to increase their level of control and reduce the costs of public asset risks.

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South Asia

The Maldives

The 2014–2016 El Niño in the Maldives: Climate, Impacts, and Response

Lareef Zubair and Ashara Nijamdeen

Abstract Sitting atop an oceanic ridge running from the Lakshadweep Islands to the north to the Chagos Islands to the south, the Republic of Maldives dots the periphery of 26 atolls in the Indian Ocean. It has a total land area of 298 km^2 (115 mi^2) but the Republic as an archipelago encompasses 90,000 km^2 of ocean surface. The Maldives 1192 islands are low-lying and small and face environmental risks due to geophysical hazards, water availability, disease, and food insecurity. The dispersed population of 350,000, as well as the livelihoods of expatriate workers, are highly vulnerable to climate variability. They are also affected by El Niño impacts, which tend to be modulated by the influences of other air-sea interactions such as the Indian Ocean Dipole (IOD). The impacts of El Niño are also influenced by an ever-warming Indian Ocean as well as by atmospheric waves. In this chapter, the variation of indices for these influences are compared in order to extrapolate the impacts of climate change from mid-2014 to mid-2016. This study concludes that some of these impacts—including coral bleaching, drought (in the northern islands), flooding (in some seasons), infectious disease, and fishery and agriculture loss—are due to the very strong El Niño that formed in 2015.

Keywords El Nino · Climate · Maldives · Arabian Sea · Indian Ocean

The combination of an El Niño event and the ongoing warming of the Indian Ocean made the 2014–2016 period the warmest on record with regard to both sea and land surface temperatures. Bleaching due to this warming led to a large loss of live corals, and rainfall anomalies led to flooding across the country. Along with El Niño, both the oceanic Indian Ocean Dipole (IOD) and the atmospheric Madden Julian Oscillation (MJO) were drivers of flooding. As a result, the incidence of dengue picked up during the El Niño, particularly in the Central and Southern Atolls, though such an increase

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was not typical during other recent El Niño events. During the 2015–16 event, fishery production also declined in the Northern and Central Atolls, though the catch in the Southern Atolls increased, a trend similar to previous El Niño events for which data is available.

1 Political and Economic Setting

"The Maldives faces environmental risks that leave the population highly vulnerable due to its far-flung geography of 1192 small islands, the majority of which are at elevations less than 2 m above mean sea level (MEE 2017, MEEW 2007). The islands are scattered on the periphery of 26 natural atolls on a north–south axis from 0.5 °S below the equator to 800 km above" (Zubair et al. 2017a (Fig. 1).

Population has risen considerably from approximately 100,000 in 1960 to 350,000 in 2016. This precipitous increase has contributed to threats to the sustainable use of finite resources such as water (Fig. 2). Furthermore, an expatriate worker population of 63,637 (2014 census) also puts enormous stress on limited resources, especially since the number of expat workers is believed to be substantially higher than official statistics indicate (MNPI 2018).

The Maldives underwent constitutional reform that led to a multi-party election in 2008. Only two years later, however, a turbulent period began with questions about

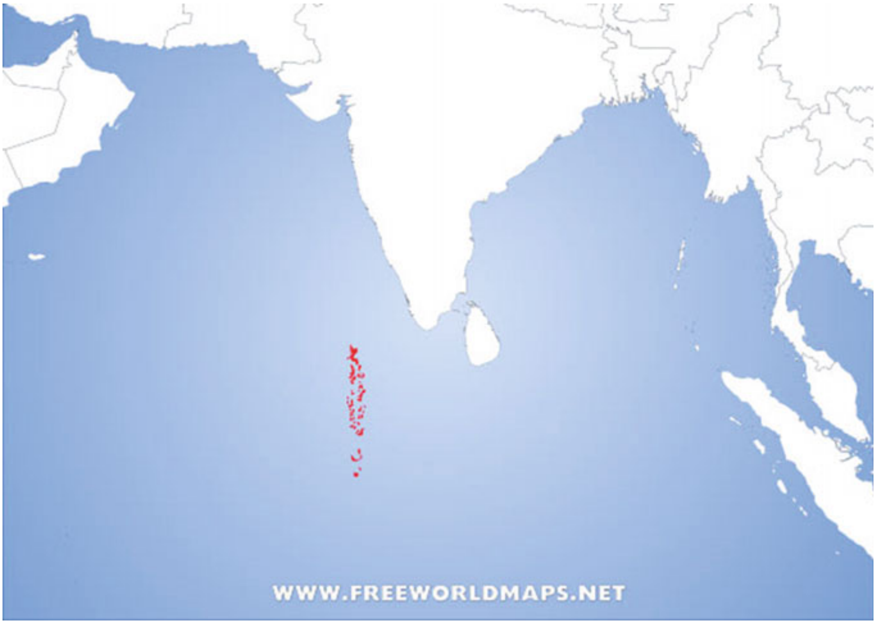

Fig. 1 Regional Map of The Maldives (Free World Maps 2020)

Fig. 2 Dense population of Malé Maldives (Wikipedia 2017)

the legitimacy of the government, resulting in deep societal divisions. More recently, the elections of 2018 brought to power a stable government with a two-thirds majority in parliament and a commitment to addressing sustainability.

Despite its remoteness, the Maldives is an important player in Indian Ocean geopolitics for a number of reasons, including territorial water disputes, relations with India, strategic location, the presence of China, US-China geopolitical competition, and sea level rise due to global warming. Perhaps the most immediate geopolitical issue, however, is the Maldives position as a proxy battleground in escalating regional conflicts between China and India. Although India maintains a "Neighborhood First Policy" that encompasses the Maldives in its strategic security considerations, China's current "outgoing" foreign policy agenda, most visibly through its multi-trillion dollar "One Belt, One Road" (OBOR) infrastructure development initiative, increasingly destabilizes regional relations. Kapoor succinctly sums up the situation:

> The Indian Ocean is a key highway for global trade and energy flows (Albert 2016). The Maldives is geographically positioned like a 'toll gate' between the western Indian Ocean chokepoints of the Gulf of Aden and the Strait of Hormuz on the one hand, and the eastern Indian Ocean chokepoint of the Strait of Malacca on the other. Thus, while the ISLs [international shipping lanes] in the vicinity of the Maldives have broad strategic significance for global maritime trade, they are of particular importance to India. Fifty per cent of India's external trade and eighty per cent of its energy imports transit these ISLs (Singh 2019). It is obvious, therefore, that any significant Chinese presence in this region has the potential to impede trade movement that is vital to India's economic interests, and such a possibility must be guarded against. (2020: 1)

Of great concern to India, for example, was the unique layover of Chinese warships in the Maldives in 2017. Later that year, the Maldives joined the Maritime Silk Road, part of China's OBOR initiative (also called the Belt and Road initiative, BRI), in order to receive financing to develop its domestic infrastructure such as the USD$200 million China-Maldives-Friendship Bridge (Gan 2020). Joining, however, eventually rendered the Maldives a debtor to China. This move was also very concerning to India, and rightly so, for not long after the Maldives government found itself falling behind on its OBOR loan payments, which turned out to be a "debt trap" similar to that into which the Sri Lankan government had fallen in 2015. When the Sri Lankan government defaulted on its OBOR loans, China was able to negotiate favorable terms for a 99-year controlling lease of the strategic Sri Lankan Port of Hambantota (Glantz et al. 2019). The Maldives government was close to defaulting in 2018. India, however, could not countenance a similar geopolitical encroachment upon another of its South Asian neighbors, so, moving tactically, it intervened to finance the Maldivian government's shortfall with China. In 2020, India funded a causeway to link Malé with 3 nearby islands for USD$500 million (Gan 2020). This geopolitical proxy drama in India's "neighborhood" continues even now, unabated.

2 Climate of Maldives

Even though the Maldives total land area is quite small, the country as a whole is spread from just south of the equator to 7 °N of the equator, a large swathe of ocean that results in often marked variations in climatic characteristics. The Maldives Meteorological Service (MMS) has five main stations (Fig. 3) positioned along this north–south expanse.

In the descriptions below, Hanimadhoo is taken as representative of the northern atolls, Hulhule as representative of the central atolls, and Gan as representative of the southern atolls. In addition, it is also useful to consider the respective stations in the Lakshadweep islands of India (Minicoy and Amini) and that in the Diego Garcia Islands in the Chagos Archipelago, as these have longer records and can help interpret the climate. The rainfall and wind averages at the main stations are as follows:

Rainfall: The Maldives receives an annual average rainfall ranging from 1700 mm in the northern-most station of Hanimadhoo to 2350 mm in the southern-most Gan station (Fig. 3). The mean annual cycle of rainfall in the Maldives shows a dry season from February to March and a wet season from April to November, with the southernmost islands receiving high rainfall during the December-January period when the Inter-Tropical Convergence Zone (ITCZ) is over the Southern Maldives. The northern stations receive their highest rainfall during the summer monsoon month of June, and the southern-most stations show a rainfall peak in December (FECT ND).

Wind: The Maldives tends to see a seasonal reversal in wind direction, with northeasterlies from December to March and southwesterlies from April to November. For the northernmost islands, the southwesterlies tend to last from May to October. The wind speeds peak in the northern region in June and in the southernmost islands in December. Storms and cyclones tend mainly to affect the northern islands (MEEW 2007).

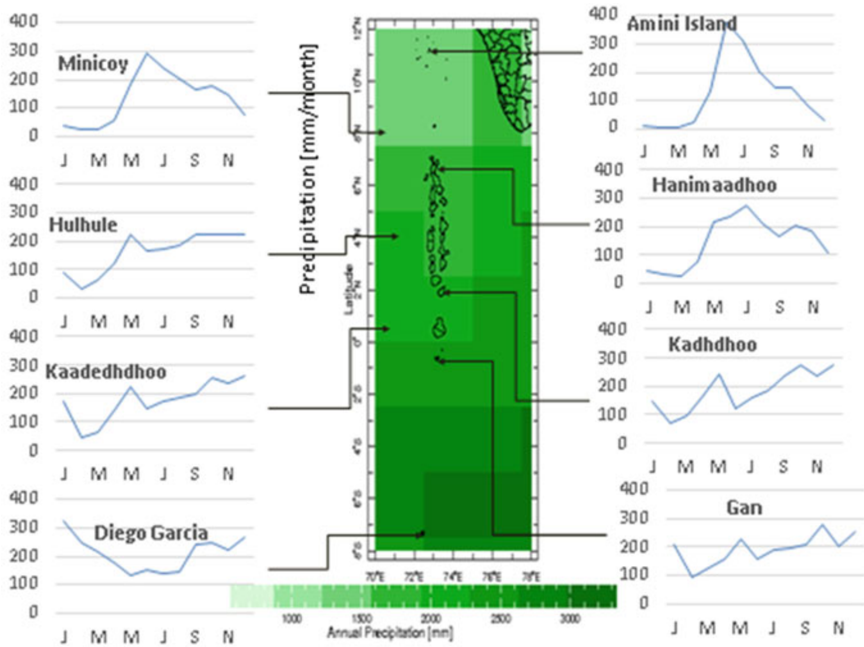

Fig. 3 Annual Rainfall of Lakshadweep-Maldives-Chagos Archipelago along with rainfall climatology of the synoptic (WMO) weather stations (Vose et al. 1992)

3 Strength of El Niño Teleconnections in Maldives

El Niño has significant impacts on rainfall, sea surface and land temperatures, winds, and other associated climate features across the Maldives. Its impacts, however, tend to vary by region, by decade, and by season as well as from event to event (Zubair et al. 2016). El Niño also tends to generate additional contrasts between northern, central, and southern islands.

The temperature warms during El Niño throughout the Maldives, with some modulation by sea conditions due to Indian Ocean dynamics. This interannual warming, in conjunction with the general warming of the regional seas, has resulted in temperature increases (Fig. 3) that exceed the tolerance levels of coral reefs. Significant coral bleaching associated with El Niño occurred, for instance, in the Maldives in both 1997 and 2016. Other discernible impacts have also been observed with regard to water resources, droughts, floods, fisheries, agriculture, health (especially dengue transmission), and coral reefs. The impact on coral reefs is particularly critical, given the islands' coral reef-based geology.

4 Challenges in Communicating El Niño to and Its Impacts on Society

MMS communications on seasonal and regional nuances of teleconnections to sectoral experts has been tricky, particularly in relation to El Niño's influence on rainfall. Communicating temperature influences in the seas and on land has been more straightforward, especially with regard to temperature-based impacts on coral reefs and health.

5 Forecasting El Niño for Maldives

National preparedness for El Niño is under the umbrella of the ministries in charge of Environment and Energy, Defense, Aviation, Fisheries, and Agriculture. The primary responders to climate extremes and disasters are the Maldives Meteorological Service (MMS), the Water Supply division under the Ministry of Environment, and the Disaster Management Centre.

The Maldives Meteorological Service (MMS) is the mandated department for weather and climate prediction and communication of usable information to the public. There have been considerable advancements in prediction capability in the last decades, mainly through the installation of prediction systems and the sustained attention of officials at MMS. Collaboration with organizations such as the World Meteorological Organization (WMO) and the Foundation for Environment, Climate, and Technology for Research (FECT) has also been beneficial. Furthermore, the Maldives Marine Research Centre and other organizations under the Ministry of Fisheries have been proactive in monitoring coral reef bleaching after the damage from the 2014–2016 El Niño.

The MMS relies on WMO and other international forecast centers for global and regional monitoring and prediction information. The officers of the MMS participated in the annual South Asia Climate Outlook Forum (SASCOF). The SASCOF of April 2014 projected a slight dry tendency over the central and northern islands and a slight wet tendency for the southwest (summer) monsoon from June to September. The SASCOF held six months later in October of 2015 predicted a slight wet tendency for October to December across the Maldives.

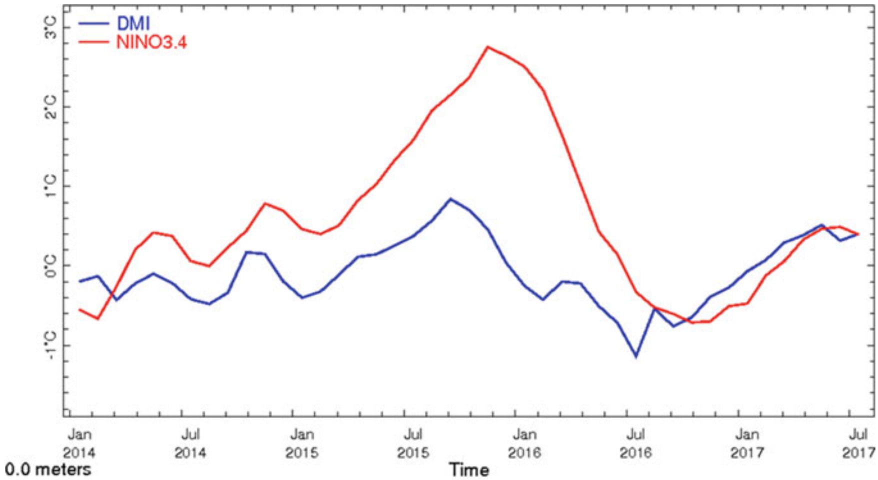

Fig. 4 The monthly variation of Oceanic Niño Index (NIÑO3.4) and Dipole Mode Index (DMI), 2014–2017 (Zubair et al. 2003)

6 Teleconnections During the 2014–16 El Niño and Their Impacts

6.1 2014–2016 El Niño Event

Based on the Niño 3.4 indices (Fig. 4), an El Niño began to form in October 2014 and persisted until April 2016. Transition to the La Niña phase extreme occurred beginning in October 2016. As per the Niño 3.4 record, the 2014–2016 El Niño proved to be among the three strongest events on record (since at least 1950), even challenging the intensity of the 1997–1998 event.

6.2 Indian Ocean Dipole (IOD)

Usually, El Niño is associated with a positive Indian Ocean Dipole (IOD), which is characterized by seasonably warmer central Arabian and Indian Ocean sea surfaces temperatures accompanied by cooler seas adjacent to the Sumatra Islands (Zubair et al. 2003). The air–sea coupling that sustains the IOD picks up around June and dies off by late December. A positive IOD compounds the warming of the ocean due to El Niño. Rainfall has no discernible association with IOD from January to May, a weak dry tendency from June to August, and a significantly wetter tendency from September to December. The IOD index of DMI (Fig. 3) was weak during 2014, positive during 2015, and negative during 2016 in terms of the classification presented in Zubair et al. (2003).

The Dipole Mode Index (DMI) was above the standard deviation of + 0.3 °C from July to November 2015 and below -0.3 °C from May to November 2016 (Fig. 4). DMI was also below the -0.3 °C threshold from July to September 2014, although it was weakly positive for the rest of 2014. The impact of the interplay of the NIÑO and DMI has to be interpreted by region and by season. For example, from September to December, DMI influences on rainfall would typically be found to complement that of the 2015 El Niño across the Maldives central islands.

6.3 Indian Ocean Warming

The Indian Ocean has been warming around the Maldives at a much faster rate than can be explained only by global warming. This rise has been compounded by El Niño, leading to an unprecedently high rise in SSTs close to the Maldives. The oceanic temperature (SST) around the Maldives during the 2014–2016 period was comparable to that recorded during the 1997–1998 El Niño event (Fig. 5).

6.4 Madden–Julian Oscillation (MJO)

The Madden–Julian Oscillation (MJO) has a significant impact on Maldivian rainfall and temperature and can also modulate the impact of El Niño, even though MJO's impact tends to be shorter lived than El Niño's. MJO oscillations are characterized by eight phases (Wheeler and Hendon 2004). In phases one and two, MJO has a significant enhancing influence on Maldivian rainfall, with some influence in the northern islands stretching into phase three. When MJO is in phases five, six, and seven, rainfall tends to be suppressed.

In mid-October of 2014, MJO was in phase one and its impacts strengthened over the Indian Ocean. In 2015, rainfall increased from March to mid-June, and then again in July and October. Rainfall increases were also observed in 2016 (mid-January, June, July, and late November), but significantly decreased in October and December.

7 Climate Over Maldives, 2014–2016

7.1 Rainfall

The rainfall from April 2015 to May 2016 (Fig. 6) followed historical trends for the northern and central islands. These trends are represented for El Niño, near neutral, and La Niña in Fig. 6 as red, green, and blue, respectively, for the three regions. In

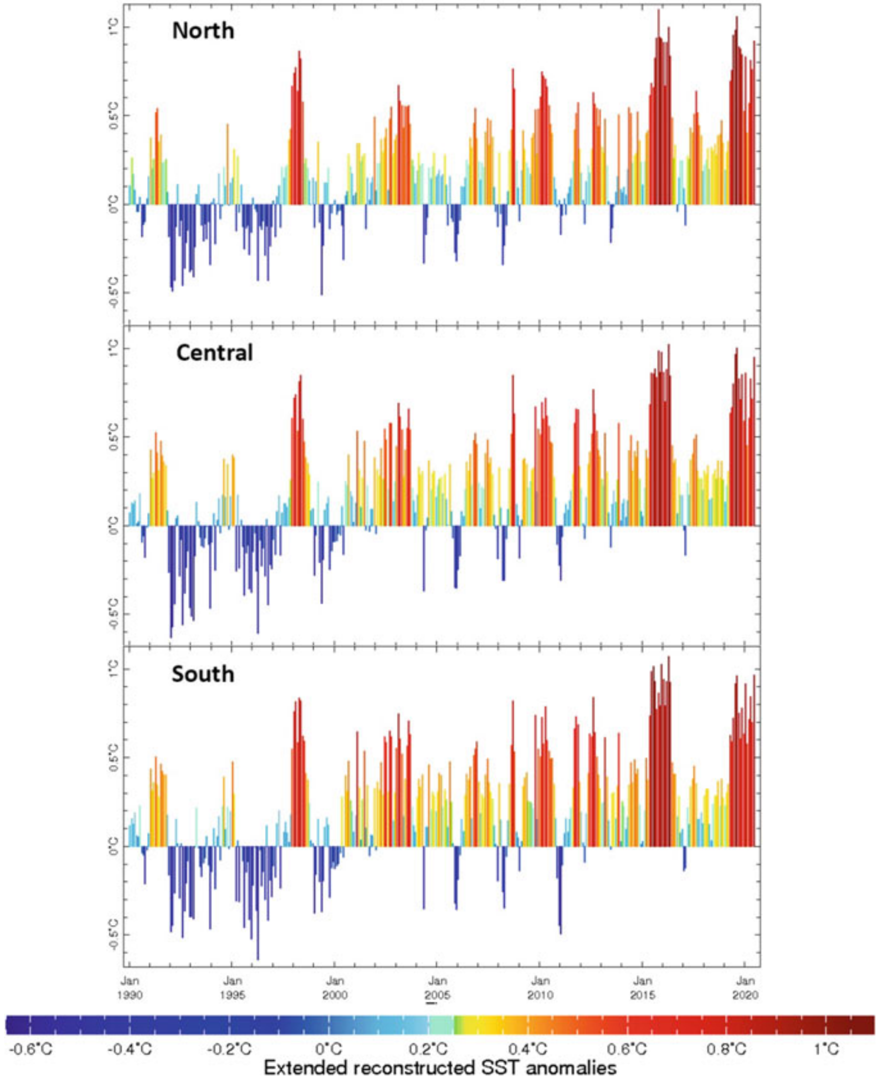

Fig. 5 SST Anomalies for **a** Northern Region, **b** Central Region and **c** Southern Region of Maldives during 1990 to 2020, using the NOAA ERSST data. (Huang et al. 2017)

the northern islands, the high climatological rainfall for June to September (Panel 1) is diminished due to El Niño. In the central islands, El Niño led to increased rainfall in May and from October to December, and deceased rainfall from June to August and again from January to April. In the southern Islands, rainfall is usually lower from June to August and higher from October to November.

During the 2014–2016 period:

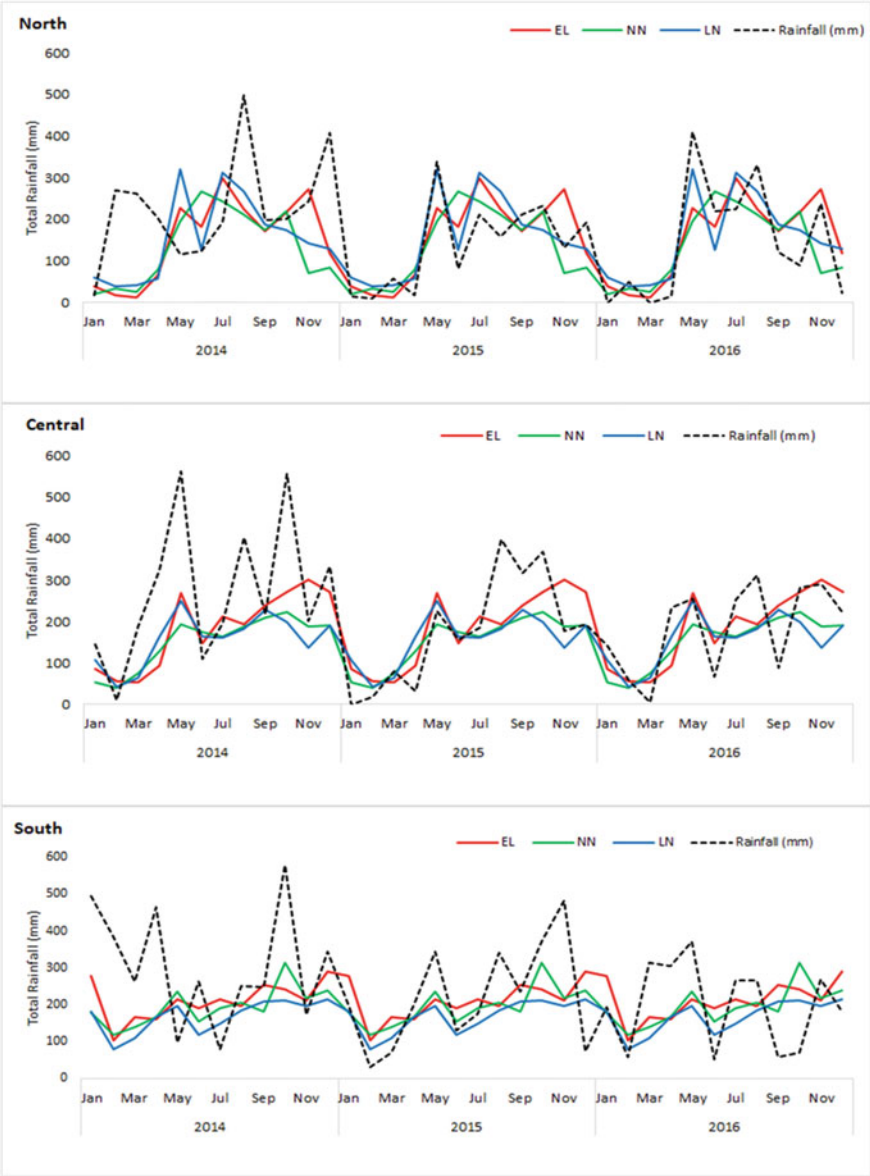

Fig. 6 Average monthly rainfall for different geographical regions of Maldives during El Niño (red line), Neutral (green) and La Niña (blue). Rainfall from Jan 2014 to December 2016 is also shown. Rainfall data is from the Maldives Meteorological Service

From June to October 2015 in the north, rainfall decreased but the impact of this reduction was ameliorated by the high rainfall in May 2015.

In the central islands, rainfall from July to October 2015 was high, an increase El Niño alone does not explain. Rainfall in November and December 2015 was not as high as expected.

In the southern islands, rainfall was highly variable from month to month, with large extremes that did not have a clear relationship trend during past El Niño events.

7.2 Temperature

The temperature during 2014–2016 in Northern, Central, and Southern Maldives were the warmest on record. Warming SSTs and the El Niño/IOD event drove this increase.

8 What Were the Impacts on the Maldives?

The principal El Niño-related impacts were on coral bleaching, flooding, dengue, and fisheries.

8.1 Coral Bleaching

Large areas of coral were bleached in the strong 1997–1998 El Niño event. Most areas recovered up to 40 percent in the following years (Pisapia et al. 2016). As the El Niño event persisted throughout 2015 and worsened in 2016, however, reefs bleached again starting in May of 2015. The 2015–2016 El Niño caused the largest episode of mass bleaching in the Maldives since 1998 (Ibrahim et al. 2017; Muir et al. 2017, Gomez et al. 2016).

The timing of this bleaching event can be interpreted based on "Degree Heating Weeks" (DHWs), a product of NOAA's Coral Reef Watch (Gomez et al. 2016) which shows how much heat stress has accumulated in an area over the previous 12 weeks by adding up sea surface temperatures that exceed the bleaching threshold during that timeframe. When an area reaches four DHWs, significant coral bleaching is likely, especially for more susceptible coral species. In the Maldives, thermal stress peaked at five DHWs during May 2016.

Table 1 Reported flood/landslide disasters and their effects in different provinces and regions (Northern, Central and Southern) in Maldives during 2014–2016

Time		Rainfall Anomaly (mm)	Average Annual (mm)	Affected Provinces	Damages
2015	May June	Southern 59 Central—59 North—42	Southern—194 Central—194 Northern 212	Upper North, North, Upper South, South Central, South	Infrastructural and crop damages
	Aug	76	189	North Central	Sections in Maafannu flooded
	Nov	27	156	South	80 houses were damaged; about 200 households were flooded
2016	Jan	− 29	43	South Central	
	Apr	100	120	North Central	Flooding at the Maldives' main airport and in the capital Malé

Source http://floodlist.com/asia

8.2 Flooding

In the 2014–2016 period, there were floods (Table 1) and droughts (MEE 2016). It is possible that the El Niño event, intensified by MJO, spawned some of these events, though such hydrometeorological extremes do not follow the patterns anticipated with an El Niño.

8.3 Dengue

Dengue first emerged in the Maldives in 1979 and now occurs perennially, with seasonal peaks and regular epidemic outbreaks. Dengue dynamics are strongly influenced by human behavior, demographics, and environmental and climate factors that affect mosquito vectors more than they do humans. The incidence of dengue for the northern, central, and southern regions are shown in Fig. 7.

The "seasonality" of dengue experiences a delay of one to two months with rainfall and tends to be consistent in the seven provinces of the Maldives (Zubair et al. 2018).

Dengue epidemics have been identified in 2006, 2007, 2008, and 2011. Epidemics appear to be coincident with a narrow range of temperatures (i.e., minimum temperature of 25–27°C and maximum of 29–32°C) in most of the provinces.

From mid-2014 to mid-2016, there was a major rise in dengue cases in the central region in mid-2015 and a substantial rise across the Maldives from April to August

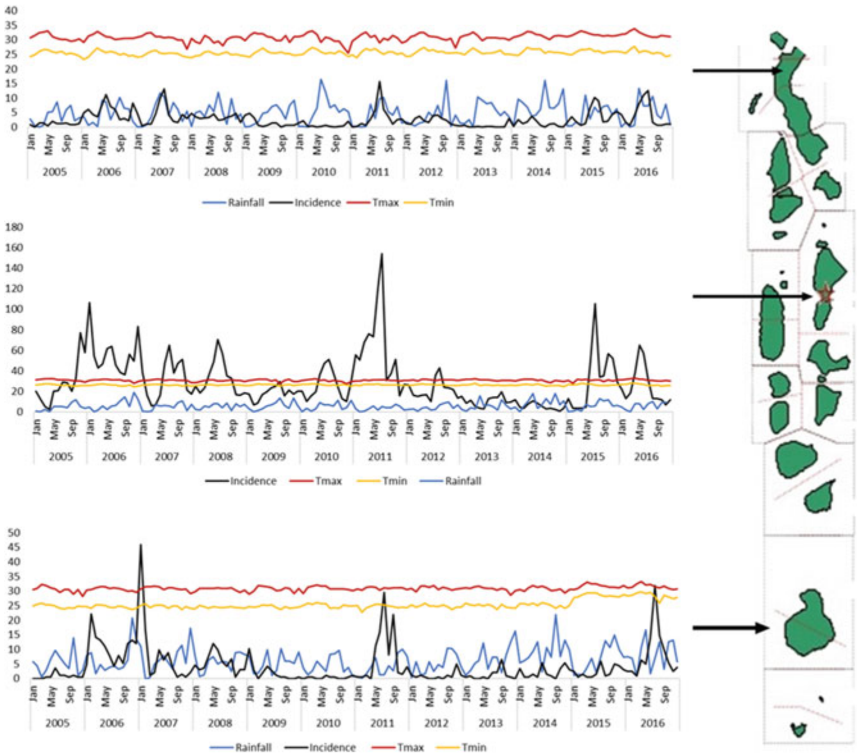

Fig. 7 Dengue incidence, rainfall, temperature climatology in the north, central, and southern regions of the Maldives from 2005 to 2016. Dengue data was provided by the Health Protection Agency of the Maldives Ministry of Health and the rainfall and temperature data are provided by the Maldives Meteorological Service

2016, which was a period of low Niño 3.4 SST values. From 2005 to 2014, dengue incidences coincided three out of four times with low Niño 3.4 SST values.

8.4 Fisheries

The fisheries sector is the second most important economic sector after tourism and the most important source of livelihoods across the Maldives. Tuna, which is the major catch, has become an important commodity for both export and domestic consumption.

Climate has profound effects on oceanic fish habitats. One of the environmental factors that generally affects the biology and migration of many fish species is temperature (Magnuson et al. 1979; Gulland 1980). The geographical distribution of fish populations, particularly pelagic species, is influenced by fluctuating SSTs even small changes to which may lead the fish stock to higher latitudes (Cushing and Dickson 1976; Pörtner and Peck 2010). A dramatic influence of seasonality on the distribution of Mantas has, for example, been documented in the Maldives (Anderson et al. 2011). Overall fishery production shows seasonal peaks in April to May and in October to November (Fig. 8).

During SST warmings from 2014 to 2016, there was a significant drop in fish capture for the North and Central Maldives, while there was an increase in the Southern region. Interannual variation (Fig. 9) shows that the catch in the south does not correlate with that in the north. Further data collection and analysis is called for.

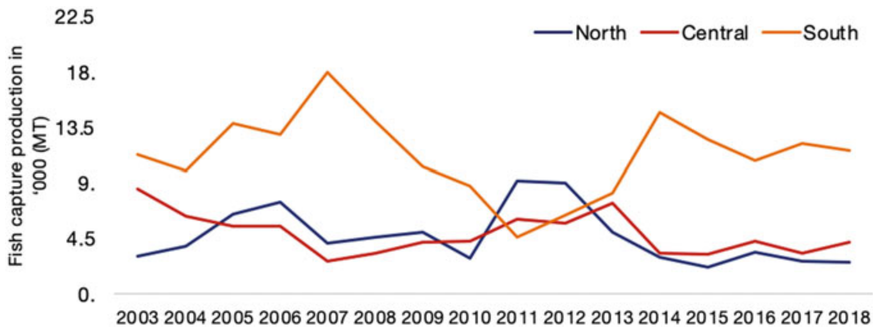

Fig. 8 Annual fish capture production in '000 metric tons (Statistical Yearbook of the Maldives 2017)

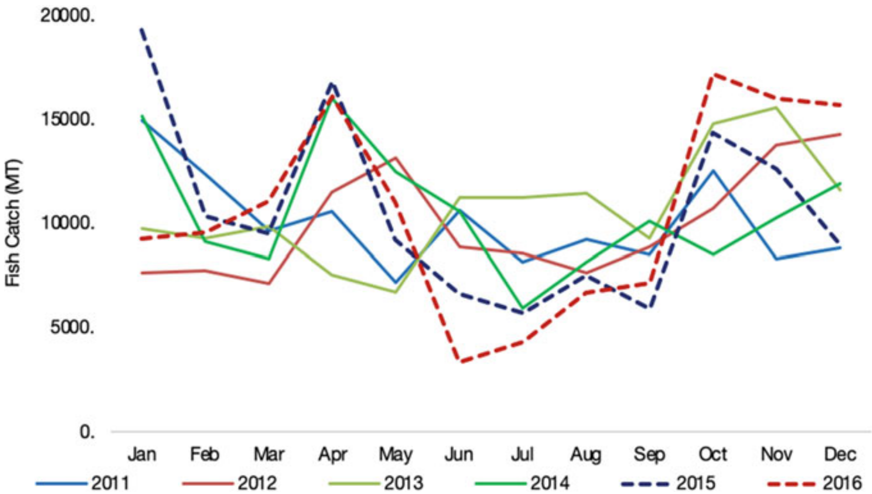

Fig. 9 Monthly fish capture in the Maldives (Statistical yearbook of Maldives 2017)

9 Hurdles and Obstacles

The Maldives Meteorological Service provided extended-range weather forecasts. The Foundation for Environment, Climate, and Technology (FECT) provided a monthly climate bulletin to sectoral experts. The information from both services was provided via social media and email (Agalawatte et al. 2016, Zubair et al. 2017a, b). While El Niño is a clear concern, the regional and seasonal nuances, and communication of those nuances, have confounded several agencies. The only exception was the study of coral bleaching during the 2015–2016 El Niño, as a USAID-sponsored effort led by the IUCN monitored bleaching. Other sectors were not as proactive.

The identification, prediction, and communication of El Niño impacts is particularly challenging in the Maldives. Given all the nuances and the regional complexity of climate variability, studies on impacts have to be deepened and extended to new areas. El Niño education has to be extended to the community level and to schools. In this regard, the pilot project on STEM education by FECT, with support from the PEER program of the US National Academy of Sciences, could be expanded from its pilot program in just three schools.

During the 2015–2016 event, there was occasional news coverage in the English press, but it was mainly focused on coral bleaching. Overall, if media coverage is taken as a whole, while the average person could rely on these reports for an alert, the reports were not adequate for people to be able to make informed, educated responses.

The Maldives has had success in bringing together scientists to work on monitoring bleaching. Building on these successes, analysis of the historical evidence for El Niño impacts on key sectors such as fisheries and tourism must still to be carried out. Our own work on dengue transmission, which is the primary disease of current concern, shows direct relationships with climate variability. The evolution of this 2014–2016 El Niño has lessons for future preparedness and merits study.

10 Lessons

During the 2014–2016 period there was awareness of coral bleaching hazards and water shortages, particularly in the Northern Islands. There was also interest in the media seeking explanations for the climatic anomalies.

The provision of seasonal climate information has been led by the Maldives Meteorological Services working with various international institutions. The predictions from international forecast centers, however, often do not well-represent Indian Ocean dynamics and the influence on El Niño's teleconnections in the region. As a result, the MMS uses caution with these forecasts. El Niño's influence is modulated by other factors such as cyclonic events, MJO, and other Indian Ocean characteristics, which need to be better understood. Prediction models also need to be better assessed through historical validation.

Impact studies should be expanded and deepened, particularly with regard to fisheries, water resources, agriculture, and disasters. Sea level influences of El Niño need to be better understood. The combined influence of El Niño and Indian Ocean warming needs to be better addressed to improve future impact predictions. What is known about the El Niño, including its nuances and its impacts, should be made accessible to the general public. Educational programs with sectoral experts and STEM programs for students will help inform the public (Zubair et al. 2020).

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Pakistan

Pakistan and the 2015–2016 El Niño Event

Asim Zia, Mujahid Hussain, and Kashif Hameed

Abstract Pakistan is a high-risk country due to its exposure to precipitation variability induced by El Niño. In northern parts of Pakistan, El Niño induced above-average winter precipitation followed by increased snowmelt may cause severe flooding. By contrast, the central and southern parts of the country may experience drought conditions. Analysis of the historical data reveals that cumulative seasonal (April to September) rainfall with spatially variable intensity is suppressed during El Niño events, while a surfeit of rainfall is observed during La Niña years. This finding implies that, during the summer monsoon, drought can be expected in Pakistan during El Niño years and floods can be expected during La Niña years. For forecasting El Niño in Pakistan, the Pakistan Meteorological Department (PMD) mainly relies on NOAA and Regional Forecast centers. Our field research shows that there is some basic level coordination between the PMD and the National Disaster Management Agency (NDMA) in disseminating country level national early warnings. But no formal level of cooperation exists among all concerned stakeholders with regard either to El Niño detection or to implementation of preparedness measures in response to an El Niño early warning. There is also lack of awareness among local language news media on El Niño and little reporting is available on El Niño impacts or preparedness issues. Systematic deployment of El Niño early warning early action systems in Pakistan has the potential to save millions of lives and billions of socio-economic damages in Pakistan.

Keywords El Niño impacts · Droughts · Floods · El Niño early warning early action systems

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1 Political and Economic Setting

Pakistan faces multiple types of challenges, a number of which threaten the future of the country. Such major challenges include terrorism, national insecurity, the Baloch separatist movement, religious extremism, ethnic division, poor governance, rising poverty, gender discrimination, a fragile economy, deficient public institutions, and ill-planned development processes, and a political system that has been vulnerable to repeated domestic military interventions (Zia and Wagner 2015). Prolonged conflict on both its eastern and western borders is another major challenge to the development and security of Pakistan. Four decades of protracted conflict in Afghanistan as well as an ongoing “war on terror” in Federally Administered Tribal Areas (FATA) has resulted in an influx of millions of Afghan refugees and thousands of Internally Displaced Persons (IDPs) across the country. Kashmir also continues to be a source of geostrategic and political conflict with India (Ali and Zia 2017).

Pakistan has three levels of governance—national, provincial, and district. At the mid-level, Provincial Disaster Management Authorities are the focal points of disaster management. Corresponding to these authorities at the top level, Provincial Disaster Management Commissions (PDMC) are headed by the Chief Minister of the respective provinces (the Prime Minister, in Azad Jammu and Kashmir Provinces), who chair the respective commissions. At the lowest level, District Disaster Management Authorities (DDMA) have been established in select hazard-prone areas. Furthermore, Pakistan Humanitarian Forum (PHF), an alliance of international NGOs (INGOs) in coordination with numerous national and grass-roots NGOs, also works on emergency response/DRR and climate change mitigation efforts across the country.

Typically, natural disasters in Pakistan are caused by hydrometeorological phenomena—floods, severe storms, cyclones, landslides, and droughts. Geophysical conditions such as earthquakes have also caused a number of disasters. Significantly increasing the vulnerabilities to such disasters of many within Pakistani society are climate change and variability as well as several ongoing drivers of dynamic social change, including population growth, rural–urban migration, globalization, and haphazard economic development.

Rapidly changing climate conditions across the Indian subcontinent over the last several decades have increased the frequency and intensity of extreme events in Pakistan. For example, the Indus River Delta, a vast tract of low-lying fertile land that provides a large proportion of the Pakistani population with both food and fiber, has already been directly impacted by changes to climatic conditions in the high Himalayas to the north. The last few decades of the 20th century began to see heightened risk of both water deficits (i.e., drought) and surpluses (i.e., floods) due to accelerated glacial melt—a scenario that is expected to become dire by the second half of the twenty-first century (Zia 2013). In fact, research indicates that the Himalaya-Karakoram-Hindukush region, which hosts the world’s largest ice mass after the poles, has already warmed by more than 1.5 °C above pre-industrial norms, a temperature impact of climate change that is strikingly almost twice that rate (mean

= 0.76 °C) observed in other areas of Pakistan over the last three decades (Rasul et al. 2012).

The increased frequency of torrential rains, prolonged heat waves, and tropical cyclones along with recurring flood events punctuating periods of persistent drought have all been experienced with greater frequency in this deltaic region. The rapidity of glacial melt in the high north has also caused increases in flooding along the plains as well as in coastal areas (Panikkar et al. 2019). Notably, increased intrusion of sea water from flooding along the coast has already severely affected broad swathes of the fertile agricultural lands of the delta region.

Rapid population growth in Pakistan—among the highest in the world—has become a major pressure affecting all aspects of social, economic, and environmental life, including increasing the overall vulnerability of many Pakistanis to hazards. Population pressures have, for example, pushed more and more poor and marginalized people into hazard-prone areas like flood plains, steep slopes, and coastal margins. Many of these areas had traditionally been considered uninhabitable. Furthermore, population growth has also increased the demand for fuel wood, fodder, and timber, which has led to uncontrolled deforestation and, in turn, intensified soil erosion and higher peak stream flows. As expected, these pressures have ultimately resulted in severe flooding in downstream areas. Taken together, increasing population densities in hazard-prone areas have measurably increased losses of both life and property during extreme precipitation events in Pakistan. Indeed, records show that once unusual occurrences have become expected annual disaster events across the country.

2 Strength of El Niño Teleconnections in Pakistan

Pakistan was recently listed as a high-risk country due to its exposure to anomalous precipitation variability induced by El Niño (FAO 2018). In northern parts of Pakistan, above-average winter precipitation followed by increased snowmelt may cause severe flooding. By contrast, the central and southern parts of the country may experience drought conditions (FAO 2018: 8). Synthesizing these projections, our key finding is that both the suppressed monsoon rainfall observed during El Niño years and the surplus monsoon rainfall observed during La Niña years will adversely affect crop yields, total production, and even prices (Zia et al. *In Review*).

Analyses by Zawar and Zahid (2013) show that cumulative seasonal (April to September) rainfall with spatially variable intensity is suppressed during El Niño events. They also show that a surfeit of rainfall is observed during La Niña years. What can be concluded from this research is that during the summer monsoon drought can be expected in Pakistan during El Niño years and floods can be expected during La Niña years.

More specifically, during an El Niño event precipitation tends to drop dramatically throughout Pakistan, resulting in little rainfall in both summer and winter seasons. The El Niño of 1997–98, for example, resulted in scant monsoonal precipitation, triggering drought across southwestern Pakistan (Naheed et al. 2013). Furthermore, Rashid (2004) found that El Niño also has a negative effect on winter rainfall over Pakistan. Comparing the bi-monthly Multivariate ENSO Index (MEI) to monsoon monthly rainfall shows suppressed rainfall for the whole of Pakistan (Afzal et al. 2013). This result is consistent with Rashid (2004), who concluded that in an El Niño year warming in April, May, and June will likely continue or increase in July, August, and September, which means that monsoonal rainfall over Pakistan will likely be in deficit.

In a recent study, Sadiq and Saboor (2018) estimated the Palfai Drought Index (PDI)—from Palfai and Herceg (2011)—for 15 agro-climatic zones of Pakistan from 1983 to 2010. Figure 1 plots the annual average MEI against PDI for the arid Sindh and Baluchistan regions in the Lower Indus Basin. During El Niño years, when MEI > 0 in Fig. 1, the drought intensity in Sindh and Baluchistan increases dramatically (i.e.,, PDI reaches above 100 in comparison to the reference point of PDI > 30, which indicates severe drought).

More recent El Niño events in 2015–2016 and 2018–2019 brought about drought conditions in south-western Pakistan that were consistent with historical patterns (as shown in Fig. 1). FAO (2018: 8) documented that, in 2018, "prolonged periods of

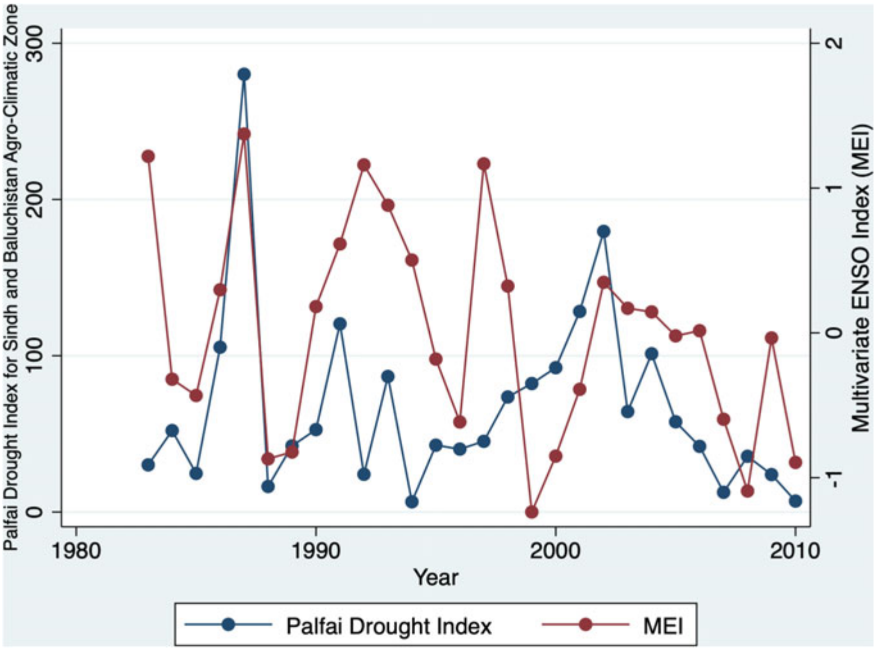

Fig. 1 Palfai Drought Index (PDI) for Sindh and Baluchistan agro-climatic zone of lower Indus plotted against Multivariate ENSO Index for 1983–2010 timeframe. A PDI > 30 indicates severe drought (derived from https://psl.noaa.gov/enso/mei/)

below-average rains resulted in severe drought conditions in southeastern and southwestern parts of Sindh Province and western and southwestern areas of Balochistan Province. Such conditions caused crop failures and livestock losses." Earlier, in 2015–2016, the winter snowfall was delayed and reduced (Wasif 2017). Further, consistent with climatological records, northern Pakistan experienced relatively wetter conditions in the summer of 2016 (Wasif 2017). Ahmad et al. (2018) estimated the Agricultural Stress Index and the Normalized Difference Vegetation Index (NDVI) for Pakistan for the 2015–2016 El Niño and found that more than 80 percent of the decrease in precipitation can be attributed to the warm El Niño phase transition. This effect in turn forced drought monitoring indices, such as NDVI, to signal a severity, with eight percent of crop areas having been affected. Correlating with this measure, Ahmad et al. (2018: 45) reported data from Pakistan's Ministry of National Food Security & Research that showed that the drought-affected production of wheat in Sindh Province totaled 92,000 tons less in 2014–2016 than in the 2012–2014 growing season.

Another adverse impact of the 2015–2016 El Niño as documented in recent literature concerns the record-breaking heatwave in 2016 and coincident suppression of the summer monsoon season. Dr. Rasul, chairman of the Pakistan Meteorology Department (PMD), reported that "during the summer of 2016, temperatures in rural Sindh continuously remained above 50 °C for 23 days while in Jacobabad, the mercury level touched 54° C" (quoted in Wasif 2017). Wehner et al. (2016) applied climate change attribution analysis to evaluate the deadly combination of heat and humidity in India and Pakistan in the summer of 2015 and discovered complex interaction effects between El Niño and climate change-induced warming. Wehner et al. (2016: S81) also found that "in Hyderabad, the daily maximum heat index was about 2–4° C higher than temperature during the heatwave. In Karachi, this difference was about 7–12° C, reflecting a much higher relative humidity." For both cities, the daily maximum heat indices were among the highest ever experienced (Wehner et al. 2016: S82). Attribution analysis revealed that changes in temperature and humidity were caused by human-induced climate change, even after accounting for El Niño effects.

3 Forecasting El Niño in Pakistan

The Pakistan Meteorological Department mainly relies on NOAA and Regional Forecast centers. There is some basic level coordination between PMD and the National Disaster Management Agency (NDMA) in disseminating country-level national early warnings; however, no formal level of cooperation exists among all concerned stakeholders with regard either to El Niño detection or to implementation of preparedness measures in response to an El Niño early warning. The current forecasting system is primarily restricted to the issuance by PMD/NDMA of early warnings on El Niño to concerned national- and provincial-level public service departments. There is also no specific policy or operational mechanism for El Niño specific post-detection cooperation between concerned stakeholders. What this means is that a lot of room exists to improve the capacity of PMD to generate high resolution flood and drought forecasts, both during and outside of El Niño years. Improved understanding of localized impacts of El Niño events requires that the forecast capability of PMD be tracked, improved, and evaluated over the long haul, though current PMD financial and technical resources do not permit such an expansion of capacity.

The potential impacts of recent past El Niño events on Pakistan received some coverage in the national print media, though such coverage has been quite rare historically. The PMD-issued early warning on the 2015 El Niño was published in a couple of English print media outlets, but local language newspapers scarcely mentioned El Niño-related news, providing only post-event coverage of specific impacts across Pakistan (Wasif 2017).

Like other nationally and provincially concerned stakeholders, there is lack of awareness among local language media on El Niño and little reporting available on El Niño impacts or preparedness issues. In most cases, newspapers have published stories on El Niño only in international contexts or about countries in and around the Pacific Ocean. Much less has been written and published in the context of Pakistan, especially with regard to preparedness.

That said, improved local-level understanding of specific impacts of El Niño is quite important for Pakistan because it is an agrarian country and 80 percent of the population depends on predictable monsoon rainfalls and glacial meltwaters. The Indus Basin has one of the highest dependencies on glacial melt, as compared with other Himalayan and Hindukush river basins (Immerzeel et al. 2010), and warming in the region that mirrors general global trends is rapidly reducing glacial mass (Archer et al. 2010; Sharif et al. 2013). At the same time, monsoon variability induced by El Niño events has recently further affected the availability of freshwater for agriculture, energy, and drinking. Consistent with these trends, future projections of water availability in Pakistan are very grim (Yang et al. 2016). Heatwaves attributable to complex interactions of global warming and El Niño events are becoming more intense as well (Wehner et al. 2016). What these data show is that Pakistan, like other countries in South Asia, primarily faces secondary impacts of El Niño on its food, energy, and water sectors.

Increased likelihood of drought in the rainy season is particularly important to acknowledge because it has many social and environmental impacts, especially in the Lower Indus arid agro-climatic zones (see Fig. 1). El Niño-induced droughts adversely affect rain-fed agriculture, lower agricultural productivity, and increase food insecurity among vulnerable populations, especially children, the elderly, and women (see Ahmad et al. 2018, for El Niño 2015–2016 impacts, as noted above). Wasif (2017), for example, in a scathing critique of Pakistan's poor governmental response to the 2015–2016 El Niño, analyzed the event's various social and environmental impacts due to flash floods in the north and drought and poor crop production in the south on such vulnerable populations.

Despite issues with government capacity and other associated challenges exacerbated by rapid population growth, there has been increasing research interest—as expressed by stakeholders in interviews and a focus group organized by the authors in 2016—to explore the societal impacts of El Niño in different parts of Pakistan. This research identified that populations in southwest and north Punjab, lower Sindh, eastern Baluchistan, the entire KPK, and North Pakistan including Kashmir are growing increasingly vulnerable to the impacts of both ENSO extreme phases (Zia et al. *In Review*).

Furthermore, the politics of risk governance has impeded effective public response to El Niño-induced droughts, especially in areas like Baluchistan and FATA where ongoing rebellions against the central government have become protracted (Zia et al. *In Review*). Changes in weather patterns in the form of extreme heat and cold waves as well as an increased frequency of flood events (particularly over the last six years) have adversely impacted these regions. Existing research has been limited with regard to such risks, however, as it has mainly focused on El Niño impacts on summer monsoon rains. Thus far, it has been incapable of developing region-specific forecasts of the physical, social, and economic impacts of El Niño and its associated weather divergences. Quality research work is especially lacking with regard to social, ecological, and political impacts of ENSO extreme phase events in Pakistan (Zia et al. *In Review*).

4 El Niño Information and Forecasts

The main sources of El Niño warnings are international agencies, mainly WMO and the US Climate Prediction Center (CPC.NCEP.NOAA.gov). Regional-level weather forecasting agencies in India, China, and other South Asian countries are secondary sources in relation to the early warning indicators of El Niño in the region. NDMA first receives information from PMD and, later, circulates it to disaster management structures and government departments at national and provincial levels.

As noted, the current forecasting system is mainly restricted to the issuance by PMD/NDMA of early warning about detection of El Niño activity to the concerned national and provincial level public departments. No specific policies or operational mechanisms exist for coordinating El Niño-specific post-detection cooperation among concerned stakeholders.

Nor is there a specific mechanism in place for response to an El Niño forecast or early warning. Forecasts are limited to the issuance of a statement on potential drought conditions in the south or excessive rains in the north. What this means is that there are really no formal El Niño readiness- or preparedness-related activities in Pakistan. Recently, growing discussion has circulated among experts about developing better understanding of the impacts of El Niño in Pakistan and on the types of responses and preparedness measures that would be required to reduce its impacts, especially on the most vulnerable areas of the country. This discussion has become a part of ongoing flood and drought monitoring activities of PMD projects funded by the World Bank and different OECD bilateral cooperation mechanisms.

While the 2015–2016 El Niño saw marked improvement with regard to PMD/NDMA issuances of early warnings to local and provincial government agencies, there were no specifically triggered responses, preparedness activities, or mitigation actions taken at either the national or the provincial level. Fundamental to such lackluster response was and continues to be the shortage of technical, financial, and human resource capacities at all levels of governance. Even if the political will existed along with more stable political conditions (for example, the end of insurgencies in Baluchistan and in tribal regions along the Afghan border), the ability to generate spatially accurate forecasts would still be limited by the poor technical and financial capacity of Pakistan's relevant agencies.

Over the last two and half decades, emerging national and provincial/regional level research has explored the relationship between El Niño events and summer monsoon rainfall patterns, SST variability along the coast, and historical warming trends in annual mean temperatures across the country. This research, mainly been conducted by PMD, has mostly been published in its own "Pakistan Journal of Meteorology."

5 2015–2016 El Niño

5.1 Detection

PMD is mainly responsible to monitor El Niño events and issue early warnings to NDMA. A warning of the onset of the 2015–2016 El Niño was issued by PMD in 2014 and subsequently reported in the national media. This forecast can be said to have failed, however, as the nascent El Niño that was first detected collapsed, only to reappear as a newly detected event at the end of 2014. More specialized websites, such as Accuweather (2015), communicated early warnings about the El Niño of 2015–2016 and its potential impacts in terms of weakening the summer monsoon and exacerbating drought across India and Pakistan.

5.2 Governance and Policy Response

In Pakistan, various national and provincial disaster management agencies have shown marked improvement over the last half decade in early warning, emergency response, and short-term recovery in the face of various hydrometeorological hazards. Disaster preparedness (e.g. DRR) is, however, on the whole still largely neglected by politicians and peoples alike. Although there are strategies and policies on paper, they are not systematically enforced. In relation to El Niño, PMD issues early warnings and provides seasonal weather forecasts based on known impacts; however, no El Niño-specific preparedness policies have been developed or implemented in Pakistan. For example, our field research found that PMD communicated an increase in the intensity of drought for the 2015–2016 El Niño (and, more recently, for the 2018–2019 event) to various government agencies, but warnings about drought did not translate into any meaningful tactical responses to mitigate the known, likely impacts of the hazard on vulnerable populations in the Lower Indus Delta. Medium- to long-term planning to reduce the risk from extreme hydrometeorological events, such as droughts, floods, and heatwaves, continues to seriously suffer due to a lack of human resources, financial resources, and administrative capacities (Zia and Wagner 2015).

As per the existing legislation, NDMA working under the Ministry of Climate Change should have the main responsibility to oversee national El Niño-related preparedness, but no El Niño-specific preparedness activities or functional positions have been established, save for early warnings and seasonal impact statements issued by PMD.

A lack of technical knowledge, skilled human resources, high-tech computers for advanced model simulation, coordination, and financial resources also restrict El Niño preparedness activities. Nonetheless, there is vast potential for cooperation on El Niño preparedness in Pakistan. Such cooperation could be instituted by building up the respective capacities of the Ministry of Climate Change, NDMA, PDMAs, Ministry of Planning and Reforms, and the Finance Ministry. They could also come from integrating El Niño preparedness with existing national-level DRR programing. Finally, the promotion of social safety nets for vulnerable communities living in El Niño-affected parts of the country could also help to realize this vast potential.

There is no specific research or documentation available that can provide quantitative estimations or qualitative descriptions about the social and environmental impacts of El Niño in Pakistan. Neither is there any systematic data about specific responses undertaken by concerned institutions to mitigate the impacts of El Niño. Our team's qualitative research also identified a lack of awareness among national- and provincial-level public institutions and humanitarian organizations about El Niño's foreseeable impacts in Pakistan. At the community level, concerned grass root organizations also showed a lack knowledge about even the well-known (and so foreseeable) impacts of El Niño events in their respective regions.

An acute need exists to strengthen the capacities of relevant institutions at national and provincial levels by establishing an El Niño Inter-Agency Section in the Ministry of Climate Change/NDMA. Also necessary is the establishment of operational and tactical arms of this Section in respective provincial and local government agencies. Similarly, special working groups on El Niño that can undertake future research on the various impacts of El Niño in different regions should also be established within PDMAs. This proposed Inter-Agency Section can work on improving coordination and resilience planning among relevant public, private, and civil society organizations with the goal of improving El Niño preparedness, including both prevention and mitigation, activities.

6 Lessons Identified

- Lesson: Flood and drought forecast and mitigation capacity (as well as political will) is severely lacking in the current political and security environments.
- Lesson: "Once is not enough," which means that generating awareness is an ongoing process. Even though El Niño is an irregularly recurring phenomenon with a return period between two and seven years, societies at all levels have to be disciplined in generating awareness continually, especially through the media.
- Lesson: PMD and concerned academic centers need to build capacity to undertake scientific work on measuring the impacts of El Niño in various regions of Pakistan.
- Lesson: El Niño must be included in the country's national risk matrix.
- Lesson: In view of the apparent increase in the frequency of El Niño events over the last two decades, awareness and knowledge gaps must be filled if a broad-based Pakistani action plan on El Niño preparedness (strategic) and readiness (tactical) is to be designed and implemented.
- Lesson: A focused training and sensitization program on El Niño impacts for print and electronic media in Pakistan is needed.

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Sri Lanka

The 2014–2016 El Niño in Sri Lanka: Climate, Impacts, and Response

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Abstract Sri Lanka is affected by the El Niño phenomenon as well documented by multiple research studies. However, the El Niño influence is modulated by the sea-surface-temperature and atmospheric phenomenon in and above the Indian Ocean and other atmospheric processes. As an island with year-round rainfall, the influences vary by region and season. The impact of El Nino on water resources, agriculture, disaster risk and health are nuanced. Here, we document these nuances along with efforts to manage the risks and opportunities through communication of predictions of the major El Nino events in recent decades.

Keywords El nino · Climate variability · Indian ocean · Sri Lanka

1 Introduction

Sri Lanka's population of 21 million is supported on an island of 65,000 km^2 (Fig. 1). The dense population is sustainable only because of a favorable climate with equable temperatures through the year and ample rainfall overall, though not in all regions. The influence of El Niño on the country varies by region, season, and event. Its influence is modulated by the Indian Ocean Dipole (IOD), Indian Ocean Warming, and other atmospheric phenomena.

Leading up to the 2015–16 El Niño, Sri Lanka was already under a sustained dry spell. A combination of the El Niño, the positive phase of the IOD, and the warming Indian Ocean made the 2014–16 period the warmest on record for the country and its surrounding seas. The rainfall for the October to December season increased during 2014 and 2015, as is typical during an El Niño. This increase during 2015 was also consistent with the positive IOD phase. Usually during an El Niño, furthermore, the high variability of rainfall in May is amplified. While rainfall during

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Fig. 1 Sri Lanka's position in the Indian Ocean. Epmistes, MediaWiki Commons (2010)

May 2015 was seasonable, the rains in May 2016 were heavy across the slopes of the southwestern hills, which in turn led to landslide and flood disasters. El Niño along with Indian Ocean warming led to record land and sea surface temperatures (SSTs), which resulted in significant coral bleaching and other impacts.

With regard to social effects, the risk of dengue fever near the end of the El Niño event in mid-2016 was amplified, priming the resulting epidemic of 2017. Hydropower production was also elevated above the norm, as has been the case for past El Niños. The event also diminished coconut production in 2017. Finally, there were numerous challenges in communicating predictions of El Niño and its impacts in Sri Lanka, which led to shortcomings in the overall response.

2 Political and Economic Setting and Vulnerability

Sri Lanka is still emerging from a sustained period of ethnic conflict and civil war that persisted for three decades until 2009. This instability affected the financial resources that could have been allocated to infrastructure. It also affected community trust in government, scientific advancement, and resilience to hazards.

Sri Lanka's population increased from 10 million in 1960 to 20 million by 2014, creating a density problem that has pushed marginal populations into more and more hazardous areas (Zubair et al. 2006). People in the war-affected Northern and Eastern Provinces (Fig. 2) tend to be more vulnerable than those in other provinces because of poor infrastructure and services. These regions, along with the hill country region, are particularly prone to hydrometeorological hazards. In these regions, ethnic and language differences tend to undermine communications, effective political representation, and efficient distribution of services from the state.

Notably, rapidly urbanizing regions such as the Colombo Metropolitan region and the cities of Kandy, Kurunegala, Galle, Jaffna, Trincomalee, and Batticaloa have seen rapid increases in vulnerability among their respective populations. This increase has

Fig. 2 Provinces of Sri Lanka (Wikipedia Maps 2020)

often been due to unregulated infrastructure constructure and other poorly managed urban development.

3 Climate of Sri Lanka

Sri Lanka is in the monsoonal equatorial region—westerly winds prevail over the country from May to September, and northeasterly winds prevail from December to February. Relative humidity varies between 60 and 90 percent.

Sri Lanka receives 1800 mm of annual rainfall on average. Precipitation is, however, distributed unevenly around the country in a broad range from 500 to 5500 mm/year (Fig. 3). Rainfall tends to follow a bimodal climatological pattern, with the main rains coming from September to December and the shorter rainy season arriving in May and June. The eastern and western hills see orographic rainfall from December to March (with the northeast winds) and again from May to October (with the westerlies). The northeast usually receives cyclonic rainfall from November to December.

The mean annual island-wide temperature (Fig. 4) is ~27 °C, with lower temperatures being recorded in the mountains that rise up over 2500 m above the Indian Ocean. The temperature drops during December and January and increases from April to September. The mean daily temperature range is ~6 °C.

4 Teleconnections with the Sri Lankan Climate

As described briefly in the following paragraphs, Sri Lanka's climate is mainly affected by El Niño, the Indian Ocean Dipole (IOD), Indian Ocean Warming (IOW), and the Madden Julian Oscillation (MJO).

4.1 Impact of El Niño on Sri Lankan Climate

Sri Lanka has been identified by researchers Rasmusson and Carpenter (1983) and Ropelewski and Halpert (1987) as a country with significant El Niño impacts, including prominent rainfall deficits during the Indian southwest monsoon (June–September) and excess rainfall during the Indian northeast monsoon (October-December). Further research since the mid-1980s has shown other seasonal influences as well (Suppiah 1996, 1997; Zubair et al. 2008). El Niño has significant impacts on rainfall, temperature, wind, and associated climatic features. Following Zubair et al. (2008), a composite of rainfall during each ENSO phase—El Niño, neutral, and La Niña—is presented in Fig. 5.

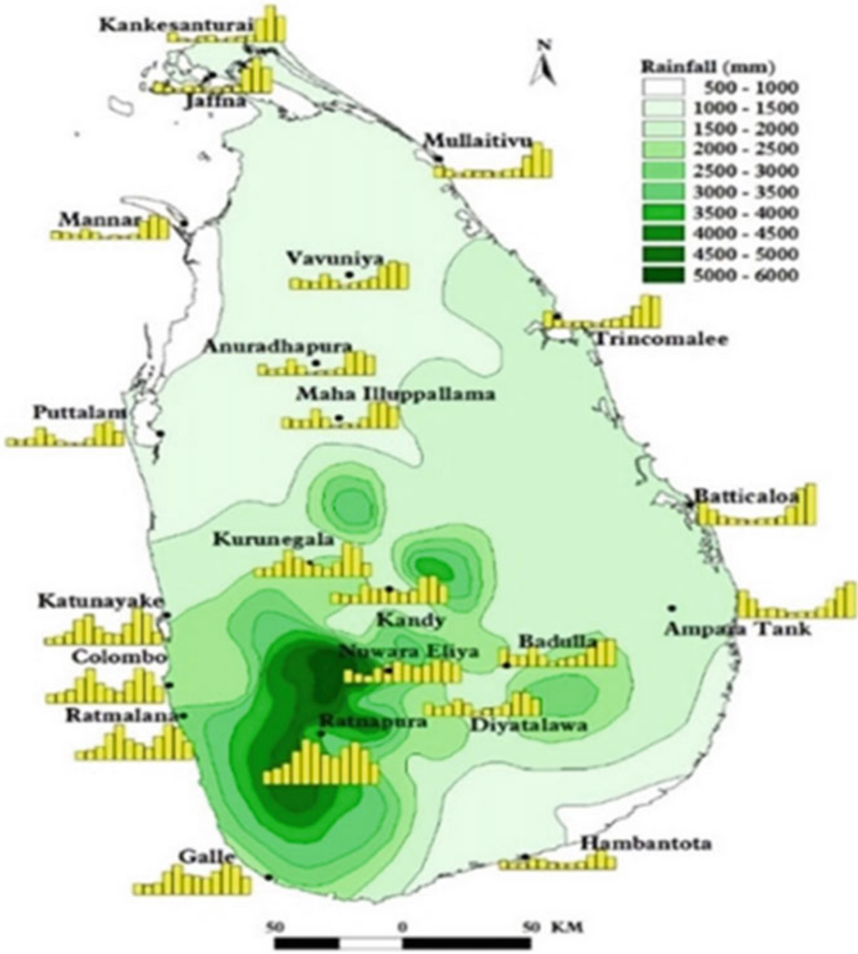

Fig. 3 The color gradation shows annual average rainfall distribution based on observations from 1960–90. The bar chart shows monthly means from January to December for the main stations (Zubair et al. 2008)

El Niño's influences on rainfall change by season, with increased rainfall in May and from October to December, and reduced rainfall from June to August and again from January to April. The temperature remains warmer during all seasons during an El Niño event (Halpert and Ropelewski 1992). A composite of temperature variations during each of the ENSO phases, based on Zubair et al. 2008, is presented in Fig. 6.

As in other regions, El Niño influences can vary from event to event—or decade to decade— depending on a particular event's intensity as well as other factors affecting its teleconnections (Zubair and Ropelewski 2006, Zubair and Chandimala 2007). For example, the hydrological responses in locales of different El Niño influences require

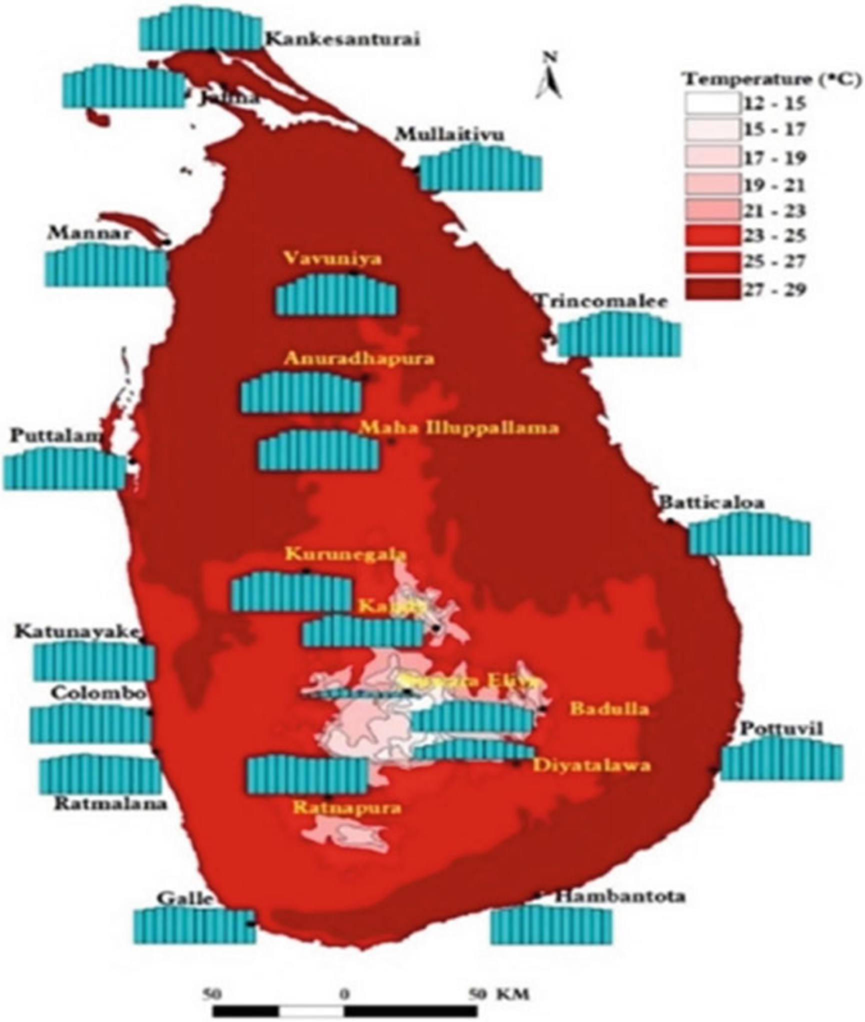

Fig. 4 The mean annual temperature from observations at 37 stations from 1960 to 1990. The bar chart shows monthly means (+15 °C) from January to December (Zubair et al. 2005)

deciphering. Even though October to December rainfall might be increased by El Niño, that is, the drier January to September period that preceded the event, will likely result in an overall diminished level of soil moisture and streamflow (Mahanama et al. 2007).

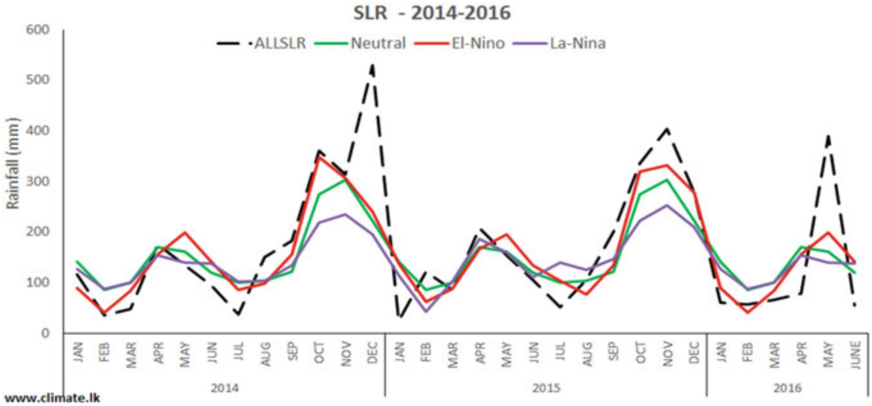

Fig. 5 All Sri Lankan rainfall (ASLR) constructed using averages from 15 weather stations. Average monthly rainfall climatology during El Niño (red line), neutral (green), and La Niña (blue) are shown. SLR (dashed black line) from Jan 2014–June 2016 is given for comparison (Zubair et al. 2008)

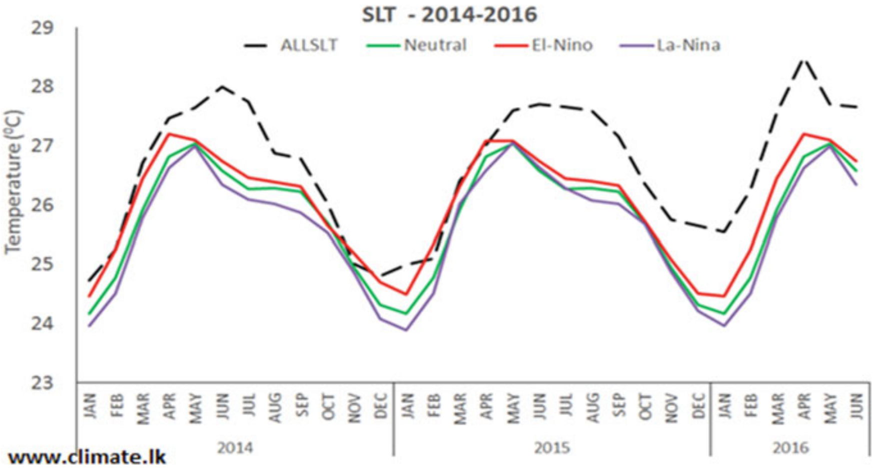

Fig. 6 All Sri Lankan temperature (ASLT) constructed using averages from 15 stations. Average monthly temperatures climatology during El Niño (red line), neutral (green) and La Niña (blue) are shown. ASLT (dashed black line) from Jan 2014–June 2016 is given for comparison (Climate. LK)

4.2 Influences of Indian Ocean Dipole

Usually, El Niño has been associated with a positive Indian Ocean Dipole (IOD) characterized by a seasonably warmer Central Arabian and Indian Ocean that is offset by anomalously cooler seas around Sumatra. The air–sea coupling that sustains the IOD usually picks up in the northern hemisphere summer and dies off by late December. Rainfall from January to May has no discernible association with IOD,

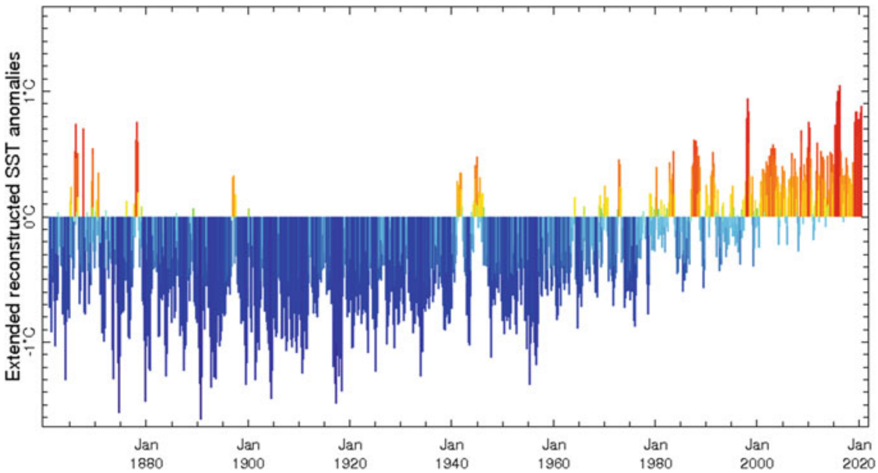

Fig. 7 Sea Surface Temperature (SST) anomalies in a rectangle around Sri Lanka (75–85°E, 0–10°N) obtained from the ERSST compilation (NOAA NCDC ERSST). Prepared by the Authors using the IRI/LDEO data library (iridl.ldeo.columbia.edu)

only a weak tendency to cause dry conditions from June to August and a likelihood to produce significantly wetter conditions from September to December (Zubair et al. 2003).

4.3 Indian Ocean Warming (IOW)

The Indian Ocean has been warming around Sri Lanka at a much faster rate than can be attributed solely to global warming. This warming acts to compound the rise in surface temperature in Sri Lanka, which has its own impacts. The oceanic temperature around Sri Lanka in 2015–16 was the warmest on record, surpassing that associated with the 1997–98 El Niño event (Fig. 7). Elevating average sea surface temperatures (SST) and combining with El Niño impacts, warming of the central Indian Ocean has profound consequence for Sri Lanka's coral reefs.

4.4 Madden–Julian Oscillation (MJO)

MJO has a significant impact on Sri Lanka's rainfall and temperature and can modulate the impact of El Niño, though such impacts tend to be short lived. MJO oscillations are characterized by eight phases (Wheeler and Hendon 2004). The significant influence on rainfall arises during phases two and three and tends to be suppressed during phases five and six. Influences during the other phases are weaker. MJO is considered weak if its amplitude is within −1 and +1.

5 Forecasting El Niño

In addition to the Department of Meteorology, some experts in other departments also pay attention to El Niño events and to predictions from international prediction centers. Global prediction models in use are, however, typically not so adept at predicting the micro-climate of the Indian Ocean and its rim. The complex nuances of El Niño and its impacts, and the communication of these nuances, have confounded several prediction agencies.

With the Inter-Tropical Convergence Zone (ITCZ) passing over Sri Lanka in May and again in November each year, a higher chance of flooding occurs in these months, depending on whether cloud formations are triggered over Sri Lanka (Gadgil et al. 2011). The triggering of such formations can be caused by either cyclonic storms or MJO. Rainfall in May is highly variable but if high can offset the dry conditions that typically build up during an El Niño. If the rainfall in May is low, then the dry period can extend for up to nine months (Lyon et al. 2009).

6 El Niño Information and Forecasting

The Department of Meteorology uses products from WMO and international forecast centers. Its officers participated in the South Asia Climate Outlook Forum (SASCOF), which was held during the 2015–16 El Niño. The SASCOF held in April 2014 predicted a dry tendency for the southwest (summer) monsoon over Sri Lanka, while the 2015 Forum predicted a drier trend for all of Sri Lanka except the northern region, which was predicted to have a near-normal tendency. If relying only on information from the annual SASCOF, then predictions cannot be issued for seasons other than the Indian southwest monsoon. The Department of Meteorology does month-ahead predictions from time to time, but it does not communicate these predictions widely nor does it address the impacts of these predictions on other sectors.

The Foundation for Environment, Climate, and Technology (FECT) has been issuing a weekly climate advisory for over a decade (Chandrasekara et al. 2013, Gunathilake et al. 2020). FECT provides information to selected researchers in government agencies and at research centers as well as to water resource, hazard, health, and hydropower sectors. It also provides information for the national water resources planning infrastructure.

The earliest local media reports of the 2015–16 El Niño were from the Pathfinder Foundation. Based in Colombo, the foundation issued press statements warning of an El Niño in June 2014. It stated that El Niño-related drought impacts would start in the fourth quarter of that year (Pathfinder 2014). The Department of Meteorology was

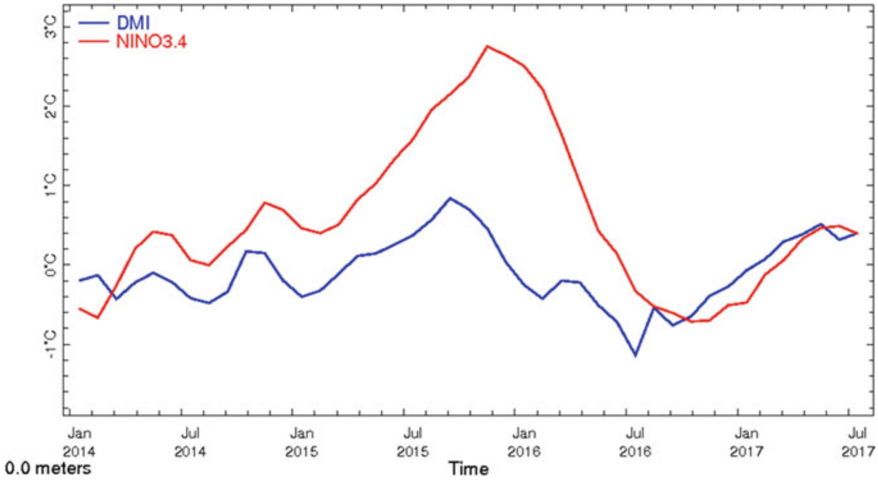

Fig. 8 Monthly variation of the Oceanic Niño Index (NIÑO 3.4) and the Dipole Mode Index (DMI), 2014–2017 (NOAA NCDC ERSST)

more circumspect though, warning of wetter impacts in the country by September 2014. The prediction from SASCOF held in Colombo in April 2016 also received press coverage, but by then the El Niño was already phasing out.

7 Events During the 2014–2016 El Niño

Based on NIÑO 3.4 values, an El Niño began at the beginning of October 2014 and persisted until April 2016 (Fig. 8). Then, around October of 2016 ENSO transitioned into a La Niña phase. The 2014–2016 El Niño was very strong in magnitude, challenging the record-setting 1997–98 "El Niño of the twentieth century."

The Dipole Mode Index (DMI) of IOD (Fig. 8) was weak during 2014, positive during 2015, and negative during 2016. The positive DMI compounded the warming associated with El Niño around Sri Lanka.

8 Climate During the 2014–2016 El Niño

Overall, Sri Lankan rainfall for 2014–2016 followed historical norms, with increased rainfall in May and then again from October to December and decreased rainfall in other months (Fig. 3). During this strong event, the temperature in Sri Lanka followed the higher values associated with El Niño until May of 2015, and then increased to much higher values until the end of 2016 (Fig. 4). The major climate "surprise" during the 2015–16 El Niño was how much it warmed. Indian Ocean sea surface temperatures around Sri Lanka followed similar patterns and could have been the driver of this unexpected warming.

Due to MJO, rainfall increased in November 2014 and decreased in December. It significantly decreased again in February 2015 and then increased from May to July, and also in September and in November. Rainfall decreased significantly again in March 2016 but increased in May and June and again in November. MJO was active during the flood event of May 2016.

9 El Niño's Sectoral Impacts

El Niño's discernible impacts are widespread across socioeconomic sectors, especially on water resources, agriculture, health, hydropower, and coral reefs. Hydrometeorological hazards include droughts, landslides, and floods.

9.1 Coral Bleaching

The Sri Lankan coastline has coral reefs along the Gulf of Mannar, along parts of the east and south coast, and around Jaffna's eastern littoral (Fig. 9). During the past 50 years, SSTs in the Indian Ocean have increased at a rate of ~0.12 °C per decade. Additional increases in SSTs associated with El Niño led to widespread coral bleaching in 1997–98 (Rajasuriya 2005) and again in 2015–2016.

According to NOAA's Coral Reef Watch (CRW), patterns of higher bleaching stress in Sri Lanka were consistent with higher thermal stress from March to August in 2015 and in 2016 for the Gulf of Mannar as well as for the southern and eastern coasts of Sri Lanka.

In 2015, CRW estimated a maximum Degree-Heating-Weeks index (DHW) value of 1.5 °C in the Gulf of Mannar and southern Sri Lanka and a value of 0.2 °C in eastern Sri Lanka. DHW of 4 °C typically leads to bleaching. In 2016, CRW estimated a DHW value of 11 °C–weeks in the Gulf of Mannar and the south of Sri Lanka and a value of 6 °C-weeks in the east of Sri Lanka.

Across the Gulf of Mannar on the Indian coastline, Thinesh et al. (2019) monitored bleaching for three different periods: pre-bleaching (March 2016), during bleaching (2nd week of May 2016), and post-bleaching (July 2016). Severe bleaching was found during the month of May 2016 when SSTs rose above 32 °C, with a maximum 33.3 °C. Among the 508 colonies surveyed, 53.8 percent of corals were bleached, and 20.9 percent of the colonies were dead.

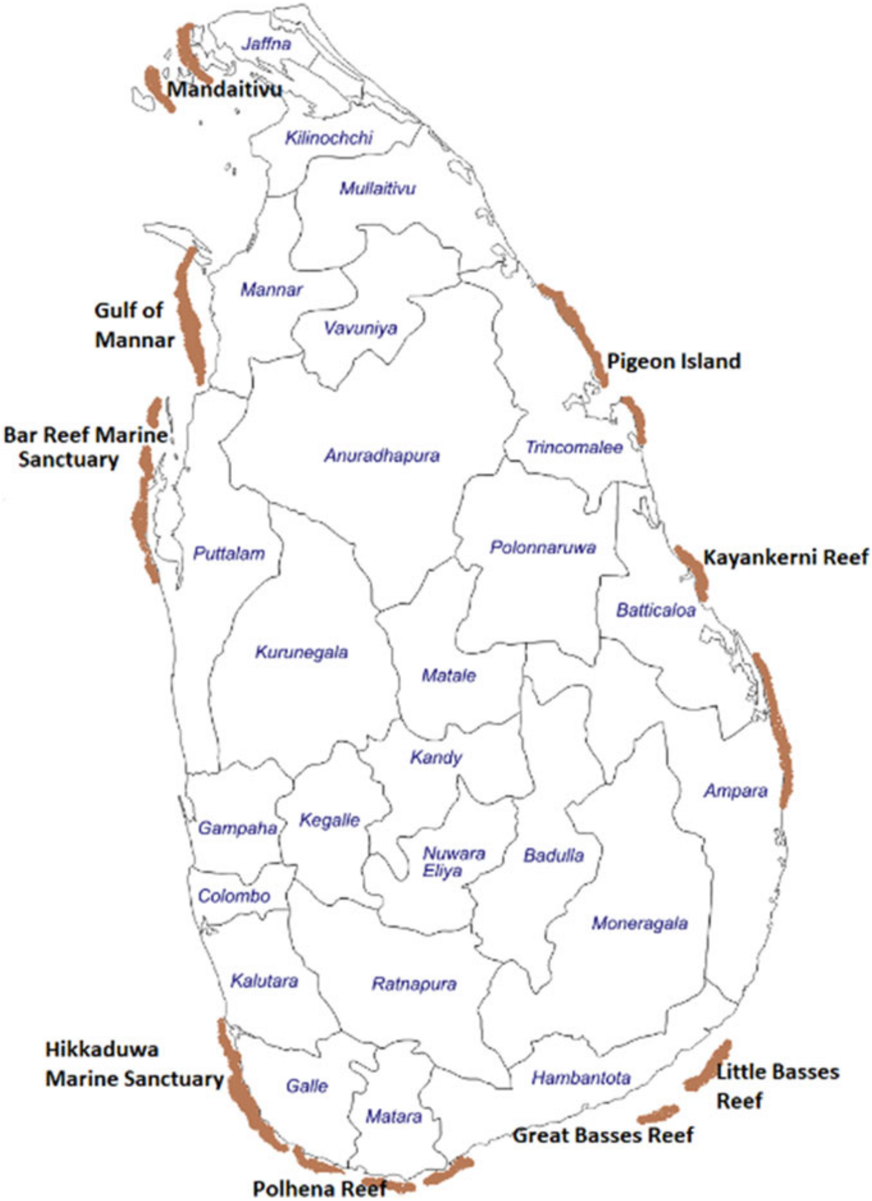

Fig. 9 Coral reefs of Sri Lanka (Kularatne 2014)

9.2 Drought in 2013–2014

Below-average rainfall between September 2013 and March 2014 led to a prolonged drought in Sri Lanka (Lokuhetti et al. 2017a). Estimates at the time show that by April 2014, more than 728,000 people were food insecure and in need of assistance as a consequence of the drought (WFP 2014). This situation occurred during a period of ENSO's neutral phase. By August 2014, the drought had affected more than 1.8 million people in 16 districts. The government allocated USD$ 680,000 to drought relief, while the UN Emergency Response Coordinator approved a USD$ 2 million disbursement for food, drinking water, and health services (OCHA 18 Aug 2014). The 11-month drought eased in early October, when formation of an El Niño event led, as is typical, to increased rainfall from October to December 2014.

9.3 Flooding, October–December 2015

With both an El Niño event and a positive IOD, rainfall increased significantly in Sri Lanka in 2015. This increase, in conjuncture with the prevalence of MJO phases that tend to enhance rainfall, led to flooding that affected some 5600 people, including three deaths in October of that year. As the rains continued into December, another 447,500 people, primarily in the eastern part of the country, were affected, including four deaths.

9.4 Landslides and Floods, May 2016

Cyclone Roanu and orographic rainfall triggered landslides in Aranayaka in May 2016 (Lokuhetti et al. 2017b). The aggregate rainfall for May 11–20, 2016 was 300–500 mm in the western half of the country. In the final ten days of May 2016, an additional 250–300 mm of rain fell in the Western Province. Even though the El Niño had technically abated by then, the extreme rainfall in the west at that time can still be attributed to the event.

9.5 Hydropower

Hydropower production has historically been enhanced by an El Niño event (Lochard and Zubair 2012). Expected heavy rains from October to December 2014 during an El Niño compounded by the seasonable rainfall of May 2015 offset the low rainfall totals from early 2015–2016. As a result, overall hydropower production was consistently higher than average during the event.

9.6 Rice Cultivation

Rice production during the principal growing season of Maha (October–March) in 2014–2015 and again in 2015–2016 was above normal. Rainfall during the first half of Maha was 25 percent above normal for 2014 and 12 percent above normal for 2015. During the second half of Maha (January-March), rainfall dropped by 40 percent in 2014–2015 and by 90 percent in 2015–16. Both of these rainfall and rice production anomalies are typical during an El Niño (Zubair 2002).

Rice production and rainfall during the secondary cultivation season of Yala (April–September) was above normal for 2015. This is not typical for El Niño, particularly for those events that coincide with an active phase of the Indian Ocean Dipole (Zubair et al. 2003). The reductions in rainfall and rice production during the following Yala (of 2016) did follow patterns typical of El Niño.

9.7 Coconut Cultivation

Coconut production is affected most significantly by drought from January to September of the preceding year, as coconut takes 2 years from flowering to harvest. The early stages of this period are particularly climate sensitive (Peiris et al. 2008). The significant drop in production during 2017 is likely because of the rainfall deficit in early 2016; this drop off from January to April is typical under El Niño. Historically, a significant drop in production in the years following the end of an El Niño is common.

9.8 Tea Cultivation

Tea is a mainstay of the Sri Lankan economy. "Ceylon Tea" derives its fabled flavors and relatively high prices from the regional and seasonal climatic history, soils, and terrain. Nijamdeen et al. (2018) showed that tea production is influenced by rainfall and temperature as follows:

- Higher rainfall in January to March and in August to September leads to higher production;
- Higher temperatures in February to March lead to a reduction in production;
- Warmer temperatures from September to November lead to reduced production in subsequent months; and
- El Niño leads to lower rainfall and production from January to March in higher elevations.

As expected, there was a modest drop in tea production during the 2014–2016 El Niño.

9.9 Dengue

Dengue transmission involves dengue parasites, mosquito vectors, and human populations. Dengue-transmitting mosquitos are particularly sensitive to climate. The gonotrophic cycle shows sensitivity to rainfall, temperature, and humidity (Hopp and Foley 2001). Models that account for these variations are able to mimic the history of dengue increases and epidemics (Hopp and Foley 2003). Overall, dengue has shown an exponential rise over the last 30 years in Sri Lanka, with epidemics occurring every 3–6 years.

Dengue incidence (cases per 10,000 persons) follows rainfall seasonality by about a month in Sri Lanka. Epidemics coincide with a narrow temperature range of 23–28 °C (Salih et al. 2018). Each rainfall peak has been followed by a dengue peak within 1–2 months.

The incidence of dengue in Sri Lanka dropped during 2015 but picked up alarmingly at the beginning of January 2016. The high values in mid-2016 was a precursor, leaving a reservoir of infected patients that enabled the disease to surge to the end of the year and continue into 2017. The causes for the 2017 epidemic had several contributory factors, including the introduction of a new serotype to Sri Lanka (Tissera et al. 2020). Historically, dengue epidemics have coincided with neutral ENSO conditions such as those that prevailed in mid-2016.

10 Government and NMHS

No national funds are dedicated for El Niño preparedness. There is, however, an allocation for disaster management. The Disaster Management Centre and the Ministry of Social Services have annual funding allocations to deal with disasters, which in Sri Lanka are largely climate-driven.

Separately, there were a few internationally funded projects in partnership with the Department of Irrigation, the Mahaweli Authority of Sri Lanka, and the National Buildings Research Organization, whose goals include the dissemination of climate information. Though funded by UNDP, the US National Science Foundation, and the World Bank, these projects have not, however, been effective in broadly communicating about El Niño impacts and preparedness.

The Department of Meteorology relies on international seasonal predictions. A weekly Agro-meteorological advisory from the Department of Meteorology that includes model outputs from Numerical Weather Predictions has been released online regularly, and press reports from the Department of Meteorology acknowledged the formation of an El Niño. Water management authorities also consult predictions from the meteorological service, online sources, and information assembled by FECT. Episodically, researchers provide information as well. For the general public, however, little more than a confusing array of information is typically available.

11 Interagency Activities Dealing with El Niño Forecasts and Impacts

Several ministries are directly involved in responding to El Niño, though these ministries do not coordinate risk management adequately. These include:

- Ministry of Disaster Management
- Ministry of Water Resources, Mahaweli River Basin, and Water Supply
- Ministry of Agriculture and Ministry of Plantation Industries
- Ministries of Social Services and Local Government
- Ministry in charge of Fisheries and Aquatic Resources
- Ministry with portfolios for Environment, Science and Technology and Defense.

International agencies also contributing to El Niño advisories in 2015–2016 were WMO and ESCAP. International NGOs such as the International Red Cross engage in disaster relief. NGOs, both national and local, also engage in different forms of disaster management and response.

In the case of large disasters, people tend to organize themselves to make up for the shortcomings of the government as well as international and established local NGOs. This is common. In every disaster situation, 'victims,' in order to survive, are often forced to improvise timely tactical and strategic response to warnings and impacts (Glantz 2015, Glantz and Ramirez 2018).

12 Media Coverage

At the formation of the 2014–2016 El Niño event, there was quite a keen awareness of drought hazards, as the event followed on immediately from a consequential drought (Mosbergen 2017). The drought that preceded the 2015–2016 El Niño event led to an interest in climate-related articles from news media. Some of the journalists who focused on El Niño even searched for climate change connections.

A few articles actually reported on overall impacts on the monsoon for India. This was misleading as they did not make distinctions by season or by region for South Asia. These forecasts tended to appear in April or May, as predictions for the Indian southwest monsoon frequently do. There was also less coverage of northeast monsoon rainfall, which is more consequential for Sri Lanka. El Niño was largely seen as leading to "doom and gloom," despite the increase in beneficial rainfall from October to December.

A feature article from a policy thinktank in June 2014 alerted early on of the formation of an El Niño event (Pathfinder 2014), but it missed key nuances in seasonal distinctions and impacts. No updates on these articles appeared either in newspapers or through other channels. In sum, the average person relying on media reports would have obtained confusing information, which would not have helped him or her with preparedness or mitigation activities.

13 Lessons Learned from El Niño Events

- Although the predictions from the various international forecast centers often do not well-represent the dynamics of the Indian Ocean, analogue methods can prove useful (e.g. Glantz 1988). As Sri Lanka sees rainfall in all seasons, and El Niño influences vary from season to season, nuances in terms of impacts need to be worked out. Further and deeper studies on impacts by sector are, however, also needed.
- The identification, prediction, and communication of El Niño impacts is particularly challenging in Sri Lanka given the nuances of its seasonal and regional variations. That scientists have shown some reticence in communicating the complex nature of El Niño's evolution and its impacts means that others have had to fill in the gaps, often with simplistic messaging or incorrect information. Better science communication to the general public is needed.
- Past failures to communicate well has held back risk management actions based on El Niño predictions. For example, during the 1997–1998 event, drought was predicted and communicated in Sri Lanka, but little was done to flesh out the nuances of its seasonality. This resulted in damaging mitigation actions, such as growing chilies and not harvesting tea. In the ensuing wetter than normal conditions in 1997–1998, there were massive losses in agriculture due to this poor communication.
- As another example, the action proposed by the Pathfinder Foundation in mid-2014 was to plant crops other than rice and to hastily bring online a coal power plant to make up for predicted shortfalls in hydropower generation. These proposals do not, however, conform with what subsequent research (as here) has shown, which is that El Niño overall leads to increased rainfall, rice production, and hydropower capacity. Once again, the failure to adequately understand and communicate the nuances of impacts in Sri Lanka, as during the 1997–1998 event, led to detrimental preparedness and mitigation efforts.

Remedial action is needed. What is known about El Niño and its impacts needs to be made more accessible to the general public. The Departments of Meteorology and Agriculture as well as FECT have such expertise and have a challenge to address. Two modest but sustained efforts along these lines that can help and that are being undertaken by the Department of Meteorology and FECT are described as follows:

- The Department of Meteorology annually convenes a "Monsoon Forum" for officials. This forum is meant to provide policymakers with a better understanding of the impacts of climate variability.
- FECT has been issuing predictions to water managers and researchers through its weekly, seasonal, and annual climate reports. Water managers who are weekly advised by FECT decide on amounts of water to release from the different reservoirs. Advice is also given to farmers in terms of crop choices and areas to be cultivated. Some adjustments to water releases are also made based on the overall predictions by water managers. Such long-term engagements as

these, with more attentive and engaged users, are needed over a sustained period to develop confidence and understanding of El Niño-related forecasts and foreseeable impacts.

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Southeast Asia

The Philippines

Uncovering the 2015–2016 El Niño and Online Discourse in the Philippines

Jaime Manuel Q. Flores and Anthony Joseph R. Lucero

Abstract This report explores the multiple perspectives and points-of-view that have shaped the public's understanding of the 2015-2016 El Niño event in the Philippines, revealed primarily through the lens of online media. Discourse analysis was used to uncover how certain issues and events are understood and appreciated by a mainstream audience. This chapter attempts to uncover the deep and complex meanings behind the public's understanding of El Niño and the concept of readiness. The discussion is contextualized in recognition of social, economic, and geopolitical factors that may potentially shape public discourse, as observed through articles posted on the internet, effectively constituting the online public sphere.

Keywords El Nino · Discourse analysis · Online media · Philippines

In this chapter, the multiple perspectives and points-of-view that have helped shape public understanding of the 2015–2016 El Niño event in the Philippines, particularly through the lens of online media, are explored. Discourse analysis is the main methodological approach used in this report. It is a significant way to uncover how certain issues and events are understood and appreciated by a mainstream audience. Through an analysis of online discourse surrounding the El Niño event of 2015–2016, this paper uncovers deeper, complex meanings behind the public's understanding of El Niño and the concept of "readiness". The discussion is contextualized in recognition of social, economic, and geopolitical factors, as observed through articles posted

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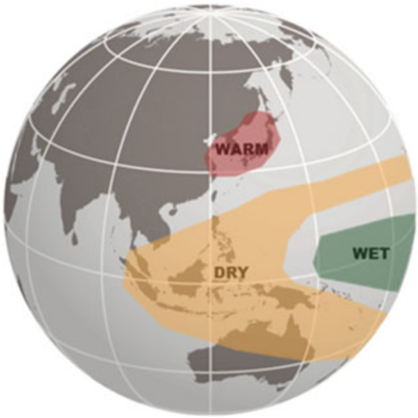

Fig. 1 El Niño conditions in the Pacific (OCHA 2015)

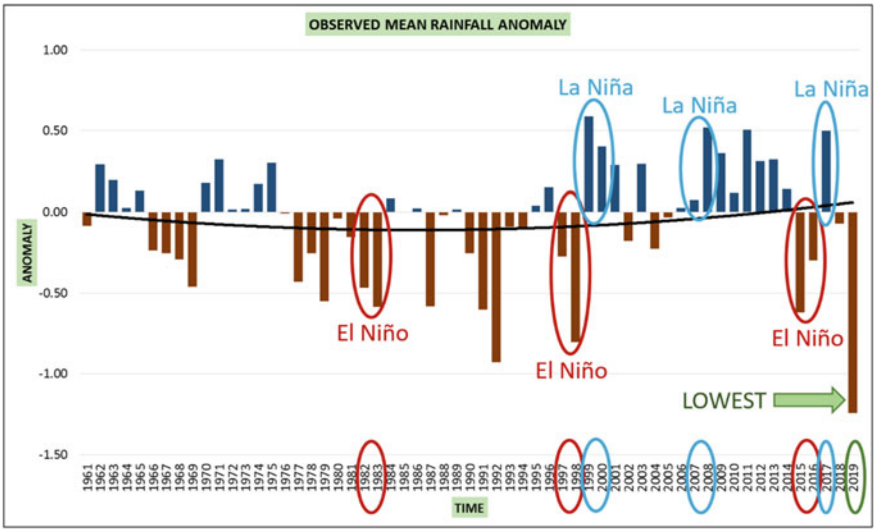

Fig. 2 Standardized Anomalies of Mean Annual Rainfall in Mindanao (1961–2019) (Climate Report Booklet 2019)

on the Internet, that may potentially shape public discourse. It thus effectively constitutes the online public sphere. Interviews were also conducted as a complement to this primary methodology.

The Philippines has a unique relationship with the El Niño Southern Oscillation (ENSO). It is adversely affected by both extremes of ENSO, El Niño and La Niña. One could effectively argue that the Philippines is truly "ground zero" for El Niño in the western Pacific (Fig. 1). That said, Fig. 2 clearly shows the impacts of ENSO's extremes on rainfall in the Philippines. Interestingly, the rainfall time series (1960–2019) represented in the graph shows that while 2015–2016 has been acknowledged as one of the three strongest El Niño events since the 1950s, if not earlier, the 2018–2019 event was apparently more serious, drought-wise, than the earlier event. It also suggests that El Niño's impacts can vary from one event to the next for a variety of geophysical *and* socioeconomic and political reasons.

1 The Philippines Context

Like many countries, the Philippines has a complex and distinct history, including a rich colonial history as well as distinctive political and economic struggles since it gained independence in 1946. Accounting for this history is important in order to truly understand how and why the 2015–2016 El Niño event was discussed and understood as it was. It requires a brief look at various factors—societal, economic, political, and geographical—that have shaped Philippine society.

2 Society

Two important facets of Philippine society should be considered to understand the context behind various Philippine reports on El Niño. First, though the country is predominantly Catholic, it had a strong indigenous precolonial culture that remains active today (Toohey 2013). The impact of this reality is that El Niño and other weather and climate events tend to be explained not only through scientific but also through local cultural models. During Typhoon Haiyan, for example, much of the discourse—both online and in casual conversations among Filipinos—reflected that even among policymakers and some scientists the event was widely framed as an "act of God." To be sure, the Catholic Church has always been an influential voice in the Philippine public sphere. As such, despite the constitutionally mandated separation of church and state, it has long had an outsized influence over public policy and governance.

Second, the Philippines consists of a highly culturally diverse society made up of people of varying ethnicities and socioeconomic classes. Historians and cultural anthropologists often attribute this diversity to the archipelagic nature of the country's geography, which has had strong implications for the geopolitical landscape. Nonetheless, this diversity has led to significant disparities among people who identify with different social groups, many of which not only have their own normative behaviors and attitudes but often also even have distinct languages and worldviews. In fact, the Philippines is home to almost 170 distinct languages and 12 major ethnic groups, figures which do not even include smaller ethnic groups that remain extant within the peripheries of the country (Ethnic Groups of The Philippines 2020). Indeed, Filipinos are said to have a very 'regionalistic' mindset, which is often perceived of as an obstacle to achieving national unity and a genuine collective identity.

3 Economy

At the time of the 2015–2016 El Niño, the Philippine economy was said to be in a good condition. Remittances from overseas Filipino workers (OFWs) as well as a booming outsourcing industry had led to the rise of a strong middle class. Unfortunately, this growth also led to rapid urbanization over the last decade, which, in turn, led to congested metropolises plagued with heavy traffic, hundreds of informal urban settlements, and deficiencies in housing space and urban transportation. Metro Manila is now considered one of the most uninhabitable cities in the world (Middleton 2016).

As of 2012, 25.2 percent of the Philippine population was below the poverty line, excluded from access to basic services like education and health. The labor force was dominated by the service sector (55 percent), followed by agricultural workers (29 percent, including fisheries), and then industrial workers (16 percent) (CIA 2020). In the rural areas, agriculture continued to be the main source of employment and livelihood.

4 Geopolitical Structure

The Philippines, as an archipelago, is physically divided into three main island groups: Luzon (in the north), Visayas (in the middle), and Mindanao (in the south) (Fig. 3). As of July 2015, the Philippine population totaled 101 million people, making it the thirteenth most populace nation in the world (CIA 2020). More than ten percent of the population, 13 million people, reside in Metro Manila.

The Philippines has a presidential system of government, which is divided into three branches: the executive, the legislative, and the judiciary. Power is equally distributed among these three branches (Philippine Information Agency 2020). Historically, the seat of government, as well as a large majority of government agencies and government-funded research institutions, have been located in Metro Manila, which is in the southern part of the Luzon archipelago.

During the 2015–2016 El Niño, Benigno Aquino was the president. His term ended on 30 June 2016, after which President-elect Rodrigo Duterte took over. Much of the discourse described in this chapter is reflective of how the Aquino government coped with the 2015–2016 event.

As an aside, Duterte's 2016 election victory was the first time a "*Mindanawon*" was elected President. Mindanao has always been at the fringes of development, geographically farthest from the seat of government. One of President-elect Duterte's most widely known political agendas was to promote and facilitate the country's shift to federalism. This move was favored by some sectors, as it was generally believed

Fig. 3 Main regions of the Philippines: Luzon (north), Visayas (central), and Mindanao (south) (Global Security 2020)

that the new system would decentralize bureaucracy and enable genuine regional and rural development. This shift has been of utmost geopolitical significance for El Niño readiness because the federalist system has enabled each region to work more and more from its own distinct experiences and struggles with weather and climate. As such, adaptation and mitigation strategies have increasingly been determined by respective region's or community's own interests, shaped by varying considerations concerning terrain, sea level, agriculture, and land use.

5 Research Method

Content analysis is a method used by social scientists to uncover and understand the kind of discourse that surrounds a particular subject matter (Matthes 2009). It may be quantitative or qualitative in nature. Extracting the information for this chapter entailed a close reading of various types of online articles about El Niño and its impacts on the Philippines, including news and technical reports, press releases, blogs, and feature stories, written between January 2014 and May 2016.

A total of 143 online articles were reviewed. To gather the articles, a thorough Google search was conducted using the keywords "El Niño + Philippines." All 143 articles sampled were unique. There were 39 articles sampled from 2014, 45 articles from 2015, and 59 articles from January–May 2016.

6 An Overview of the 2015–2016 El Niño Event

When the Philippine Atmospheric, Geophysical, and Astronomical Services Administration (PAGASA) released its first public advisory on El Niño in May 2014, a notable surge in the number of relevant articles published online ensued. As El Niño's impacts were not immediately seen or felt at that time, however, the number of articles steadily declined throughout the rest of the year. Not until the third quarter of 2015 was there a comparative increase in the number of posted articles. These articles primarily focused on how El Niño was already being experienced on the ground, and how the government was responding to these effects. Then, the first quarter of 2016 immediately saw a rise in the number of articles about El Niño, gradually increasing until April 2016, when the number of articles posted online (23 total) was at its highest. Many of these articles focused, however, on the so-called "Kidapawan Massacre," where farmers who were suffering from the negative impacts of El Niño took to the streets and demanded government support, that occurred on 2 April 2016. The incident ended in a violent dispersal of the protestors that resulted in one fatality and 13 injuries (Manlupig and Magbanua 2016).

The earliest warning of the formation of a 2014–2015 El Niño event was publicly announced on 1 May 2014. PAGASA based its warning on information from Columbia University's International Research Institute for Climate and Society (IRI), NOAA's Climate Prediction Center (CPC), the Australian Bureau of Meteorology, and the Tokyo Climate Center. As the country's primary hydrometeorological service, PAGASA is the first to receive information on an event's possible formation. It is also the main agency responsible for the analysis and preparation of public advisories on weather and climate-related processes and events. Following its first warning, PAGASA released regular public advisories and climate outlooks as part of its information and outreach strategy (see Table 1).

Although the official PAGASA press conference on the 2014–2015 El Niño event took place on the first of May 2014, news reports on the possibility of an El Niño had been reported as early as the previous January (Agence France-Presse 2014). The agency's online news site released an advisory by the World Meteorological Organization (WMO) to warn of a possible "weak El Niño" by the middle of 2014.

At the time of the 2015–2016 El Niño, the 1997–1998 and 2009–2010 strong events were often mentioned in comparison due to their unprecedented physical characteristics, intensity, and societal impacts. The comparisons were meant to provide some insight and guidance that might be useful in coping with the new very strong event.

Table 1 Timeline of El Niño-related events in the Philippines, 2014–2016 (PAGASA 2016)

Date	Event
1 May 2014	PAGASA issues first advisory on the possibility of an El Niño event in 2015
4 May 2014	Philippine government declares "readiness" for El Niño and La Niña
11 March 2015	PAGASA holds press conference officially announcing the formation of an El Niño; it releases the very first of a series of El Niño advisories
26 May 2015	Philippine government declares a state of calamity in eight provinces due to El Niño
5 August 2015	PAGASA issues its sixth advisory, informing the public that El Niño will intensify in the last quarter of 2015
18 August 2015	President Aquino orders the establishment and immediate implementation of the Roadmap for Addressing the Impact of El Niño (RAIN)
1 October 2015	PAGASA, WMO, and other meteorological service agencies declare the El Niño 2015–2016 event "worse than" the 1997–1998 event; WMO calls it the "biggest El Niño in history"
7 October 2015	The Catholic Bishops' Conference of the Philippines (CBCP) steps in and reminds the government of El Niño's social impacts
7 December 2015	PAGASA warns the public that El Niño will "continue into 2016"; the UN issues a similar advisory three days after
6 January 2016	PAGASA warns of "dire consequences"
20 February 2016	Media begins reporting on El Niño's decline, issuing warnings of La Niña's formation
18 March 2016	PAGASA declares the onset of the 2016 dry season
26 March 2016	A forest fire occurs at a section of Mount Apo in Mindanao; media sources attribute it to intense heat brought on by El Niño
1 April 2016	Mindanao farmers rally for increased agricultural support; police retaliate violently, resulting in the highly publicized "Kidapawan Massacre"; netizens begin #bigashindibala (#ricenotbullets) campaign which instantly becomes a trending topic on social media
4 April 2016	Philippines' heat index hits 49° C
7 April 2016	Media reports on the Philippine "heatwave"
15 April 2016	News agencies intensify La Niña warnings

7 Forecasting El Niño

PAGASA is an exemplary NMHS with regard to forecasting El Niño and warning about its adverse, as well as its beneficial, influences, especially considering events' various disruptions of normal seasonality across the Philippines. The agency regularly receives updates on SST changes in the tropical Pacific from various international forecast centers in Japan, Europe, and the U.S. It relies in large measure on the NOAA/CPC Oceanic Niño Index (ONI) for early warnings (Table 2).

For the 2015–2016 El Niño, PAGASA created 15 public advisories, the first of which was released on 11 March 2015 to warn the general public, agencies, and

Table 2 NOAA's Oceanic Niño Index (ONI) as an early warning (PAGASA 2019)

Observed sea surface temperature anomaly**	Observed Oceanic Niño Index (ONI)	Forecast from CPC (NOAA) and other Int'l Prediction centers	Warning type	Recommended action/response	Form of issuance
	between <0.5 °C and >−0.5 °C or neutral	Neutral; no foreseeable El Niño conditions within the next six months	N/A	Be aware	Monthly climate assessment and outlook***
One month 0.5 °C* or greater is observed	Between <0.5 °C and >−0.5 °C or neutral	Issued when conditions are favorable for the development of El Niño within the next six months and probability is 55 percent or more	Watch	Be aware/Be prepared	Press statement
Five consecutive months of 0.5 °C* or greater is observed	Three consecutive ONI of +0.5 °C or greater is already observed	Issued when ONI of +0.5 °C or greater is forecasted to persist in the next 2 months or more and El Niño is likely/probable by 70 percent or more (to satisfy 5 ONI)	Alert	Early action	Press statement Issuance of dry spell/drought assessment to monitor early impacts
Seven consecutive months of 0.5 °C* or greater is observed	Five consecutive ONI of +0.5 °C or greater is already observed	Issued when El Niño is observed and expected to continue	Advisory	Take action	El Niño advisories Press statement Issuance of dry spell/drought assessment and Outlook for areas affected and likely to be affected

(continued)

Table 2 (continued)

Observed sea surface temperature anomaly**	Observed Oceanic Niño Index (ONI)	Forecast from CPC (NOAA) and other Int'l Prediction centers	Warning type	Recommended action/response	Form of issuance
	ONI is between <0.5 °C and >−0.5 °C or neutral	Issued after El Niño has ended	Final advisory	Assess and take action as necessary	Press statement

*at the Niño 3.4 region, (5°N-5°S, 120°W-170°W). **based on consensus ENSO Probabilistic forecast of NOAA/CPC and Philippine Rice Institute. *** issued during ENSO-neutral condition. N/A = no active alert during neutral conditions with no foreseeable El Niño or La Niña

El Niño-sensitive sectors. PAGASA is responsible for disseminating information on forecasts, updates, and warnings to government agencies. Four key agencies rely on PAGASA information (including El Niño advisories):

1. *National Economic and Development Authority* (*NEDA*)—Coordinates all official actions taken by government agencies, particularly on matters related to spending of public funds on infrastructure, providing agricultural production support, and managing relevant water management or irrigation projects.
2. *Office of Civil Defense (OCD)* and,
3. *National Disaster Risk Reduction Management Center* (*NDRRMC*)—Together responsible for initiatives and coordination of public safety and risk reduction on local and national levels. Small towns and municipalities, as well as urban centers, are mandated by law to have their own disaster risk reduction (DRR) units. Both OCD and NDRRMC are chaired by the same individual.
4. *Department of Public Works and Highways* (*DPWH*)—Responsible for water management concerns.

Together with PAGASA, these agencies are tasked with overseeing the implementation of all national preparedness measures related to El Niño and other potential disaster events.

Various sectors also make use of climate and weather information released by PAGASA. These include but are not limited to the following:

1. *Agriculture*. Some of the biggest users of information include agricultural agencies such as the Department of Agriculture (DA) and its subordinate agencies like PhilRice, fertilizer and pesticide companies, and farmers. Recently, the fisheries sector also realized the importance of using PAGASA's prediction services. The DA noted that the reliability of weather information is key to ensuring that the sector is prepared for any impact that an El Niño might bring (*Mindanao* Examiner 2015).
2. *Food security*. The National Food Authority (NFA) in particular is responsible for ensuring that the market prices of rice and other important crops are stable

despite El Niño impacts. Weather outlooks provide useful information for estimating local production outputs so that necessary recommendations can be made with regard to importation of certain products such as rice, corn, and sugar. Importation is often seen as a necessary preparedness strategy to prevent price manipulation.

3. *Water.* Rainfall outlooks provided by PAGASA normally allow these agencies to estimate water needs for irrigation, power generation, and potability. During El Niño, water management and conservation plans must be implemented by dam operators, water management councils, water service providers, etc.
4. *Disaster management.* The law requires local government units, even at the local *barangay*-level, to form disaster risk reduction and management councils to oversee enforcement of preparedness measures locally and to ensure that all citizens are provided security, rescue, and rehabilitation in every possible scenario, El Niño included. As such, the NDRRMC down to the *barangay* councils are given information by PAGASA to use for timely implementation of mitigation strategies.

8 The Media

As our chapter focuses on public discourse, a brief description of the Philippine media landscape is appropriate. The media as an industry in the Philippines operate freely. At the time of the 2015–2016 El Niño, it was considered to be among the most liberal in the world, with its institutions being largely self-regulating.

That said, the Philippine media is often described as oligarchic. For example, two of the country's major media networks, ABS-CBN and GMA, are owned by two of the wealthiest Filipino families. Both these institutions are extremely dependent on financial support from advertisers, many of which have huge interests in power, energy, and the use of environmental resources. The possibility conflicts of interest are readily apparent, as in 2015 the family that owns ABS-CBN (2016) controlled half of the country's water and energy sector. A third competitor, TV5, is owned by a Filipino industrialist who also controls important industries such as telecommunications and mining.

Here, however, we mainly focus on online news media as a shaper of environmental discourse. Almost every major media company in the Philippines already has its own online news portal. Apart from these web-based identities of major news agencies, new startup online news agencies, the most notable being Rappler, have also become quite prominent and influential among online audiences (2020).

PAGASA also provides its own media channel dissemination of information to the Filipino public (Fig. 4). The following is an example of an awareness and educational poster created by PAGASA.

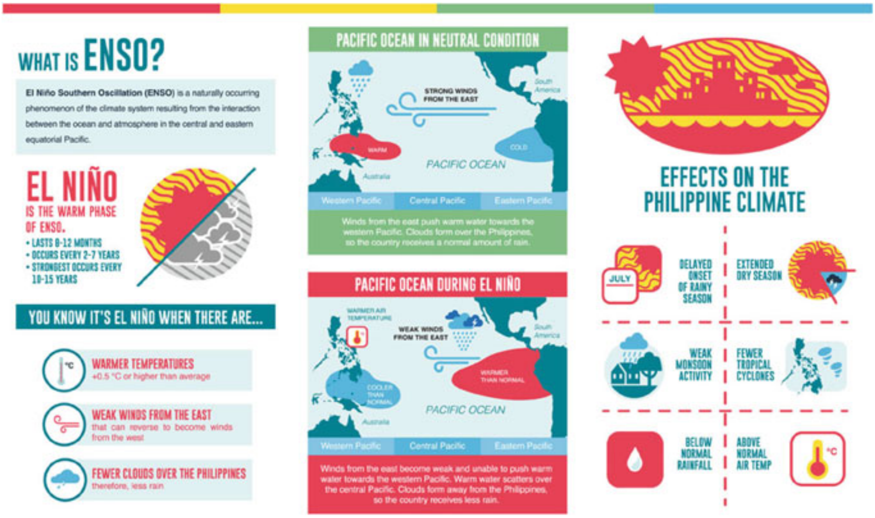

Fig. 4 A PAGASA poster to generate El Niño awareness (PAGASA 2020)

9 "El Niño Readiness" Discourse: A Thematic Analysis

After a close reading of each article sampled for this analysis, three key themes emerged out of a total of 310 themes identified: preparedness strategies, impacts, and warnings on El Niño. These three themes are defined as follows:

Preparedness—words, phrases, or statements that reflect strategies and programs needed to be ready for the impact of an El Niño event.
Impacts—words, phrases, or statements that reflect the various impacts of El Niño—whether potential or current—on agriculture, economy, society, or other sectors.
Warnings—words, phrases, or statements that reflect some kind of notice of an upcoming El Niño or La Niña event. Statements such as "prepare yourselves for the coming El Niño" (Tacio 2014) or "El Niño conditions continue to persist" (Philippines News Agency 2015) were coded in this category.

Other significant themes indicating alternative views on how El Niño was described in online media were also identified:

"El Niño science" articles discussed the science behind El Niño. Descriptions of ENSO and detailed or condensed explanations for how an El Niño forms were mentioned.
"State of calamity" articles described how a drought disaster is declared in areas affected by the dry spell due to an El Niño. They explained that this formal executive branch declaration is based on recommendations from PAGASA and other relevant agencies (NDRRMC, EN Task Force, RAIN, etc.).

"Previous El Niño events" articles often described the 1997–1998 or the 2009–2010 events, comparing a current event with previous ones.

"Declaration of readiness" articles informed the public about government readiness for responding to El Niño impacts (Department of Agriculture 2014), usually a few weeks after PAGASA issued its first public El Niño advisory.

"End of El Niño" articles focused on the dissipation of El Niño conditions but would also always include information on an upcoming La Niña (e.g. Rio 2016a).

10 El Niño Impacts

Online articles revealed various El Niño-related impacts on the Philippines. The surveyed articles identified the following major sub-themes:

Drought or dry spell. The main concern of the Philippines as a country with 41.7 percent of its arable land devoted to agricultural production. Drought is crucial, affecting all the other impacts mentioned below.

Decline in crop production. Many articles warned of a significant decline in crop production, prompting the government to institute mechanisms to support farmers.

Crop damage. The Department of Agriculture (DA) reported that the 2015–2016 El Niño event resulted in almost P4.7 billion worth of losses in agricultural production. A majority of losses were in rice, corn, and other high-value crops (Rappler 2019).

Reduced economic growth. Mainly as a result of crop damage and reduced agricultural productivity, economic agencies expressed concern over negative effects on GDP, which reduced gains made during the last three years of the Aquino administration (Mariano 2015). Unemployment was also foreseen as a major impact (Torres 2015).

Food shortage/Food security. Due to crop damage and low farm output, many affected communities experienced hunger, often as a direct result of income loss.

El Niño-induced conflict. In the second quarter of 2016, a majority of articles focused on an unexpected impact of El Niño: On 1 April 2016, a large group of farmers, mobilized by left-leaning activist groups and farmers' associations, took to the streets to demand needed government assistance and humanitarian action as they were already suffering the harsh impacts of the 2015–2016 El Niño event. Frialde (2016) reported that "The farmers wanted rice and drought-resistant vegetable seeds as El Niño had dried up their crops and refused to leave the highway unless their demands were met." The rally ended violently as farmers clashed with police.

11 Additional Noteworthy Impacts

The Bureau of Fisheries and Aquatic Resources (BFAR) reported that almost 279,000 metric tons of catch, almost half of 2014's catch, were brought in from 2015 to 2016 (Padin 2016). Fishery and aquaculture declines were unexpected El Niño impacts.

The Sugar Regulatory Agency (SRA) reported a sharp drop off in production, with losses amounting to nearly half of the previous years' totals (e.g. from 2.3 metric tons in 2014 to 1.2 metric tons in 2015) (Galvez 2016).

Food prices were expected to rise as a result of agricultural production losses. Hunger as a direct result of food shortages is a widely recognized impact of El Niño. International NGO World Vision asserts that El Niño preparedness plans—and all DRR initiatives—should include nutrition plans that address not only shortages but also nutritional quality (World Vision 2016). Farm families resorted to eating rats due to hunger during the 2016-2016 event (Asia News 2014).

12 Preparedness

To be "El Niño ready" requires adequate preparation for all foreseeable impacts. A close reading of each online article revealed numerous insights as to what various sectors believed were the preparations needed for the Philippines to be truly "ready." Themes identified ranged from cloud-seeding and drought-resistant crops to law enforcement to summits and forums.

After tracking discourse on "preparedness" in online media and going through the themes extracted from the articles, various "strategies for preparedness" were identified and sorted into the following general categories:

Agricultural. A commonly discussed theme, this category refers to strategies that involve mitigation initiatives targeted toward the production of food supplies, whether crops or livestock. Support mechanisms such as cloud-seeding, production support (in the form of cash, fertilizer, alternative crops, etc.), and technical support for use of innovative farming techniques or new rice varieties were suggested by technical experts.

Technical. Those strategies that involve some kind of technology or innovative practice. Examples of technical strategies are energy and water conservation approaches, rainwater harvesting, water management systems, and the provision of preemptive health care to affected communities.

Institutional. Entails measures requiring the formation of necessary structures and groups to facilitate the conceptualization and preparation of strategies to be 'ready' for El Niño. The creation of an El Niño taskforce, for instance, is commonly cited in many of the articles. Other approaches include the need to train farmers and rural community workers and to intensify communications in order to inform and educate affected communities about how to prepare for impacts. Having had done so explains why communities were able to cope with the impacts of El Niño by engaging in other income-generating activities such as handicrafts as well as through the cash-for-work program developed by the Department of Social Welfare and Development (DSWD).

Important contributions by NGOs were also made for engaging with grassroots communities. One key example would be the Rice Watch and Action Network (RWAN/RI) that partnered with PAGASA to promote and educate communities on "the use of climate information." This particular partnership was so successful that it was cited by the Philippines' Climate Change Commission as one of the best practices recommended for DRR and CCA initiatives for local government units.

Governance. Reflects discourse that looked at 'El Niño readiness' as a responsibility of government and legislation. Calls for proper enforcement of laws, better governance (at national, regional, and local levels), appropriate allocation of funds, precise and regular monitoring of affected areas, and local participation and involvement in El Niño preparation are cited as examples of this responsibility.

13 Barriers to Preparedness

In terms of preparations for El Niño, all initiatives and programs were carried out quite well. In the earlier stages there were no significant barriers to the implementation of preparedness programs; however, because of the commencement of the election season in the Philippines in February 2016, distribution of assistance to affected areas and communities had to be discontinued in accordance with Philippine election laws. Such laws prohibit the provision of any form of government assistance in the lead-up to an election as it may be used for unfair political leverage.

According to Claudius Gabinete, Food Security and Agriculture Specialist at FAO in the Philippines, government initiatives were adequate. The timing of events like El Niño are usually unexpected, however, and can increase pressures when they do arise on already limited budgets. Also, toilsome bureaucratic procedures such as those involving allocation and procurement requests can significantly delay the timely delivery of needed interventions.

Gabinete also stressed the need for technical agencies like PAGASA to improve its efforts to effectively interpret and communicate scientific information such as climate forecasts into information that is readily understandable to farmers and local community members. While such understandable forecast products enable end users to understand the expected impacts and duration of an event, however, users still often have difficulty appreciating the severity of an El Niño event. This lack of full understanding can lead to relief strategies that are insufficient or inappropriate, a tendency that planners must account for.

14 El Niño Discourse's Dominant Voices

It appears that the government remained the main voice that shaped El Niño discourse throughout the 2015–2016 event. Journalists and news agencies relied heavily on information coming from relevant government institutions mandated to address El Niño's impacts. Among the 130 online articles collected, two government agencies were the main contributors of information: PAGASA and DA (2014). Both represented the government position on El Niño. Table 3 illustrates and compares the key themes that emerge from a close reading of the sampled online articles.

DA's descriptions of El Niño reflected its views on expected agricultural impacts and preparedness. The department was also quite vocal in presenting El Niño as an issue requiring concrete government attention, frequently articulating the need for sufficient funds and various institutional mechanisms that its leadership believed would facilitate readiness for various impacts. It also joined NGOs and farmers' communities in asserting the need for more attention to Mindanao as the hardest-hit region (Saunar 2016).

PAGASA presented multi-dimensional descriptions of El Niño in its articles, advisories, and interviews. Its discourse was mainly about providing scientific and technical information about El Niño—why it happens, what its impacts might be, and how these can be mitigated. PAGASA also explained the implications of climate and weather events on sectors such as energy, agriculture, and industry. As a government agency, even prior to El Niño's onset, it had always been 'ready' for foreseeable impacts. It insinuated in the early stages that a "weak" El Niño was possible (Pazzibugan 2014), while acknowledging uncertainties in El Niño prediction (Manila Standard 2015). PAGASA discourse on El Niño included constant updates.

Table 3 A comparison of the discourses from both PAGASA and DA (Authors)

PAGASA	DA
• Information about the 1997–1998 and 2009–2010 El Niño events • Declaration of readiness • The science behind El Niño • Regular El Niño warnings • Impacts: crop damage, drought or dry spell, extreme heat, strong rains and typhoons in other areas, water shortage, changes in weather patterns • Preparedness strategies: comprehensive approach, monitoring of affected areas, task force creation, water conservation • Uncertainty of El Niño/Possibility of a "weak El Niño" • 2015 El Niño is the strongest in history • El Niño to continue in 2016 • La Niña to follow El Niño in 2016 • El Niño declines	• Information about the 2009–2010 El Niño event • Declaration of readiness • Impacts: crop damage, decline in crop production, decline in livestock supply, drought/dry spell, reduced economic growth, Mindanao as hardest hit region • Success of preparedness strategies • Preparedness strategies: cloud-seeding, comprehensive approach, drought-resistant crops, early planting, funds allocation, monitoring of affected areas, production support, summits and forums, task force creation, water management • Systems, water-saving technologies • Assessment of vulnerable communities

Fig. 5 The RAIN El Niño impact mitigation roadmap (NEDA ND)

The Philippine central government was another important voice. Based on articles on its own website (www.gov.ph), the government's discourse reflected a systematic and deliberate approach to addressing El Niño's impacts. As early as 4 May 2014, just three days after PAGASA announced the possibility of an upcoming El Niño event, the Philippine government declared that it was "ready" (Philippines Star News Service 2014). In support of this claim, the government explained that it already had in place specific protocols to address the foreseeable impacts of the impending El Niño event.

First, the Roadmap to Address the Impacts of El Niño (RAIN) was established and implemented. On 18 August 2015, President Aquino ordered formation of the multi-sectoral initiative to identify the necessary strategies and tactics to reduce the foreseeable negative impacts of El Niño on four priority areas: food, energy, health, and public safety (Fig. 5). The roadmap was to be designed and implemented by the El Niño Task Force, which included a number of government agencies and NEDA.

As a public service, NEDA also released a directory of all involved agencies to enable transparency and immediate communication and feedback on RAIN initiatives and concerns. Some of these agencies were DA and PAGASA, DSWD, NFA, the Department of Labor and Employment (DOLE), the National Irrigation Administration (NIA), the Technical Education and Skills Development Authority (TESDA), the Department of Trade and Industry (DTI), the Department of Health (DOH), the Department of Energy (DOE), the Department of Public Works and Highways (DPWH), and the Department of Interior and Local Government (DILG).

Under the Aquino government, RAIN was specifically tasked with gathering important data and presenting recommendations on the following concerns:

- Availability of budgets of line agencies and local government units (LGUs);
- Appropriate actions that could be taken by line agencies and LGUs;
- Strategies to be exercised by different sectors that would be affected by El Niño;

- Availability of funds to finance action plans drawn up by line agencies and LGUs;
- Evaluation of effectiveness and cost of action plans (specifically for NEDA); and
- Necessity of additional financing, to be reported directly to the President who would determine where to allocate funds.

Furthermore, the Aquino government called for:

- *Quick response fund (QRF).* Government agencies at the national level were mandated by the Aquino administration to provide immediate assistance to local communities affected by the drought via a quick response fund (QRF). This was a key responsibility of agencies like DA, DSWD, and the Department of Budget and Management (DBM). Other agencies that had available QRFs earmarked for allocation to El Niño preparedness programs are DPWH, the Department of National Defense and Office of Civil Defense (DND/OCD), and the Department of Education (DepEd) (DBM 2016).
- *Declaration of a state of calamity in seriously affected areas.* The Philippine government responded quickly after being urged by representatives from local government units to declare a state of calamity in affected areas. As of June 2016, there were 18 areas where a state of calamity had been declared (Remo 2016).
- *Comprehensive El Niño mitigation strategy.* Key government agencies were tasked with implementing mechanisms including:

(a) production support to mildly affected and nonvulnerable communities;
(b) timely importation of rice, sugar, and corn; and
(c) price freezes in state-of-calamity areas.

Other government agencies also provided perspectives on El Niño. Table 4 summarizes what each government agency contributed to the overall discourse.

Among the agencies mentioned in Table 4, the most engaged in the discourse were NEDA and NIA, as these agencies were directly involved in addressing El Niño impacts. Also, NEDA was considered as another influential voice in the discourse, as its main responsibility was to ensure that government funds were used properly.

15 Other Voices

Some other minor but no less significant voices were also featured in online articles (Table 5). Local government units (LGU) provided important information as to how the impacts of El Niño were being addressed on the ground. Many of the articles that presented the LGU's point-of-view reflected an alternative appreciation of the programs and initiatives that were to come from the central government.

A minor but highly significant voice in the discourse came from the affected communities themselves, particularly farmers. A review of online articles showed that for 2014 and 2015, perspectives from affected communities/sectors had for the most part been muted; the sentiments of farmers took center stage during the

Table 4 Other government agency perspectives and contributions to El Niño discourse

Government agency	Theme(s)
Department of Budget and Management (DBM)	• Allocation of funds for El Niño mitigation projects
Department of Interior and Local Government (DILG)	• Disaster risk reduction measures • Enforcement of laws pertaining to energy conservation, land use, and environmental protection
Department of Social Welfare and Development (DSWD)	• Allocation of funds for El Niño mitigation projects • Cash-for-work initiatives for affected communities
National Dairy Authority (NDA)	• Need for production support for the dairy industry
National Economic and Development Authority (NEDA)	• Concern over compromised economic growth • Concern for farmers and rural communities • Concern over possible unemployment (impact of El Niño) • Need for timely importation to augment production losses • Need for involvement of local government units • Observed economic growth despite the presence of El Niño RAIN Task Force successful in its task
National Food Authority (NFA)	• Need to import rice
National Irrigation Administration (NIA)	• Concern over damages to crops • Concern over water shortages • Concern over decline in crop production Need for water conservation • Need for effective water management systems
Philippine Rice Research Institute (PhilRice)	• Need to develop more drought-resistant varieties of crops • Need to train and provide technical support to farmers on the use of new technologies and research
Sugar Regulatory Administration (SRA)	• Concern over decline in sugar production • Need to import sugar

highly publicized farmers' rally on 1 April 2016, however, when 6,000 farmers from North Cotabato in Mindanao took to the streets of Kidapawan City to demand government support for El Niño-related impacts, claiming that they had been largely ignored by the central government. Police forces were present to keep peace, but tensions escalated into a full clash between police and the protestors. It ended in a bloody confrontation and violent dispersal (Rio 2016b). The event sparked an online campaign among netizens, with many Filipinos using the hashtag #bigashindibala, which means "rice, not bullets" (Manila Today Staff 2016). Prior to this clash, the sentiments of farmers would have been covered only by international organizations such as IRRI and WFP, which would carry El Niño reports from the perspective of affected communities. National news agencies would typically cover only the government stance on preparedness but not necessarily actual on-the-ground impacts.

Table 5 Other sectors and their contributions to the El Niño discourse

Sector	Sources	Themes
NGOs and humanitarian organizations	EcoWaste Coalition Environmental Science for Social Change (ESSC) Greenpeace International Greenpeace Philippines Oxfam Peace Direct World Vision	• Agricultural impacts of El Niño • Water and energy conservation • Climate-induced conflict • Concerns about food security/scarcity • El Niño's impacts on hunger and nutrition • Action steps needed against deforestation (in line with water resource management) • Effective governance • Need for proper funds allocation • Need for reliable weather information
Academic and scientific communities	Commonwealth Scientific and Industrial Research Organization (CSIRO) Environmental Science for Social Change (ESSC) National Oceanic and Atmospheric Administration (NOAA) Project NOAH Tambuyog Development Center Xavier University	• Comparisons to previous El Niño events (especially 1997–1998 and 2009–2010) • 2015–2016 El Niño is strongest in history • Science behind El Niño • El Niño warnings and alerts • Need for humanitarian response • Need for a comprehensive approach to preparedness • Need for further research on El Niño's effects
Legislators	Senator Loren Legarda Senator Francis Pangilinan	• Need for proper funds allocation • Water conservation • Effective governance • Declaration of a state of calamity
The Catholic Church	Bishop Roderick Pabillo Catholic Bishops' Conference of the Philippines (CBCP)	• Effective governance • Drought/dry spell • Prayer for rain • Mindanao as hardest hit region

International organizations also contributed to the discourse by providing technical information about the event. In many instances, the voices of international organizations were also presented as a validation of information from the government. Two main contributors of technical information were WMO, on which PAGASA bases a significant amount of its advisories, and the Laguna Province-based International Rice Research Institute (IRRI), which has historically provided many of the technical strategies, scientific breakthroughs, and agricultural innovations that have enabled farmers to overcome El Niño-related crop losses. Most significantly, the public relies on information coming from these organizations to be able to make sense of an event, the complexities of which can be quite confusing for the average person. On the first of April 2016, WMO identified the 2015–2016 El Niño event as the strongest in history (IFRC 2016), which represented an important turning point in the Philippine discourse as it placed El Niño at the forefront of the public agenda.

According to FAO's Claudius Gabinete, some international organizations have a pro-farmer bias because farmers are often at the receiving end of El Niño's impacts. He goes on to say:

> When we talk about El Niño, it would mean less water, less rainfall. Less rainfall means less irrigation water. And if you have less irrigation water, you cannot plant. [Even] if you are able to plant, it will not grow that much. Even if you harvest, you will harvest less — if at all. So, for us [in FAO], El Niño is drought, dry spell, no water, no crops, low production. If you have low production, you have a problem of food insecurity. If you are food insecure, the government will try to provide some relief. That is why we always look at how best we can mitigate the impact of El Niño in agriculture.

There were also other voices, coming from various sectors at the peripheries of El Niño discourse. These included NGOs and humanitarian groups, academic and scientific communities, some legislators, and even the Catholic Church.

NGOs and humanitarian groups were instrumental in offering alternative voices in the discourse on El Niño. Many issues that seemed to be ignored, or perhaps simply left uncommunicated by the government, were raised by these groups. Apart from calling for effective governance and allocation of government funds to El Niño mitigation measures, NGOs and humanitarian groups also expressed the need to address other peripheral issues such as hunger, nutrition, and deforestation (Gray-Bloc 2015), as well as the need for PAGASA to provide reliable weather information. These groups had a very loud voice in the days following the Kidapawan incident. They demanded accountability from no less than incoming President Duterte. Understandably, humanitarian organizations such as Oxfam and World Vision also expressed the need for greater humanitarian involvement in El Niño-affected areas (World Vision 2016). Despite their calls for action, however, the Philippine government did not ask for assistance from humanitarian organizations with regard to response to El Niño impacts.

Other important voices in the discourse came from academic and scientific communities. These groups provided detailed, often comprehensive information regarding the science of El Niño, which complemented the simple messaging by PAGASA in its public advisories. Articles provided the sufficient technical and scientific background necessary for a more comprehensive understanding of El Niño. While the messaging was not meant for general audiences, these communities nonetheless provided meaningful contributions to the discourse, especially for those who took a deeper interest in such information. They were also instrumental in providing lucid comparisons between the 2015–2016 and past El Niño events.

Finally, the Catholic Church contributed to the discourse by offering a prayer for rain. The Catholic Bishops' Conference (CBCP) of the Philippines, for example, appealed to the public that, in light of the ongoing El Niño, prayers were needed to help affected communities survive drought. In fact, the CBCP recommended the public to use a specific prayer: the *Oratio Imperata* (Latin for "obligatory prayer"), which is often used by Catholics when praying for a special intention (GMA News 2016). The Church and one of the bishops also appealed for better governance in light of the event, particularly calling on leaders to pay special attention to those affected in the Mindanao region (Torres 2015).

16 Conflicting Voices

Warning of the forming El Niño event was one of the most recognizable themes that cut across all sectors. Warnings came from scientists and meteorologists of PAGASA, from the international scientific community, from leaders of environmental NGOs, from some legislators and local government and community leaders, as well as from the Philippine national government. This comprehensiveness indicates the dominant sense of urgency in the Philippines to address the impacts of El Niño. The demand for more effective and judicious use of public funds earmarked for El Niño mitigation activities was another theme that seemed to resonate across these diverse voices.

The sociopolitical landscape in the Philippines is muddled with so much controversy and allegations of corruption that the appropriate use of public funds is something that many actors—especially those outside the government—monitor carefully. During the 2015–2016 event, the government attempted to ensure full transparency by providing frequent updates on how and where money was being spent. NEDA was the principal agency tasked with overseeing the appropriate allocation of funds.

A third cross-cutting theme found to be consistent among all groups was discourse on the conservation of both water and energy. Various government agencies and non-government organizations recognized that El Niño provided an opportunity to bring conservation issues forward within the public agenda.

A number of issues where there seemed to be some conflicts between different points-of-view were also identified. Discussions on effective governance as a crucial factor in preparing for the El Niño was specifically undertaken by both government (from the President down to line agencies) and non-government groups (e.g. NGOs, farmers, and academic communities). While the government publicly declared its readiness and capacity to address the needs of communities affected by El Niño, others argued that the government's response left much to be desired.

Furthermore, there were several allegations of corrupt government dealings within El Niño mitigation practices. For instance, in September 2014 NGOs and farmers' associations questioned the practice by local DA representatives of collecting "irrigation fees," despite large budgets given to the National Irrigation Authority (Dalangin-Fernandez 2014).

Opposing viewpoints were also prevalent with regard to the use of localized approaches for addressing El Niño, especially at the *barangay* level. While national discourse was often concerned with macroeconomic policy having to do with imports and price freezes, the discourse of farmers' associations and NGOs at the community level had more to do with mitigative and response efforts at that level (Peregrina 2015).

Farmers even asserted that, in lieu of government support, there should be more localized or indigenous approaches, such as controlled irrigation and local knowledge of drought-resistant crops, for addressing the impacts of El Niño (Inquirer Central Luzon 2014). They claimed that government should focus on providing support for such local methods and indigenous knowledges before introducing new, often costly water-saving technologies or farming innovations.

Finally, there also appears to have been some conflict in the discourse between humanitarian organizations and the national government with regard to the need for humanitarian assistance. While the government publicly declared its readiness, humanitarian groups like Oxfam feared that the government might manage only what World Vision (2016) called "inadequate response" if it did not seek the involvement of humanitarian organizations.

17 Concluding Comments

The findings of this study reveal that the Philippine government remained the most dominant voice in El Niño discourse during the 2015–2016 event. This means that the onus remains on the government to lead information campaigns, mobilize institutions, and educate and prepare communities for the foreseeable impacts of future events. Online media also asserted its relevance, as it continued to be the space for alternative voices that contributed to more balanced and comprehensive coverage of the multiple perspectives that surround public understanding and appreciation of events like El Niño.

The data support the idea that readiness in the Philippine context revolved around the physical reality that agriculture and agricultural production were and continue to be the top concern on all fronts. A close reading of all the articles gathered for this chapter supports the proposition that the government was in fact as ready as it could be and that appropriate measures were in place. There also appeared to be general agreement among all sectors with the idea that El Niño is as much about effective governance as it is about the mitigation of impacts.

The previous recent El Niño events affecting the Philippines, 1997–1998 and 2009–2010, provided important lessons, which enabled the country to better prepare for future events like the strong event of 2015–2016. The following are six key lessons identified from previous events:

1. The occurrence of El Niño's formation can be predicted months in advance.
2. Appropriate preparations can be made.
3. Coordinated actions from different government agencies can be effectively carried out.
4. Adverse economic impacts can be minimized.

5. Scientific institutions like PAGASA can help implement early warning strategies so appropriate actions can be taken to prevent major economic losses from disaster events.
6. Communities can be capacitated to help mitigate, if not prevent entirely, climate disasters. They can also assist institutions like PAGASA to monitor for such events.

Finally, protest incidents such as the clash in Kidapawan, whether politically motivated or not, must not be ignored. The fact that farmers had (and continue to have) clear sentiments toward the delivery of government assistance exposed a disconnect between what government claimed and what communities actually experienced. By understanding what readiness means across levels from the institutional down to the grassroots, governments can develop realistic, sustainable programs to genuinely support communities in times of foreseeable weather, climate, and water disasters (Lara 2016).

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Myanmar

Managing the El Niño Risk Together: Report on the El Niño 2015–2016 Outlook Forum and Stakeholder Consultation in Myanmar

Atiq Kainan Ahmed and Senaka Basnayake

Abstract Management of El Niño risk often depends on a host of issues including early detection and warning of the phenomena, interpretation of its impacts (on the sectors and regions), and more importantly having a consultative development of risk management actions that can be conceived through timely dialogue among the key stakeholders. Reflecting these issues, Asian Disaster Preparedness Center (ADPC) in collaboration with the Department of Meteorology and Hydrology (DMH) have rolled out stakeholder consultations in Myanmar and a few other countries in the Asia-Pacific region for building readiness and resilience towards El Niño risks. This paper uniquely shows how these consultations have grown useful understanding of the El Niño Outlooks in year 2015–2016 and how the Outlook Forum enabled sectors and stakeholders to integrate those El Niño outlooks into their sectoral operations and management of the risks. This paper provides a very practical instance of integration of science products into anticipated practices and formulate policy recommendations in a dynamic way to manage the El Niño risk 'together' rather than in isolations. A strategy that can be pursued in future as well.

Keywords El Niño · Disaster risk reduction · Climate risk management · Myanmar

Editor's Note: The following chapter is a report of a Myanmar workshop convened in mid-February 2016 in the midst of the 2015–16 El Niño. Myanmar was impacted during the 2015–2016 event along with other countries in Southeast Asia. The February 2016 workshop was collaboratively organized by the Myanmar Department of Meteorology and Hydrology (DMH) and the Asian Disaster Preparedness Center (ADPC), with financial support from Norway's Ministry of Foreign Affairs (MOFA-Norway). The forum brought together stakeholders from the various socioeconomic sectors in Myanmar likely to be impacted by El Niño. It provides a glimpse of real-time discussion about tactical coping possibilities for the expected impacts of the 2015–16 event.

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1 Introduction

El Niño is a natural phenomenon that occurs at irregular periodic intervals ranging from three to seven years and resulting in extreme drought conditions in several parts of the world, particularly in Africa, Indonesia, and northern Australia. It originates in the eastern and central Pacific Ocean, where anomalous sea surface temperatures (SSTs) disturb cold water upwelling off the coasts of Peru and Ecuador and weaken the easterly trade winds over the tropical ocean. El Niño events often last for over a calendar year, starting in April/May and peaking around December before decaying in the first half of the following year. As a result of this oceanic phenomenon, extreme heavy precipitation events are observed over Peru and adjacent countries. El Niño, as a slow-onset event with wide-ranging impacts, is now regarded as a key disaster risk management-related concern in countries across the globe, including in the Asia–Pacific region where the Asian Disaster Preparedness Center (ADPC) operates.

Given observation of indicative characteristics as well as increased levels of global and regional predictions of the onset of an El Niño event in 2015, the Department of Meteorology and Hydrology (DMH) under the Ministry of Transport, in collaboration with ADPC, organized an El Niño Outlook Forum in Myanmar to discuss the impact outlook for the country in 2016 (Table 1).

The forum aimed for a wide sharing of knowledge, dialogue, and interaction to help participants understand adverse impacts and early actions on the ground as higher levels of information and knowledge was produced about the El Niño phenomenon, which was already forming when the workshop convened. It was thought that this workshop model would help concerned authorities and stakeholders to make informed decisions in order to better predict, monitor, and manage impacts in Myanmar. ADPC's specialized technical professionals from the Climate Change and Climate Risk Management (CCCRM) Department now known as Climate Resilience (CLR) Department provide technical support to DMH and other sectoral departments to generate dialogue and share knowledge for action. This El Niño Outlook Forum was organized on 16 February 2016 in Nay Pyi Taw, the capital of Myanmar, where the involvement of key sectors and multi-agency stakeholders would be assured.

The event was organized as part of an ongoing regional project on "Strengthening weather and climate services of Myanmar, Bangladesh, and Vietnam to deal with hydrometeorological hazards," a project supported by the Ministry of Foreign Affairs of the Royal Norwegian Government (MOFA-Norway) and implemented by ADPC's Climate team through a technical collaboration with the MET-Norway.

2 The Global El Niño Situation in Early 2016

Beginning in 2014, global and regional centers predicted that the developing El Niño of 2015–2016 could become one of the strongest on record. We are now observing the impacts globally with increased risk to extreme weather and adverse effects on

Table 1 Workshop topics for discussion

Opening ceremony • Opening Remarks from DMH and ADPC
Global and regional El Niño Outlooks
Seasonal outlook for Myanmar
Q&A and discussions on the initial presentations
El Niño 2015–2016: Global and Regional Impacts and Preparedness
Possible impacts of El Niño on Agriculture sector
Possible impacts of El Niño on Water Resources sector • Water resources • Irritation • Water utilization
Possible impacts of El Niño on Energy sector
Possible impacts of El Niño on Health sector • Public health and Epidemiology • Health Services
Q&A and discussions on the sectoral presentations
Group discussions on possible risk management measures: (a) Agriculture; (b) Water Resources, irrigation and utilization; (c) Public health; and (d) Energy
Plenary Discussions • Group presentations and Q&A • Discussions and Feedback consolidation
Way forward and closing

vulnerable peoples in Asia, Africa, the South Pacific, and Central America. Just prior to the 11 February 2016 Myanmar El Niño Forum, for example, the global ENSO diagnostic discussion—issued jointly by the NOAA Climate Prediction Center (CPC) and the International Research Institute (IRI)—indicated that the El Niño had already produced significant global impacts (Fig. 1). As expected, the event had already contributed significantly to seasonal climate anomalies across the globe.

These anomalous fluctuations often had social and economic implications for human populations and the environment. At the same time, NOAA (2015) and IRI (2015) also forecasted that the El Niño would soon weaken, transitioning to ENSO-neutral conditions during the late spring or early summer of 2016. Thereafter, the chance of a subsequent La Niña event forming would increase into the fall, though considerable uncertainty about such a shift remained, even though modeling, history, and physical indicators all supported the tendency for La Niña conditions to eventually follow on from a strong El Niño event.

The Oceanic Niño Index (ONI) is used as one measure of the El Niño-Southern Oscillation (ENSO). Other indices can confirm whether features consistent with a coupled oceanic-atmospheric phenomenon accompany these anomalous SSTs in the

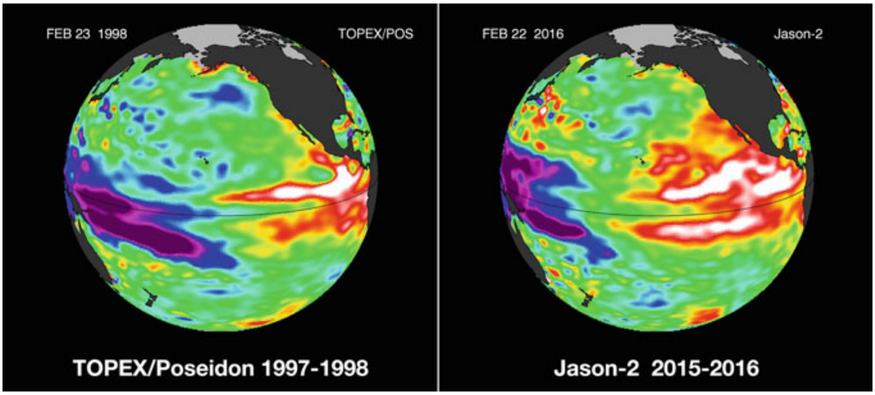

Fig. 1 Sea surface height (SSH) compared between 1997–98 and 2015–16 El Niño events. During an El Niño, westward flowing winds that "pushed" the ocean water toward Asia relaxed allowing the buildup of warm SSTs to shift toward the central and eastern equatorial pacific. As a result, sea level in the western pacific drops, while the level in the eastern pacific rises by 10's of centimeters (NASA/JPL-Caltech 2016)

central Pacific region called Niño 3.4. A portion of the ONI time series is shown in Table 2. It indicates the historical episodes of El Niño and La Niña (1990-2016). The red text indicates El Niño episodes; the blue indicates La Niña months and years.

3 A Brief History of El Niño in Myanmar

Although Myanmar has been known to be vulnerable to El Niño-related impacts for decades, little evidence exists to understand more deeply the level of impacts of past El Niño events. It is evident, however, that many parts of Myanmar have been vulnerable to slow-onset hydrometeorological hazards (such as drought conditions) during past El Niño years. Such conditions had a strong impact on water resources, agriculture, and health. Only scattered evidence exists for the most recent El Niño events in 1982–83, 1997–98, and 2009–10.

The World Meteorological Organization (WMO 2015) noted in an outlook issued in November 2015 that El Niño and La Niña are not the only factors that drive global climate patterns, and that at the regional level especially seasonal outlooks need to assess the relative impacts of both the El Niño/La Niña state and other locally relevant climate drivers. Examples of these other drivers include the Indian Ocean Dipole (IOD), the Madden–Julian Oscillation (MJO), the North Atlantic Oscillation (NAO), etc. Regionally and locally usable information on each of these various factors is available from WMO Regional Climate Centers (RCCs), Regional Climate Outlook Forums (RCOFs), and National Meteorological and Hydrological Services (NMHSs).

Table 2 ONI 3-month running mean indices as of NDJ (Nov-Dec-Jan) (NOAA/CPC 2016). [NB: At this Forum only the DJF (2016) value was available. The editor added + highlighted values for JFM to JJA]

Year	DJF	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	NDJ
1990	0.1	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.4	0.3	0.4	0.4
1991	0.4	0.3	0.2	0.2	0.4	**0.6**	**0.7**	**0.7**	**0.7**	**0.8**	**1.2**	**1.4**
1992	**1.6**	**1.5**	**1.4**	**1.2**	**1.0**	**0.8**	**0.5**	0.2	0	−0.1	−0.1	0
1993	0.2	0.3	0.5	0.7	0.8	0.6	0.3	0.2	0.2	0.2	0.1	0.1
1994	0.1	0.1	0.2	0.3	0.4	0.4	0.4	0.4	0.4	**0.6**	**0.9**	**1.0**
1995	**0.9**	**0.7**	**0.5**	0.3	0.2	0	−0.2	**−0.5**	**−0.7**	**−0.9**	**−1.0**	**−0.9**
1996	**−0.9**	**−0.7**	**−0.6**	−0.4	−0.2	−0.2	−0.2	−0.3	−0.3	−0.4	−0.4	−0.5
1997	−0.5	−0.4	−0.2	0.1	**0.6**	**1.0**	**1.4**	**1.7**	**2.0**	**2.2**	**2.3**	**2.3**
1998	**2.1**	**1.8**	**1.4**	**1.0**	**0.5**	−0.1	**−0.7**	**−1.0**	**−1.2**	**−1.2**	**−1.3**	**−1.4**
1999	**−1.4**	**−1.2**	**−1.0**	**−0.9**	**−0.9**	**−1.0**	**−1.0**	**−1.0**	**−1.1**	**−1.2**	**−1.4**	**−1.6**
2000	**−1.6**	**−1.4**	**−1.1**	**−0.9**	**−0.7**	**−0.7**	**−0.6**	**−0.5**	**−0.6**	**−0.7**	**−0.8**	**−0.8**
2001	**−0.7**	**−0.6**	**−0.5**	−0.3	−0.2	−0.1	0	−0.1	−0.1	−0.2	−0.3	−0.3
2002	−0.2	−0.1	0.1	0.2	0.4	**0.7**	**0.8**	**0.9**	**1.0**	**1.2**	**1.3**	**1.1**
2003	**0.9**	**0.6**	0.4	0	−0.2	−0.1	0.1	0.2	0.3	0.4	0.4	0.4
2004	0.3	0.2	0.1	0.1	0.2	0.3	**0.5**	**0.7**	**0.7**	**0.7**	**0.7**	**0.7**
2005	**0.6**	**0.6**	**0.5**	**0.5**	0.4	0.2	0.1	0	0	−0.1	−0.4	−0.7
2006	−0.7	−0.6	−0.4	−0.2	0.0	0.1	0.2	0.3	**0.5**	**0.8**	**0.9**	**1.0**
2007	**0.7**	0.3	0	−0.1	−0.2	−0.2	−0.3	**−0.6**	**−0.8**	**−1.1**	**−1.2**	**−1.3**
2008	**−1.4**	**−1.3**	**−1.1**	**−0.9**	**−0.7**	**−0.5**	−0.3	−0.2	−0.2	−0.3	−0.5	−0.7
2009	−0.8	−0.7	−0.4	−0.1	0.2	0.4	**0.5**	**0.6**	**0.7**	**1.0**	**1.2**	**1.3**
2010	**1.3**	**1.1**	**0.8**	**0.5**	0	−0.4	**−0.8**	**−1.1**	**−1.3**	**−1.4**	**−1.3**	**−1.4**
2011	**−1.3**	**−1.1**	**−0.8**	**−0.6**	−0.3	−0.2	−0.3	**−0.5**	**−0.7**	**−0.9**	**−0.9**	**−0.8**
2012	**−0.7**	**−0.6**	**−0.5**	−0.4	−0.3	−0.1	0.1	0.3	0.4	0.4	0.2	−0.2
2013	−0.4	−0.5	−0.3	−0.2	−0.2	−0.2	−0.2	−0.2	−0.2	−0.2	−0.2	−0.3
2014	−0.5	−0.6	−0.4	−0.2	0	0	0	0	0.2	0.4	0.6	0.6
2015	0.5	0.4	**0.5**	**0.7**	**0.9**	**1.0**	**1.2**	**1.5**	**1.8**	**2.1**	**2.2**	**2.3**
2016	**2.2**	**2.2***	**1.7***	**1.0***	**0.5***	**0***	**−0.3***					

This ENSO context has a rippling impact on food security, especially impacting the conditions that often decrease crop production in various parts of Myanmar. Since a strong signal of impacts arises in the country during El Niño years, the Department of Meteorology and Hydrology and other relevant sectoral departments have held discussions and other forums on a regular basis in order to acquire further knowledge and information (see also UNESCAP 2016). They have facilitated such events for sector-specific policymakers, planners, researchers, academics, etc. These discussions and forums have been critical both for disseminating El Niño-related information and outlooks months ahead of time and for discussing possible adaptive measures to minimize expected and foreseeable risks.

In Myanmar, the Department of Meteorology and Hydrology (DMH) has responsibility for providing to the public and other concerned stakeholders relevant information, forecast products, alerts, and warnings of the likelihood of hydrometeorological hazards.

4 The 2016 El Niño Outlook Forum (ENOF)

The 2016 El Niño Outlook Forum (ENOF) in Myanmar aimed at the wider sharing of knowledge, at encouraging forecaster-user dialogue, and at discussing early action and risk management measures. ENOF's objective was to bring together relevant stakeholders to discuss the local El Niño outlook, to share knowledge, and to discuss possible impact and adaptation measures for relevant socioeconomic sectors like Agriculture, Water Resources, Health, and Energy.

Opening ceremony. The forum was opened by the then Director General of the Department of Meteorology and Hydrology (DMH) in Myanmar. DMH Director General noted that the Department of Meteorology and Hydrology is responsible for providing to the public and concerned agencies relevant information, forecast products, alerts, and warnings on the likelihood of meteorological phenomenon. These products are meant to enable proactive measures for sector-specific planning to minimize negative impacts, and so, the Director General stated, the 2016 ENOF would help all participants and their respective agencies to prepare with more information and knowledge about the ongoing El Niño event.

The Director General also mentioned that climate-sensitive sectors would present their related activities, highlighting how to minimize the anticipated adverse impacts of the event on their respective sectors. DMH representative thanked ADPC and all distinguished participants for sparing their valuable time to share their knowledge and to discuss possible impacts and adaptation measures for all climate sensitive sectors. Representatives from ADPC highlighted that this forum could bring more information and analysis to support policymakers in formulating strategic plans to manage the risks and impacts of El Niño events in the country.

Technical session on past El Niños and the current situation, and predictions for the future. The forum convened participants from various sections of DMH, all the key sectoral departments in Myanmar, journalists, international organizations, and technical experts from ADPC. Dr Senaka Basnayake from ADPC shared and discussed global and regional predictions. Some of the available predictions from early February onward were presented by Mr Hla Tun of DMH's forecast division then shared the seasonal outlooks for the country (DMH 2016). Finally, Mr Atiq Kainan Ahmed, Senior Program Manager of ADPC, illustrated the anticipated regional impacts and preparedness issues for the 2015–16 El Niño.

Participants went on to discuss the characteristics of the six El Niño events that had formed since 1980 as documented by the International Research Institute (IRI) (these events were in 1982–83, 1986–87, 1991–92, 1997–98, 2002–03, and 2009–10). Each event had impacts in Myanmar. Among these, the 1986–87 and 1997–98 events were especially notable for having had significant impacts in terms of increased temperatures and changes in precipitation patterns. Furthermore, during the 2010 El Niño high temperatures were recorded at 25 stations, most of which were located in the central areas of Myanmar. Until that time, the highest maximum temperature ever recorded in Myanmar was 47.2 °C at Minmu, Sagaing Region in May 2010.

Several international centers and institutes reported that El Niño began strengthening after August 2015 and that it continued to strengthen into early 2016. Knowing well the impact of El Niño, concerned authorities instructed relevant ministries to take preparedness measures to manage foreseeable impacts of this emerging, very strong El Niño. In September 2015, DMH submitted a report that included details about the strengthening event. These details included expected weather patterns during the months of October, November, and December (2015), and their possible impacts on the agriculture, water resource, and health sectors. This DMH report was issued in a local newspaper as well. Then, on 26 January 2016, DMH updated both the El Niño Report (for Feb-April 2016) and the weather forecast for the coming summer period, adding an advisory for at-risk sectors. The Ministry of Agriculture and Irrigation also issued advisories for farmers, and the Ministry of Health issued one for the general public on how to manage the impacts of El Niño. These measures demonstrated the government's concerns in responding to the impacts of El Niño.

Sectoral presentations. A number of presentations on impacts on water resources, agriculture, energy, health, and other sectors were made by the respective government agencies. Each discussed their points of view and the actions they were taking on the ground. Several presentations were made to inform the forum about the El Niño phenomenon, its current forecasts, and its foreseeable impacts. About sixty participants attended the event, representing various government agencies, media outlets, international organizations, and other stakeholders. The national media also published news of the ENOF forum after the event. Participants also highlighted the need for organizing subsequent El Niño forums with the involvement of relevant sectoral agencies, including agriculture, fisheries, forestry, services, and trade.

Break-out group discussions and plenary. During the second half of the ENOF forum, a facilitated group activity was conducted using the results of key working groups. The group discussions identified impacts and possible risk management measures by the respective broader socioeconomic sectors for both short- and long-time horizons. The following four breakout groups (Table 3) were formed: (a) agriculture; (b) water resources, irrigation, and utilization; (c) public health; and (d) energy. Some of the discussions and findings from this group work are outlined in the tables.

Table 3 Discussion and finds of the breakout groups

Impact on the sector	Short-term risk management measures	Long-term risk management measures
Sector: Agriculture		
(a) Reduce agricultural areas (50 percent)	• Change to drought resilient short-term variety (Aerobic Rice) (100 Days)	• Climate-sensitive land use planning • Development of Irrigation systems
(b) Reduced crop production(major crops)	• Substitute other suitable crops (e.g. Sesame, Green Gram) • WD (Alternate wetting and drying) • CRH (Carbonized Rice Husk, Biochar)	• Development of a seed industry
(c) Failure of crops (especially upland, and summer rice and oil crops)	• Resistant variety to biotic and abiotic stresses (e.g. Green Gram, Yezin 14)	• Use advanced technology and infrastructure
(d) Poverty (Household income)	• Crop insurance • Market control	• Income-generating activities (e.g. upgrading traditional careers)
Sector: Health		
Impact 1: Increase in morbidity and mortality of communicable diseases (Vector-borne diseases: Malaria, Dengue Hemorrhagic Fever, Zika; Rodent borne diseases—Plague; Water borne diseases—cholera, etc.)	• Increase surveillance • Immediate logistics management HR, other logistics, budget management • Strengthen existing cooperation mechanism among sectors	• Continue above activities • Prioritize health problems related to El Niño and La Niña • Research communicable disease vs. climate change • Sector-wide coordination and cooperation, including international cooperation
Impact 2: Disaster- related health problems (communicable and non-communicable diseases)	• Disaster risk reduction (DRR) • HE on disaster-related health problems • Logistics management • Cooperation among sectors	• Continue above activities Prioritize high risk areas and management • National and International cooperation • Disaster resistant communities and health services
Impact 3: Public health infrastructure (buildings, equipment, human resources)	• Risk communication • Evacuation plan • Readiness and activation of contingency plan	• Mainstreaming DRR into health sector • Climate change and variability • Regional and national multi-sectoral management body to reduce health impacts of El Niño and climate change

(continued)

Table 3 (continued)

Impact on the sector	Short-term risk management measures	Long-term risk management measures
Sector: Water resources, use, and irrigation		
• Agriculture • Hydropower • Domestic • Navigation	• Water harvesting scheme • Irrigation planning and cropping patterns • Optimum operation plan • Alternative water sources • Education and awareness raising • Information sharing and coordination	• Watershed management • Reforestation • Silt detention • Dams/supplementary reservoirs • Rules and regulations for sustainable development • Education and awareness raising
Sector: Energy		
• Fire safety challenges • River transportation difficulties • Raw water and boiler feed water qualities decreasing	• Water saving and stockpiling • Enforcement in fire lighting preparation arrangements • More stocks of chemical firefighting agents	• More water storage/retention facilities and associated infrastructure • Awareness raising about El Niño for management and staff • Alternative transportation, including ways to move petroleum products

5 Way Forward

Forum participants made various critical comments for paving the way forward in Myanmar to manage the risks of El Niño in a more integrated manner (see Table 4).

Table 4 A reflection from the participants on recommended priorities for managing El Niño 2015–16 and bottlenecks in implementing such actions

No	ENOF Participants recommended priority actions for managing El Niño 2015/2016 in Myanmar	Bottlenecks and barriers in implementing priority actions
1	To control global warming	Coordination
2	Action plan for various sector and community awareness programmes	Coordination and cooperation among agencies
3	Inventory and assessment of all existing and potential sources of water supply	Cooperation and collaboration
4	Agriculture	Coping capacity
5	Specific impact assessment	Limited awareness system
6	Action plan for fire	Contingency-detailed drill to community / Decision making for rescue plan
7	Enhanced EWS and climate information	Technical assistance
8	Select the zone (AEZ) and crops (suitable)	Good infrastructure and the understanding /Follow-up training
9	Water harvesting scheme	Proper design for structure measures
10	Reforesting (Nurse green land)	Low level of knowledge and education
11	Prepare the El Niño adaptation activities	Need to know the useful information everyone
12	Fire safety preparation enhancing	At El Niño time high surrounding temperature and water shortage occur, therefore water stock may be insufficient
13	Forest conservation and management	Budget allotment
14	Selecting suitable crop for agriculture, livelihood (for local people do not know well)	Technical support / Seeds availability and market
15	Necessary to manage for preventing water shortage	Technology and awareness (make use of water)
16	Drought-resilient crop variety, change cropping pattern, information on climate	Sort policy, long term planning
17	To establish forest plantations	Less staffs for conservation
18	Emerging and reemerging communicable diseases related to El Niño	HR management and technical support
19	Specific impact assessment	Weak awareness system
20	Specific impact assessment	Weak awareness system

For example, participants mentioned that this type of forum is particularly critical for understanding complex phenomena such as El Niño. They also noted that there is a great need for increasing technical knowledge regarding this issue in each of the following sectors: (a) agriculture; (b) water resources, irrigation, and utilization; (c) public health; and (d) energy.

- Particularly in the current season (early 2016) and future months, it is critical that issues relating to ENSO in general and more specifically El Niño are discussed regularly among the various stakeholders in Myanmar. DMH can play a key role in starting this process.
- Particularly when the forecasts of an event's possible onset are triggered and a clear trend is predicted, forecast information should immediately be communicated and the participation of the respective sectors and stakeholders systematically initiated. Multi-stakeholder engagement is critical for reducing El Niño impacts.
- El Niño forums, such as this one, should be organized by the respective climate-sensitive sectors. DMH and ADPC could also participate. Stakeholders could share knowledge and information for improved understanding and risk management.
- DMH in collaboration with international and regional climate prediction centers and WMO should develop additional analyses of the ENSO quasi-periodic phenomenon in order to identify more reliable information on monitoring the observations and impacts at national and sub-national scales.
- Each climate-sensitive sector must continue on with this forum's initial discussions within their own sector and hold serious discussions among the sector's officials and decision makers.
- For reducing El Niño-induced risks, all sectors should develop their own immediate as well as long-term strategies to prepare for future events. Immediate, tactical actions for risk management were essential for El Niño 2015–16 but could also be useful for future long-term strategies.
- Unbundling the impacts of the El Niño phenomenon for Myanmar and its respective climate-sensitive sectors is urgently needed for devising future risk management plans.
- Numerous education and awareness campaigns should be carried out targeting the general public, professionals (especially in socioeconomic sectors), the media, and government representatives in at-risk regions of Myanmar.
- Media should play an active role and maintain close contact with DMH and the sectoral departments for creating awareness of developing El Niño events. It can play a dual role in disseminating forecast products to wider communities and in increasing mass awareness and education about El Niño impacts.
- DMH capacity is increasing gradually but further strengthening of its capacity for seasonal forecasting needs to be a priority in the modernization of Myanmar's NMHS.
- Future analyses and research relating to El Niño and to seasonal forecast-related factors should be a priority.

- Further enhancement and increasing numbers of in-country, "hands-on" trainings for professionals and managers is needed. Departments and professionals across disciplines (i.e., physical sciences, social sciences, humanities, etc.) need to collaborate on this clearly defined need.
- Science policy- and practice-related platforms and collaborative mechanisms in Myanmar should be enhanced. Regional and international centers such as ADPC, among others, can play an important role in this process.

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Timor-Leste

El Niño Readiness: Critical to Addressing Hunger in Timor-Leste

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Abstract Timor-Leste continues to suffer from very high rates of chronic food insecurity and malnutrition despite progress across a range of sectors. This chapter investigates the interlinkages between drought, agriculture and food insecurity in the country. Using the 2015–2016 El Niño as a case study, it illustrates the role of El Niño in amplifying climate risks which significantly contributes to triggering food insecurity. It shows that a critical component of enhancing the country's readiness to mitigate the risks of food insecurity would be to reinforce the modernization process of the country's national meteorological service, the National Directorate of Meteorology and Geophysics (NDMG) to support food security objectives.

Keywords Timor-leste · Food security · Drought · Climate information · Climate services

1 Introduction

The El Niño Southern Oscillation (ENSO) amplifies climate risks in Timor-Leste (Fig. 1), a country where the climate is considered risky even during "normal" years due to high rainfall variability. The 2015–16 drought, as well as droughts in 1997–98, 2002–03, 2004–05, and 2006–07, were all associated with ENSO (UNDP 2013). Characterized by impacts of drought and generally dry conditions, El Niño is implicated in the precarious food security situation of the country (CEPAD and Johns

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Fig. 1 Regional map of Timor-Leste

Hopkins University 2017). The 2015–16 El Niño triggered a protracted food crisis emergency.

All dimensions of food security—availability, access, utilization, and stability—are a concern in Timor-Leste. Globally, the stresses on these dimensions come from both climate and non-climate factors (IPCC 2019). In Timor-Leste, climate-related stresses represent a critical challenge for food security. Food production surplus and crop diversity is low, so even minor climatic disruptions undermine households on a regular basis. Every year, the country experiences a hunger season between November and February during which the previous harvest is consumed before the cultivation of the following year's crops (Twigg 2017), and nearly two-thirds of the population suffer food shortages for at least two months (UNOCHA 2017). This transient food insecurity is triggered by seasonal changes.

According to government figures, over one-third (36 percent) of Timor-Leste's 1.3 million people suffer from chronic food insecurity. The island nation also has one of the highest malnutrition rates in the world. While child stunting is declining, it remains very high (Government of Timor-Leste 2019). Writing on the twentieth year of the UN World Food Programme's (WFP) operations in Timor-Leste, then President Jose Ramos-Horta stated, "In Timor-Leste's 20-year history, we have made significant development progress across a range of sectors, yet we have not seen gains in food and nutrition security consistent with this growth" (WFP 2019).

Addressing high rates of child malnutrition and food insecurity is a priority strategic and tactical issue for the government and development agencies (e.g. NAPA 2010, SDG Implementation Plan). In 2014, the government adopted a National Action Plan for a Hunger and Malnutrition Free Timor-Leste, a ten-year initiative that seeks to achieve 100 percent access to adequate food all year round, zero stunted children less than two years of age, completely sustainable food systems, a 100 percent increase in smallholder productivity and income, and zero loss or waste of food (KONSSANTIL 2014). These targets were later reinforced by the country's commitment to the Sustainable Development Goals (SDGs), which include a dedicated goal (SDG 2) on ending hunger.

Given the crucial role of El Niño in destabilizing the country's agricultural productivity, enhancing Timor-Leste's El Niño readiness could contribute to stabilizing its food availability in all seasons. This chapter will highlight how a critical component of this readiness involves reinforcing the modernization of the country's national meteorological service—the National Directorate of Meteorology and Geophysics (NDMG)—to support its food security objectives.

The first section of the chapter discusses the interlinkages between drought, agriculture, and food insecurity in Timor-Leste. The section that follows further illustrates this nexus in the context of the 2015–16 El Niño event. The final section discusses specific aspects of NDMG modernization that are relevant to supporting Timor-Leste's food security objectives.

2 Drought, Agriculture, and Food Insecurity in Timor-Leste

Timor-Leste's climate is dry, with an average monthly rainfall just above 100 mm during the wet season and less than 30 mm during the dry season (BOM and CSIRO 2011). It is not so much the lack of rainfall, per se, that undermines crop production but the high rainfall variability, including late starts to the rainy seasons, excessive rainfall, or longer than normal rainy seasons. As a coping strategy, farmers have developed systems that can cope with high levels of uncertainty but that also tend to be less productive than other, maximizing systems might be. This risk-averse choice in turn makes it difficult for island farmers to produce any surpluses.

Rural poverty is a significant concern in Timor-Leste and is one of the major drivers of food insecurity. Sixty-nine percent of the total population (World Bank Open Data 2020), and 80 percent of the poor population (Government of Timor-Leste 2019) live in rural areas. This rural population consists primarily of agrarian households whose food security depends largely on their respective abilities to produce food for themselves (Twigg 2017). For these households, food security is the most significant concern. Insecurity within this population persists to this day, however, despite recent economic growth in the country, a result of a complex interplay of socioeconomic, environmental, and climatological factors.

There is a high reliance on agriculture for food and income in Timor-Leste. According to the 2015 census, agriculture provides direct employment to approximately 64 percent of the total active workforce (World Bank 2018), and approximately 75 percent of the total population is dependent on subsistence or near-subsistence agriculture. Figure 2, which indicates the proportion of men working in the agriculture sector, shows that the highest reliance on agricultural incomes are in the municipalities of Oecussi, Cova Lima, Ermera, Ainaro, Aileu, as well as in some parts of Manatuto, Manufahi, Baucau and Lautém.

Many of Timor-Leste's farmers are smallholders with less than two hectares of land, which limits their ability to earn income and produce a surplus. The highest concentration of smallholder farmers is found in Oecussi and Cova Lima, as shown in Fig. 3.

The agricultural system on the island faces many challenges. Only 40 percent of the total land area is suitable for crop production and/or livestock rearing, and

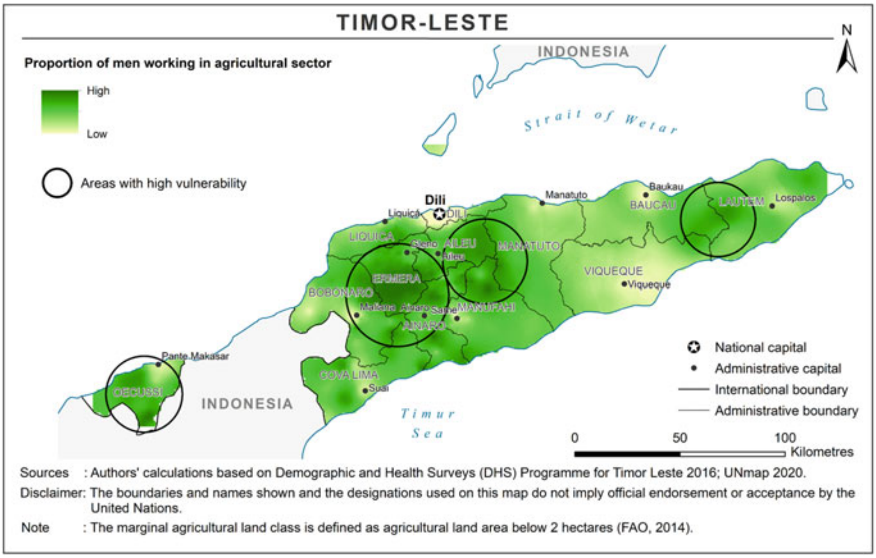

Fig. 2 Proportion of men working in the agriculture sector

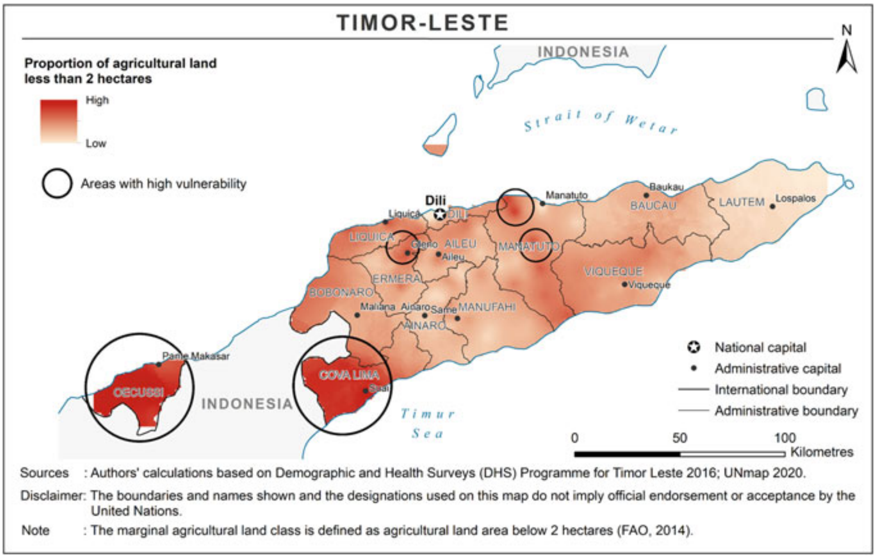

Fig. 3 Farmers who own less than 2 hectares of land

only 80 percent of this fraction of that total is currently being used (Government of Timor-Leste 2019). Agricultural activities consist predominantly of rainfed dryland farming and are characterized by low crop diversity and low productivity. Maize and rice are the main staple foods, but in recent years both staples have had lower yields than other low-income, food-deficient countries tend to average. This situation has led to persistent, and sometimes significant, food shortages.

As a result, the macroeconomy, people's livelihoods, and food security have proven highly vulnerable to changes in rainfall, the variability of which is mainly driven by ENSO and the Indian Ocean Dipole (IOD) on seasonal to interannual scales. During El Niño years, for example, reduced rainfall tens to lead to catastrophic drought conditions. On average, rainfall tends to decrease by ~110 mm from normal levels during those years. Such years also tend to see a later onset and earlier retreat of the wet season (<6 months), with wet season rains also tending to be more concentrated (in February and March). On the other hand, La Niña years are associated with increased rainfall, which has led to topsoil erosion, landslides, and flooding. Due to a longer wet season (9 months) in La Niña years, annual rainfall tends to increase by ~140 mm above the norm (National Directorate of Meteorology and Geophysics of Timor-Leste 2017).

It is important to understand how anthropogenic climate change threatens to exacerbate these various hazards, as a hotter and drier climate will lead to harsher drought conditions. This means that the food system of Timor-Leste, which is already often unable to meet the nutritional needs of the population, will be challenged further as climate conditions continue to change rapidly.

Another significant contributor to food insecurity in Timor-Leste is the lack of infrastructure, especially for irrigation and transport. As of 2018, there were 220,000 hectares of cultivated land in Timor-Leste, but only 25.8 percent of that land was equipped for irrigation. Of that proportion, 98 percent was irrigated from surface water and two percent from ground water (World Bank 2018). The remaining cultivated land area receives water from a combination of water harvesting, soil moisture management, and wetlands.

Essential for ensuring that farmers and consumers have unimpeded access to markets to generate income and secure food supplies, even during droughts and floods, is a road network that is resilient to all weather conditions. Government expenditures on roads has risen sharply in recent years. Now, 89 percent of the rural population lives within two kilometers of an all-season road (Government of Timor-Leste 2019). Within rural areas, however, much of that network remains in poor condition due to both unsuitable engineering and lack of maintenance. A 2015 survey found that only 13 percent of rural roads were rated good, while 30 percent were rated fair, 44 percent were rated poor, and 13 percent were rated bad (World Bank 2019b).

Combined, these several factors explain the high levels of food insecurity across the country. As is observed in many countries, however, food insecurity in Timor-Leste tends to affect different populations unevenly. Children and women of reproductive age are worst affected, as evident in measures of health and nutrition (Government of Timor-Leste 2019). Amongst children, for example, the prevalence of stunting is very high—overall, it is 46 percent, and in some municipalities, as in Ainaro, it can reach as high as 59 percent. Also observed is variation between households of different levels of wealth, although even households in the highest income quintile show quite high rates of stunting, with 36 percent of children in these wealthier households still showing characteristic signs (Government of Timor-Leste 2019). Furthermore, while the dietary intake of women of reproductive age (15–49 years) is mostly improving, the prevalence of undernutrition among this group is again still characterized as very high (27 percent) (Government of Timor-Leste 2019).

Fortunately, in recent years some improvements have been made to childhood nutrition in Timor-Leste. For example, the rate of stunting in children under five decreased from 58 percent in 2009 to 46 percent in 2016 (Government of Timor-Leste 2019). Most of this improvement occurred in urban areas, however; no comparable decline was observed in rural areas. Indeed, levels of food insecurity on the island remain high even in comparison to countries with similar income levels. For example, according to the 2019 Global Hunger Index, a composite measure that considers indicators of undernourishment, child wasting, child stunting, and child mortality, Timor-Leste ranked 110 out of 117 qualifying countries (Concern Worldwide 2019a). As the island's already fragile food system remains particularly vulnerable to the effects of climatic change, any further stress on it will likely have catastrophic consequences for the overall health of the population (Twigg 2017).

The impacts of El Niño events on food security are not inevitable—they can be either strengthened or weakened by the implementation of strategic policies and specific policy instruments, depending on the timeliness and effectiveness of those instruments. The next section illustrates the extent of this choice in the context of the 2015–16 El Niño.

3 The El Niño-Triggered Food Crisis of 2015–16

3.1 El Niño Impacts in Timor-Leste

During the 2015–16 El Niño, and consistent with the historically known impacts of previous events, drought was observed over most of Timor-Leste (Government of Timor-Leste 2019). The three-month Standardized Precipitation Index (SPI-3) shows the extent of the exceptional and extreme drought that occurred during the main cropping season of December to February (Fig. 4). Moderate to severe drought conditions then persisted during the second rainy season, from March to May 2016. Figure 4 also shows the varying extent of drought across the country: moderate drought conditions were recorded in the municipalities of Oecussi, Ainaro, Manatuto, Viqueque, Baucau, and Lautem, while severe and extreme drought conditions were observed in Cova Lima, Bobonaro, Liquiçá, Ermera, Ainaro, Dili, Aileu, Manatuto, Baucau, Manufahi, and Lautem.

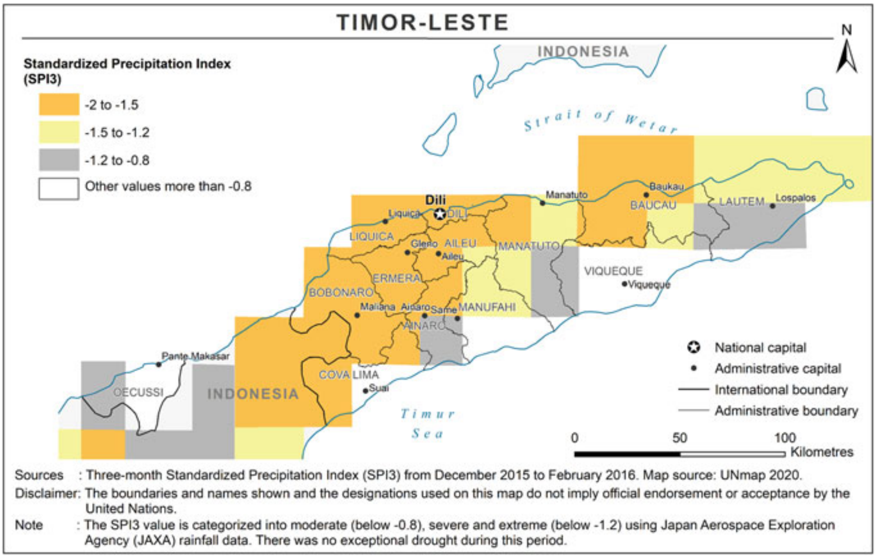

Fig. 4 Drought conditions across Timor-Leste during the 2015–16 El Niño

The vulnerability to drought of the Timorese economy and population became all too obvious during the 2015–16 El Niño. Figure 5 shows how drought affected all major agricultural systems in the country. Overall, approximately 31 percent of land

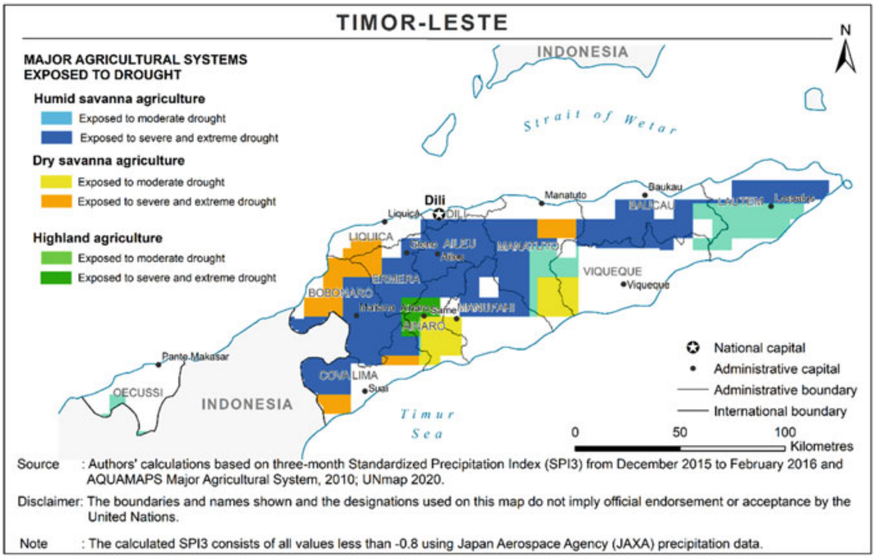

Fig. 5 Exposure of major agricultural systems to drought during 2015–2016

area used for dry savanna agriculture, 50 percent of land used for humid savanna agriculture, and 73 percent of land used for highland agriculture was affected by the drought. Humid savanna agriculture was affected in almost all municipalities (namely Cova Lima, Bobonaro, Liquiçá, Ermera, Ainaro, Manufahi, Manatuto, and Viqueque) and highland agriculture was affected in Ainaro, Ermera, and Cova Lima.

The resulting disruption to agricultural production was extensive, with far-reaching consequences. The estimated 64,000 metric tons of maize and 65,000 metric tons of rice produced in 2015 were, for both staple crops, about 30 percent below the five-year average and well-below the country's estimated requirements of 245,000 metric tons (World Bank 2019a). The government estimated that 78 percent of the population across Baucau, Bobonaro, Cova Lima, Lautem, Oecusse, and Viqueque municipalities were directly affected (UNOCHA 2017; Government of Timor-Leste 2019). Furthermore, numerous humanitarian reports estimated that upwards of 400,000 people—about one-third of the island's total population—needed not only food, water, and sanitation but also health, nutrition, livelihood, and educational support.

The extent of drought impacts on Timor-Leste during the 2015–16 El Niño event was further exacerbated by the high levels of poverty and malnutrition already endemic to the areas that were hit the hardest. Figure 6 characterizes the distribution of poverty across the island, particularly showing how many of the areas with high proportions of men engaged in agriculture work also have low levels of overall wealth. Figure 7 then shows that these same hotspot areas (i.e., Baucau, Cova Lima, Dili, Ermera, Liquiçá, and Viqueque municipalities) bore the brunt of drought conditions in 2015–16.

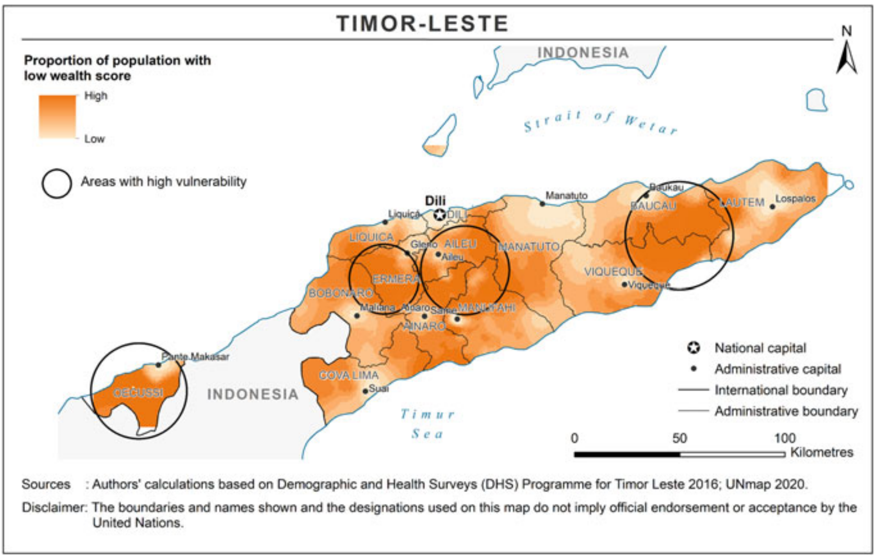

Fig. 6 Proportion of population with a low wealth index based on 2016 surveys

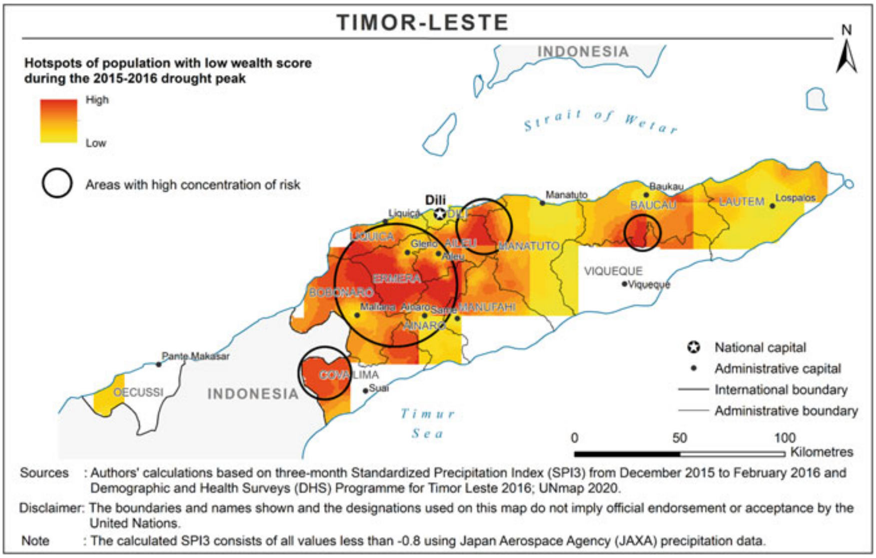

Fig. 7 Hotspots of intersecting poverty and drought conditions during 2015–16

The drought also affected many areas with high levels of malnutrition. Figure 8 shows how the prevalence of malnourishment among children varied across the country. Figure 9 then shows how many of the areas with the highest prevalence of malnutrition experienced drought conditions in 2015–16, with hotspots particularly identified in Baucau, Cova Lima, Bobonaro, and Ainaro municipalities.

Overall, variations in the extent of drought, agricultural exposure, and the underlying vulnerability of the population meant that the impacts of drought were most severe in the eastern and southern parts of the country, particularly along the coastal plains (UNDP 2017). There, harvests were heavily disrupted, and much livestock was lost. For example, production of maize and rice in 2016 fell by 13 and 71 percent, respectively. Furthermore, 48 percent of drought-affected households (around 60,382) reported an animal death, while 21 percent (around 29,050) reported sick animals due to shortages of water and food (FAO 2019). As of March 2016, at least 100,000 people were estimated to have been food insecure, and 70,000 head of livestock had been lost (ACAPS 2017). As 41 percent of the population was living below the poverty line before the onset of the drought, most households were unable to benefit from available support systems such as the limited provision of subsidized food at local markets or to migrate out of the drought-affected areas (Twigg 2017). Households resorted to using negative coping measures such as reducing meal portion sizes and dietary diversity. Many also depleted their household savings.

Further impacts such as water shortages, disruptions to education, and reductions in capacities to generate income were also reported. For example, livestock deaths meant that families were not only unable to till land in preparation for the next

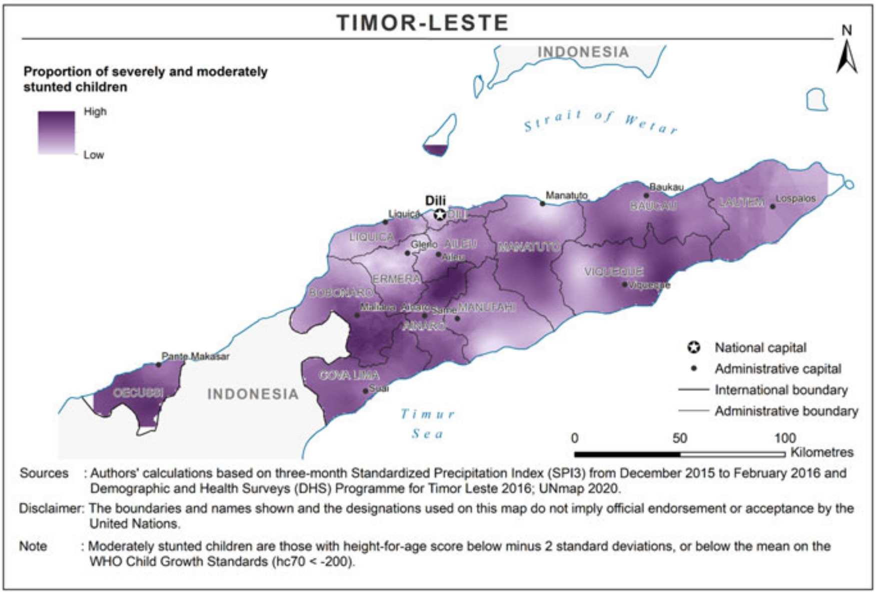

Fig. 8 Proportion of malnourished children based on household level surveys

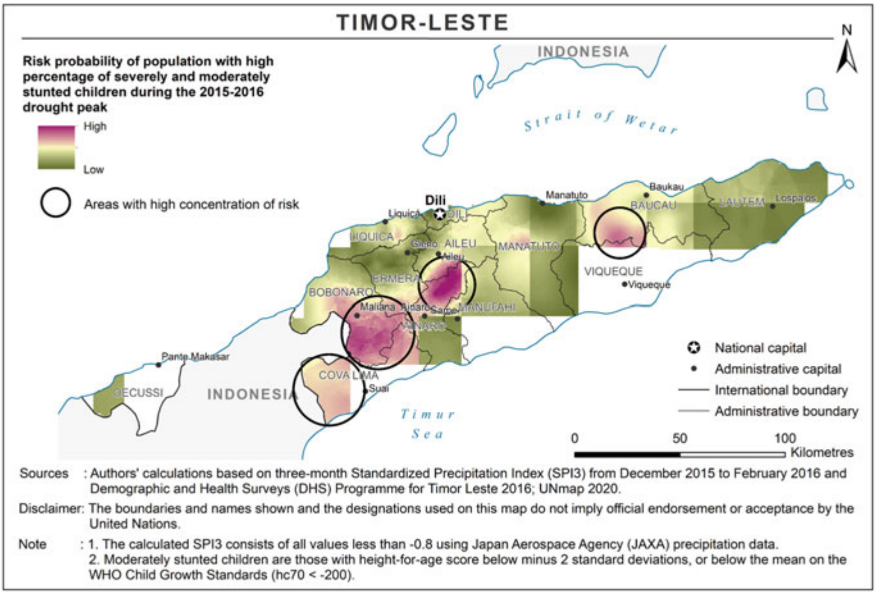

Fig. 9 Hotspots where high levels of severely and moderately stunted children intersected with drought conditions during 2015–16

planting season but also that they lost savings held in that stock that would have been used to send children to school (IFRC 2016).

Beyond these immediate impacts, what must be understood is that drought conditions also interacted with the underlying vulnerability of the food system to create impacts that persisted well after the drought conditions themselves had passed. For example, institutional capacity to cope with increased food insecurity has been undermined by cumulative disruptions to agricultural productivity. This has meant that by 2016, food stocks were completely insufficient—2015 had already seen a shortfall of 129,000 metric tons of cereal (Twigg 2017), and in 2016 the projected cereal production fell to 70,080 metric tons compared to the required 258,000 metric tons, thus creating a total annual shortage of 188,000 metric tons (UN Office of the Resident Coordinator Timor-Leste).

The cumulative impacts of drought are also found at the household level, where continuous monitoring of drought-affected municipalities found that by the latter part of 2016 households were already using coping mechanisms usually reserved for the "hungry season" (November to February). These mechanisms included selling stock and assets, borrowing cash and food, reducing food portions, consuming seed and food from stores for the lean season, and finding new water sources. While they increased access to food in the short term, over the long term these mechanisms likely eroded savings, reduced incomes, and depleted food stores that would have been needed when the hungry season finally did arrive in earnest.

What these more pernicious, cumulative impacts meant in this case was that as the drought subsided with the onset of the rainy season in early 2017, many households continued to struggle. A rapid assessment conducted in late spring 2017 of six drought-affected municipalities indicated that 67 percent of the households in the most affected areas were still experiencing the effects of drought and relying on those coping mechanisms that are typically reserved for the hungry season (IFRC 2017).

3.2 Timing of Impacts and Mitigative Actions Taken

El Niño conditions impacted the onset of the main rainy season in both 2014–15 and 2015–16. Despite lack of evidence of a coupling between higher sea surface temperatures and the atmosphere in late 2014, above average sea surface temperatures at that time seem no less to have disturbed the pattern of Timor-Leste's expected rains. Figure 10, for example, shows the observed rainfall monthly variations during 2014–16 from selected stations across the country. Notably, a pattern similar to that shown in Fig. 10 is also apparent in Fig. 11, which provides a spatially representative gridded dataset. Clear from both of these data sources is that there was a slight delay in the onset of the rainy season in October–November 2014.

In the months that followed, however, El Niño conditions slackened (until April 2015), and sea surface temperatures decreased, returning the ENSO quasi-periodic cycle to a neutral phase. This return brought back, albeit delayed, some of the seasonal

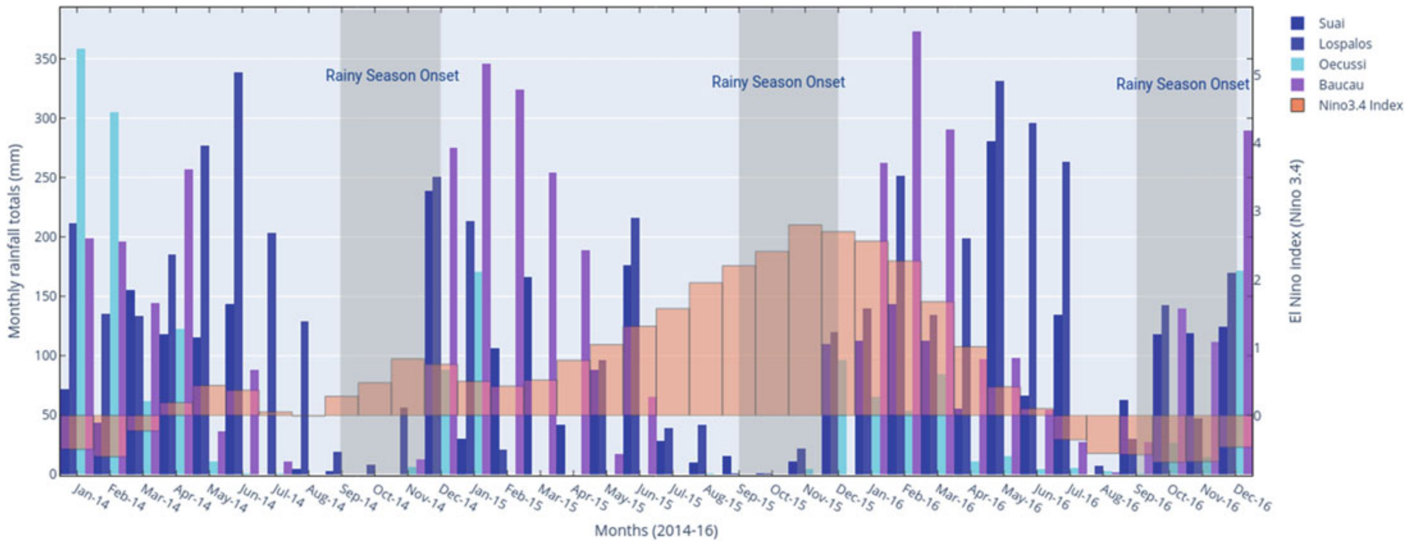

Fig. 10 Monthly rainfall over selected stations in Timor-Leste vis-à-vis the Niño 3.4 Index. Rainfall data from NDMG. Oceanic Niño Index (ONI) from NOAA/CDC

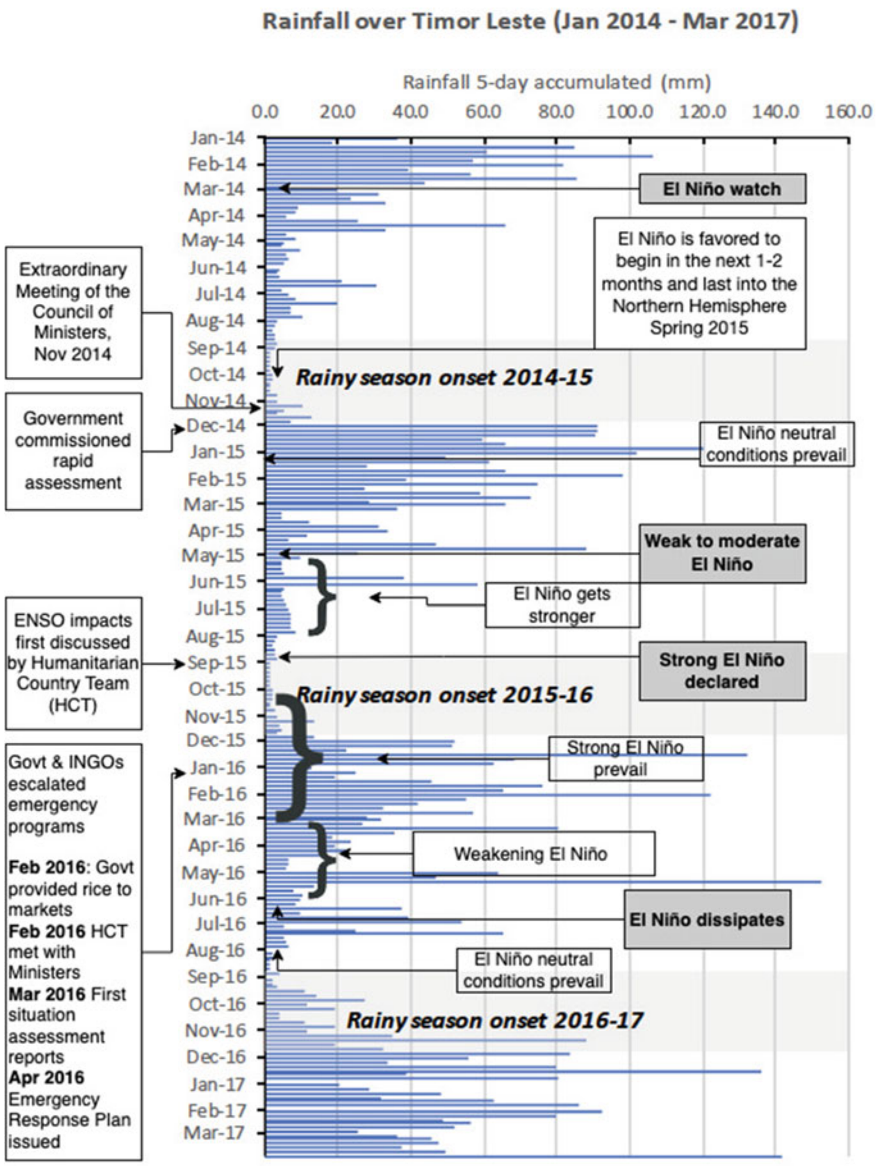

Fig. 11 The evolution of the ENSO cycle and actions taken by government and development partners. Rainfall data from Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS). Reconstruction of events on the left-hand side. From UN Office of Resident Coordinator Timor-Leste (2016)

rains. It also seems to have been met by some confusion and pause in terms of preparedness actions. After this brief interlude, though, El Niño conditions started gaining strength again from early summer 2015, when the dry season became considerably prolonged. Like in 2014, the onset of the rainy season was again delayed (October to December 2015), but with an even more pronounced suppression of rainfall than was observed the previous year.

Relevant actors—including those at the highest levels of government—were only at this point informed of the impending El Niño conditions, and numerous delayed actions were taken to reduce expected impacts. Figure 11 provides an indicative overview of what climate information was available and when, and which key decisions were taken, over the course of the entire 2015–16 El Niño event.

As Fig. 11 indicates, an Extraordinary Meeting of the Council of Ministers received a briefing on November 30, 2014, soon after NOAA/CPC (Climate Prediction Center) advised that there was a 58 percent chance of an El Niño forming in the tropical Pacific by the end of the year. Soon after, in December 2014, the government of Timor-Leste commissioned a rapid assessment to consider the potential impacts of the new event based on past experiences and observations.

The results of a community-level survey conducted by a group of major international non-governmental organizations (INGOs) operating in Timor-Leste at the time revealed that although the internationally known term "El Niño" is not known among community members, a high level of awareness based on past experiences does exist about El Niño impacts. The local term for El Niño translates to "long, dry season," and those surveyed identified just such periods in 2002–03 and 2004–05 in talking about potential impacts (HPA survey).

As El Niño conditions grew stronger by the end of summer 2015, declining agricultural yields and delayed rains were increasingly reported by farmers. Humanitarian agencies continuously monitored the situation through satellite mapping and needs assessments. The government responded by disseminating warning messages to farmers via radio and procuring rice stocks for sale and distribution to ease price inflation. INGOs distributed drought-resistant vegetable seeds and water filters. They also installed water tanks and rainwater harvesting equipment, gave unconditional cash assistance, and conducted awareness sessions on drought mitigation (RSIS 2017).

Despite these tactical actions, the situation escalated into a humanitarian crisis. The government and international intergovernmental organizations scaled up their emergency programmes accordingly. When in September 2015 the event was declared a strong El Niño, but after conditions around the country had already become quite desperate, the Humanitarian Coordination Team (HCT), the top interagency humanitarian body in the country met to discuss the impacts of the ongoing situation. Not until April 2016, however, did the HCT release an Emergency Response Plan to mobilize resources to respond to the mounting food crisis.

A month after the HTC plan was released, the International Federation of the Red Cross (IFRC) launched an appeal to mobilize USD$814,000 to support 20,000 people in the worst-affected areas (International Federation of the Red Cross and Red Crescent Societies, 18 May 2016). By this time, however, the failure of two successive rainy seasons had resulted in the widespread devastation of crops and livestock, which in September 2016 triggered release of USD$1 million from the United Nations Central Emergency Response Fund for critical, life-saving nutritional assistance. Still, heightened food insecurity across much of the island lasted until well after summer 2016, when the strong El Niño conditions finally ended.

3.3 Challenges Faced During the Drought Response

Aware by early 2016 of the potential for enhanced food insecurity, many actors became involved in preparedness and response to the drought (FAO 2016). Still, this mobilization of resources was not capable of completely mitigating the devastating impacts of El Niño on the food security of the Timor-Leste population. Several key reasons for this incapability have been identified, including a lack of on-the-ground climate information, institutional barriers, and challenges with defining drought.

First, the government and INGOs were constrained by limited funding, global competition for resources, and local capacities. Programs for delivering the emergency food supplements Plumpy'Doz and Timor Vita, for example, had a funding gap of approximately USD$22.51 million. High global demand in 2015–16 also led to wait times of four months for relief supplies of Plumpy'Doz. Additionally, the limited local capacity for storage and delivery meant that at least nine metric tons of the supplement along with 0.2 metric tons of the locally produced Timor Vita supplement spoiled in warehouses prior to delivery.

Combined, these difficulties with food supplement supply and storage meant that only one-third of intended relief, reaching 4,388 individuals instead of the projected 20,650, was actually delivered (WFP 2016). These difficulties highlight the need for effective preparedness so that cooperation agreements between all actors, strong contingency planning, and effective financing mechanisms can all be in place *before* the onset of drought conditions.

A second set of challenges relates to the difficulty in predicting, defining, and declaring a drought emergency. Despite its relatively small land area (15,000 sq km), Timor-Leste has four major agro-ecological zones with slightly different rainfall patterns (i.e. some are bimodal while others are unimodal). As a slow-onset hazard the impacts of which vary across agro-ecological zones, drought is notoriously difficult to define.

The situation is even more complicated on Timor-Leste due to the existence of the annual hungry period (November to February). Households on the island have established coping strategies to manage this annual period, but to be effective these mechanisms require careful planning of food and livelihood resources. It is known that if the period becomes protracted, households will need external assistance (Humanitarian Partnership Agreement, February 2016). The problem in 2015–16 was that not until after they could be clearly distinguished from the normal conditions that define the hunger season could the outsized impacts of the strong El Niño event be clearly assessed, which significantly limited the necessary lead time to scale up adequate responses to the already unfolding crisis (RSIS 2017).

Compounding the problem of this delayed assessment of abnormal conditions, humanitarian agencies did not have strong evidence to justify scaling up their responses to the level that was necessary, nor did they have access to the additional funds intended for emergency situations because of the delayed drought emergency declaration (RSIS 2017).

These challenges highlight the need to develop a strong early warning system that is integrated (and mainstreamed) into a comprehensive decision-making process that defines what actions need to be taken in response to both forecasts and early warning information. To be sure, the capacity to generate and use climate information for all timescales is one of the most fundamental elements of such a system. The next section discusses how Timor-Leste might develop such capacity.

4 Modernizing Timor-Leste's NDMG to Support a Food Security EWS

The 2015–16 El Niño event provides an opportunity for governmental, developmental, and humanitarian actors to learn important lessons about how to improve preparedness for, response to, and long-term recovery from drought. Seasonal variations in climate pose a significant risk to food security in Timor-Leste. This risk is amplified during El Niño years.

Advances in forecasting El Niño and its corresponding climate impacts can be utilized to trigger early action to mitigate the impacts of drought on food security, water shortages, livelihood losses, and levels of poverty. Furthermore, actions can be taken now to reduce the extent of agricultural drought caused by climatic variations in the future. Enabling both the capacity for such early decision making and the will to take long-term (strategic) action to mitigate drought impacts must be done now, before the formation of the next El Niño event.

These crucial steps must also be part of broader efforts to adapt to climate change. Managing climate risk requires reliable seasonal climate information combined with weather forecasts, like projected rainfall amounts and intensities, and other medium- and short-range products. Figure 12 illustrates the food security and agriculture-related decisions in the Timor-Leste context that could be improved with better use of forecast products and services. These improvements can be realized through enhancement of the capacities of institutions to generate, translate, and connect to sector-specific decisions at both national and subnational—municipality and community—levels.

Modernizing any national meteorological service and hydrological service (NMHS) is an ongoing process; the technologies and requirements for meteorological services to remain on the cutting-edge constantly evolve. In the discussion that follows, three critical aspects of NDMG modernization that might enable it to

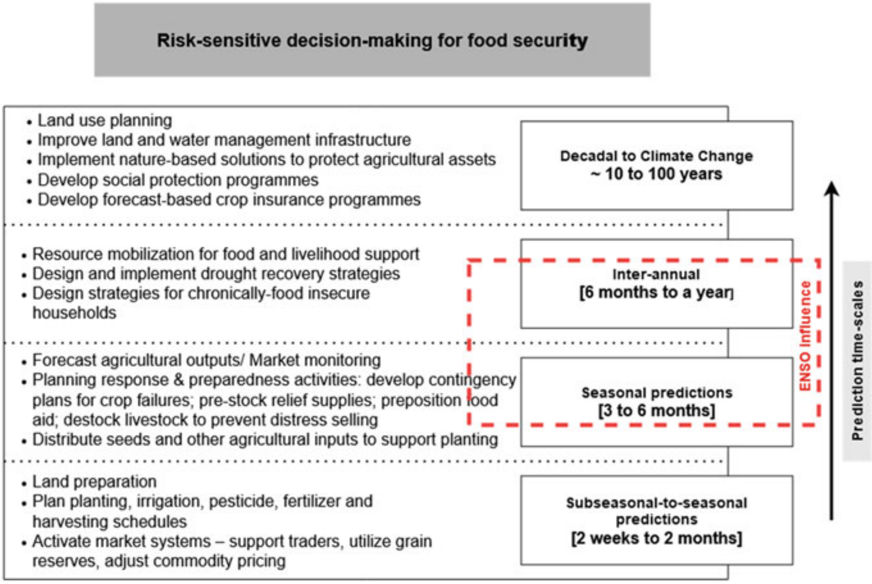

Fig. 12 Risk-sensitive decision making for food security. *Source* Modified by authors from UNESCAP, ASMC and RIMES (2019)

better support food security and other ongoing agriculture objectives in Timor-Leste are highlighted.

4.1 Food Security-Focused Climate Products and Services

Established in 2003, a year after Timor-Leste's independence from Indonesia, NDMG is a young institution. Notwithstanding staff shortages, incomplete historical data, and a sparse observation network, the directorate has managed to acquire enough functional capacity to be able to deliver a basic number of the products and services typically expected of a national meteorological service. It has worked closely with BMKG Indonesia on data rescue as well as with the Bureau of Meteorology Australia (BOM) on digitization. It has also actively supported higher education training for its technical staff through government-sponsored scholarships. Furthermore, NDMG has worked closely with BOM and Regional Integrated Multi-hazard Early Warning System (RIMES) to access and assimilate global and regional products into its own forecasting products and services.

During the 2015–16 El Niño, NDMG did not have the capacity to issue a seasonal climate prediction. El Niño briefings for government agencies and development partners were carried out with technical assistance from RIMES. The 2015–16 event did, however, prompt NDMG to accelerate the development of its own capacity to produce seasonal climate predictions. It now produces seasonal climate predictions as part of its routine services, with three dedicated technical staff assigned to manage and archive climate data analyses.

While it has acquired the basic functional capacities required for providing weather and climate services, much is still to be done if NDMG is to develop the full capacities required to provide tailored services for sectoral decision-making for agriculture and food security. This situation is hardly unique to Timor-Leste, and so lessons can be learned from capacity development efforts elsewhere. WMO (2019), for example, has observed that many countries still lack the more advanced “essential” and “full” capacities needed to support specific decisions in the agriculture sector. The capacity constraints faced by a young meteorological service like NDMG make acquiring such capacities—at an accelerated pace, no less—even more difficult.

Further capacity building is especially needed to improve NDMG staff’s ability to translate global ENSO forecasts into national and local-level applications. The crisis triggered by the 2015–16 El Niño in Timor-Leste demonstrated that predictions of the timing and duration of rainfall are critical for food security. In addition, NDMG needs further support to produce more targeted and user-specific products and services to integrate operational El Niño information into the risk management protocols of climate-sensitive sectors. For example, tailored bulletins for user sectors such as agriculture, disaster management, health, water resources, and fisheries are important. These user sectors have expressed that regularly receiving products with accurate seasonal and 10-day medium range forecasts are among their most urgent needs.

4.2 NDMG and User Interface

As described above, the food security crisis of 2015–16 was a slow-onset disaster that played out over several cropping seasons. With the benefit of hindsight, climate information could have facilitated the implementation of early, mitigative action rather than merely response measures as impacts manifested.

Admittedly, climate information alone is necessary, but it is not sufficient to guide preparedness and response measures; it needs to be combined with information regarding food stock and water availability, agricultural yields, livelihood information, market prices, and the baseline coping capacities of households. Climate information can only translate into action if it is connected to the preparedness (strategic) and response (tactical) plans that detail the actions that need to be taken once certain thresholds are reached. Such responsiveness will require more systematic engagement between NDMG and other actors in agriculture and food security.

In 2019, NDMG began convening an annual Monsoon Forum just prior to the start of the rainy season in order to brief and elicit feedback from sectoral users on the outlook for the season. In collaboration with partner agencies, the directorate

Fig. 13 Farmers in Timor-Leste studying the impacts of climate on crops through the Climate Field School for Farmers program. Photo Credit: Ruby Rose Policarpio

also scaled up its Climate Field School—a capacity building initiative for farmers—to another five municipalities after it was successfully piloted in Liquiçá (Fig. 13). Weather and climate bulletins in the local language, *Tetum*, are also now conveyed to communities through local radio broadcasts. These initiatives have been important steps toward making the products and services of NDMG more useful to national- and local-level decision makers and farmers.

In addition to these face-to-face platforms, the development of forecast-based decision support tools would further facilitate the integration of climate information with sectoral decision-making. It would also enable more rapid delivery of information and guidance to municipalities and communities.

Experiences from other countries in Asia suggest that these interface platforms and decision support tools increase awareness of and confidence in using climate information. They also increase the demand for more specialized forecast products and services, as users become more aware of how such products and services can be leveraged for making more risk-informed decisions. Increased calls for such products will place additional demands on NDMG, which could prove challenging unless several improvements to the directorate are implemented. Improvements might include a commensurate investment in staffing, an increase in the density of the observation network, an increase in connectivity, and other capacity building measures. In the next section we discuss the opportunities for resourcing the modernization of NDMG.

4.3 NDMG Modernization: Part of Broader Development and Investment Planning

Investing in long-term efforts to provide climate services in line with the Sendai Framework, the Paris Agreements, and the SDGs is one of the key recommendations from the Special Meeting on the "Impacts of the 2015–16 El Niño phenomenon: Reducing risks and capturing opportunities," which was convened in May 2016 by the Economic and Social Council (ECOSOC) at the request of the UN General Assembly (ECOSOC 2016).

Given the high climate sensitivity of food security in Timor-Leste, a full consideration of climate risks—particularly the impacts of El Niño—in policies and their corresponding investment frameworks is warranted. Several national policies and plans are in place that recognize the need to build resilience to disasters and to achieve food security. For example, the country's Zero Hunger Plan has a dedicated goal of implementing sustainable and climate resilient agricultural practices. It recognizes the need to "understand, adapt and develop coping mechanisms to handle climate variability" and to enhance disaster risk reduction and management capacities at both national and sub-national levels.

Although these policies and plans do not clearly articulate how investments will be used to modernize NDMG, they provide critical entry points for resourcing its modernization to better support food security goals. Budgeting for and implementing these policies and plans should, therefore, enable investments in NDMG modernization.

Plans for adaptation to climate change could provide another entry point. The country's National Adaptation Programmes of Action (NAPA) (2010) identifies food security as one of its priorities. This priority is again considered in the country program framework for the Green Climate Fund (GCF) (2019), which highlights enhancing government and community strategies to respond to drought as one of the priorities for GCF funding. The NDMG's modernization would play a critical role in achieving this priority to assure the long-term food security of the people of Timor-Leste.

5 Conclusions

Effectively addressing food security requires long-term efforts to develop sustainable food and agricultural systems. Investments are needed in building capacities from national to local levels, community infrastructures, and preparedness systems. Improving climate information and early warning systems will be a critical part of this effort, particularly in a country like Timor-Leste where even the slightest variation in rainfall can have disproportionate impacts on the availability of food supplies and basic nutrition.

The 2015–16 El Niño event clearly demonstrated the urgent need to build the resilience of agriculture and food systems to extreme climate, water, and weather events. At the level of strategic plans and policies this need is already recognized, but greater advocacy is also needed to ensure the inclusion of NDMG modernization in longer-term implementation efforts. These plans, as well as the resources available for adaptation and implementation of the SDGs, should be leveraged to mitigate the impacts of future El Niño and other extreme climate events on the country's food security. The modernization of NDMG, therefore, must be viewed as an important strategic development investment.

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Vietnam

Vietnam in a Time of El Niño

Nguyen Huu Ninh and Hop Thi Bich Hoang

Abstract Vietnam suffers from many kinds of climate-related disasters, such as storms, floods and droughts. Those extreme events have been increasingly severe in terms of magnitude, frequency and volatility in Vietnam recently as a consequence of climate change impact and the extremes of the El Niño-Southern Oscillation (ENSO). Extreme weather events are causing more damage to people and property and impacting Vietnam's economy significantly. However, in comparison to research on extreme events relating to climate change and sudden-onset events, there is a lack of studies on slow-onset events, especially the linkage on extreme weather events and slow-onset events such as El Niño even though they frequently impact on weather conditions in this country. Applying end-to-end model, this study not only shows how risk governance and local perspectives influence the impacts of El Niño in Vietnam, but also illustrates lesson learned about risk governance and El Niño 2015-16.

Keywords El Niño · Drought · Readiness · Perspective · Risk governance

1 Political and Economic Setting

Vietnam is a developing country in Southeast Asia. In 2018, the country had a total population of about 95.5 million people and a total GDP of USD$245, 214 billion. Agriculture still plays an important role in the socioeconomic development of the country, contributing about 14.7 percent to Vietnam's GDP in 2018. Besides providing food and raw materials, agriculture also provides employment for a large portion of the population, employing over 37.7 percent of the national labor force (GSO 2020). In Vietnam, the agricultural land area is about 27.3 million hectares, equivalent to 82.3 percent of the total area of Vietnam (GSO 2019). The actual number of people living in rural and mountainous areas amounted to 64.3 percent of Vietnam's population in 2018. The rural economy continues to depend mostly on rice production and other water-intensive crops (Lohmann and Lechtenfeld 2015).

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Fig. 1 Sub-regions of Vietnam (CC BY-SA 2016)

In general, monsoons and Vietnam's topography strongly influence its climate. Regarding the differences in radiation, temperature, and rainfall conditions, Vietnam is classified into seven subregions (Fig. 1): Northwest, Northeast, Northern Plains, Northcentral, Southcentral, Central Highland, and Southern Plains regions (Phan et al. 2009). The rainy season normally starts in June and ends in December, accounting for approximately 75–85 percent of annual precipitation across the country (Ngu and Hieu 2004). The average annual rainfall over the country is approximately 1400–2400 mm, a range that can vary from 700 to 5,000 mm depending on the region. Moreover, the country relies on a transboundary water management system, with about 60 percent of its total water resources coming from neighboring countries (FAO 2016).

Vietnam suffers from many kinds of climate-related hydrometeorological disasters, especially storms, floods, and droughts. Natural disasters in Vietnam in recent years have been increasingly severe in terms of magnitude, frequency, and volatility. Extreme weather events are causing more damage to people and property and significantly impacting Vietnam's economy. During one recent twenty-year period (1998–2017), for example, the country was exposed to 220 extreme events, and was listed as one of the ten countries worst affected by climate change. These events resulted in annual economic losses equivalent to 0.5 percent of GDP, which corresponds to roughly USD$2.06 billion (David et al. 2019).

Drought causes the third greatest amount of loss in Vietnam, following only typhoons and floods (Le and Nguyen 2008, WHO 2014). Drought is frequent in the Central Highlands and in the South during the dry season (IMHEN and UNDP 2015). Vietnam's rural areas are dependent on agriculture and sufficient rainfall is crucial for subsistence and income generation (Nguyen 2011). Drought can lead to a deterioration in health conditions and noticeably higher health expenditures in affected rural households (Lohmann and Lechtenfeld 2015).

Before the drought of 2015–16, Vietnam had been afflicted by several serious recent droughts—1997–98, 2004–05, and 2010. As a result of global warming, the incidence of drought is likely to increase in the twenty-first century in most climate zones of Vietnam. This increase is also expected to reduce precipitation and increase evaporation (IMHEN and UNDP 2015). Extreme droughts, such as those of 1997–98 and of 2004–05, are now an expected outcome of El Niño events (Vu-Thanh et al. 2013).

2 ENSO-Related Risk Management Systems in Vietnam

Storms and floods accounted for 87 percent of disaster loss in Vietnam between 1980 and 2000 (IMHEN and UNDP 2015). Hence, most of the legislation and disaster risk reduction (DRR) activities in Vietnam deal with these two hazards. Vietnam traditionally uses a top-down approach for dealing with such issues, disaster risk management (DRM) activities that include both DRR and climate change adaptation (CCA).

Vietnam has developed a legislative system to reduce disaster risks, especially for storms and floods. Traditionally, construction solutions are considered the main way to reduce the impact of disaster risk. The country has, for example, passed the Ordinance on Dykes (1989), the Ordinance on Prevention and Control of Floods and Storms (March 1993), the Law on Water Resources (1998), and the Ordinance on the Management and Utilization of Hydraulic Structures (2001). Additionally, it has also established the Hydro-met Service Law, the Dike Law (No. 79/2006/QH11), the Red Cross Law, and the Forest Law. The Dyke Law, together with the protection of mangrove forests mandated in the Forest Law, provides a key system of physical barriers for coastal communities to manage storms coming in from the Pacific.

The Law on Natural Disaster Prevention and Control, which came into effect in 2014, was the first law to directly mention natural disasters in its title. It brought together the main elements of disaster response and risk management systems in Vietnam, which had been under different units. The new law maintains existing good practices and addresses gaps in the prior legislative framework for disaster risk management activities in the country. In the new law, water stress-related extreme events (except for fire) received more attention than they had previously.

With regards to the DRM Law, the Central Steering Committee for Natural Disaster Prevention and Control (CSCNDPC) and the National Committee for Search and Rescue (VINASARCOM) play the main roles in the DRR system. At the provincial level, CSCNDPC and VINASARCOM member agencies are represented under the single combined organization of Provincial Natural Disaster Prevention and Control (PNDPC) and the Search & Rescue (S&R), which is chaired by the Provincial People Committee (PPC).

This structure is again repeated at the district and commune levels. Vietnam also uses a community-based approach in disaster risk management with support from UN agencies, non-governmental organizations, and other international agencies. There is also a national Community-Based Disaster Risk Management (CBDRM) program.

3 El Niño Teleconnections in Vietnam

The warm extreme of ENSO (El Niño) is known to more strongly influence lower latitude regions, especial in the equatorial Pacific and bordering tropical zones (Ropelewski and Halpert 1987). In Southeast Asia, abnormal rainfall depends strongly on the phases of ENSO (Juneng and Tangang 2005). Moreover, the severity and extent of tropical droughts clearly have a relationship with the strength of El Niño events (Lyon 2004). El Niño has caused severe droughts in the dry season in 1997–98, 2002–03, 2004–05, 2009–10, and 2014–16. In the past 50 years, El Niño has occurred 16 times, with the 1982–83, 1997–98, and 2014–16 events having been the strongest, causing serious droughts and saltwater intrusions especially in the Mekong River Delta.

The linkages between ENSO extremes and some climate elements in Vietnam have been documented. Central Vietnam, for example, has less rainfall in El Niño years, while the opposite is true in La Niña years (Yen et al. 2011). Consequently, El Niño could cause a decrease of 25–50 percent in the volume of rainfall compared with long-term average rainfall patterns. In the South-central part of Vietnam, rainfall patterns can be reduced by 30–60 percent in the wet season (Ngu 2007). Drought conditions mainly occur in El Niño years, and wet conditions are also frequently observed in La Niña years in the southern subregions. Such ENSO influences are, however, not clearly observed in the northern subregions. That said, no particular meteorological drought index well-represents drought conditions in Vietnam, and understanding the relationship between drought and climate remains a challenge (Vu-Thanh et al. 2013).

In the October–November period, the tropical cyclone rain ratio in Central Vietnam significantly decreases in El Niño years and noticeably increases during La Niña years (Ngu 2007; Nguyen-Thi et al. 2012). A number of very strong typhoons (e.g. Linda 1997; Xangsane 2006; and Ketsana 2009) have, however, also formed in El Niño years. These typhoons caused enormous losses of life and property. For example, 1997's Typhoon Linda resulted in 4,502 persons dead or missing. Also lost were 440,000 hectares of rice fields, with 133,000 houses lost or seriously damaged (Ninh et al. 2001).

More broadly speaking, of the 14,962 deaths attributable to natural disaster from 1977 to 2000, 43 percent occurred in El Niño years. From 1976 to 1998, the percentage of the Vietnamese population with dengue fever also strongly correlates with El Niño. During the 1997–98 El Niño in particular, 51 provinces and cities witnessed an increase in dengue fever, with an average rate of 306/100,000 (Ninh et al. 2001).

Although the relationship of El Niño to weather and disaster risks in Vietnam has to some extent been proven, the related research is still limited. In the early 1980s, information about El Niño was mentioned in scientific studies from Vietnam, but independent research on ENSO in Vietnam remains quite uncommon. ENSO is mostly mentioned as a factor leading to changes in climate, water, and weather in some climate-related studies. The knowledge of ENSO itself has mainly been acquired and updated from international sources, and research specifically relating its social impacts remains lacking.

4 Analogue Year Data

During El Niño years, especially during strong events (1982–83, 1997–98, 2014–16), maximum temperature records have been set in many places. For the drought in 2005, the estimated economic damage was USD$110 million, or roughly 0.2 percent of the country's GDP (UNISDR 2011). Furthermore, due to El Niño-related drought in 1997–98, about three million people were affected, and the total losses in terms of agricultural production were estimated to be about USD$400 million (Ministry of Agriculture and Rural Development, cited in Vu et al. 2015). Other damages, such as environmental degradation, soil erosion, desertification, food shortages, malnutrition, psychological crises, and the decline in health of millions of people, were not calculated in economic terms. The 1997–98 dry season witnessed a rainfall decrease of 30–70 percent. There was rain in the Central Highlands, the Mekong River Delta, and the Southeast of the country from March to June 1998 (Yenbai.gov.vn 2011).

5 Forecasting and Early Warning El Niño

In Vietnam, the NMHS within the Ministry of Natural Resources and Environment (MONRE) is generally tasked with monitoring conditions and forecasting updates for scenarios of climate change. NMHS also coordinates with the Ministry of Agriculture and Rural Development (MARD)—the standing office of CSCNDPC—to strengthen monitoring and forecasting of water resources and saline intrusion, and issue timely information for agencies, localities, and people. The Southern Institute of Water Resources Research (SIWRR), a representative of the Vietnam Academy for Water Resources in the Ministry of Agriculture and Rural Development (MARD), is in

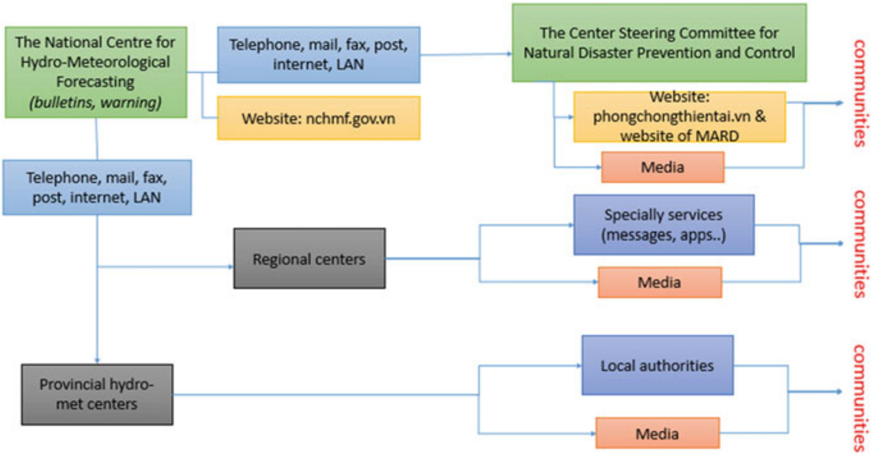

Fig. 2 Early warning information dissemination (nchmf.gov.vn and phongchongthientai.vn)

charge of monitoring and forecasting the salinization situation in the Mekong River Delta and in the south of Vietnam.

Vietnam's NHMS provides its forecasting services mostly through its operational units at various levels: The National Centre of Hydrometeorological Forecasting (NCHMF) at the central level, regional hydrometeorological centers (RHMC) at the regional level, and provincial hydrometeorological centers (PHMC) at the provincial level. The media play a key role in distributing the products from these units (Fig. 2).

For El Niño-related forecasting, NMHS could not forecast or monitor SOI or El Niño alone but cooperates with international partners from the World Meteorological Organization (WMO) to establish climate forecasts and outlooks with three-month lead times based on ENSO information. These forecasts provide information on the possibility of temperature extremes and drought events. Climate forecasts and outlooks have been published (in Vietnamese) on the website of the Institute of Meteorology, Hydrology, and Climate Change (IMHEN) every month since January 2015. For DRM activities, NCHMF will issue reports and undertake forecasting under the CSCNDPC system. Forecast users at local levels normally trust the NCHMF's short-term forecasts.

In those forecasts and outlooks with a three-month lead time, data and information are used that have been collected primarily from NOAA's Climate Prediction Center (CPC), the International Research Institute for Climate and Society (IRI), and Australia's Bureau of Meteorology (BOM). This information is prepared as a "Summary of Climate" for the previous months, which is then aggregated along with assessments of the European Centre for Medium-Range Weather Forecasting (ECMWF) and forecasts by statistical models of IMHEN to prepare a "Climate Forecast" for the following three months.

6 The 2015–16 El Niño

Information collected through interviews with private organizations and governmental stakeholders, supplemented by official reports or statements from the government, indicates that much of the focus during the drought of 2015–16 was 'reactionary.' Most of the processes initiated under the government response took place when the consequences of the drought were already felt, and farmers were being harshly affected. It was quite similar to past drought responses. Even the government had to request—and received—international assistance after March 2016. The timeline of government intervention, international agency response, and media coverage for this extreme event are illustrated in Table 1.

The first warning about the possibility of an El Niño's formation came not from a WMO El Niño Alert but from Mike Halpert, Deputy Director of NOAA's Climate Prediction Center. The warning, dated August 15, 2015, was reported as international weather information in (online) newspapers in Vietnam. On August 27, 2015, NCHMF announced a special report on El Niño 2015 (No. 312/BC-DBTƯ) with expected trends of hydrological and meteorological change from September 2015 to February 2016. This report was prepared by CSCNDPC.

In general, the Ministry of Information and Communication provides El Niño-related information for public use. To get a picture of media coverage regarding El Niño and its related weather disasters, online news and articles in the dry season (2009–2016), especially news relating to El Niños having formed in the preceding decade (i.e. 2009, 2010, 2014), were collected and analyzed. Regarding the dry season annual data, the appearance of news would depend on the seriousness of the dry season. Normally, writers used words like "drought," "sea water intrusion," and "climate change" in their outlines to report about the dry season. "El Niño" appeared in few headlines. The frequency of the news reports depended on the magnitude of the extreme impacts, a trend that could make users misunderstand those events and make wrong decisions. Media articles on El Niño were mostly gloomy in tone. A few articles mentioned El Niño and El Niño-related hazards in Vietnam without raising alarm; however, most news about the phenomenon used headlines like "most serious," "historical drought," and "worst drought."

To reduce the negative impacts of the 2015–16 El Niño, the Vietnamese government used the country's DRM system. NMHS continued overseeing hydrometeorological forecasting. From October 2015 to the end of dry season 2015–16, SIWRR issued Vietnamese reports about the situation, including forecasts on salinization and guidance for river water irrigation in the country's southern regions. Among ministries, as a standing office of CSCNDPC, MARD led the overall sectoral responses. At the local level, along with support of Department of Agriculture and Rural Development (DARD) in the provinces, PPC coordinated responses and collected damage and needs assessments in the country daily in order to prepare reports for the CSCNDPC network.

For recovery plans, Vietnam tended to link ENSO and climate change issues together with social, educational, and policy solutions. Also linked were technical

Table 1 Drought related El Niño 2015–16 and responses in Vietnam. (Information for the following chart was collected and analyzed from online news sources: Dantrinews, VnExpress, VietnamNet, Baomoi.com/Vietnam News, Vietnamplus, Thanhnien, etc. as well as Morning and Evening news on VTC.)

Timeline	Governments responses	Response from INGOs, international agencies	Media coverage Key words: "El Niño," "drought," and "seawater intrusion."
Dry season 2014–15	Managed weather-related extreme events normally with the network of CSCNDPC, including weather forecasting; needs and damage assessment; and quick relief in Mekong Delta, Central Vietnam, and the Central Highlands. [NB: Since 2015, the Vietnamese government spent USD$60.5 million on emergency needs by providing rice, water, and other food, distributing water purification tablets, upgrading or repairing water infrastructure, and delivering agricultural inputs and financial aid to the affected areas (Govt. Viet Nam/UNCT/OCHA, 21 Oct 2016)]	Worked normally and focused on sudden onset events and "climate change" issues	Most frequent key words were "drought," "seawater intrusion" and "climate change." Related news in Vietnam reached its peak—at least one article per each news agency in the middle of the dry season (February–March) before declining in April (one new article/2–5 days/new agency) Like others dry seasons
May–August 2015	Managed weather-related extreme events normally within the network. The first official report on the appearance of El Niño. Special report on El Niño 2015 was sent to CSCNDPC network, NCHMF (27 August 2015). [NB: 27 August, 2015-the special report on El Niño 2015 was sent to the CSCNDPC network the NCHMF]	Worked normally and focused on sudden onset events and "climate change" issues	"climate change" most frequent key word. "Heatwaves" and "drought" mentioned sometimes in international and Vietnam news. El Niño rarely mentioned in news. Few wrote about "heatwaves" and "drought" mentioning El Niño as element increasing those events

(continued)

Table 1 (continued)

Timeline	Governments responses	Response from INGOs, international agencies	Media coverage Key words: “El Niño,” “drought,” and “seawater intrusion.”
September 2016	CSCNDPC managed DRM systems as usual		New articles on El Niño, drought, salinization, temperature, heatwave, and flood in Vietnam or other countries every 4–7 days
October 2015 to January 2016	In October, MARD, NHMS, and CSCNDPC issued reports/directives to show potential weather and drought, saltwater intrusion trend due to the El Niño 2015–16 as well as some solutions (e.g. temporarily changing crop structure, reconstructing irrigation systems, building temporary dikes to reduce salinization in affected areas, regulating irrigation, etc.). [NB: October 6, 2015, CSCNDPC report No. 350/BC-DBTƯ on the hydro-meteorological trend for the winter-spring crop season 2015–16; October 12, 2015, CSCNDPC telegraph No. 32/ CĐ-TW on strengthening measures to prevent and combat drought and saltwater intrusion in 2016; October 23, 2015, MARD directive No.8718/CT-BNN-TCTL on implementation solutions to prevent and combat drought and saltwater intrusion in 2016.] The CSCNDPC managed the DRM systems as usual	Worked normally and focused on sudden-onset events and “climate change” issues	New articles on El Niño, drought, salinization, temperature, floods, and heatwaves in Vietnam and other countries every 3–4 days “El Niño” was rarely mentioned in headlines

(continued)

Table 1 (continued)

Timeline	Governments responses	Response from INGOs, international agencies	Media coverage Key words: "El Niño," "drought," and "seawater intrusion."
February to April 2016 (the peak of the drought)	The government involved disaster management more seriously. Along with MARD and MONRE, other ministries and agencies became more involved in CSCNDPC management activities. [NB: February 4 & March 12, 2016 Prime Minister directives No. 04/CT-TTg & No.09/CT-TTg on the implementation of urgent measures to prevent and cope with drought and saltwater intrusion; March 7, 2016 Ministry of Foreign Affairs dispatches a diplomatic note (No. 128/NG-DBA) to Embassy of the People's Republic of China in order to increase water discharge in the Mekong's upstream reaches to support a reduction of salinization in the Mekong River Delta; March 9, 2016 the Governor of the State Bank of Vietnam directive No. 03/CT-NHNN on supporting Mekong River Delta provinces; March 24, 2016 Ministry of Health document No.1598/BYT-MT for collaboration among provincial departments of health and related agencies to provide sanitizers to citizens.] Asked for international assistance on March 15, 2016 and started to utilize international support	Assisted the Vietnamese government in drought response activities (conducted multi-agency and multi-sector assessment in March and the Emergency Response Plan in April)	Peak of related news-headlines usually directly mentioned El Niño impacts in Vietnam, using key words such as "drought," "seawater intrusion," "agricultural impacts," "experts' comments," "support"-governmental actions (meetings, solutions, etc.), with 1–3 articles per day per each online news agency. The words "El Niño" and "drought 1997–98" were mentioned more in the news. "El Niño" appeared more in headlines. By the end of April 2016, the frequency of El Niño-related news started to decline

(continued)

Table 1 (continued)

Timeline	Governments responses	Response from INGOs, international agencies	Media coverage Key words: "El Niño," "drought," and "seawater intrusion."
May – December 2016	Worked with the related stakeholders to do quick relief in the most affected areas and planned for further recovery activities. Established Drought Recovery Plan in October CSCNDPC network and MARD also started to work on flood and storm issues after August 2018. A forecast for La Niña impacts used by NHMS via CSCNDPC network	Worked with Vietnamese government and related stakeholders to do quick relief in the most affected areas and planned for further recovery activities. Established Drought Recovery Plan in October in 2016. [NB: In 2016, the UN, (I)NGOs (IFRC, Care International, World Vision, Oxfam, etc.), The Red Cross and other partners (e.g. The governments of other countries such as Japan) helped to mobilize millions of US Dollars from various sources for quick relief activities.] Followed and supported sudden onset events during storm seasons as usual	Frequency of key words such as "drought," "seawater intrusion," and "agriculture impact" decreased continuously after the first rain appeared in the South of Vietnam, while key words such as "climate change," "flood," and "storm" appeared more. "El Niño" sometimes was mentioned in the news, as before August

improvements to hydrometeorological and disaster forecasting as well as salinity monitoring. Links to actionable agro-weather advisories for farmers and agricultural planners for restructuring crop production, building capacity, and so forth were important also. The government especially focused on improving water-use efficiency, particularly through improvements to infrastructure for water supply, irrigation, and dike and reservoir systems. As noted in the drought recovery plan (2016–2020):

> MARD and the Ministry of Finance will collaborate to review irrigation systems of the Mekong River Delta, Central Vietnam, and the Central Highlands in order to serve multiple purposes: adapt and respond to climate change, actively prevent salinization, and control erosion. Cooperation should be based on the planning, selection, and ordering of priority projects (e.g. dams, sewers, dikes, freshwater reservoirs) for investment in the period 2016-20.

7 Impacts of the 2015–16 El Niño on Vietnam

The 2015–16 El Niño caused several weather and water-related hazards, such as floods, saltwater intrusions, droughts, and heatwaves, in Vietnam. Indications of an El Niño forming in 2015–16 first appeared in the dry season, 2014–15. Even as the event's formation was being officially reported, drought conditions in Vietnam were already considered the worst in over 90 years (FAO 2016), with 52 of 64 provinces being affected. Among the affected provinces, 18 were declared to be in states of emergency. About 400,000 households in the Central Highlands, South Central Coast, and Mekong Delta needed urgent relief for drinking water (UN System 2016). In the most affected 18 provinces, 2 million people, including 520,000 children, needed potable water relief and 1.1 million people needed food support.

The average temperature was 1–1.5 °C higher than the annual average. A dramatic reduction of precipitation in the whole Mekong Basin combined with upstream hydropower generation needs reduced the flow of the Mekong River through Vietnam, causing an increase of saltwater intrusion in the Delta region. By the end of February 2016, seawater with a salinity of 4 g/l had reached more than 90 km inland in some areas in the South of Vietnam (nongnghiep.vn 2016). This was 10–40 km further inland than the average annual intrusion (SIWRR 2016). Consequently, river water became too salty for human or animal consumption or for crop irrigation or even for fish-farming practices.

7.1 Agriculture and Food Security

The extent of drought and seawater intrusion in Vietnam in 2015–16 cost the agriculture sector about VND9,020 billion (USD$404 million) (CSCNDPC-MARD 2016). For the 2014–16 period, the total economic loss was VND15,032 billion (USD$674 million), which amounted to 0.35 percent of GDP. About VND27,241.2 billion

(USD$1,221 million) was at the time projected as the amount required, over four years, for quick relief and recovery needs in the 18 most drought-affected provinces (Govt. Viet Nam/UNCT/OCHA 2016).

The negative impact of this El Niño on the agriculture sector of Vietnam lasted until the end of 2016. Due to weather conditions, especially in the first six months of 2016, rice production decreased by 2.8 percent and rice yields declined by 3.3 percent. Pepper, coffee, and cashew production showed a similar trend. Productivity of pepper and coffee in the Central Highlands, for example, decreased by 6.7 percent and 0.4 percent, respectively, while cashew yields declined 13.7 percent even though the area of cashew production had increased by 0.9 percent (MARD 2016b).

Extreme weather conditions caused increases in shrimp/fish diseases and seawater intrusion on diked fish and shrimp farming in the South of Vietnam. As a result, shrimp processing companies had to halve their capacity in the first six months of 2016 (MARD 2016a). The most affected households lost 30 to 70 percent (or more) of their annual paddy yields (FAO 2016). During the peak of the drought (February-May 2016), 1.1 million people were food insecure (Govt. Viet Nam/UNCT/OCHA 2016), and 1.75 million people lost their income because of impacts on other parts of the agricultural sector (UNICEF 2016b).

7.2 Electricity Production

The volume of available hydroelectricity declined by six percent because of El Niño. Overall, in 2015, rainfall diminished by 20–40 percent from multi-year averages. Specifically, the volume of rainfall in the South-central region was 30–50 percent less than the long-term average. In the Central Highlands and the South, rainfall decreased by 20–70 percent. Illustrating these declines is how 15 of 51 hydropower plants in the country withdrew from the competitive electricity generation market in mid-March of 2016 (taichinhplus.vn 2016).

7.3 Health and Water Security

Estimates indicate that 360,000 people were at risk of water-related disease outbreaks in the 18 most impacted provinces during the 2015–16 drought (Govt. Viet Nam/UNCT/OCHA 2016). In October 2016, the annual Mekong Delta flooding began as usual, but the water level was around one meter lower than the same period in previous years, which increased the risk of saltwater intrusion during the coming dry season (UNICEF 2016b). Lack of food, drinking water, and an increase in the number and duration of heatwaves were expected to combine to further adversely affect human health.

In Vietnam, bacterial enteric diseases tend to have distinct temporal trends and seasonal patterns, and climate often plays a role in defining high- and low-disease periods. Changes over time of incidences of malaria and selected water-borne diseases in Vietnam have been correlated with primary temperature and rainfall data as well as with El Niño (Mai-Kien et al. 2011). The 1997–98 El Niño, for example, resulted in extremely hot conditions across the country the led to an increase in cases of typhoid in the Northwestern region (Kelly-Hope et al. 2008). High temperatures (>28 °C) also showed significant association with hospital admissions of young children (Phung et al. 2015).

Cases of dengue also increased due to the impact of El Niño. Data analysis of dengue fever in Hanoi (2008–16) suggests that heatwaves might delay the timing of dengue outbreaks but increase the magnitude of outbreaks (Cheng et al. 2020). In fact, the 2015–16 period witnessed a significant increase of dengue outbreaks in Hanoi (about 15,500 cases) that paralleled increases in heatwaves. The data in the first nine months of 2016 in Hanoi indicate about 13,300 dengue cases, more than double the past average of 5,000–6,000 cases for that same period. Furthermore, in Ho Chi Minh City, the number of cases of dengue fever for the first nine first months of 2015 was 10,624 cases, an 80 percent increase from 2014 (Tuoitre news 2015).

7.4 Sudden-Onset Extreme Events

During the historical El Niño and drought of 2015–16 in the Central Highlands, almost the entire country suffered not only heatwaves and an increase in average monthly temperatures but also more extreme events such as snowfall and hailstorms. From March to May 2016, hailstorms occurred in many provinces such as Nghe An, Ha Tinh, Hue, etc. Notably, the North experienced a six-day cold spell in late January 2016 that resulted in the lowest temperatures (−4.4 ºC) recorded in Vietnam in 40 years. The event negatively impacted agriculture in affected areas, including the deaths of livestock (9,409) and poultry (43,242), the loss of 9,453 hectares of cropland and forest, thousands of hectares of paddy and vegetable fields, and 849 hectares of aquaculture (CSCNDPC-MARD 2016). Furthermore, after the 2016 dry season, the ocean conditions in the central Pacific shifted toward La Niña, resulting in a wet season that brought extreme rainfall and storms that flooded many provinces. For example, heavy rainfall in December 2016 flooded four Central provinces, inundating 111,851 houses, and affecting approximately 450,000 people (UNICEF 2016a).

7.5 Biodiversity and Ecology

El Niño brings changes in weather conditions that impact biodiversity and ecosystems. The abnormally warm water in the tropical Pacific Ocean, for example, leads to a global wave of coral bleaching (Gross 2015). It is documented that a prolonged increase in anomalously warm sea surface temperatures in 1998 and again in 2010 caused global-scale coral bleaching events (Bruno et al. 2001, Burke et al. 2011), and about 14 percent of the coral bleaching in Vietnam's Con Dao National Park is thought to have resulted from the 1997–98 El Niño (Quy & Dong 2019). In 2016, the area of coral bleaching in the National Park was about 400–500 ha, making up 25 percent of the total coral area in the park (vietnamplus.vn 2016).

The period of 2015–17 is a good example of changes in the state of coral reefs correlating with changes in sea surface temperatures in the ENSO process. More specifically, having been found only in shallow water (<7 m) in 2015, when the El Niño peaked in 2016 coral bleaching was also found in deeper water (up to 10 m) with a higher rate than that in 2015. Bleaching was reduced again in 2017 after ENSO returned to its neutral phase (Tuan et al. 2018).

The increase in sea surface temperature in El Niño years also comes with an increased risk of forest fires. For the period 2008–16, for instance, MARD estimates that about 2354 ha of forest was consumed annually. During the 2010 drought, however, 5618 ha of forest was damaged by fires (MARD 2010), and in the first 9 months of 2016, fire had broken out in 3256 ha, triple the area for 2015 and higher than that of the yearly average (MARD 2016b).

8 Hurdles and Obstacles

According to interactions with the media as well as interviews with experts and stakeholders, this research points out that along with technical and funding issues some main hurdles and obstacles in response to the 2015–16 drought stand out. The first obstacle was a lack of experts who could interpret forecasts for real-time responses. Coordination between experts and stakeholders, especially between forecasters and users, was also weak. With more capable staff and better coordination down the end-to-end forecasting chain, necessary response guidelines for different sectors and local communities would be available in a timelier manner, regardless of whether the first forecast was on time or not.

During the 2015–16 event, for example, the first official El Niño alert was issued and sent to relevant ministries on August 27, 2015, but it took weeks or even months for those ministries to understand and then release their first guidances. It took even longer for local authorities to understand the content of those guidances and apply them to their respective situations. For example, MARD did not issue its first guidance for the winter-spring crop seasons until October 2016, which is six weeks after the first official alert had been disseminated. By the time local farmers were informed of recommended mitigative responses, the winter-spring crop season had already begun, causing a significant decrease in overall agricultural productivity.

A second obstacle had to do with weak inter-ministry cooperation. Weak interactions between MARD and Vietnam Electricity in the Ministry of Industry and Trade over river water usage and multi-reservoir management in Central Vietnam, for example, accelerated the impacts of drought in the region. During a drought period, hydropower reservoirs keep water to generate electricity, a strategy that could, however, increase negative impacts downstream. In 2016, several hydropower reservoir operators were fined because they withheld water in order to generate power instead of letting it flow to irrigate agriculture areas in the river basins (cand.com.vn, 2016).

A third obstacle centered around bureaucratic uncertainty in passing legislative instruments that delayed government response. For instance, in March 2016 thousands of drought-impacted farmers in Daknong Province in the Central Highlands still had not received about VND15 billion in support for drought impacts during the 2015 spring–summer crop season. The inadequacy of this response resulted from a combination of disagreements among local authorities and the slowness of the bureaucratic process (dantri.com.vn 2016), which was primarily an outcome of arguments over damage assessments. Updates to decisions on regulating 61 reservoirs in 11 river basins were quite new and at that time contributed to a slowdown of solutions for users.

A hurdle highlighted by the 2015–16 drought was the inappropriateness of previous development planning and management of water resources, especially with the establishment of a series of small and medium hydropower plants in Central Vietnam. The lack of an appropriate plan for the use of underground water in Vietnam was also revealed. Underground water resources within the Mekong River Delta are thought to be enough to supply domestic demand; however, the inappropriate use of underground water in the delta has increased salinization in many areas (baohaugiang.com.vn 2016). Furthermore, continued deforestation in the Central Highlands for farming could also make the region more vulnerable to drought.

The fifth obstacle or hurdle is the increase in transboundary water issues and conflicts because more hydropower plants have been built by countries upstream. Hydropower dams in upstream countries have changed the amount and timing of flows to the Mekong River Delta. As a result, Vietnam has had to work with the Mekong River Commission, sending diplomatic documents to the Chinese government to ask for an increase in water discharge from Chinese hydropower stations in order to mitigate drought and seawater intrusion.

The sixth obstacle is a general lack of knowledge about El Niño combined with lack of stakeholders concern. Stakeholders are likely to focus on sudden-onset weather extremes, believing that slow-onset events cannot have serious impacts. International agencies only joined the drought-related El Niño response in March 2016, so there is some hope that responses might become more efficient in the future.

The seventh obstacle is the communication sector. Many stakeholders within this crucial sector are skeptical about El Niño, climate change, and even early warnings about drought. This skepticism impacted the coverage of these topics in the news, which tended to lead with dire but sensational headlines. Additionally, although many people watch weather forecasting in the daily news on TV at 6 a.m. and 7 p.m., at that time the weather forecasting program on TV simply provided short-term forecasts and information without guidance for viewers, farmers included.

An eighth obstacle or hurdle is how misunderstandings over the difference between climate change, El Niño, and other slow-onset events like drought and seawater intrusion have delayed better responses by decision-makers and other stakeholders to such events. In the 2015–16 El Niño event, for example, stakeholders in impacted areas typically thought the drought was just the annual norm, which lent to their passive response to the extreme hydrometeorological event. Furthermore, the lack of monitoring systems and accurate forecasting, especial over longer time periods, were also reasons responses were delayed by managers and stakeholders (Ninh 2017).

Finally, neither Vietnam's water management nor its disaster risk management system are prepared to handle extreme hydrometeorological events. One reason for this lack of preparedness is that managers have misunderstood extreme data as signals of climate change for which they thought they had more time to prepare.

9 Some Lessons Learned from El Niño Events in Vietnam

Many experts have agreed that the Ministry of Agriculture and Rural Development (MARD) plays a crucial role in overseeing El Niño-related preparedness in Vietnam. For preparedness actions, it should have the involvement of all agencies, ministries, and people (Ninh 2017). The above-mentioned obstacles were identified from previous El Niño events, but many of them have never been addressed. Vietnamese authorities did not seem to deal with this El Niño proactively. The country has suffered from many El Niño events in the past, but El Niño-related impacts have apparently not been well-remembered. In other words, lessons that have been identified have not really been learned. These lessons include better understanding the need for:

- Enhancement of collaboration between stakeholders, especially between forecasters and users (and across different economic sectors), which will enable more efficient interpretation of and timelier response to forecasts;
- Capacity building for assessment of climate change and climate-related extreme events as well as for forecasting, especially of slow-onset events;
- More publicly available information about El Niño impacts for Vietnamese civil society to be able to lobby the government about the importance of El Niño research, especially regarding teleconnections and their impacts on environment and society;
- Policymakers to be more aware of slow-onset events, El Niño events, and climate change for all stakeholders in order to better prepare to respond to future hydrometeorological events;
- Improvements to water resource management, agriculture development, and other development strategies using El Niño-related information;
- Early warnings and other information about El Niño communicated through a more diverse range of outlets, including in short videos about El Niño and other DRM strategies that could be played during news broadcasts;

- Undertaking post-event assessments that go beyond mere collection of damage data;
- More information for and early warnings of uncertain events beyond drought, salinity intrusion, flood, and typhoon, especially in northern Vietnam where sudden cold and hailstorms are endemic hazards; and
- Changes to reservoir management strategies to cope with hazard situations more effectively in order to provide information that stakeholders can use in real-time decision-making.

10 Vietnam Country Case Study Executive Summary

Vietnam has developed systems of climate change adaptation (CCA), disaster risk management (DRM), and disaster risk reduction (DRR) by a top-down approach. Responsibility for those administrative systems are scattered across ministries, which each have different functions and responsibilities based at local levels. The Central Steering Committee for Natural Disaster Prevention and Control (CSCNDPC) and the National Committee for Search and Rescue (VINASARCOM) play the main roles in the DRR/DRM system. But Vietnam's emphasis has been mainly on the construction of sea dikes for disaster risk reduction and irrigation systems.

El Niño could be considered as an important factor in DRM in Vietnam. The effects of El Niño on weather and, more generally, hydrometeorological disaster risks have been a concern. The frequency and intensity of El Niño and La Niña events have trended upward; however, relevant research in the country remains rather limited. Studies on ENSO-related hazards such as tropical cyclones, floods, and droughts are being conducted by various agencies in Vietnam, but overall knowledge of the quasi-periodic ENSO cycle has mainly continued to be acquired from international sources.

The National Meteorological and Hydrological Service (NMHS) provides information on hydrometeorological hazards to DRR/DRM agencies and early warning system (EWS) stakeholders. NHMS cooperates with international partners such as the World Meteorological Organization (WMO) to establish monthly climate forecasts and outlooks for three-month periods based on current ENSO information in order to provide guidance on the possibility of anomalous temperature extremes and drought events. When concern arose of a potential El Niño in 2014–15, monthly climate forecasts and outlooks for three-month periods were usually following ENSO updates from WMO. The first official early warning of an El Niño event in 2015–16 in Vietnam was issued on August 27, 2015 based on a forecast from NOAA's CPC.

During the drought of 2014–15, every week and month brought news items and longer articles mentioning climate change and/or El Niño issues. Those articles also often mentioned impacts of El Niño and heatwaves in different countries. The frequency of "over-hyped information" in articles or online news sources increased from August 2015 and reached its peak in March 2016, after which it began to decline in mid-April. Similar to other El Niño events, information drew immediate attention, but soon the media and the people focused more on potential impacts.

At present, public awareness and understanding of El Niño and the ENSO phenomenon in general as well as of climate change-related hydrometeorological hazards is still limited in Vietnam. Responses to events tend to be reactive, and many stakeholders do not yet know about frequencies, socioeconomic or environmental impacts, or how or when to respond tactically or strategically, as through sustainable DRR mechanisms. People tend to believe that the Vietnamese government should take the main role in responding to the phenomenon and its impacts. Their comments tend to illustrate their perceived powerlessness in the face of hydrometeorological hazards. The people are often not ready to handle such hazards.

The 2015–16 El Niño had significant impacts on Vietnam, especially in the agriculture sector and on hydro-electricity production, health, and water and food security. In the first three months of 2016, the agriculture sector experienced a decrease in production because of El Niño, and many hydropower plants were forced to idle because of a lack of water. Many citizens were threatened by harvest loss and shortages of fresh water. In addition, the event also raised tensions of over managing trans-boundary rivers like the Mekong.

In summary, it appears that the Vietnamese government could likely remain passive in dealing with future El Niño events. Given that lessons experienced from previous events are, unfortunately, unlikely to be considered in future DRR planning. However, the government has become active on an official Facebook Page established in 2014. Today, about 1 M Vietnamese follow the page.

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South Pacific

Fiji

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Abstract Fiji is prone to many hydrometeorological hazards such as floods, droughts and tropical cyclones. El Niño Southern Oscillation (ENSO) plays a significant role in determining the climate of the Pacific Island nations, including Fiji. This connection is of great concern with the ongoing risk of climate change likely to exacerbate the frequency and severity of future extreme weather events. The 2015-16 El Niño is now considered one of the three strongest El Niño events on record. This event was marked by the significant impacts on livelihoods and the environment. This was primarily caused by supressed rainfall leading to severe drought conditions with over 50% of Fiji's population needing humanitarian assistance, and the devastating impacts caused by the increased cyclonic activity of Tropical Cyclones Pam and Winston. The lessons learned about prediction, communication and action during the 2015-16 El Niño provides valuable information to inform future early warning systems. These lessons can further implement disaster risk reduction actions such as the need for sustained commitments and investments from hydro-met institutions. Such investments would improve climate services and the need to strengthen multi-hazard early warning mechanisms, to reduce the impacts on at-risk communities of extreme weather and climate events, including those associated with El Niño.

Keywords El Niño · ENSO · Early Warning · Forecasting · Disaster Risk Management · Fiji

1 Fiji Context: Political and Economic Setting

The Republic of Fiji has a population of about 885,000 and is an archipelago of 332 islands—only about 100 of which are inhabited—in the South Pacific (Fig. 1).

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Fig. 1 Map of Fiji showing the location in Oceania (Freevectormaps 2020)

The two largest islands, Viti Levu and Vanua Levu, are home to 70 percent of the population (Fiji Bureau of Statistics 2020).

As of 2017, Fiji, one of the largest and most developed economies in the Pacific region, had a per capita GDP of USD$3,594 (Fiji Bureau of Statistics 2020). It is classified as a middle-income nation (Fiji Bureau of Statistics 2020). Fiji's top-earning industries are tourism and sugar cane production, though upwards of 75 percent of its people's livelihoods come from subsistence agriculture (Heritage Foundation 2016). These three industries are climate dependent and highly vulnerable to damages resulting from tropical cyclones (World Bank 2015), especially with regard to income and food security (Heritage Foundation 2016).

Despite a strong economy, more than 30 percent of the rural population live below the poverty line. This rural population has a high dependence on resources that are vulnerable to natural hazards (Van Beukering et al. 2007). It also includes the majority of Fiji's population under age 14 and over age 65, the two age groups that are traditionally most vulnerable to the impacts of natural hazards (Fiji Bureau of statistics 2007). Each of these factors contributes to the difficulty the Fijian government has faced in developing effective disaster risk reduction (DRR) measures.

2 Strength of El Niño Teleconnections in Fiji

The impacts of the El Niño Southern Oscillation (ENSO) are felt worldwide. ENSO plays an especially significant role in determining the climate of Pacific Island nations such as Fiji. It is also linked to geological and hydrometeorological hazards such as floods, droughts, and tropical cyclones (Kelman 2019). This connection is of great concern, with the risk of climate change likely to create more extreme weather events and possibly to increase the frequency and severity of future El Niño events (UNOCHA 2016).

Given its geographic location and geophysical characteristics, Fiji regularly experiences natural hazards of geological and hydrometeorological origin. During the period 2015–2020, tropical cyclones like Winston (Fig. 2), Tino, and Harold were a devastating hazard in and around Fiji. Tropical cyclone activity over the Fiji Islands, Tonga, and Samoa, however, typically shows large regional variations associated with the three phases of the ENSO quasiperiodic cycle. Variations in sea surface temperatures and weather fronts, in addition to the microclimate of the region, increase the complexity of predicting, modelling, and forecasting cyclonic behavior in the South Pacific (T + TI 2019).

In the South Pacific Ocean (SPO) region, El Niño events can cause tropical storm activity to occur farther eastward than normal and can also bring about a general suppression of storm activity in the Coral Sea. Fiji is highly vulnerable to tropical storms, which across the islands cause mostly dangerous and damaging weather events associated with flooding. In addition to the inherent difficulties associated with prediction of extreme events in general, historical records for the various tropical storm basins demonstrate significant interannual variability in the temporal and spatial distribution of such storms.

While the worst coastal inundation occurs from tropical cyclones, it can also occur to a lesser extent from severe monsoons or tropical lows as well as from wind-driven storm surges, waves, river flooding, and tides. Tropical storms may also bring extended periods of heavy rain to Fiji, causing inundation due to either flash flooding or riverine flooding. When hydrological flooding occurs in conjunction with a storm surge, the resulting inundation may be much more extensive and damaging. On the other hand, the decrease in the strength of trade winds and reduction in rainfall over Fiji, especially during moderate to strong El Niño events, can lead to severe drought, impacting food security and agriculture production.

Fig. 2 Devastation in Fiji after Tropical Cyclone Winston made landfall in mid-February 2016. Photo courtesy of Fiji government (T + TI 2016)

3 Response to the 2015–16 El Niño Forecast

On a regional scale, the onset and progression of El Niño is closely monitored and reported by all major meteorological and climate analysis centers in the Pacific, including the Bureau of Meteorology (BOM, Australia), the National Institute of Water and Atmospheric Research Ltd. (NIWA, New Zealand), the National Oceanic and Atmospheric Administration (NOAA, United States) and the Fiji Meteorological Service (FMS). Seasonal and monthly climate outlooks track meteorological conditions that are indicative of El Niño's formation and forecast the likelihood and probable timing of an event onset.

As early as November 2013, the US Climate Prediction Center (CPC, NOAA) and the International Research Institute for Climate and Society (IRI) collaboratively predicted an elevated chance of the formation of an El Niño event. The suggestion that an event was imminent gained credence in January 2014, when the World Meteorological Organization (WMO 2014) forecasted an enhanced possibility that an El Niño event would begin in 2014.

Then, in March 2014, CPC issued another El Niño watch indicating that the risk of an El Niño forming had increased significantly. The purpose of this updated issued forecast, even though the event itself was, per NOAA, still only about 50 percent likely to fully form and its timing remained uncertain (L'Heureux et al. 2017), was mainly to provide concerned agencies with enough lead time to implement their response plans. At the time, scientists hypothesized that the impending 2014 event would be similar in intensity to the 1997–98 El Niño. This hypothesis was based on the forecast of strong westerly wind bursts, kelvin waves, and warming in the central Pacific Ocean. All that said, however, the conditions that led to the forecast did not continue, and the emerging event abruptly collapsed during the northern hemisphere's "Spring barrier." Its collapse was largely attributed to a weakening of the westerly wind bursts.

4 First Forecast of the 2015–16 El Niño

In September 2014, the Fiji Meteorological Service (FMS) briefed the Parliament about the likelihood of an emerging El Niño event, reporting a 65 percent chance of its beginning in December 2014. Also presented in the briefing was the likelihood of an increased chance of cyclonic frequency and intensity should a strong El Niño occur. Possible impacts of an event—especially the likelihood of drought conditions across the islands—were also discussed. At the end of 2014, however, despite some meteorological agencies declaring a weak El Niño had emerged, the FMS (2014) stated that conditions were just below the customary threshold for the declaration of such an event.

By February 2015, however, seven of the ten climate models monitored by NIWA indicated the likely emergence of an El Niño within three months. The three other models indicated only an uncertain, borderline value (i.e., a sea surface temperature anomaly ≥ + 0.5 °C but < + 0.7 °C) (NIWA 2015). Over the coming weeks, FMS continued to issue updates until finally, in March 2015, it reported that conditions in the tropical Pacific had surpassed standard El Niño thresholds. These conditions continued to intensify through the spring until the event was classified as of moderate strength by June.

In August 2015, FMS and the Fiji Mitigation and Preparedness Committee for National Disaster met to discuss the El Niño's likely impacts on Fiji's communities. Based on rainfall models that predicted below average precipitation over the coming months, the National Disaster Management Office (NDMO) began issuing public advisories instructing people to conserve water (Fijian Government 2015). At that time, reports of a steady intensification of conditions even after June indicated that the event had become a strong El Niño, the peak intensity of which would be reached no sooner than late November. Following its peak near the end of 2015, the event began to weaken until it again reached an ENSO neutral phase in mid-May 2016.

In December 2015, predictions indicated that over the course of the 2015–16 El Niño, 10 to 14 tropical cyclones would develop across the whole Area of Responsibility (AoR), with four to eight of those storms expected to reach Category 3 status and three to seven expected to reach Category 4 or 5 status (UNOCHA 2015b). Because of the El Niño, not only was the tropical cyclone risk for Fiji considered elevated but the possibility of cyclonic events occurring outside of the officially designated season was also increased. In response, communities island-wide were warned to remain alert and prepared throughout the 2015–16 tropical storm season. for Fiji specifically, the Regional Specialised Tropical Center (RSMC-TCC) predicted that two to three cyclones would affect at least some parts of the country (RSMC-TCC Nadi 2015). At least one of these cyclonic events was expected to reach or exceed Category 3 status.

5 Analogue Years Noted Before the 2015–16 El Niño Event

With characteristics comparable to El Niños in both 1982–83 and 1997–98 (L'Heureux et al. 2017), the 2015–16 event proved to be one of the three strongest El Niños on the historical record. To be sure, outlooks and comparisons with two previous strong events caused considerable concern about the potential for significant global impacts in 2015–2016.

The 1997–98 El Niño, for example, which was by some measures the strongest event chronicled since systematic recordkeeping began in the 1870s, had significant socioeconomic impacts due to its effects on weather, ecosystems, and fisheries.

Even though the 2015–16 event showed similar if not stronger signals, however, it differed in several important ways. For example, the west-central Pacific at the time followed a trend that was observed across the globe—the warmest average sea surface temperatures ever recorded (Lindsey 2016). Another key difference was that

2015–16 saw weaker trade winds and pressure differences with less amplitude than were seen in 1997–98 (L'Heureux et al. 2017).

6 Forecasting the 2015–16 El Niño

Unlike previous extreme El Niño events and due to advances in operational observing and prediction systems, widespread information disseminated through the Internet and social media, combined with frequent updates, conveyed important information to nations—including Pacific Island countries—to help them prepare for the impacts of the 2015–16 El Niño. During the 2015–16 event and with the assistance of neighboring forecasting centers, for example, the FMS provided monthly bulletins, seasonal forecast updates, rainfall predictions, two-monthly El Niño outlooks, media releases, drought analyses, and ENSO forecasts (PICOF 2017).

FMS was able to inform the Fijian Government of potential impacts, enabling the country to prepare. It also continuously highlighted the importance of improving forecast accuracy for future events. Now, it provides ENSO updates every two months on its website. Important to note, however, is that applications of global El Niño forecasts are not fully utilizable or adoptable around the country, where proper understanding of the quasi-periodic ENSO cycle and its forecasting and application is limited. Increasing this understanding will be essential if improvements to the understanding of tropical storm climatology and variability will ultimately reduce the risks and damages associated with tropical storm occurrences nationwide.

7 The 2015–16 El Niño Early Warning

Strong El Niño events are linked to extreme weather, so establishing early warning systems based on robust scientific evidence is critical to effective response. Although progress is being made in this area, most forecasting at the time was limited to a six-month lead time (Ludescher et al. 2014).

Fiji has a strong dissemination network to alert the public in order for it to respond and prepare. The main means of dissemination of national warnings include national broadcasts through AM and FM radio stations, television, and social media platforms. Radio is heavily relied on, as all major population centers receive both AM and FM broadcasts, and remote communities are covered by AM stations. Gold FM, an English-language station, typically serves as the information hub, with all other stations linking to the information it receives. Radio stations broadcast live 24/7 in most cases, and radio weather updates are typically provided every 30 min. Some stations, however, may switch to pre-recorded programming overnight. Fijians with access to television are provided with major news bulletins at 6:15am, 1:00 pm, and 7:00 pm. During a hazard event, updates are also continuously made on TV by chyron (the news information banner scrolling across the bottom of a TV screen).

Fiji continues to improve its communication and dissemination networks to better reach the most at-risk people in preparing for natural disasters.

8 The 2015–16 El Niño Impacts in Fiji

The 2015–16 El Niño is now considered one of the three strongest El Niño's on record. It impacted Fiji until as late as July 2016, when it entered a weak La Niña-ENSO neutral state (FMS 2017). The event was marked by significant impacts to livelihoods and the environment. Due to a 2 °C increase in sea surface temperature, for example, Fiji's reefs suffered widespread coral mortality from bleaching. Coastal erosion and inundation, particularly in low-lying areas, were a direct impact of the heightened sea levels caused by this surface water temperature increase.

With the exception of intense tropical cyclonic activity, the 2015–16 El Niño suppressed rainfall across the region, leading to severe drought conditions. Such conditions had direct and indirect effects on Fiji's agriculture, fisheries, and water resources. At the start of the 2015–16 event, the Fijian Government estimated that more than 67,000 people (13 percent of the population) would be affected by the country's El Niño-related drought (UNOCHA 2015a). In response, water delivery operations commenced via trucking systems, which provided populated areas and less-populated villages with water for people, agriculture, and livestock. Emergency water supplies were also delivered to outer islands and schools in need. Additionally, the government distributed rice and canned fish to drought-affected communities (UNOCHA 2015a).

The drought was so severe that 50 percent of the nation's population needed humanitarian assistance (WHO 2015). One of the biggest concerns was around food security and production, with drought conditions causing a reduction in sugar cane production by 50 percent and a loss of fresh produce, resulting in widespread economic impacts (ESCAP 2015, WHO 2015). Adding to the socioeconomic stress was a number of instances of saltwater inundation, which further limited agriculture production and created significant additional costs.

One of the most serious impacts of the 2015–16 El Niño was the increase in cyclonic activity in the region. Major systems forming during the 2015–16 El Niño included Topical Cyclones Pam and Winston, which both impacted Fiji in significant ways (United Nations Economic and Social Council 2016). Winston, a Category 5 storm, made landfall in Fiji on February 20–21, 2016. It was the first Category 5 cyclone to directly impact Fiji in recorded history, and at the time, the most intense cyclone on record with maximum average wind speeds of 233 km/hr (145miles/hr). The unprecedented ferocity of the storm led to widespread destruction, impacting upwards of 540,000 people (62 percent of Fiji's population). One in five households experienced the complete destruction of their homes and loss of personal belongings, resulting in widespread displacement throughout the country (UNDP). Winston also damaged or destroyed nearly 500 schools and early learning centers. It interrupted power supplies (80 percent power loss countrywide) and communication links, and significantly reduced health-related services, leading to widespread outbreaks of respiratory and vector-borne diseases (Ministry of Economy 2016; UNICEF 2016).

Farmers were further affected by both infrastructure and crop losses. The Pacific Island Farmers Organization Network (PIFON) highlighted that work needed to be done around pre- and post-cyclone crop mitigation. Farm organizations would need to take on specific roles to support post-disaster rehabilitation (PIFON 2016).

9 Tropical Cyclone Winston: Early Warning and Response

Fiji's National Disaster Management Office (NDMO) issued regular bulletins during Winston. The first of these was issued on February 11, 2015. The warnings tracked the path of Winston from then until it made landfall nine days later, on February 20. Over that time, RSMC-TCC issued "Cyclone Alerts" every six hours or whenever a significant probability arose of Winston moving into the area of Fiji. A "Cyclone Alert" means that conditions producing gale force winds are not expected within 24 h but have the possibility of arising within 48 h. Soon after, as the threat of landfall became imminent, a "Cyclone Warning" with information about predicted wind strengths was issued every three hours (RSMC-TCC NADI 2016).

The devastating effects of Winston led to the creation of Lessons Learned Workshops that were funded by ACP-European Union Safety and Resilience in the Pacific Project and conducted by South Pacific Community (SPC) (Pacific Community 2016). Several other Pacific Forums (e.g. the Star Conference, CIFDP meetings, etc.) also highlighted the lessons identified from Winston and how to improve cyclone early warning, rapid mapping, and community resilience. These review sessions explored how NDMO responded and how its response could be improved in future events.

Winston also provided important lessons on public–private partnerships. Rapid Damage Mapping (RDM), a tool developed by Tonkin + Taylor International Limited (T + TI), integrated disaster mapping information within the first 24 h of Winston's formation. A web-based GIS platform called Project Orbit had also been established to facilitate access to factual and interpretative reconnaissance information to assist aid organizations and UNOCHA to coordinate their responses. Key information added to this platform included high resolution oblique aerial imagery taken by the New Zealand Defense Force in the days following the cyclone. Regional-scale building damage assessments were completed by data analysts in New Zealand within two days of the images having been processed.

Following on from these developments, the Coastal Inundation Forecasting Demonstration Project was operationalized in Fiji in 2019 through a joint effort by WMO-IOC Joint Technical Commission for Oceanography and Marine Meteorology and WMO's Commission for Hydrology. This project developed and implemented a multi-hazard early warning system that promotes an integrated approach to forecasting, monitoring, and warning for coastal flooding no matter the source (i.e., river or tidal). The project's approach was innovative and unique in that for the first time it

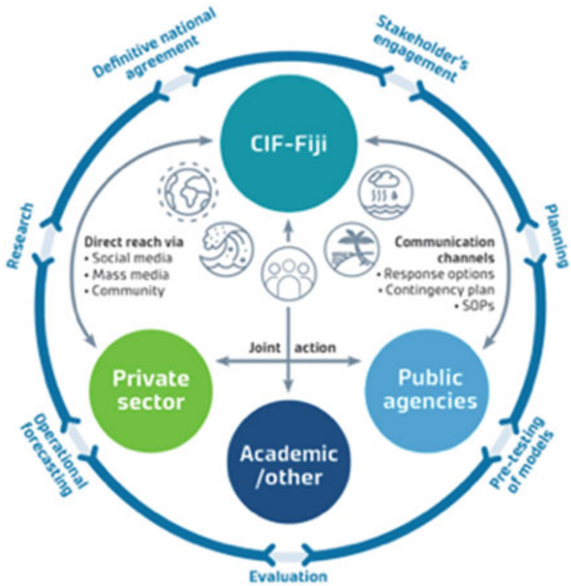

Fig. 3 Public and private engagement in coastal inundation forecasting in Fiji (WMO 2020)

brought together hydrological, oceanographic, and meteorological communities to develop an enhanced capability for effective coastal warnings that is accessible to and actionable by communities at risk. The project is an example of how engagement by both public and private sectors is vital to ensuring consistency in the skills and knowledge used to carry out forecasting, monitoring, and warning (WMO 2020) (Fig. 3).

10 Media Coverage of the 2015–2016 El Niño

A keyword search of 'El Niño' in the *Fiji Times*, the *Fiji Sun Online*, and *Fiji Live* revealed that numerous articles referencing the event appeared from mid-to-late 2015 and into early 2016. The majority of articles did not explain the El Niño phenomenon but rather covered specific impacts in Fiji. Most were related to either drought conditions or the impacts of Tropical Storm Winston. The information in these articles was generally cursory, containing only one or two sentences on the possible effects of an extension of the cyclone season, the increased frequency of storms, or changes in storm distribution patterns.

Most articles mentioned the difficulties the country would face in terms of changing conditions and the possible impacts on the water supply. Some made explicit reference to advancements in forecasting technology, mentioning the ability to infer the likely onset of an El Niño event six months prior to its formation (Naleba

2015). Media outlets also referenced government strategies and assistance available. Multiple commentators addressed the need for drought preparation—“use water wisely” was a common tagline.

UNOCHA (2015a) provided more in-depth information on what El Niño is, how it can affect the country, and possible strategies the government and individuals can pursue to prepare for an event. Reference was also made to the 1997–98 El Niño to emphasize the possible severity of conditions during the 2015–16 event.

11 Regional Impacts of El Niño 2015–16

The 2015–16 El Niño illuminated the gap between humanitarian funding requirements in countries to address El Niño-related emergencies and the capacity of the international community to respond The following paragraph is taken from the UN ECOSOC Special Meeting (2016).

> In countries with ongoing high levels of exposure and vulnerability to extreme weather and climate events, the compounding effect of the 2015-16 El Niño phenomenon additionally burdened their national and local capacity to manage risk and disasters. This increased burden led to calls for humanitarian assistance totaling nearly USD$3 billion [of which only an estimated 33 percent had actually been donated] by April 2016. Regions and countries that have put in place longer term policies to make climate predictions through regional and national climate centers, and those that have the capacity to act on such predictions, are [typically] experience lower impacts.

12 National Hydrological and Meteorological Services (NHMSs)

The El Niño Southern Oscillation is a main driver of climate variability. Prior to the 2015–16 event, the primary focus of El Niño impacts in Fiji’s geographic region was drought (SOPAC 2009). Research conducted after the last major event (1997–98) also showed how tropical cyclones during an El Niño were often generated farther eastward and to the north of Fiji than normal, which means that most major cyclonic activity generated during El Niño years fails to reach Fiji (SOPAC 2009).

Furthermore, funding and planning for El Niño events is split between the Ministry of Environment and the National Disaster Management Office (NDMO 2018). This means that El Niño preparedness falls under climate change adaptation and disaster risk reduction strategies. The Fijian Government had previously drafted El Niño response plans and worked with the National Disaster Management Office to activate emergency operating centers for situation monitoring (WHO 2015).

The Fiji Meteorological Service (FMS) is responsible for weather research and forecasting. It provides hydrometeorological forecasts, including tropical cyclone warning services, to regional countries and flood warning and climate services to Fiji. The Hydrology unit of FMS is mandated to forecast flooding for the whole of

Fiji. The FMS vision is to ensure "safe and secure communities through the provision of dynamic and quality weather, climate, and hydrological services."

In October 2016, the Second Pacific Islands Climate Outlook Forum (PICOF-2) brought together national, regional, and international experts from the Meteorological Services Sector and the National Disaster Management Office to provide a platform to improve understanding on climate phenomena and consolidate seasonal forecasts from multiple sources to issue a consensus climate outlook for the Pacific (SPREP 2016). During this forum, statements on impacts and lessons learned from the 2015–16 El Niño for Climate and Disaster Risk Management were identified. Outlooks to prepare for the 2016–17 La Niña (SPREP 2016) were also provided. Key lessons learned from the 2015–16 El Niño included:

- A national process is needed for disseminating information and developing an El Niño-related forecast consensus statement
- Synthesizing information from smaller NMHSs in the region is difficult, so more resources—including the development of a complete weather-climate glossary—as well as additional training are needed to improve scientific knowledge
- A consistent template for official El Niño and La Niña declarations should be developed
- Readily available and accessible information from Met Services and NDMOs is essential
- High-level (reliable and credible) information needs to be provided early to governments, which would among other things assist with funding decisions
- Collaborative relationships between agencies—utilizing existing networks and working groups—should be strengthened
- Forecast products should be simplified whenever possible to make scientific information easier for government officials and the public to understand, and
- Developing systems to disseminate information from the national—to the community-level should be made a priority (PICOF 2017).

There are several global projects of the World Meteorological Organization (WMO), such as the Severe Weather Forecasting and DRR Demonstration project (SWFDDP) and the Coastal Inundation Forecasting Demonstration Project (CIFDP-F), that are ongoing in Fiji. These projects are meant to enhance severe weather and cyclone early warning systems.

13 Hurdles and Obstacles

The societal need for warning or forecast information that is localized, timely, and easily understandable has never been greater (Fakhruddin 2017). Major hurdles and obstacles to making such products available include:

- Lack of capacity to generate localized and reliably operational science-based information;

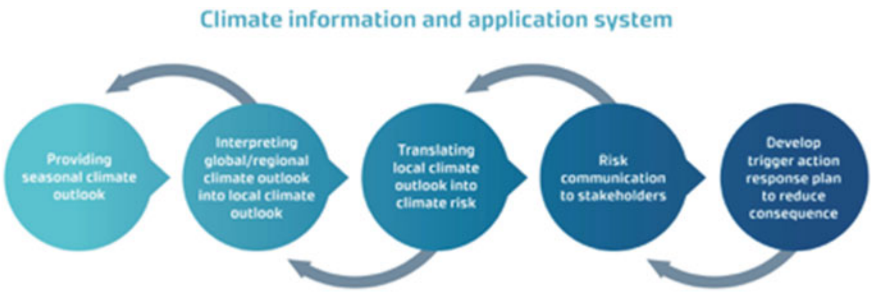

Fig. 4 Climate information and application system (Fakhruddin et al. 2020)

- Lack of advancement in generating hazard risk information that can be incorporated into operational forecast systems;
- Lack of operational forecasts that have been integrated into decision-making processes in order to reduce disaster risk; and
- Lack of experience in communicating probabilistic scientific information for practical use by end users.

A proposed climate information and application system to address these obstacles is shown in Fig. 4.

14 Lessons Learned from the 2015–16 El Niño

The following lessons and recommendations (1–4) are taken from the United Nations ECOSOC Special Meeting (UN 2016).

1. Investments are required for long-term efforts to provide climate services that reduce the risk to extreme events and increase local and national preparedness capacity and resilience—particularly in the agriculture and food security, water, and health sectors—in line with the Sendai Framework, the Paris Climate Change Agreements, and the SDGs.
2. Though no two El Niño impacts are identical, past El Niño-associated risk patterns provide guidance for anticipating and managing future El Niño-associated risks. Lessons learned about prediction, communication, and action during the 2015–16 El Niño can provide valuable information for future early warning systems. These lessons can also help understanding disaster risk for future events, including drawing from institutions that contribute observations, regional and national climate centers, and key sectors and other end-users of climate information. The Global Framework for Climate Services provides a useful resource (WMO 2012).
3. Sustained commitments and investments are needed to improve climate services and to establish and strengthen multi-hazard early warning mechanisms to

reduce the effects of extreme weather and climate events, including those associated with El Niño.

4. Implementation of livelihood-based safety net programs that incorporate traditional knowledge and social structures should be accelerated to reduce the vulnerability of affected populations.
5. Risk reduction plans and activities supported by adequate assessments and forecasts should be developed to prevent future crises from becoming protracted.

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Pacific Islands Region

Pacific Island Regional Preparedness for El Niño

Ilan Kelman

Abstract The El Niño Southern Oscillation (ENSO) is often blamed for disasters in the Pacific island region. From a disaster risk reduction (DRR) perspective, which includes climate change adaptation (CCA), the challenges with the El Niño part of the ENSO cycle are more related to inadequate vulnerability reduction within development than to ENSO-induced hazard influences. This chapter illustrates El Niño-related preparedness for Pacific islands, condensing and updating the more detailed work in the open access article: Kelman, I., (2019), Pacific island regional preparedness for El Niño, *Environment, Development and Sustainability*, *21*(1), 405–428. Overall, El Niño preparedness should sit as part of DRR including CCA—in effect, as a part of development. Yet the attention El Niño garners might bring resources to the Pacific region and its development needs, albeit in the short-term while El Niño lasts. Conversely, the attention given to El Niño could shift blame from underlying causes of vulnerability to a hazard-centric viewpoint. Instead of focusing on one hazard-influencing phenomenon, opportunities should be created for the Pacific region to tackle wider DRR and development concerns.

Keywords Climate change adaptation · Disaster risk reduction · Islands · Pacific · Resilience · Vulnerability

1 Introduction

El Niño—more than either the La Niña or neutral phases of the El Niño Southern Oscillation (ENSO)—is often blamed for weather-related hazards—such as floods, droughts, and fires—whether or not this blame is legitimate, especially for Pacific islands. This chapter illustrates El Niño preparedness measures for Pacific islands, condensing and updating material from the open access article Kelman (2019) which covers the following states and territories:

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• American Samoa	• Northern Mariana Islands
• Cook Islands	• Palau
• Federated States of Micronesia	• Pitcairn Islands
• Fiji	• Samoa
• French Polynesia	• Solomon Islands
• Guam	• Tokelau
• Kiribati	• Tonga
• Marshall Islands	• Tuvalu
• Nauru	• Vanuatu
• New Caledonia	• Wallis and Futuna
• Niue	

Disaster risk reduction (DRR) provides a useful framing within the context of development to deal with El Niño impacts, especially since DRR includes climate change adaptation (CCA). Pacific islands experience El Niño primarily as seasonal-scale changes to their environments, including alterations to ocean temperatures, sea level, precipitation, and winds. The effects tend to last several months and to deviate from expected seasonal patterns, often being described as weather extremes, such as drought during the 2015–16 El Niño (UNESCAP 2015).

Media, scientists, and practitioners often adopt a disaster discourse that suggests that El Niño episodes cause or manifest as disasters. Arguing against such attribution, Goddard and Dilley (2005) suggest that disaster-related losses are not necessarily more or less during any of the three ENSO phases, seemingly because forecasts help when actions are taken based on those forecasts—basically, standard DRR actions. This point is emphasized by UNDP et al. (2017) as a key lesson from the 2015–16 El Niño.

2 El Niño's Potential Impacts in the Pacific Region

Table 1 illustrates some prominent El Niño impacts that have been observed in the Pacific island region, categorized by country because impacts tend to be reported at that level. Table 1 shows the challenges of determining El Niño impacts for the Pacific island region. In addition to several blank cells, the descriptions are vague, indicating qualitative trends but not describing degrees of variation. Few quantifying data are available. In some cases, the values indicate only projections of change due to a specific El Niño without making clear whether or not such change constitutes a pattern that is generalizable for all El Niño events.

Since sources do not always list the same impacts, Table 1 might not fully reflect all the citations. For example, the general assessment of sea-level changes in Table 1 includes some countries labelled as "higher" and some countries labelled as "no

Table 1 Some reported El Niño impacts in the Pacific island region

Country	Rainfall	Cyclones	Sea level
American Samoa		More frequent	
Cook Islands	More in north Less in south	More frequent More intense	Higher
Federated States of Micronesia	Less	More frequent	Lower
Fiji	Less	More frequent More intense	Lower
French Polynesia		More frequent More intense	Lower
Guam			
Kiribati	More	No change	Higher
Marshall Islands	Less	More intense	Lower
Nauru	More		Higher
New Caledonia		No change	
Niue	Less	More frequent More intense	
Northern Mariana Islands	Less		
Palau	Less	No change	
Pitcairn Islands			
Samoa	Less	More frequent More intense	Lower
Solomon Islands	Less	More frequent More intense	Lower
Tokelau		More frequent More intense	
Tonga	Less	No change	Lower
Tuvalu	More in north Less in south	No change	No change
Vanuatu	Less	More frequent More intense	No change
Wallis and Futuna		More frequent More intense	

Compiled from Annamalai et al. (2015), Glantz (2000, 2001), Rupic et al. (2018), Shea (2003), Thomson (2009), UNESCAP (2014), UNOCHA (2016), and Wyrtki (1985)

change". The data (such as from BoM 2010 and Rupic et al. 2018) give much more complicated and nuanced pictures, with both increases and decreases having been observed in many countries over the course of each of the El Niño events in 1997–98, 2002–03, 2007–08, and 2015–16. Another problem with Table 1 is that it represents overall impacts on climate from El Niño, even though temporal differences can emerge as an event progresses, such as with shifts from wetter-than-normal to drier-than-normal conditions (Annamalai et al. 2015). Despite changes in tropical cyclone frequency and intensity in some places (Magee et al. 2017), Table 1 is further problematic because no suggestion is made of the out-of-season or near-equator tropical cyclones that can, and do, occur due to El Niño. In fact, even in places where tropical cyclone frequency increases due to El Niño, rainfall is nonetheless often less prevalent overall and severe drought is experienced, which is another failing of the representations in Table 1.

Consequently, what Table 1 indicates in the shortcomings it exposes is that the understanding of El Niño's environmental impacts for a specific Pacific island location or country is often too coarse to be useful or useable for considering specific impacts or necessary responses. Instead, Table 1 can indicate only the necessity of preparedness for a range of conditions and the need to be flexible, which in effect articulates the prime ethos of DRR.

3 Preparedness for El Niño

The Pacific islands regional focal points for DRR and El Niño-related topics are the Secretariat of the Pacific Community (SPC) and the Secretariat of the Pacific Regional Environment Programme (SPREP). They have embraced the principal intergovernmental document pertaining to preparedness, the *Sendai Framework for Disaster Risk Reduction* (SFDRR; UNISDR 2015). SFDRR provides a conceptual framework for exploring Pacific regional preparedness through its four priorities:

> "Priority 1: Understanding disaster risk
>
> Priority 2: Strengthening disaster risk governance to manage disaster risk
>
> Priority 3: Investing in disaster risk reduction for resilience
>
> Priority 4: Enhancing disaster preparedness for effective response and to 'Build Back Better' in recovery, rehabilitation and reconstruction."

These priorities deploy plenty of jargon, which has been extensively theorized and critiqued (e.g. for "Build Back Better," see Williams 2008), but they form the baseline for examining Pacific islands regional initiatives for El Niño preparedness. Because such work has been in progress for decades with numerous programs and donors, not confined to intergovernmental organizations, a comprehensive review is not possible. Instead, illustrative examples have been selected to set the stage for discussion, critique, and recommendations.

Priority 1, "understanding disaster risk" with respect to El Niño, is conducted principally through research and analysis, even if that research was not completed primarily for academic publication. When considering disasters which might be linked to El Niño, most of the research is targeted at specific countries or communities, such as original research into Fiji's experiences during the 1997–98 El Niño (Glantz

2000); ecological changes in the central equatorial Pacific during the 2015–16 El Niño (Brainard et al. 2018); and ciguatera food poisoning (from toxic fish) increasing with El Niño-associated sea surface temperature increases around several Pacific islands (Hales et al. 1999).

In the run-up to the 2015–16 El Niño, SPREP became involved in coral reef monitoring to help detect bleaching and establish a data baseline for the future. SOPAC was working on freshwater management in the context of climate variability and change, including El Niño. These examples illustrate how the risks of El Niño for the Pacific islands are understood at a coarse level, usually articulated in terms of rainfall, drought, and tropical cyclones. The view is thus hazard-centric, rather than focusing on vulnerability which is core of DRR including CCA.

Part of understanding disaster risk involves understanding El Niño impacts and vulnerabilities, with the most evident impacts in the Pacific region being on food and freshwater availability. Risks to agriculture and fisheries are well-documented, as are strategies for reducing associated vulnerabilities (e.g. Campbell 2009, 2015; Lefale 2010; Shea 2003). Given the richness of traditional, local, and external knowledge forms, information about Pacific island regional preparedness for El Niño is readily available, from both hazard and vulnerability perspectives.

This information is, nevertheless, not always put into action for El Niño preparedness. Macpherson and Macpherson (2017) provide a poignant example with respect to freshwater in Samoa. They point out how El Niño significantly varies annual rainfall in Samoa, but social contexts based on culture, religion, and politics dictate freshwater source ownership, access, and use. Even if forecasting, warning, and planning for freshwater during El Niño were perfect, the disaster risk might still be managed inadequately because the risk contributions from vulnerabilities based on social structures often dominate the risk contributions from hazards.

SFDRR's Priority 2 "strengthening disaster risk governance to manage disaster risk" and Priority 3 "investing in disaster risk reduction for resilience" are hard to differentiate on the ground for El Niño and Pacific islands. Even as "governance" is termed a process and "resilience" is termed a characteristic, the two concepts (despite numerous definitions and disputes about the definitions) are neither synonymous nor mutually exclusive. Resilience can be seen as a characteristic of good governance, while good governance is one process required to achieve resilience. In small settlements with a large degree of isolation and self-sufficiency, traits common for Pacific islands, the overlaps and synergies are particularly poignant, which means that for a specific hazard-related phenomenon such as El Niño, SFDRR's Priorities 2 and 3 meld.

In the melding of Priorities 2 and 3, warning systems are an example which cover both disaster risk governance and resilience building. An example of El Niño warning at the Pacific regional level is from Chowdhury and Chu (2015), who looked at sea-level forecasts mainly for the U.S.-affiliated islands and including but not limited to El Niño years. Forecasts had been given 3–6 months in advance, but they report moves toward 6–12-month forecasts due to increasing demand.

Earlier work from Kaloumaira (2002) and Lightfoot (1999) discusses early warning and preparedness in Fiji specifically for El Niño. The largest impact observed is drought affecting sugar cane, a cash crop that introduced vulnerabilities to Fiji by increasing dependency on external factors such as global markets and commodity prices while taking land from more locally based livelihood production regimes. The root causes of El Niño's impacts, however, are neither identified nor addressed by highlighting sugar cane impacts. While communities could and should make decisions regarding the disaster risks they accept (noting that communities are not homogenous, so sectors or groups within the same community might disagree), which might still entail a choice to grow sugar cane, it can be counterproductive to both Priorities 2 and 3 to assume that sugar cane is the solution for their livelihoods.

Recognizing this situation, both Kaloumaira (2002) and Lightfoot (1999) explicitly move away from simple meteorological monitoring for early warning, instead suggesting approaches that would support Fijians irrespective of ENSO's vagaries. Examples are agricultural diversification, avoiding a culture of aid dependency, and dealing with chronic, background levels of malnutrition and water mismanagement. Fletcher et al. (2013), for instance, highlight the importance that many Pacific islanders, in Fiji and elsewhere, place on remembering and applying traditional knowledge for warning and food security when contending with El Niño and other climate-related variations and trends. Glantz (2001) notes that El Niño-linked drought in Fiji magnified, but did not cause, ongoing problems of malnutrition and low income. In fact, Kaloumaira (2001) makes the point that the 1997–98 El Niño hit Fiji so hard partly because it had been preceded by five years of many other disasters, so the country never had the time to recover and then respond to the El Niño event. Kaloumaira (2001) goes on to point out that the best early warning and preparedness for El Niño occurs at the household level.

Capacity building plays a major role with respect to El Niño and SFDRR's Priorities 2 and 3. In 2015, for example, South Korea launched a three-year program to support climate prediction information and skills in the Cook Islands, Federated States of Micronesia, Fiji, Kiribati, Marshall Islands, Nauru, Niue, Palau, Samoa, Solomon Islands, Tonga, Tuvalu, and Vanuatu (and also PNG). Similar work has long been ongoing, such as through a Canadian-funded project on capacity building for climate change for the Pacific (Nakalevu 2006). Another example is the planning involved in developiung the capacity necessary in order to establish by 2002 Nauru's National Meteorological and Hydrological Service (Koop 2000).

Clear progression in risk governance and resilience for El Niño is seen from these initiatives—from lacking dedicated national agencies for weather, climate, and water to having such agencies plus continual capacity building efforts for them. Irrespective of El Niño, but supporting work for preparedness through DRR, these initiatives continue (see also Santoso et al. 2017). For instance, the First Pacific Islands Regional Climate Outlook Forum was held in Fiji in October 2015 to link seasonal climate projections with community-based, daily decision-making. Other aspects of this forum included linking the water and climate sectors, training for interpretation and use of climate forecasts, and DRR capacity development. The Forum culminated in the release of the first regional Pacific statement on El Niño and potential impacts. Even more recently, Japan began funding a Pacific Climate Change Centre in Samoa, which opened in 2019.

All these initiatives linked to SFDRR's Priorities 2 and 3 are hazard-related. Plenty exists regarding the vulnerability side, but those programs tend not to be explicitly linked to El Niño.

Finally, SFDRR's Priority 4, "enhancing disaster preparedness for effective response," is acknowledged as a large challenge from previous El Niño experiences in the Pacific islands region. For the 2015–16 El Niño, many donors indicated their "effective response" as being aid deliveries, such as water to communities in Fiji and food to communities in Vanuatu (see also Savage et al. 2021). Allen (2015) describes UNICEF assisting communities affected by El Niño induced drought, highlighting Vanuatu but then generalizing to the rest of the Pacific. Few specifics are given apart from alluding to food and water deliveries, measures that seem to be no different from UNICEF's regular day-to-day and year-to-year activities around the region.

It is unclear how different the situation is from non-El Niño time periods. Lightfoot (1999) explains the importance of water delivery to Fijian households during the 1997–98 drought, but then describes how water deliveries to houses and schools in Fiji occur regularly irrespective of El Niño. Water shortage is symptomatic of underlying, chronic vulnerabilities which are then exposed by an El Niño event. Funafuti, Tuvalu experiences significant rainfall variations during El Niño—and sometimes outside of El Niño time periods, such as during the 2011 drought linked to La Niña and associated with a diarrheal outbreak (Emont et al. 2017). Enhancing El Niño preparedness means enhancing all disaster preparedness for all phases, which effectively means DRR including CCA.

4 Conclusions

The attention garnered by El Niño, especially by focusing on assumed anomalies rather than on the problems that persist during the "normal" (including certain aspects of La Niña), can shift blame from underlying causes of vulnerability to a hazard-centric viewpoint. It can also shift blame to a hazard influencer, which is quasi-periodic (as opposed to annual), even when the hazards it influences appear to different degrees irrespective of El Niño.

The distraction of El Niño can degrade vulnerability reduction efforts but could also be used constructively to pursue a wider DRR and development agenda, tackling the fundamental aspects of uncertain impacts and of vulnerabilities by springboarding off the attention given to El Niño. While a danger exists of DRR being of less interest outside of El Niño times, the key is not to set up a contrast or tension. Instead, recognizing the opportunities that El Niño's attention brings and then trying to move beyond El Niño specific approaches could yield the most successful outcomes by supporting DRR including CCA.

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Sub-Saharan Africa

Ethiopia

Ethiopia: The Case of the 2015–16 El Niño

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Abstract Ethiopian society has historically been vulnerable to climate-related hazards. The main hazard drivers are the ENSO extremes of El Niño and La Niña. The diversity of microclimates due to the topography of this tropical country paired with weak economic and institutional development, have made the impact of climate on society very complicated. Before the 1990s, there were no planned disaster risk management (DRM) strategies that strongly contributed to coping with the societal impacts of El Niño (impacts that were not only directly related to the strength of ENSO but also to weak social responses). The 2015–16 El Niño is now considered stronger than the 1982–83 event that was associated with the historic Ethiopian famine of the 1980s. Ethiopia's socioeconomic development was improving during the 2015–16 El Niño which prompted some stakeholders to conduct monitoring, early warning, and various preparations in response to the very strong event. Therefore, the impacts of El Niño's effects were minimal and were managed by the government and its partners. Political stability including the strengthening of DRM through the autonomous Disaster Prevention and Preparedness Commission (DPPC) had been important between 1991–2020. The disaster that could have taken place due to the 2015–16 El Nino was averted because of the lessons taken from previous El Niño impacts. The war that erupted in 2020 and the government-imposed embargo on its Tigray province has led to man-made famines in the region.

Keywords Ethiopia · El Nino · DRM · Famine

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Fig. 1 Map of Africa highlighting Ethiopia

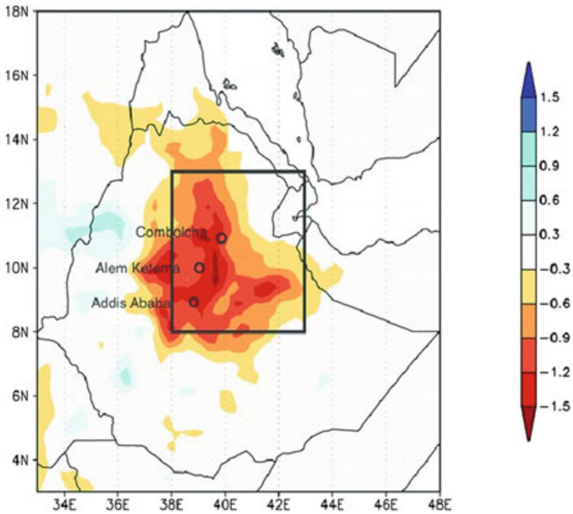

Fig. 2 Anomaly in precipitation (CHIRPS; precipitation minus 1981–2010 climatology) averaged over February-September 2015 (mm day-1). (Sjoukje 2018)

Note: From June 2015 until the end of 2016, Ethiopia (Fig. 1) experienced one of the worst droughts in decades, which had a devastating impact on people's lives and livelihood (Fig. 2). At the peak of the crisis in April 2016, 10.2 million people were aided with life-saving food assistance, and an additional 7.9 million people benefitted from the Productive Safety Net Programme (PSNP). The El Niño-induced drought was followed by extensive flooding that affected 480,000 people, of whom 190,000 were displaced. The severe drought combined with floods and disease outbreaks, such as Acute Watery Diarrhea, substantially eroded people's coping capacities, further increasing the level of need. The impact of the crisis on livelihoods people's nutritional and health status, and the provision of basic services has also been significant (OCHA 2016).

1 Introduction

In the last 60 years Ethiopia has been exposed to a wide range of climate-related hazards. This exposure has particularly been severe in northern and eastern parts of the country that are often vulnerable to droughts (Fig. 3), floods, vector-borne epidemics, and frosts (Degefu 1987). Other climate-related problems such as heat waves and climate-sensitive disease outbreaks have affected Ethiopia. These include rainfall-related landslides on mountain slopes that have been eroded due to deforestation and steep-slope plowing and flooding in lowland areas that often kill grazing animals as well as people. Climate-sensitive health hazards such as malaria, meningitis, and Rift Valley Fever (RVF) are prevalent in lowland areas.

The countries main climate-related hazards have, however, typically been driven by ENSO's extremes, El Niño and La Niña (Goitom and Assefa 2017). Drought has affected both agricultural and hydropower generation (Teshome 2015). The most notable droughts, dating back to the late nineteenth century, were all El Niño-related events (Kelem and Derbew 2017). Other notable El Niño drought events occurred in 1957–58, 1965–66, 1972–73, 1982–83, 1997–98, and 2015–16.

The leadership of Ethiopia's National Meteorology Agency (NMA) has long acknowledged the connection between El Niño and Ethiopian droughts (Haile 1988; Nicholls 1993). Significantly, however, one of its former directors admitted that NMA only mentioned El Niño in its forecasts for the first time in 1987 (Kassahun 1998). As Diriba Korecha (2015), a long-time scientist at NMA, stated, "Evidence has shown that there is strong lag and concurrent relationship between Ethiopian seasonal rainfall and ENSO parameters."

The impacts of El Niño on Ethiopia depend on the time of its formation in relation to the main onset of the seasons. When the onset, distribution, and cessation of rainfall mismatch with the seasonal agricultural calendar, crop failures often result. El Niño also leads to anomalous climate variability, which creates favorable environmental

Fig. 3 Drought conditions in Ethiopia during the 2015–16 El Niño (UNICEF 2016a)

conditions for these health hazards in the lowland areas. Global warming related to manmade climate change might also be driving the intensity of recent El Niño events (Wolde-Georgis et al. 2017).

El Niño events have led to crop failures and food insecurity in the country. It is now believed that the historic Wollo Famine of 1973–74 was caused by the 1972–73 El Niño (Wolde-Georgis 1997). El Niño also led to the notorious famine of 1983–85 that killed close to one million people in Ethiopia (Richman et al. 2016). Neither the monarchy that was deposed in 1974 nor the self-declared communist military government that replaced it (1974–1991) could handle the impacts of those two El Niño events. But the strong 1997–98 El Niño also caused severe droughts and floods, though the human impact was seriously minimized by the establishment in the intervening years of effective and institutionalized early warning, preparedness, and response systems.

The focus of the following chapter is the 2015–16 El Niño, its impacts on society, and the "readiness" of Ethiopia to contend with the event, both at the time and subsequent to it. When the arrival of an El Niño was forecast in 2014, many of the disaster management institutions in Ethiopia were mobilized to cope with the situation and to reduce the impact. In retrospect, the 2015–16 El Niño is now considered stronger than the 1982–83 El Niño in its intensity and almost as strong as the 1997–98 El Niño, with especially north and central Ethiopia suffering their worst drought in decades as a result (CDKN 2017). Some places in these areas recorded a rainfall deficit of 167 mm from long-term averages (Funk et al. 2015). Only one half to three quarters of expected rain fell from February to September of 2015, the period during which 90 percent of Ethiopia's food supply is typically produced.

2 Climate-Related Hazards and Disaster

Ethiopia's climate is characterized by three seasons, locally known as *bega* (October to January), *belg* (February to May), and the primary rainy season of *kremt* (June to September). Most of Ethiopia's agricultural production takes place during *kremt* (JGHP 2015b). Situated just north of the equator, seasonal classification in Ethiopia is mainly based on these rainfall patterns. The key to the primary rainy season of *kremt* is the Inter-Tropical Convergence Zone (ITCZ) (Gleixner et al. 2017; Haile 1987). Close to 80 percent of the rural population is dependent on *kremt* rains, and 20 percent is dependent on *belg* rains for food production (OCHA 2015a). Playing an important role in the onset, duration, and distribution of rainfall, the lifecycle of an El Niño event can dramatically influence the emergence of climate-related droughts and floods during either season.

There is not yet a complete understanding of the role of El Niño as a driving force of Ethiopia's seasonal rainfall variability. Gleixner et al. (2017), for example, note that "El Niño is known to cause failure of kremt (boreal summer) rainfall in Ethiopia, though the mechanisms are not fully understood." Other researchers have made similar observations. In fact, no single correlation between ENSO's warm extreme (El Niño) and the whole country's seasonal rainfall variability has been identified, likely because some areas are more significantly correlated with El Niño than others. This complexity is due to the existence of various microclimates and a range of topography in Ethiopia.

Global warming may have made the 2015–16 El Niño more intense, which would likely have contributed to the decline in precipitation observed in Ethiopia at that time. The impacts of the 2015–16 El Niño continued into subsequent years, even though the physical event ended by May of 2016. This amplifying effect might explain why CDKN (2017) estimated that the 2015–16 El Niño drought affected nearly 10 million Ethiopians and that ~5.6 million people required emergency food assistance through June 2017 (FEWS NET 2017).

3 Different Governments, Different Levels of Preparedness

The imperial government that was deposed in 1974 did not have any established institutions for disaster preparedness or response. Anyone who died due to famine was considered either a police issue to verify or the victim of "an act of God." The military government that removed the emperor after the 1973–74 famine initiated the practice of food security preparedness, establishing the Relief and Rehabilitation Commission (RRC). The focus of RRC was on mobilizing resources to feed famine victims. The post-1991 Ethiopian People's Revolutionary Democratic Front (EPRDF) government, which replaced the military government, went beyond this start by creating a more robust disaster risk management (DRM) strategy. EPRDF, whose policies were rural-oriented, made disaster preparedness and prevention—including consideration of El Niño impacts—one of its key priorities. It strengthened disaster risk management institutions and designed and updated Ethiopia's DRM strategies, including for early warning and response. A national committee for disasters was created at the highest level of government, signaling the country's deliberate shift from a reactive to a proactive approach to disaster management.

In the 1990s the government strengthened disaster management by developing a new policy and introducing a disaster prevention and preparedness strategy. RRC was transformed into a comprehensive Disaster Prevention and Preparedness Commission (DPPC). It incorporated mechanisms to provide early warning for climate-related disasters as well as prevention mechanisms. DPPC was also tasked with undertaking needs assessments and resource mobilization. One of the institutional changes made to deal with climate impacts was the streamlining of DRM institutions.

A criticism of DDRC was that it was in constant fund-raising mode to respond to chronic non-disaster food insecurity. Another criticism was that donor fatigue tended to result whenever food production declined due to non-climate-related factors. In 2004, the Ethiopian government responded to this criticism by separating emergency demands from poverty-related food insecurity in the country, establishing the Food Security Bureau (FSB) under the Ministry of Agriculture. FSB was meant to deal with chronic poverty and food insecurity during normal weather years in order to reduce the burden on DPPC so it could focus only on disaster-related issues.

DPPC remained focused on disaster until 2009 when it was put under the Ministry of Agriculture and into the Disaster Risk Management (DRM) and Food Security Sector (DRRFSS). The revised strategy was meant to enable affected populations to withstand the impacts of climate-related hazards and to “reduce damage caused by a disaster through establishing an effective, people centered, integrated, coordinated, accountable, and decentralized disaster risk management system... [and] measures that need to be taken before, during, and after the disaster period” (FDRE 2013a, 2013b). DRRFSS was run by a high ranking official at the Ministry of Agriculture (FDRE 2016a, 2016b). Though why exactly DPPC was incorporated into the Ministry of Agriculture is unclear, it was likely because crop failure is the leading cause of disaster in Ethiopia. The National Disaster Risk Management Commission was established in 2017.

By the end of the second decade of the twenty-first century, Ethiopia had seemed to have learned some of the previous lessons of drought-related disaster risk management. The introduction of various disaster preparedness and prevention policies were important milestones in this process. Even so, Ethiopia’s capacity to respond to El Niño-related disasters, and its political commitment to doing so, were tested on several occasions in the intervening years, especially during the 1997–98 and again during the 2015–16 very strong El Niño events. In neither case did the famines that had characterized such events in Ethiopia prior to 1991 occur. What these successes suggest is that the investments in El Niño preparedness that Ethiopia had made since the early 1970s had reduced the impacts of the hazards produced by El Niño events, despite the likely climate-induced increase in those events’ intensity.

A further constraint in dealing effectively with climate-related impacts such as famine in Ethiopia was the significant logistical issues of food delivery and distribution across the country’s poorly connected regions. One of the main problems that contributed to famine in Ethiopia during the military government was the inability for surplus food in one part of Ethiopia to reach food-deficit communities elsewhere in the country in part because of basic communication and infrastructure problems, including a bureaucratically tangled food distribution system, unavailable or inadequate transportation infrastructure, and poor or nonexistent local storage facilities. In response to these problems, Ethiopia has worked to build up its strategic grain reserves, risk-financing mechanisms, logistical coordination procedures, and systems of community recovery (Rashid and Lemma 2011). Following the downfall of the military, free movement of food from one region to another by traders became an effective livelihood strategy, which had the effect of further diminishing the logistical challenges the country has faced in what were once disasters but are now merely challenging situations.

4 El Niño and the Ethiopian Economy

According to the World Bank, Ethiopia had a per capita income of USD$590.00 in 2015, making it one of the world's eleven poorest countries (IEG CLR 2017). According to most indicators, Ethiopia has also recently been one of the five fastest growing economies in the world (Carroll 2014). Nasdaq.com (Bajpai 2019), for example, notes that "Ethiopia is the fastest growing economy in Africa and the second fastest growing economy in the world... The country is projected to grow at 8.1 percent during the 2018–2021 [period]."

The leading sectors for investment in the country are service, infrastructure, manufacturing, and large-scale farming. There have been many foreign direct investments in the agricultural sector focused on exports of mainly nontraditional cash crops like rice, flowers, and biofuel production. For example, Ethiopia now competes with other flower export leaders, such as Kenya, in the region. Coffee, which has long been cultivated for both export and domestic consumption, is mainly grown by small holders but also still grows wild in the bush. It is extremely susceptible to climate variations, however, as was shown during the unseasonal El Niño-driven rainfall in October 1997–98 when coffee beans were reported to have sprouted before having been harvested.

Ethiopia has been commended in recent years for having reached most all of the Millennium Development Goals, including having lowered under-five mortality by two-thirds three years before 2015 and reducing the maternal mortality rate (Haileamlak 2015). The government has in recent years also taken upon itself to invest in infrastructure such as power, roads, railways, and even subways. It is focused on urban and rural development, industrial parks, and actively supporting foreign direct investment opportunities. The first five-year Growth and Transformation Plan (GTP1 2010–15) was unveiled in 2010 under the leadership of the late Prime Minister Meles Zenawi. In conjunction with GTP1, the country also declared its intention to build a climate-resilient green economy as its path to growth and transformation (FDRE 2011). When GPT2 (2015–20) was instituted, the government had plans to make Ethiopia a middle-income country by the end of the third plan, in 2025.

GPT has been described as an "ambitious five-year growth plan, with projected Gross Domestic Product (GDP) growth of 11–15 percent per year from 2010 through 2015" (FDRE 2010). Even though the Ethiopian economy grew faster than the sub-Saharan Africa average of 4 percent, however, a World Bank Review stated that its growth rate slowed to 6–7 percent in 2015–16 due to the El Niño-induced drought (IEG CLR 2017). Despite this setback, Ethiopia had until recently shown an excellent socioeconomic transformation, with an average annual growth of 11 percent.

Ethiopian leaders have long realized the potential adverse impacts of climate change. The main fear has been that climate-related disasters might roll back its social and economic gains. Deliberately shifting Ethiopia's climate risk management approach from one reactive to crises to one more proactive and sustainable should be understood, therefore, as a way to protect economic growth and socioeconomic stability (FDRE 2015). The government viewed El Niño as an obstacle to the achievement of the goals of aggressive economic transformation that had to be dealt with accordingly. Therefore, a comprehensive DRM system was called for to "reduce the impacts of disasters on economic growth, and to protect development gains" (FDRE 2010). This approach was supported by diverse national policies across ministries (FDRE 2016a, 2016b). Ethiopia also took international disaster protocols and guidance into consideration in its DRM policy.

Ethiopia was in a different socioeconomic and political context during the 2015–16 El Niño then it was in during both the 1972–73 and 1982–83 events. For one, the size of the country's economy had doubled. There was also increasing confidence on the part of Ethiopia's international partners that the government would implement cooperative hydrometeorological risk management agreements effectively. Infrastructure developments such as roads that connect most parts of the country as well as the construction of food storage silos were important parts of an El Niño readiness strategy in Ethiopia.

The EPRDF governing coalition was dissolved on December 1, 2019 after many months of bickering among its member parties. It is now succeeded by a party that calls itself the Prosperity Party (PP). The Tigray Peoples Liberation Front (TPLF) refused to be incorporated into the new party. The Prosperity Party, under the leadership of Abiy Ahmed Ali, considers itself a successor of EPRDF and postponed the upcoming 2020 election due to the Covid-19 pandemic. It has been critical of its former iteration and implied that it wants to establish a liberal form of government, including plans to sell off some of the big government-owned companies. It is not clear, however, if it will introduce private ownership of land, which has been owned by the state ever since the rise of the military government in the mid-1970s.

[N.B. just prior to submitting this chapter for publication, the situation in the Tigray region in the north of the country had become quite fluid, with active military conflict having broken out between TPLF and the Ethiopian military. Uncertainty prevails as the country stands on the brink of civil war.]

5 Ethiopian Preparedness and the 2015–16 El Niño

The earliest warning of an impending El Niño for 2015 was actually in 2014. NMA announced in its seasonal early warning bulletin in December of that year that an El Niño could form within the following few weeks. This bulletin was based on a prediction of an impending event from IGAD's Climate Prediction and Application Center (ICPAC) in Nairobi. For its part, NMA noted in its *belg* 2015 outlook: "In the upcoming belg, the season is expected to be under the influence of the ENSO-Neutral SST episode of the central and eastern Pacific Ocean" (NMA 2015). It added that the onset of the rains would be erratic but that their cessation would be normal.

The 2015 El Niño was first detected by NOAA and the Australian Bureau of Meteorology (BOM). The formation of El Niño was officially announced in Ethiopia by NMA in March 2015 (Save the Children 2015). NMA incorporated El Niño in its early warning and planning process for the year. The NOAA advisory predicted with approximately 90 percent certainty that the El Niño would continue through the Northern Hemisphere summer 2015 and with a greater than 80 percent certainty that it would last through 2015 (ICPAC 2015). NMA eventually concluded that the 2015–16 El Niño was one of the strongest in its overall impact on Ethiopia (Mengistu 2020; Thompson 2015).

The 2015 El Niño is now considered the strongest in the last 50 years (Thomson 2015). It was above the +0.8 °C three-month running mean of the Oceanic Niño Index (ONI) for more than 13 consecutive months starting in March 2015 (CPC 2020). This was above the +0.7 °C three-month running mean ONI value for an El Niño event to be considered "locked in" in a review of the ONI, as Glantz and Ramirez proposed (2020). At the end of 2015, FEWS NET Ethiopia (2015) noted that central/eastern Ethiopia received the lowest level of rain in 50 years at an average of 480 mm total between March and September. It also reported that in addition to the low rainfall, March to September temperatures were also the highest recorded since 1960.

Korecha (2015) reported that the 2015–16 event significantly affected *kremt* rainfall. According to NMA, there were several extreme weather conditions in many parts of the country in 2015, examples of which include extreme low temperatures in February in the towns of Adigrat (−5.0 °C), Debre Berhane (−4.5 °C), Mehal Mada, and Wegel Tiana (−2.8 °C) (FDRE 2015). Furthermore, the following towns received extreme rainfall: Debre Berhan (67 mm), Harar (50 mm), Dilla (47.5 mm), Gode (46 mm) and Kofele (36 mm) (Ethiopian Herald 2015).

In early 2015, NMA continuously monitored the extreme drought of the *belg* season that started in February (Teshome 2015). In June 2015, NMA announced that the *belg* rains had failed, even though May had had above normal rainfall. To be understood is that the announcement of the El Niño in March 2015 was issued while Ethiopia was in the middle of that ongoing *belg* drought. Therefore, the announcement was considered an extension of the ongoing *belg* drought monitoring and was, therefore, not considered a surprise by forecast users.

From January to June 2015, monthly situation updates on the weather and food security situation were released. ICPAC also warned that the summer months would likely reflect the onset phase of an El Niño event and that suppressed rainfall over the Northern Sector of Ethiopia should be expected from June to September (ICPAC 2015). This warning proved to be correct, as most regions of the *kremt* rainfall season in Ethiopia were characterized by below average 2015 rains.

An important component of disaster management in Ethiopia had been the continuous observation and management of precipitation, harvests, and food security. Reports were written with data not only from meteorological stations but also from observations by local governments.

The Productivity Safety Net Program (PSNP), for example, is important for El Niño/disaster preparedness related to food security (FDRE 2015). It protects household assets and provides farmers with inputs during normal seasons in order to reduce their vulnerability to drought. It is funded by the government with support from donors, including the World Food Program. Household members, unless they are disabled, must work on water and soil conservation and reforestation to benefit from PSNP. This is an important program to help people prepare for El Niño. NGOs dealing with disaster have identified *woreda*-level (county) drought hotspots to provide special focus for the program (OCHA 2015b). These kinds of institutions have proven important for monitoring the emergence of hazards and their impacts and for preparing responses. There are also early warning departments from the local *woreda* to the national level. In sum, Ethiopia was prepared to face the 2015–16 El Niño.

6 Impacts of and Responses to the 2015–16 El Niño

Several pastoral and agropastoral areas of Ethiopia recorded significant rainfall deficits of up to 50 percent of normal (FAO 2016). According to FAO, the most extreme drought conditions in Ethiopia were in the northern states. In the village of Atebes near Adigrat (in Tigray), for example, farmers reported that there were only six rainy days in July 2015 (Haile-Mariam 2016). Neither *belg* nor *kremt* rains came in 2015 (Fig. 4), leading to the failure of crops and pastures (FAO 2016). In some areas, crops totally failed, and animals were allowed to graze the fields (Graham 2015). Because most of Ethiopia's agricultural production takes place during the *kremt* rainfall season (JGHP 2015a, 2015b), this crop failure led to food insecurity, malnutrition, and devastated livelihoods (UN News Service 2015). According to

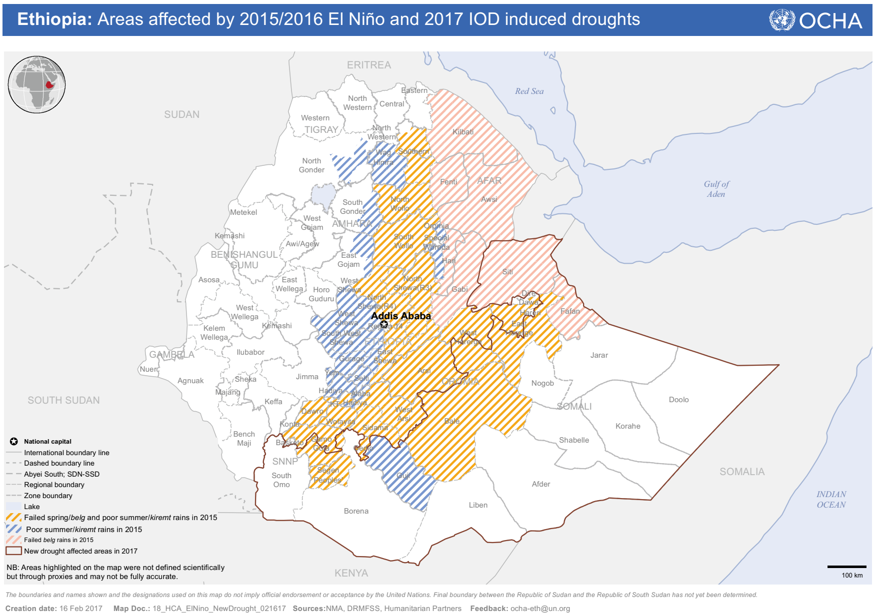

Fig. 4 Areas affected by 2015–16 El Niño and 2017 IOD-induced droughts (OCHA 2017)

EHCT/OCHA (2015), the failed *belg* rains added to food insecurity and malnutrition and wrought havoc on grain and livestock production in the country, even before the impact of the failed *kremt* rains. The El Niño severely affected "southern Tigray, eastern Amhara, Afar, and Siti zone of Somali region, eastern SNNP region, East and West Hararge, Arsi and West Arsi, and lower Bale zones of Oromia" (Solomon 2015).

The number of people in Ethiopia affected by the 2015–16 El Niño was estimated to be about 10.2 million, yet the country's mortality rate did not increase from previous years. In other words, Ethiopians were not starving to death as during earlier El Niño events (De Waal 2016). Food aid was being distributed to victims, with a standard ration per person having been 15 kg of wheat and a half liter of cooking oil per adult in the areas hit by drought (Meseret 2015). In pastoral areas there were interventions to protect the livelihood assets of pastoralists and agropastoralists alike and to revitalize the resilience of communities through a coordinated response (FAO 2016).

The arrival of the 2015–16 El Niño was communicated through the media as well as through email, fax, and hard copy documents. Once the arrival of the event and its impacts had been announced, a National Disaster Risk Management Task Force was established at the highest level under the leadership of the prime minister. The task force issued weekly appraisals and updates that were distributed to relevant offices. There were also continual situation updates. Activities such as the identification of affected populations, food distribution, and logistical arrangements were communicated to relevant stakeholders. The government developed communication plans for communities in flood-risk areas with messaging that included information about relocation, timely harvesting, and appropriate water catchment practices during the growing season.

7 Resource Mobilization

Ethiopia's traditional responses to disaster events had been early warning, assessment, resource mobilization, and response. The Ethiopian government and its partners/donors, including FAO, concluded that the 2015 El Niño would lead to food insecurity in the absence of early resource mobilization. Coordination of the agriculture and livelihood sectors during preparations was co-led by the Disaster Risk Management and Food Security Sector (DRMFSS) and FAO. FAO especially supported the Ethiopian government in coordinating initiatives to support agricultural livelihoods.

The overall coordination of resource mobilization was led by the government's National Disaster Risk Management Coordination Committee (NDRMCC), which managed the federal and regional level Disaster Risk Management Technical Working Groups (DRMTWGs) across Ethiopia and hosted a series of specialized task forces that worked in tandem with other clusters and sectors, including with food and agriculture (UNICEF 2016b). There was also multi-agency coordination at the strategy and technical levels led by NDRMCC and comprising representatives from respective sector task forces. Humanitarian partners coordinated and provided guidance to facilitate effective responses at all levels. Other notable interactions included the informal climate partners meeting that worked to communicate and update one another.

The government and its partners produced situation analysis reports on the impacts of drought on people and property (Reuters 2016). Needs assessments were completed and estimates of the number of beneficiaries agreed upon by the stakeholders. There was also disagreement on the number of people affected, due to the fluid nature of the impacts, but the number was eventually settled at 10.2 million people. A coordination mechanism was also set up with the Ethiopia Humanitarian Country Team (HCT). The team prepared an action plan based on 2015 food production and projections of need for 2016 (NDRMCC 2015). The government and the HCT developed three strategies to develop their operational plans: (1) Save lives and reduce morbidity related to drought; (2) Protect and restore livelihoods; and (3) Prepare for and respond to other humanitarian shocks, including natural disasters, conflict, and population displacement (NDRMCC 2015).

The Disaster Risk Management and Food Security Sector (FDRE 2016) of the Ministry of Agriculture was responsible for overseeing and coordinating El Niño impact preparedness and response. The Secretary of the National Disaster Prevention and Preparedness Committee (NDPPC) directed DRMFSS and also coordinated the inter-agency group tasked with assessing needs (Solomon 2015).

With increased demand for food, the Ethiopian government allocated 700 million Birr (US$35 million) to purchase food and preempt the negative impact on production (Ethiopian Herald 2015). The government later allocated USD$381 million to purchase food (Joselow 2016). Donors including WFP, USAID, and the World Bank were also involved in funding preparedness, mainly for the purchase of relief food. The additional aid brought total U.S. humanitarian assistance to Ethiopia to over USD$435 million in 2015, including increased funding for nutrition, water, food, sanitation, and hygiene (USAID 2015).

Ethiopia had also created a contingency fund to cover shortfalls in food supplies. This disaster fund was called the National Disaster Prevention and Preparedness Fund (NDPPF). For 2015–16 El Niño preparations, the government had already secured USD$287,400 from donors (DRMFS 2016). Regions had fund withdrawal rights to support their relief efforts. According to *The New York Times* (De Waal 2016), Ethiopia was more prepared for the 2015–16 El Niño than for any previous event. This preparation included the development of safety net programs.

Some barriers to action did exist, however, as multiple other disasters were ongoing before and after the El Niño formed. For example, when El Niño was forecasted in 2015 other factors had already caused the *belg* rains to fail. Another issue was the number of people affected by El Niño-related impacts. Despite these obstacles, excellent coordination existed between the government and the donors in terms of needs estimation, resource mobilization, and distribution. To be sure, if not for the effective preparedness of the Ethiopian government and its excellent relationship with donors, 2015–16 could have been a famine year. It should be noted, however, that when less than 50 percent of the needed funds were raised from the government and the donors, lack of funding also became an important constraint in implementing desired response protocols.

8 Hurdles and Obstacles

Until recently, very few researchers in Ethiopia had studied the basic science of El Niño, its teleconnections in the country, or its impacts. International collaboration and information exchanges through WMO, regional climate centers (such as ICPAC), and various weather and climate centers of the industrialized world, however, have provided information on and capacity for the use of El Niño information for seasonal climate forecasts in Ethiopia. The lack of local expertise on El Niño forecasts and the uncertainty associated with the information have been key obstacles to preparedness. Fortunately, a recent review of the ONI (Glantz and Ramirez 2020) shows that an ONI three-month running mean value of +0.7 °C indicates a "tipping point" in El Niño's locked in phase meaning that the event would continue for several months. This is an important finding for users because it could provide some months of extra lead time to prepare for foreseeable El Niño impacts.

"Constraints to action include but are not limited to the possible existence of different kinds of hazards and disaster events before as well as after an El Niño. As noted earlier, when the El Niño was forecasted in 2015 the *belg* rains had already failed due to other factors. The dependence of Ethiopian agriculture on millions of smallholders that depend solely on timely rainfall makes them vulnerable to even slight let alone significant seasonal variability" (Wolde-Georgis et al. 2017).

Another hurdle is the massive number of people affected by El Niño and the limited availability of local resources to respond. In fact, the Ethiopian government and donors combined were able to raise less than 50 percent of the funds needed at the local level to respond to the 2015–16 event.

An important issue related to the immediate use of forecasts has been that decision makers often consider forecasts from NMA lacking in desired specificity for their tactical policymaking needs. People tend to expect forecasts to be deterministic even though all forecasts are probabilistic, with an inherent amount of uncertainty. There were, for example, unsuccessful forecasts by both global and regional climate centers concerning the formation of an El Niño in both 2012 and 2014. Failed forecasts tend to erode policymakers' confidence in future forecasts.

9 Lessons Learned

The list below contains lessons from a previous study (Wolde-Georgis et al. 2017) in addition to uncovered lessons looking back at the event.

- In the last three decades, Ethiopia has been politically stable until November 2020. Political stability and the focus on economic development have been very helpful for effective disaster risk management. Political changes and recent social unrest, however, have begun to reverse these gains, which can only be improved with a return to relative stability.
- Since the early 1990s, a very effective in-country disaster risk management and food security system has been developed. DRM institutions have been strengthened at all levels of society.
- In Ethiopia, development of PSNP altered traditional responses of vulnerable communities during as well as between droughts.
- The Ethiopian diaspora's climate-related experts can be called upon to provide expertise that is not available or affordable solely in-country.
- People, including decision makers, expect forecasts to be deterministic, true–false statements, even though forecasts are always probabilistic, with an inherent degree of uncertainty. There has been very little discussion in Ethiopia about the certainties and uncertainties of El Niño information, including with regard to forecasts.
- El Niño readiness in Ethiopia has been effective because DRM institutions have been very active in responding to climate-related disasters during non-El Niño years.
- Ethiopia continues to accumulate lessons from previous El Niño events. For example, the 1982–83 El Niño proved a governmental turning point for heightened awareness in disaster preparedness and response for the country. The experience gained from the1997-98 event also added to the country's growing list of lessons learned.
- Local communities have their own coping mechanisms during El Niño-related events. They activate social mechanisms and wealth transfers among themselves as well as from those who transfer money from outside their villages.
- Communities with access to water and road infrastructure and a diversified income responded more easily to the impacts of El Niño-related disasters than those with no access. There is a need for developing infrastructure in all villages in climate-sensitive areas.
- Relevant research and teaching programs, such as the Department of Meteorology at Arba Mintch University and the graduate Institute for Climate and Society at Mekelle University, are expected to provide leadership in Ethiopia on El Niño-related research and preparedness in the future.
- Strategic preparedness efforts should be ongoing between El Niño events, not just when an event has been forecasted.
- Improved preparedness, including improving the capacity of NMA's infrastructure, should be prioritized.
- Weather communication via radio broadcasts, mobile phones, and TV must be improved.
- Non-climate scientists from a range of academic disciplines should be encouraged to learn about El Niño and other climate-related factors so that they can better communicate with civil society through various media channels.

10 Conclusions

Ethiopia has learned many lessons from previous El Niño events, with the 1982–83 event having proven a watershed in Ethiopia's disaster preparedness and response capacities. Most El Niños before 1982 led to famine, but those that have come after the 1990s have not. The 1997–98 El Niño, yet another very strong and surprising event that scientists have labeled "the El Niño of the Century," was the first test of the new EPRDF Government that came to power after the end of the military communist government (Wolde-Georgis et al. 2001). Designing a strategy to deal with climate-related disasters and building institutions to implement that strategy was important for overall El Niño preparedness. How societies respond to climate-related disasters in non-El Niño years, however, also needs to be considered in discussions about El Niño preparedness and response. According to WFP acting-Director Samir Wanmali, Ethiopia could cope with such problems because it had become a changed country with a capable disaster risk management system that could meet the needs of even its most vulnerable populations (Ethiopian Herald 2015).

NMA now routinely incorporates ENSO information in its long-term forecasts, and the expected recurrence of drought now has Ethiopia in a permanent state of preparedness for the impacts of ENSO's warm and cold extremes. The existence of a social welfare program (PSNP) for rural people also means that the most vulnerable populations in Ethiopia can be identified for what climate-related hazards are anticipated during each phase of the ENSO cycle. Although hydrometeorological hazards occur in many places in the country even outside of the ENSO extremes, drought is considered by Ethiopian policymakers as a constant hazard that constrains economic development. The political will for constant vigilance is now considered warranted.

Reasons for Ethiopia's El Niño readiness success have, until recently, been related to institutional readiness and an improved economy and infrastructure. One major achievement of the last few decades has been the development of transportation infrastructure like roads, rails, and airports that have more effectively linked different parts of the country. Food storage silos have also been constructed in several strategic regions. During the famine of the early 1980s, this infrastructure was not available, so timely food transfers could not be made even though there were surpluses in parts of the country that could have mitigated the impacts of the drought in other parts of the country.

In those former days, when the Ethiopian government imported food from overseas it was all shipped to Addis Ababa, making distribution to the people most in need in outlying areas difficult if not impossible. Today, El Niño readiness implies improved resiliency institutionally and materially to cope with national issues including droughts. DPPC was an experienced and strong DRM organization with a capacity to gather data from the field very fast and distribute it to users through email, fax, and its website. The new National Disaster Risk Management Commission (NDRMC) that replaced DPCC has also been effective, though it does not as of yet have its own website and remains quite invisible to those who could use its guidance most.

A major current concern about Ethiopia's readiness in the future with respect to El Niño is the ongoing erosion in political capital that helped the country progress in the last few decades. There are worrisome issues related to recent changes, including but not limited to the end of EPRDF and the creation of the Prosperity Party (PP) without the Tigray People's Liberation Front (TPLF). The current violence and disruption of peace in some parts of Oromia and Amhara are not encouraging signs for future El Niño readiness (Krippahl 2020; Amnesty International 2020). The political weapon of "highway closing" and the inaction of the federal government have weakened Ethiopia. Yet unknow is what the reaction of diverse political actors will be to the ruling party's cancellation of the 2020 national election. Rumors suggest that the current government and its allies (domestic and foreign, including Eritrea) are thinking of converting the federal constitution toward a more centralized state. Several autonomous states of the Ethiopian federation, including Tigray and Oromia, are anticipated to strongly oppose any changes that diminish state autonomy. Such political trends could have an adverse impact not only on Ethiopia's El Niño readiness but also on the future of the country's general well-being. The conflict that has broken out just prior to this manuscript's submission for publication will likely only reinforce this prediction on a near-future loss of readiness, which does not bode well for those who are most vulnerable to the known hazards a future El Niño will almost assuredly spawn.

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Kenya—Regional

The 2015–16 El Niño Event in Eastern Africa with Particular Emphasis on Kenya

Peter Usher

Abstract This chapter presents a brief description of Kenya and its political and economic circumstances. The East African seasonal climate is described, with emphasis on the local and external modifiers that introduce seasonal variations that can exacerbate the periodic floods or prolonged drought to which East Africa is particularly vulnerable. The events of the 2015-2016 El Nino are described and compared with previous El Nino events particularly the 1997–98 El Niño that brought devastation to Kenya, including hundreds of deaths, thousands of displaced persons, and extensive damage to infrastructure and socioeconomic systems. The role of Kenya's Government, particularly its Meteorological and Hydrological services, Health and Transport Ministries and the interactions with Aid Agencies and Charitable Organizations in preparing for and responding to the El Nino related disaster is addressed. The involvement of the media in highlighting and explaining the meteorological events and how it resulted in growing public awareness of climate variability and its impacts and concern about climate change is noted and the inaccuracies, misrepresentation and sensationalism were not helpful. Special attention is directed to the establishment and operation of the Intergovernmental Authority on Development (IGAD) who's timely authoritative information was important as a determining action for limiting the damage that a strong El Nino can induce. The development of a national plan to address ENSO events appeared to be a positive response to the danger of El Nino and the content of this Plan is outlined. Although the elements within it appeared reasonable and practical, the Plan was not universally welcomed as it was insufficiently detailed and might offer opportunities for mismanagement and misuse of the substantial funds allocated to it. Kenya has a reputation for corruption, and people and the media expressed concern that the plan provided opportunities for theft. The paper identifies several contemporary major financial scandals that provide a basis for the concern. It is noted that the substantial cash allocation to implement the Plan has not been fully accounted for. Note is also taken of the relatively limited adverse impacts of the 2015-2016 El Nino event that occurred, despite it being recognized as

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one of the strongest on record. Indeed, there were multiple agricultural and ecological benefits that are identified. Nevertheless, this chapter recognizes the importance of El Niño-related risks and events in East Africa, and that it is essential that future ENSO-related threats are anticipated, prepared for, and dealt with in an efficient and effective manner that minimizes loss of life, reduces the need for emergency evacuations, and limits economic damage. Also included is reference to the severe weather events of April and May 2016, which were associated with the seasonal Long Rains that followed the 2015 formation of El Niño resulting in loss of lives, infrastructure damage, and economic losses. This chapter concludes by recognizing the significance of ENSO events for Kenya and the need for vigilance and preparedness by the Government and people. A set of recommendations is offered that would be appropriate to address future El Nino occurrences.

Keywords Early warning · Rains · Rainy season · Drought · Disease · Monsoon · Flood · ITCZ · National Plan · Corruption · Kenya · IOD

This chapter was written in real time, during the 2015–16 El Niño. It provides a brief description of Eastern Africa climate at the time of the event, the factors that result in four distinct seasons, and how the seasons are modified by local and external influences, including the El Niño Southern Oscillation quasi-periodic cycle. Reference is also made to previous El Niño events affecting East Africa, particularly the 1997–98 El Niño that brought devastation to Kenya, including hundreds of deaths, thousands of displaced persons, and extensive damage to infrastructure and socioeconomic systems. As a consequence, people and governments in the region were sensitized to the risk posed by the extremes of ENSO events, and a Kenyan National Plan was drawn up to prepare for future events.

The chapter describes the outputs of the IGAD Climate Prediction and Application Centre (JamsTec 2012), set up as a consequence of climate-related disasters in the Horn of Africa and Eastern Equatorial Africa, including Kenya, and considers their value in addressing current and future ENSO events. El Niño is the warm extreme of the ENSO cycle. It also quotes media reports on other parts of the Kenya National Plan that express concerns over identified priorities and the substantial financial allocation for implementation of the Plan. This relates to Kenya's reputation for misappropriation of funds illustrated at the time by several massive financial scandals.

A description of the 2015–16 El Niño event and its observed impacts is made in this chapter. Note is also taken of the limited adverse impacts that occurred, despite the event being recognized as one of the strongest on record. Nevertheless, the importance and risk of El Niño events to East Africa is recognized and recommendations are made to ensure that future ENSO-related threats are anticipated, prepared for, and dealt with in an efficient and effective manner that minimizes loss of life, reduces the need for emergency evacuations, and limits economic damage. Also included is reference to the severe weather events of April and May 2016, which were associated with the Seasonal Long rains that followed the 2015 formation of El Niño resulting in loss of lives, infrastructure damage, and economic losses.

1 Introduction and Setting

Kenya is a developing democratic country in East Africa. It lies centrally on the Equator with a long coast on the Indian Ocean. It has been independent since 1963 and is considered both stable and strategically important in the region.

Kenya has an effective meteorological service that has been in existence since the earliest part of the twentieth century with records dating back at least 80 years. It has been modernized since independence and in association with international bodies like WMO and UNDP has established effective regional climate prediction services centred at the Kenya Meteorological Department (KMD). The service liaises with all relevant government ministries, particularly Health and Agriculture, to prepare and respond to meteorological conditions and expected anomalies such as ENSO's extremes.

An agricultural country with a major cash crop economy based on coffee, tea, and flowers primarily grown for export, Kenya has few natural resources and no major industries other than cement production. The climate is variable and subject to droughts and floods, neither of which are generally severe or prolonged, especially in the highlands, along the coasts, and in the lake region (Usher 2017). More vulnerable areas include the arid north, known for its pastoral communities like the Turkana, and the southeastern lowlands.

Kenya is also a water-deficient country and there is increasing stress on existing water resources due to population growth and inefficient water management. This is exacerbated at times of drought and failure of the seasonal rains. Floods result in disasters and there is concern during El Niño events when flood hazards take lives and water-borne diseases increase.

The agriculture-based economy produces grain, sugar, coffee, tea, and vegetables. More recently, cut-flower horticulture has become highly profitable. In addition, particularly in rural areas, there is considerable small-scale subsistence-based agriculture and animal-husbandry undertaken by peasant farmers. In the sparsely populated and rainfall-limited northern counties, pastoralists herd sheep, goats, and cows. All of this activity is water-dependent, from both rain-fed and irrigated sources, and is associated with river and lake water reserves that are themselves dependent on adequate seasonal rainfall.

In answer to the question of whether the average Kenyan has an awareness of weather variability and its anomalies, the response would be very much in the affirmative—their livelihoods and occasionally their very lives depend on it. Literacy levels among the general population are high with all Kenyans having high regard and desire for education. Indeed, almost every parent is prepared to make significant financial sacrifices to ensure that their children are educated to the highest standard possible. Government public schools and fee-paying private schools cater to these needs, and it is perhaps not surprising that there is considerable basic scientific awareness of climate and its impacts. Also, most Kenyans are familiar with digital communication systems, including Internet, radio, television, and mobile phones, such that even the most remotely located citizen usually has instant access to news and information, including daily weather reports and weekly, monthly, and seasonal weather forecasts.

At the same time, there is also broad, if less universal, awareness of climate phenomena such as El Niño and Climate Change. Both topics are popular media items, unfortunately often presented in inaccurate and over-sensationalized ways that diminish their value to the listener or reader. Certainly, the Intergovernmental Authority on Development (IGAD), through its regular information bulletins and prediction of weather events from its Centre in Nairobi, provides responsible and authoritative information that is widely disseminated, though not always interpreted correctly by recipients who include government departments and the media.

The Kenyan government, through its dedicated ministries, provided warnings and advice to farmers on the approaching 2015–16 El Niño, its likely impacts, and suggested preparatory and mitigative actions that might be taken. Individual counties, such as Baringo, together with World Animal Protection, the University of Nairobi, and the Directorate of Veterinary Services, provided combined educational messages, mass vaccination campaigns, and technical advice to farmers in flood-prone areas to be prepared in advance if they did not want to lose their main source of livelihood through drowning, displacement, or disease. This initiative was widely reported in the media. Interestingly, rather than the warned-of drownings and disease, the dairy industry ended up strongly benefiting from the El Niño, seeing an overall eight percent increase in milk yield. This surprising development was also reported.

There was little practical advice for farmers other than relaying the obvious such as that from the KMD Deputy Director, Peter Ambenje who said, "the rains could be a good motivation for farmers to reap maximum benefits." He also warned, however, that "the rains could interfere with harvesting in the Rift Valley, with farmers needing to be aware of the prevalence of diseases due to high moisture levels that may cause post-harvest losses." How much heed the farmers gave the warnings is difficult to gauge. I conducted a few interviews with farmers in the central highlands who gave modest acknowledgement of the forecasts and warnings, believing, with perhaps some justification, that they were sufficiently familiar with their land and the variety of weather that could occur and that their farming techniques were adaptable enough to address all conditions. Farmers in drought-prone areas may well have responded differently to the same question. I could not, however, find press interviews directly with farmers other than quotes from managers of large cash-crop enterprises.

Interest in El Niño is intense in Kenya. The reason for this is memory of the 1997–98 event. It was a devastating occurrence, looming large over Kenyan society even almost twenty years later. The severity and longevity of the event was unprecedented, and the country was unprepared. Subsequent investigations of previous El Niño years (although of course, they had not then been recognized as such) found nothing comparable to the 1997–98 event, during which at least 1,300 people died in countrywide floods, landslides, and transport accidents, while tens of thousands of people were displaced. The cost to the agricultural sector was estimated at USD$236 million and to the transport and communication sectors a total of USD$670 million (OCHA 2015).

It is not that the Kenyan government had not received early warnings of the coming event. As Karanja and Mutua (2000) note:

> It was determined during the project that the Kenya Meteorological Department (KMD) issued a forecast for the 1997-98 El Niño event as early as July 1997. According to KMD, this forecast was sent to the Office of the President, Ministry of Agriculture, and the Ministry of Information, Transport and Communications, which are usually on their mailing list. The information was also sent to the Kenya Power and Lighting Company which normally uses the monthly and seasonal rainfall forecasts for planning. This forecast was subsequently widely published through the electronic and print media. However, it was received with skepticism due to alleged earlier "wrong" forecasts from KMD. It was therefore not taken seriously and hence no mitigation or emergency response procedures were put in place. In general, a sizable percentage of the Kenyan population was aware of the impending heavy rainfall in advance but did very little to safeguard against its effects. As the heavy rains hit the country and continued into December 1997, almost everyone realized that the warnings from KMD were real and immediately thereafter, almost anything that happened to the water resources in the country was attributed to the El Niño. The interest and awareness of El Niño was enhanced when it's devastating impacts were seen throughout the country. The various articles and presentations on the print and electronic media created more interest and awareness on the subject. Due to its uniqueness, intensity and destructive power, the 1997-98 El Niño event was an intriguing phenomenon to many in the country, even to those who are involved in the ENSO research. It was therefore not surprising that the 1997-98 El Niño was blamed for almost all the problems that individuals, groups and the Kenyan population as a whole, were facing, be they the worsening national economy, social ills and diseases, retarded national development or even domestic hardships. The resultant floods had wide-ranging positive and negative impacts on various sectors of the national economy. The sectors identified to have been seriously affected were agriculture, water resources, transport and communications and health.

As a former forecaster at KMD, I can sympathize with its frustrations regarding public attitudes to its products. Necessary information is often limited or unavailable and the scientific understanding of regional atmospheric processes that generate Kenya's weather are not yet fully articulated, although technological advances and extensive research is rapidly remedying this gap in capacity.

The report on the 1997–98 event cited above made wide-ranging recommendations on how the country should prepare for future El Niños. It also drew lessons from what had occurred, especially regarding the country's lack of preparedness and inability to cope adequately with the impacts. The principal lesson was that there was a need to address the lack of preparedness for extreme weather events by developing a plan or policy and incorporating it within National Disaster Plans or the National Water Policy with clear flood warning and management mechanisms. Other lessons learned involved the need for accurate long-term weather forecasts, public awareness campaigns, infrastructure development and maintenance sufficient to cope with extreme flooding as well as to discourage settlement and activities on riverbanks and in flood-prone areas.

Before addressing the response strategies that were adopted and reflecting on their successes or failures, it is appropriate to familiarize readers with the Eastern African climate and its anomalies, including El Niño and the difficulties associated with its forecasting and the additional complications associated with climate change.

2 The East African Climate

Kenya, Tanzania, and Uganda lie wholly within the tropics and naturally have a tropical climate. Kenya and Tanzania have long Indian Ocean coastlines and enjoy a monsoon climate that controls weather along the coast and in the eastern and central regions of those respective countries. Seasonal monsoon winds originate outside the tropical regions, so East Africa's weather and climate are significantly influenced by extra-tropical forces.

In addition to those forces there are also several that are locally generated. Whatever climate system might be dominant on any given day or in any given season, East African topography itself provides local modifications that provide unique weather events different to those associated with the dominant climate pattern. Lakes, mountains, forests, and deserts all exert subtle, though sometimes dramatic, changes to what weather patterns might be in the ascendency at any given time. These factors will be addressed after consideration of why Kenya enjoys the climate that it does.

East Africa experiences four seasons each year. Simply described, two are wet seasons and two are dry. In Kenya, however, each is different enough from the others to be more specifically described:

- The hot, dry season begins in late December and lasts until mid-March;
- The Long rains start in mid-March and continue until mid-June;
- The Cool Season stretches from mid-June until mid-October; and
- The Short rains begin in mid-October and end in mid-December.

Tanzania has a similar climatic pattern although the timing varies because of its more southerly position. In the extreme south, the two rainy seasons virtually blend into one. Uganda lies inland with climatic similarities to the countries of Central Africa; however, Lake Victoria is so vast and influential that Uganda's climate is unique. Drought, especially in the south, is rare. Rainfall is frequent and plentiful and not dependent on the rainy seasons that determine Kenya's and Tanzania's planting and growing seasons. Nevertheless, maximum precipitation tends to fall in April and October and tends to be at a minimum in January and June.

Of course, anyone living in East Africa for any length of time is aware that the seasons often blur into one another. Seasons can be early or late. They might begin abruptly and then continue or falter, only to start again later or perhaps, not return at all. Rains can fail, dry seasons may see deluges, and the cool season may be cloudy and cold one year only to be sunny and warm the next.

On June 21 each year the sun is directly over the Tropic of Cancer and on December 21, it is over the Tropic of Capricorn. As it moves between the tropics, the sun produces a permanent low pressure belt, called the Inter-Tropical Convergence Zone (ITCZ), that moves north and south following the movement of the sun. Winds flow into the ITCZ from north and south, producing intense weather systems—deep convective clouds, rain, and thunder. The two East African rainy seasons occur as the ITCZ moves through the territory, and the dry seasons occur when the ITCZ has moved on, to the north and to the south, depending on the time of year. Obviously, at the equator, the rainy seasons are evenly spaced, while Southern Tanzania and Northern Kenya and Uganda have briefer periods between the end of one rainy season and the start of the next.

If there were never changes to the ITCZ's shifts, then the rainy seasons would be dependable, arriving and departing at fixed times and providing a consistent pattern of precipitation. In reality, however, the ITCZ can be broad and active or even barely detectable when low level wind convergence is weak. The air-mass within the ITCZ might be violently unstable, forcing moist air high into the troposphere and creating thunderheads that can reach 13,000 m or more. At other times, the air-mass can be relatively stable, clouds can be shallow, and rainfall can be sparse, short-lived, and relatively light. There are many explanations for these differences. Most depend on the strength and position of the wind-generating anti-cyclones north and south of the equator, the configuration of the monsoons, ocean temperatures, and a host of other meteorological conditions, both local and extra-tropical, that in total account for the difference between what manifests as a drought in one year and a flood in another.

Two monsoon seasons affect East Africa. In January and February, air flows from the winter high pressure cells over North Africa and Arabia toward solar-generated low pressure to the south, though not directly. The spinning earth generates what is known as the Coriolis Force, which gives a clockwise spin to the winds flowing from the northern high pressure cells so that the monsoon flows northeasterly down the Somalian and Kenyan coasts and then northwesterly as it crosses the equator and seeks out the low pressure ITCZ in the south. In June and July, there are high pressure anticyclones over the Southern Ocean close to South Africa. Air flows anticlockwise from the high pressure, southeasterly toward East Africa, and then changes to a southwesterly at the equator, thanks to the Coriolis Force, onward to the deep summer depressions in the Indian subcontinent. The monsoons are in this way coincident with, and a contributor to, the dry seasons. When they break down, and before one monsoon replaces the other, coastal winds blow from the east in a moist and convergent flow that intersects with the unstable ITCZ, fueling the rainy seasons. Figure 1 graphically depicts the seasons in East Africa.

A growing concern is the emergence of climate change that is possibly already altering the continental and regional climate of East Africa. The meteorological factors that govern whether crops thrive or fail are air and soil temperature and the amount of diurnal change, rainfall quantity and its temporal and spatial distribution, the amount of sunshine, wind strength and direction, levels of evapo-transpiration, and relative humidity. Global warming can change all of these to a lesser or greater degree. Change may benefit some plants as increased levels of atmospheric carbon dioxide can promote growth. Other plants with limited resistance to change may perish, however. We are drifting into an uncertain world with an unfamiliar climate that may be difficult to predict.

Unsustainable population growth adds additional strain on resource availability. Kenya is classified as a water-deficient country. One of the few benefits El Niño provided in 1997–98 was an abundance of water that replenished rivers, lakes, and dams. Over the past decade or so, Kenya has become warmer and also wetter, as shown in Fig. 2, which provides a snapshot of annual rainfall for the period 1945–

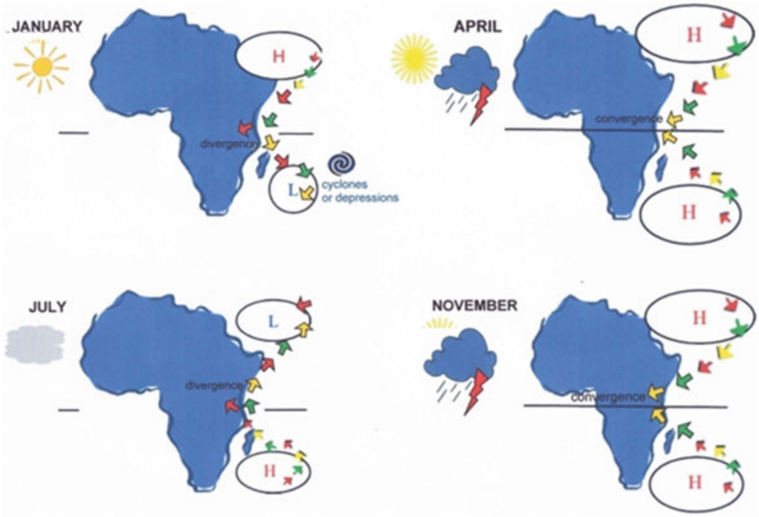

Fig. 1 East African seasons (author)

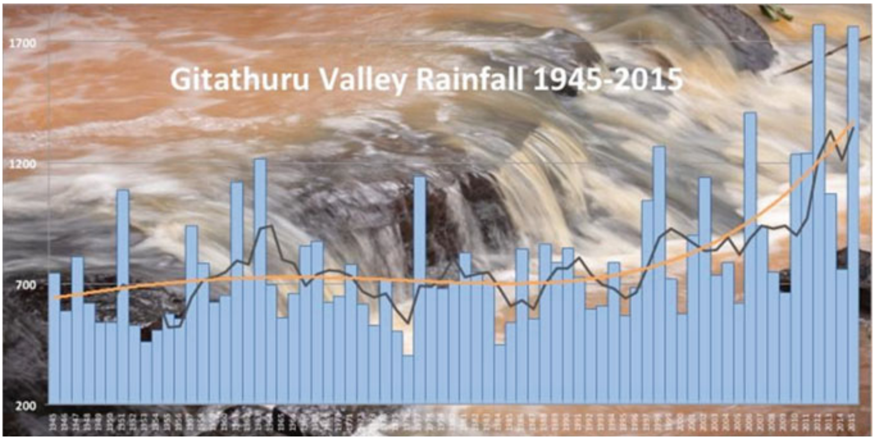

Fig. 2 Analysis of Muthaiga Country Club rainfall records (Croze 2015)

2015 in Nairobi. Whether this trend will be sustained is impossible to tell at present. What is certain is that the country lies on the edge of a crisis that will require careful management if falling off a proverbial precipice is to be avoided.

In line with decisions made following the 1997–98 strong event, a National Plan to address El Niño had been developed and was ready for implementation during the widely followed 2015–16 "Mother of all El Niños," as one national newspaper branded it. Indeed, one commends the establishment of the IGAD Climate Prediction and Applications Centre and its impressive and timely outputs on the development and progress of the 2015–16 El Niño in East Africa. The sensationalization of the predictions in media reports that ignored important caveats resulted, however, in a sense of panic in all sectors of a society still reeling from the horrors and costs it had endured just eighteen years earlier.

Other sections of the National Plan, rather than being welcomed, instead invited contempt. Putting this into context necessitates an explanation of what a multinational accounting firm described in a 2016 report on economic crime as the "Kenya Condition" (White et al. 2016). The report classifies Kenya as the third most corrupt country in the world, an achievement that most Kenyans would recognize as likely true. Even President Uhuru Kenyatta, in addressing Kenyans living in Israel during a State visit to that country, considered his fellow countrymen as "experts in stealing, whining and perpetuating tribalism" (BBC 2016). While this may well be true of the ruling elite, the ordinary Kenyan tends to be honest, God-fearing, and fed-up with the corruption that blights the country. The Chief Justice has also joined the debate on corruption. In the same week as the report (White et al. 2016), Dr. Willy Mutunga said the country was being run by criminal cartels working with politicians. "As long as I fight the cartels and they are protected, you cannot achieve anything. You are taking these people into a corrupt investigating system, through a corrupt anti-corruption system, and a corrupt Judiciary," said the Chief Justice (Lindijer 2016). Even President Barack Obama and Pope Francis, during visits to Kenya, both remarked on the historic scale of officially sanctioned corruption that is the "Kenya Condition."

Among the recent litany of multi-million-dollar political scandals invoking growing public anger over the wanton theft of public resources follows revelations of the loss of Sh791 million Kenya Shillings (USD$75 million) at the National Youth Service (NYS). This is the same Service that had been expensively mobilized to support the El Niño mitigation plan. Investigations have also been revived of the alleged role of Kenyan electoral officials in bribery by officials of a UK security printing firm to win printing contracts for 2013 General Election materials, a scam locally branded as "Chickengate" (Wasuna 2019). There are also questions on how the government spent the Sh250 billion it raised and then secretly disbursed from the issue of a Eurobond. The periodical "Kenya Today" describes the issue as "the biggest corruption scandal in post-independence Kenya" (Owalo 2015). But the crimes also strayed into other spheres. In the private sector, for example, a clique of top managers of Imperial Bank were taken to court for allegedly stealing more than Sh34 billion from bank deposits.

The relevance of this digression into political corruption is because the El Niño preparation, mitigation, and recovery strategy had been allocated a massive injection of funds, although exactly how much is not entirely clear. Press reports indicate sums between five and sixteen billion Kenya shillings (USD$50-$160 million) (Nzioki 2015). How this cash is reported to have been spent really raised concern among the public, however.

The Emergency Plan as highlighted by the Kenyan Vice President, William Ruto, in September 2015 articulates the following elements:

- County governments will be expected to implement the plan;

- The Ministry of Education will be responsible for ensuring the safety of all learners, while those of Transport and Infrastructure will make sure roads are passable;
- The Agriculture Ministry will provide farmers with seeds and fertilizer and help them recover if their crops fail due to the rains;
- 70,000 National Youth Service members will be put on standby in readiness for the destructive El Niño rains expected from October in order to prevent deaths and property destruction like those experienced in the El Niño rains of 1997;
- All Ministries will help mitigate the loss of lives and massive destruction of property expected during the event; and
- Five billion Kenyan shillings (USD$50 million) will be allocated from the Contingency Fund of the National Treasury, and the Government also plans to ask Parliament to allocate more funds for the disaster response plan.

Despite the seeming benefits of the Plan, the media response to its announcement was one of anger and disbelief. Nzioki (2016) commented in an article in the Nation newspaper that:

> A revelation of the contents of El Niño response strategy budget has left many a Kenyan furious, in what they deem to be embezzlement of public money in the name of disaster preparedness.

The Nation Newspaper, published on Sunday October 18, 2015 details of the said budget with the most despicable spending being bar soaps popularly referred to as “kipandesoap” that the government reportedly plans to buy for KSh37,500 apiece.

Most confusing here, is what co-relation soaps have with El Niño floods. The bar soaps are supposed to be given to El Niño victims. Here are other contents reported to be in the budget, that continue to expose the government’s apparent lack of commitment to tackle the corruption menace in the country:

1. National Cereals and Produce Board (NCPB) is to be paid KSh 50 million in “agency and management fees” for certain unnamed tasks. In the report, this raises questions on whether the government should pay its own department for public work.
2. The government has also supposedly put aside KSh 50 million to “carry out sensitization on disaster preparedness and risk reduction measures to fishers and fish farmers” in 30 counties.
3. The national and county governments plan to spend KSh 35 million to transport KCSE and KCPE national exams, despite Kenya National Examinations Council (KNEC) already announcing that it has made plans for the same, and even hired helicopters to reach any areas affected by El Niño.”
4. On top of this cost, there is another KSh 5 million in the El Niño response strategy set aside for “provision of psycho-social support to affected learners, teachers and parents/communities for acceptance and recovery.”
5. Another item is a post-El Niño spending which is, rebuilding of “7,000 classrooms expected to be destroyed” which will cost the government a whopping

KSh 1.1 billion. One classroom has been estimated to cost KSh 250,000 to rebuild.

6. Another thing is shipping food and non-food items to 40 different counties between October 2015 and January 2016, the period that had been forecasted to experience El Niño floods. The cost budgeted for this is KSh 200 million" (Nzioki 2016).

It is impossible to confirm the allegations made by the Nation newspaper; however, the degree of misspending by the government and the visible levels of corruption, undertaken with impunity by high-placed officials, is impossible to ignore. It is true that a contingent of the NYS was deployed for flood containment in the capital during a period of heavy rain and that the clearing and improvement of drains and other road repairs has been undertaken, but such work was needed irrespective of whether or not an El Niño event was imminent. Even modest amounts of rainfall in Nairobi and other urban centers causes floods following decades of neglect to drainage systems, inappropriate use flood control areas, and the filling of wetlands.

Theoretically, the government was well-prepared for the El Niño, and large amounts of money, equipment, and personnel had been dedicated to disaster preparedness and mitigation. During the event, however, no major response was needed. The 2015–16 event appears to have been a much more modest one than its 1997–98 predecessor, despite warnings that it would be the strongest ever. If by March 2016, however, Kenyans had thought the danger had passed as the El Niño waned, then they were wrong. The long rains of April and May 2016 were heavy with some periods of especially intense rain that resulted in flash floods, traffic chaos, and infrastructure damage including collapsed buildings, especially of those that had been built unwisely and illegally on wetlands, which resulted in considerable loss of life that matched or exceeded those attributed to El Niño. Whether or not the intensity of the seasonal rains was influenced by El Niño is not clear.

The United Nations Office for the Coordination of Humanitarian Affairs (OCHA) issued a report on December 23, 2015 confirming a death toll of more than 100 people since the previous October from flood- and landslide-related accidents following El Niño rains. A further 70,000 people were displaced by floods. While these figures are concerning, they are significantly lower than expected and need to be considered in context. The period October to December, as described earlier, is the short rains season. November, after April, is the second wettest month of the year. Rains vary from year to year and can fail or be intense due to a variety of factors other than an ENSO extreme event. The 2015 short rains had been heavier than normal though, except locally, not exceptional. The rainy season continued, sporadically, into 2016, with outbreaks of sometimes heavy, thundery rainfall throughout the dry season, although it must be stressed, not unusually so. Even during an average short rain, there tend to be floods, landslides, and water-borne diseases that cause displacements, deaths, and illness. It is clear that El Niño was a significant factor in the "wet" short rains and its prolongation into 2016, but it is also clear, for reasons yet to be determined, that the event bears little comparison with the 1997–98 event, which saw widespread intense and prolonged rain with catastrophic consequences.

In fact, as OCHA also reported, many positives for Kenya resulted from the 2015–16 event. The wetter than average conditions was prime for agriculture. Vegetation cover was well above average across most of the country, leading to a recovery of previously drought-affected areas and very good prospects for pastoralists. On the downside, there were modest but locally significant flash floods, landslides, and inundation. Also, vegetation conditions remained poor in parts of northcentral and northeastern Kenya.

In Tana River and Garissa counties, displaced families were settled in temporary shelters on higher ground as the heavy rainfall in the central highlands caused seasonal rivers to overflow downstream. Reports from the Kenya Red Cross Society indicated that, starting from November until the end of December 2015, floods and landslides/mudslides had affected 40,121 households (approximately 240,726 people), and 17,254 households (approximately 103,524 people) had been displaced across the country, while 130 lives were lost and 73 injuries were reported.

Of particular concern was a continuing cholera outbreak in 22 counties, including in the Dadaab Refugee Camp. Again, according to the Kenya Red Cross and the Kenya Initial Rapid Assessments (KIRA), in Garissa and Tana River, displaced populations lacked safe water, shelter, sanitation, food and non-food items, exposing them to the risk of waterborne diseases such as acute watery diarrhea, malaria, and Rift Valley Fever. By 28 December 2015, 10,221 cases and 174 deaths had been reported nationally in 22 counties, including 1,216 cases with 11 deaths in the Dadaab Refugee Camp. While the cholera outbreak had been brought under control, there were still pockets of disease in several places, including the heavily populated areas of Garissa, Mombasa, Nakuru, and Nairobi.

While concern in Kenya focused on rainfall, it was only part of the story. The most adverse of impacts in East Africa involved prolonged drought, with Ethiopia suffering unprecedented hardship. 18 million people in the eastern Africa region were affected by drought and the number was, at the time, expected to rise significantly in 2016. Much of Northern Kenya, a traditionally dry region, was denied what little rain it might have expected during the rainy season. Livestock died, and government and international aid was necessary if people were not to starve to death.

Concerns also grew in Southern Africa, as El Niño predictably induced drought conditions. The events of 1997–98 aside, it can be argued that Kenya is a net beneficiary of strong El Niño events. Weaker events appear to have little discernible effect on the short rains. La Niña, ENSO's cold extreme, are associated with below-average rainfall but not to the extent that Kenya could be considered seriously drought affected. Thanks to its topography, including its lakes, rivers, coastal position, and mountains, Kenya tends to have great resilience to climatic vagaries and for the most part enjoys a more benign and desirable climate than its neighbors. But knowledge of ENSO and its impacts on East Africa is far from completely understood. No two events appear to be the same, as illustrated by the IGAD poster on recent El Niño events (Fig. 3). The location and intensity of both excess rainfall and drought vary from event to event.

Research on the Indian Ocean Dipole (ICPAC 2012) has shown its importance as a moderating or enhancing feature of the ITCZ, and the monsoons that are the principal

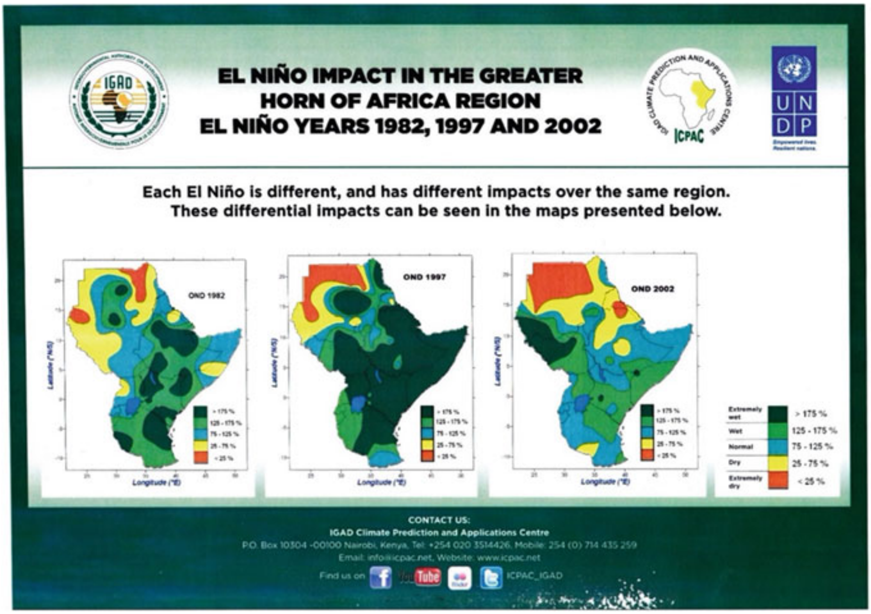

Fig. 3 El Niño impact in the greater horn of Africa Region—1982, 1997 and 2002 (Flood List News 2015)

drivers of East African weather. Although the IOD phenomenon was only first identified by climate researchers in 1999, evidence from fossil coral reefs demonstrates that it has functioned since at least the middle of the Holocene period, 6500 years ago. A positive phase sees less-than-average sea-surface temperatures and greater precipitation in the western Indian Ocean region, with a corresponding cooling of waters in the eastern Indian Ocean (Fig. 4).

In early 2016, without the masking effects of the now-ended short rainy season, showed distinct El Niño characteristics. Both January and February were wetter than average with occasional heavy local downpours, particularly in the central highlands and near Lake Victoria. There was, however, no repeat of the 1997–98 catastrophic January rainfall with its many fatalities, population displacements, and economic damages. In fact, the impacts of the short rains and their El Niño-induced extension into 2016 were largely positive with improved crops, pasturage, and foliage conditions as well as replenishment of water reservoirs. January and February, the months of the hot dry season, are not normally a time for aggressive agricultural activity, but, as stated earlier, Kenyans are weather-wise and El Niño-aware and are likely to have taken full advantage of the favorable conditions.

Of course, not all of Kenya enjoyed the benefits of the El Niño. Northern Kenya, a habitually dry area, was warmer by several degrees and was drier than average. Many people there live on the edge of existence with lives having changed little in the fifty years since independence. There are possibilities of economic development with

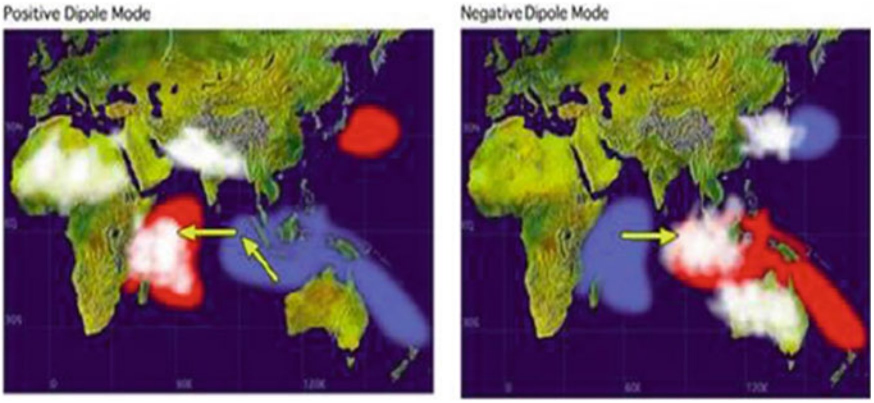

Fig. 4 The IOD is an aperiodic oscillation of sea-surface temperatures, between across the Indian Ocean (JamsTec 2012)

potentially large underground reserves of water and oil, and road networks are being improved and wind and solar power generation is benefiting the whole of Kenya. El Niño habitually contributes to drought, however, and it must be hoped that the emergency resources set aside are disbursed promptly to the affected areas.

There were floods and flood victims, as there almost always is when the rains come. If there was an additional burden attributable to El Niño, it is probably unquantifiable. Inappropriate practices associated with unsafe habitation and utilization of flood plains and riverbanks have long needed to be redressed irrespective of whether an El Niño is imminent. Water-borne disease is an unwelcome companion of flood events (and also of drought when water supplies are limited and contaminated). Outbreaks of cholera and other water-borne illnesses were a feature of the 2015–16 rains and affected thousands of people. There were fatalities but, again, it is not possible to attribute these events specifically to El Niño. Also, increased attention to sanitation and other public-health matters should be a priority for authorities at all times. OCHA reported 100 deaths in Kenya from various causes that it related to El Niño. While there is no reason to doubt the number of fatalities, and that they were weather-related, that they could be specifically attributable to El Niño is arguable.

As explained earlier, the long rains run from mid-March to mid-June. There are many variations in start and finish dates. In 2016 they began in late March, which is not unusual, and it was not easy to be sure when the El Niño rain ceased, and the seasonal rain began. February was unusually wet and reflected the influence of El Niño. The April 2016 rainfall could be categorized as normal to heavier than normal rainfall, but the period 28 April–1 May 2016 was one of heavy and persistent rain bringing floods and infrastructure damage and many deaths, including more than 50 killed when an apartment building constructed on a wetland collapsed into the Nairobi River. There was chaos on the roads and traffic jams of 12 h or more. Nairobi's floods were unprecedented.

The effects were significantly more severe than any related to the earlier El Niño. The problems were exacerbated by poor roads and drainage and the collapsed buildings reflected the shoddy building techniques and corrupt approval processes that is a feature of Nairobi's current development boom, which reflects a lack of care by the authorities that ignore regulations, approve constructions, and fail to monitor development. In this particular case, the Haruma suburb apartment building had been constructed on a wetland with the approval of county authorities in clear contravention of building regulations. The public outcry against the county as a consequence of the tragedy was immense. The beleaguered governor reacted with a call to the National Housing Authority to demolish an estimated 2,000 buildings constructed unwisely and illegally on riparian reserves. But there are 50,000 buildings in Nairobi that have been built without the approval of City Hall, so the governor's call can be seen cynically as having been nothing more than a token action.

The heavy rain had been forecast and spread from the coast which had also been very wet. Unusually, KMD spoke of a "Super Storm" at the Coast—language never before used in Kenya to categorize weather phenomena. Satellite imagery indicated a large mass of clouds moving from the ocean to the coast. During the period Thursday–Sunday, 12 inches (300 mm) of rain was recorded in Nairobi. While this is uncommon, it cannot be considered unusual for a "wet" rainy season where 4–6 inches of rain in 24 h is remarkable but certainly not exceptional.

The consequences for Nairobi were disastrous, a situation reflected in many of the other urban centers of the country, including the coastal city of Mombasa. Floods inundated commercial centers, roads crumbled, and deep potholes formed on every road. Clearly, insufficient preparations had been made to address the anticipated, and so foreseeable, rainfall, although it arrived not as expected with El Niño in the first quarter of the year, but instead with the seasonal long rains of April and May. The National Plan initiated by the Kenyan Vice President proved to be a failure and questions are still being asked by the media regarding the whereabouts of the significant financial resources allocated for implementation of the Plan. The Kenya Alliance of Resident Associations (KARA) in an open letter to the governor (Kenya Alliance of Resident Associations (KARA)—letter to Nairobi County Governor, May 2016) pointedly accused him and the Nairobi County authorities of irresponsibility. The letter stated:

> The flooding and collapsing of buildings in Nairobi are a manifestation of deep corruption at the County Government that hinder provision of services, unwillingness by the Government to implement laws and sheer incompetence of those entrusted with the responsibility of ensuring that the City is adequately prepared for such kind of calamities.
>
> The Governor, in his statement regarding the current flooding has listed a long list of what could be causing the flooding and collapsing of buildings. The Governor must stop passing the buck and take full responsibility for failure to put in place adequate mitigation measures against flooding and collapse of buildings.

The letter concluded with proposals for future preparedness measures and a demand for an accounting for the resources allocated for El Niño readiness:

> Moving forward, we expect to see a more serious approach in addressing the flooding and substandard buildings challenges in the City. We therefore demand as follows:
>
> The County Government leads the way in ensuring proper coordination between various relevant Government agencies such as the Meteorological Department, National Construction Authority, Kenya National Disaster Operation Centre and the County Government and come up with a clear action plan for preventing the negative effect of flooding and construction of illegal buildings.
>
> All relevant Government agencies must ensure full implementation of the planning laws, rules and regulations. The Governor recently launched the integrated urban development master plan for Nairobi but little has been seen in terms of its implementation.
>
> The County Government and National Construction Authority to immediately commence demolition of all substandard buildings including those on water courses, drainage way leave and riparian reserves
>
> The County Government should embrace partnership with citizen organizations such as Resident Associations to ensure proper clearance and maintenance of drainages; monitoring, reporting and/or objecting to construction of illegal developments in the City.
>
> Transparent and effective utilization of funds. In this regard, we demand full report and accounting for the Kshs.15 billion set aside to address El Niño effects last year.

3 Conclusions and Recommendations

The National Plan adopted by Kenya in preparation for the 2015–16 El Niño is an appropriate basis to address future strong El Niño events that will impact the country. Devolving the implementation strategy to county control had both positive and negative implications—rapid local assessment and action being offset by inappropriate use or diversion of existing resources. Strong central coordination and control will be necessary to guarantee effective and sufficient preparation and response. The following points suggest where emphasis should be placed:

- Strong El Niño Events such as those in 1982, 1997, and 2002 can intensify the seasonal short rainy season in Kenya. To what extent an individual event might be termed extraordinary cannot be anticipated with full confidence. Continued research is necessary to establish an El Niño early warning system that is effective from initial forecasting to information dissemination.
- While there is an emphasis on El Niño-enhanced rainfall anomalies in southern Kenya, extra attention must be given to the likelihood of drought and its associated adverse effects in Kenya, north of the equator. Drought mitigation and drought relief measures must be initiated promptly, efficiently, and sufficiently to ensure reduced hardship and protection of people and livestock.
- The establishment of the IGAD Climate Prediction and Application Centre following the devastating 1997–98 El Niño is welcomed and commended. All necessary support to the Centre should be provided to ensure accurate climate information is available in a timely manner.
- Coordination and communication among government ministries, departments, and public bodies tasked with preparing for, and responding to, extreme weather

events needs review and updating. Misleading and contradictory information and advice needs to be avoided. In this regard, responsible reporting by the media must be assured. Some skepticism may have arisen among the general public due to inaccurate and over-sensationalized reporting by the media. This needs to be addressed for the correct management of future ENSO events.

- The National Plan of Action for ENSO should be regularly reviewed and revised in the light of available information. Within the Plan, there should be sufficient emergency funds available for allocation and disbursement in a timely and appropriate manner in preparation for, and response to, either of ENSO's extremes and other natural weather events that can have serious adverse consequences for the country. Regular auditing of resources allocated for implementing the National Plan of Action is necessary to ensure transparency and accountability.

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Kenya—Local

Tigithi: Micro-Level Preparedness and Response to the 2015–16 El Niño Early Warning

Jackson Wachira and Lydia Cumiskey

Abstract The 2015–16 El Nino weather was highly anticipated in Kenya. This anticipation arose, in part, from the experiences with previous El Nino events such as the 1997–98 El Nino rains that resulted in widespread losses of lives and destruction of property worth millions of dollars. This study, undertaken in Tigithi Location of Laikipia County in Kenya sought to explore the extent to which communities were prepared to manage and respond to the 2015–16 El Nino weather. Specifically, the study sought to answer three interrelated research questions namely: 1) did rural agro-pastoral communities in Laikipia find advisories by forecasters helpful?; 2) how did communities prepare and respond to the advisories; and 3) to what extent were the preparedness and response actions helpful in managing the impacts of El Nino-influenced weather and other day to day development challenges that perpetuate their vulnerability to such hazards? The study employed a quantitative approach involving structured interviews with 238 households. The study shows that although there were several negative outcomes which include impassible roads and destruction of short term crops, the 2015–16 El Nino event in this region was rather, mainly beneficial. Improved food and livestock production and enhanced access to water marked a turning point to a prolonged drought season that had characterized this region resulting in widespread food insecurity. Yet, the extent to which the residents were able to take advantage of the enhanced rains was limited by low economic

This Kenya study used a quantitative approach involving interviews with household heads in order to capture a broad range of insights into local-level preparedness and response to El Niño. The study area was selected for this research because it reported above normal Short Rains for October, November, and December (OND). The research team was familiar with both the area and the local language.

The original version of this book was revised: Abstract has been updated with correct lines. The correction to this book can be found at
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capacities thereby causing them to invest only in low cost, short-term investments that were helpful but not for long-term risk reduction. The Kenya Meteorological Department (KMD) played an instrumental role in producing El Niño weather-related early warning information. The early warning information by KMD got clearer with time, in the backdrop of an apparent struggle to balance this information with other divergent sources and with politics of uncertainty. The El Niño early warning lead time was also significantly short, with a majority of respondents stating that they only first received the early warning messages one month before the onset of the rains. These findings underscore the importance of reliable, context specific and timely El Nino weather early warning. They also bring to the fore the critical role of long-term development efforts that support localized disaster preparedness and risk reduction initiatives.

Keywords El Niño · La Niña · Early warning · Preparedness · Response · Laikipia · Kenya

1 Introduction

Kenya's weather is significantly influenced by the El Niño Southern Oscillation (ENSO), as is the case with many other regions of the world (Stige et al. 2006, Kovats et al. 1999, Siderius et al. 2018, Gannon et al. 2018, Rembold et al. 2015). El Niño teleconnections (during warm phases of ENSO) in Kenya tend to be associated with above-average precipitation during the October-December (OND) short rains (Karanja and Mutua 2000). Conversely, La Niña teleconnections (during cold phases of ENSO) tend to be associated with prolonged drought in many parts of East Africa. El Niño teleconnections, however, vary, and it is now widely accepted that no one El Niño is exactly like another (Gannon et al. 2018; Siderius et al. 2018; Rembold et al. 2015; Karanja and Mutua 2000). The huge impact of ENSO variations on Africa's weather-dependent crop production regimes has been well described. Stige et al. (2006), for example, approximate that ENSO variations on maize production—a major food crop for many countries across Africa—corresponds to a crop that could feed 20 million people per annum.

ENSOs are generally predictable and advances in prediction models have enhanced this predictability, a development that has increased expectations of governments and humanitarian organizations to effectively mitigate and respond to adverse impacts associated with ENSO events (Stige et al. 2006; Tozier de la Poterie et al. 2018). With predictions indicating that the 2015–16 El Niño would be one of the largest in recent history, such expectations were apparent as governments across many regions were alerted to prepare for the worst—excessive rains, drought, flooding, and other weather-related impacts. The El Niño was predicted as early as 2014 and by May 2015 many national and international meteorological agencies had agreed that the event would be one of the strongest on the historical record (Bremmer 2015;

L'Heureux 2017). Preparedness advisories detailing a grim picture of possibly devastating outcomes dominated the messaging that was transmitted by print, broadcast, and social media across the globe. The *International Business Times,* for instance, wrote: "A potentially record-breaking El Niño brewing in the tropical Pacific Ocean will soon hit the eastern shores of sub-Saharan Africa, even as African leaders say they aren't sure how to prepare" (qutd. in Winsor 2015). This bleak reporting was no doubt informed by the 1997–98 El Niño that resulted in widespread deaths, disruption of lives, and destruction of property and livelihood sources for millions of people in Kenya specifically (Karanja et al. 2001a) and across the world more generally (Buizer et al. 2000).

Indeed, the 2015–16 El Niño did result in a considerable increase in the global hydrological cycle and precipitation amounts (Gannon et al. 2018); however, it did not materialize as anticipated in Kenya, as only a fraction of the country experienced very wet to extremely wet conditions that were broadly similar to—or even drier than—non-El Niño years (Siderius 2018: 9). Yet the 2015–16 El Niño is now an important point of reference for ENSO researchers, as it was one of the strongest since the 1997–1998 event (Tozier de la Poterie et al. 2018). Although many studies on the socioeconomic and hydrological impacts of ENSO events in Africa exist (see, for instance, Siderius et al. 2018; Stige et al. 2006, Glantz 2001a), generalization of results across regions remains a challenge due to the uniqueness of each event. Moreover, in Kenya the impacts of the 2015–16 El Niño were largely localized (Gannon et al. 2018), necessitating studies on micro-level experiences particularly in rural areas where El Niño public forecasts have mostly been quite limited (Glantz 2001a).

This chapter is based on field data from research conducted in February 2016 at Tigithi Location, Laikipia County (Fig. 1), Kenya and commissioned by the Water

Fig. 1 Laikipia County in Kenya (Karell Africa 2020)

Youth Network. [1]. Considering the highly anticipated impacts of the 2015–16 El Niño in Kenya, this study sought to collect scientifically relevant information on local-level preparedness and response. Specifically, the study sought to answer the following three questions: (1) Did rural, agropastoral communities in Laikipia, Kenya find forecast advisories helpful (2) Did communities prepare and respond to the advisories? and (3) Were the preparedness and response actions helpful to residents in managing the impacts of the El Niño-influenced weather as well as other day-to-day development challenges that tend to perpetuate their vulnerability to such natural hazards? In addition, the study sought to engage young Disaster Risk Reduction scientists (i.e., students and volunteers) in the collection and synthesis of event data and to share Kenyan El Niño experiences with other countries as part of the "El Niño Ready Nations" initiative (https://elninoreadynations.com/).

The next section of this chapter undertakes a brief review of the conceptual literature that provides the basis for an analysis of respondents' preparedness and response to risk early warnings. Overall, this review demonstrates the challenges to developing and communicating warnings effectively, but it also discusses the tremendous benefits available when proactive measures are taken in response to extreme weather and climate forecasts. The study methods are then introduced, followed by a brief description of the study area and the broader context within which it is situated. Finally, main findings are discussed, and key conclusions and recommendations are elaborated.

2 Enabling Effective Preparedness and Response to Early Warning

Effectively preparing for and responding to El Niño forecasts and early warnings presents similar challenges for achieving end-to-end, people-centered, or impact-based Early Warning Systems (EWSs) for other climate and weather-related hazards (Agrawala et al. 2001; WMO 2015, 2018). Warning source, lead time, communication channels, and message content are all factors that have been found to influence user response to warnings (Mileti 1995; Lindell and Perry 2003; Patt and Gwata 2002). If warnings are received and understood, a broad range of preventative, mitigative, or adaptive actions can be taken. Such actions are, however, dependent on the vulnerability and capacity of those who are at risk (Wisner et al. 2004).

The reputation and track record of the "warning source," including the extent to which observed phenomena match initial forecasts, will influence users' trust and belief in a warning (Mileti 1995; Lindell and Perry 2003; Patt and Gwata 2002).

[1] N.B. The Water Youth Network was created soon after the 6th World Water Forum in 2012 in Marseille, France, when a group of young people from all over the world met to share their solutions to address water-related issues. The group realized that together they could positively influence the water sector. The Water Youth Network is now an inclusive connector in the water sector, with a vibrant community of active young people across disciplines. This work was supported by WYN as a pilot research project conducted by the Disaster Risk Reduction (DRR) team.

Furthermore, scientific forecasts can also conflict with local traditional forecasts, making it difficult for some users to build trust in warnings (Patt and Gwata 2002; Masinde 2015). Additionally, the transparency of forecasts and the accountability of forecasters is crucial, which means that forecasting agencies need to publicly admit any limitations or weaknesses that have gone into decision-making processes (Parker et al. 2007; Baudoin et al. 2017).

The lead time an early warning provides users is crucial for effective response. The shorter the lead time, the narrower the range of actions users can undertake. Short lead times also makes it more difficult for weak governance systems to respond comprehensively—especially in support of the most vulnerable communities (Agrawala et al. 2001). To be sure, the longer the lead time, the more uncertain a forecast is, the more risk users have to consider when making decisions. In addition, the timing of forecast dissemination does not always align with the timing that local decision makers need to mitigate impacts, as with deciding on what seed varieties are to be planted (Patt and Gwata 2002).

Warnings can be disseminated through a range of channels to reach end users and play an important role in shaping user response (Mileti 1995). Such channels include technical ones like mobile services (e.g. SMS, cell broadcasting, and interactive voice response; see Cumiskey et al. 2015) and media like local and national radio, television, and print (Glantz 2001a, b), but they can also include personal channels like word-of-mouth communications form respected individuals or local religious leaders (Eisenman et al. 2007). Warning messages can also be considered more credible if they are consistent and verifiable across different communication channels (Mileti 1995; Shah et al. 2012). Coordinating consistent warning dissemination is, however, particularly challenging where there are poor institutional linkages between organizations from national- to local-levels, as between meteorologists, food security planners, and agricultural officers (Patt and Gwata 2002; Baudoin et al. 2017).

Less generic and more tailored warning message content is advocated because it can provide more specific information on expected impacts and response actions (Twigger-Ross et al. 2009; Coughlan de Perez et al. 2015; WMO 2015, 2018). On the other hand, whether or not to include information on uncertainty and probability in warning messages is a debated issue among researchers: Although some research demonstrates that forecast users such as farmers struggle to interpret probabilistic information over deterministic forecasts (Glantz et al. 1997; Parker et al. 2009), others argue that users do have the ability to understand probabilistic information but need focused and continued training to understand the limitations of such information (Patt and Gwata 2002). For example, in southern Africa many people interpreted the 1998 El Niño seasonal forecast as a deterministic prediction of drought, not having understood the forecast's probabilistic nature (Dilley 2000).

For seasonal forecasts, a range of preparedness and response actions can be taken by users such as farmers or humanitarian responders at different timescales to prepare for alterations in weather or climate conditions. These actions can result in significant economic and social benefits but are typically underutilized (Meinke and Stone 2005; Coughlan de Perez et al. 2015). Such actions include, for example, tailoring crop rotations, making planting and harvesting decisions, adjusting storage regimes, streamlining transport and export logistics, distributing water purification tablets or mosquito nets, fortifying vulnerable structures, and providing free or low-cost cash transfers (Meinke and Stone 2005; Coughlan de Perez et al. 2015; Nobre et al. 2019; Agrawala et al. 2001).

Overall, if forecasts are used effectively, they can reap large benefits for end users. An example of this for seasonal forecasts was demonstrated in one relatively small sugar milling region in Australia where the value of the climate forecasting system exceeded AUD$1.9 million for the studied season in 1998 (Antony et al. 2002). A case study in Bangladesh for five-day forecasts demonstrated an average savings of USD$472 per household, with the agriculture, livestock, and fishery sectors gaining the most benefits (Cumiskey et al. 2015). The actions taken included early harvesting, delaying seedbed preparation, netting fishponds, heightening dams around ponds, and moving cattle.

Multiple interacting societal factors influence exposure and vulnerability to extreme climate and weather events, however, thus affecting response capacity within any specific population. For example, users can only take response actions they can afford (Agrawala et al. 2001; Patt and Gwata 2002; Coughlan de Perez et al. 2015). As such, what underlying support systems are in place will strongly influence the effectiveness of responses to short-term and seasonal forecasts.

3 Data Collection Methods

This study took a quantitative approach that involved interviews with household heads so as to capture a broad range of insights into local-level preparedness and response to the 2015–16 El Niño. The study area selected for this research was Tigithi Location in Laikipia County, Kenya. This area was selected because it reported above normal short rains for October-December (OND), and the research team was familiar with both the area and the local language. Using the 'Cochrane formula' (Israel 1992: 3), a representative sample size of 227 households was selected at 95% confidence interval and ±6.5% precision;

$$n_0 = \frac{z^2 pq}{e^2}$$

n_o is the sample size, z is the selected critical value of desired confidence level, p is the estimated proportion of the attribute that is present in the population, q is 1-p and e is the desired level of precision (ibid) (Wachira and Cumiskey, 2017). The sample size was eventually increased by 13 households to account for non-responses and to allow for quality control. A total of 238 questionnaires were used for results analysis. A random sampling method was used to select households to be interviewed, targeting heads of household. Where the household head was not available, the head's spouse was asked to participate in the study. Data was collected by a team of university students under the supervision of an experienced researcher. Completed questionnaires were gathered and checked for accuracy. Data was then coded and analyzed using Microsoft Excel.

4 Study Area and Broader Context

Tigithi is one of 55 Locations in Laikipia County and is an extensive social-political and administrative region in Kenya, measuring 9,462 km^2 between latitudes 0°18″ South and 0°51″ North and between longitudes 36°11″ and 37°24′ East (Government of Kenya 2018). As with its topography, the County's socioeconomic and political systems are quite heterogeneous, which is perhaps attributable to the enormous transformations that have characterized the region over the past century. Before the onset of colonization and establishment of a settler economy, Laikipia region was inhabited by the Maasai who used the expansive semi-arid highlands for nomadic pastoralism (Hughes 2002). Early European settlers were, however, excited by the agricultural production potential of the region, which led to the relocation of the Maasai to the less favorable southern reserves through a 1914 agreement that is widely thought to have favored white settlers' imperial interests at the expense of Maasai interests (Hughes 2002, 2006).

Upon independence in 1963, a 'willing seller-willing buyer' approach to land redistribution saw some settlers return to Europe after selling their land to the Kenyan government, while others remained. Land acquired by the government at this time was to be used to settle landless "natives," though much of it ended being given to the community from which the president came, the Kikuyus (Kanyinga 2009). Other lands were purchased by companies that were controlled by an emerging class of political-economic elites aligned to the post-independence Kenyan government (Gravesen 2020).

Thus, although Laikipia County is today seen as cosmopolitan, settled by up to 23 distinct communities (Government of Kenya 2018), rural settlements and land are dominated by three distinct populations. A brief history highlighting the differences between the three main populations in the area is important to explicate because it affects the broader socioeconomic organization of the study site. The first group includes original British settlers and later British government beneficiaries who even today maintain control over most of the productive land in the region (Letai 2011, Evans and Adams 2016). They tend to be commercial farmers and own about 40% of the total land of Laikipia (Letai 2011, Evans and Adams 2016). The second distinct group is the Kikuyu people, who, as noted above, benefited from post-independence government interventions and elite cum politician-driven land acquisitions that resettled them into the semi-arid Laikipia due to increasing population pressures in their native central highlands. The last group is the Maasai, the original inhabitants of the regions, including those who never made the move to the southern rangelands as well as those who returned upon Kenyan independence after having had been relocated out of the region decades earlier (Hughes 2006).

The implication of this history is that land in Laikipia, which is the main source of livelihood among rural inhabitants and effectively their "first line of defence against a disaster" (Cannon 2008: 3), is highly contested. The Maasai and other related pastoral communities such as the Samburu, who insist on de facto ownership of the semi-arid highlands, claim original rights to land access and use. With this claim, conflicts have arisen that have typically been characterized by subtle, resource-based insecurity but have also occasionally spilled over into violent confrontations between pastoral communities and agropastoral and large-scale commercial farmers (Gravesen 2020, Letai 2011, Evans and Adams 2016; Galaty 2016; Lengoiboni et al. 2000).

Tigithi Location exists within this complex land-tenure framework. It is located about 20 km southwest of Nanyuki, the county seat that is inhabited primarily by members of the Kikuyu community who settled there in the 1970s. Annual rainfall in the Location is typically between 450 and 750 mm, and treed grassland is the main vegetation type. On the settled plots, crop cultivation and grazing are the primary land-use forms. Maize, beans, and potatoes are the predominant crops; however, agricultural production is constrained by unreliable and poorly distributed rainfall, which is characterized by periodic intra- and off-season dry spells.

For the period prior to this study, the area had experienced an extended dry season spanning five years and resulting in crop losses, livestock death and wasting, and a severe disruption to food security. According to a local NGO Caritas Nyeri, 40–66% of the population had required some sort of food relief in most years between 2005 and 2011 (Wachira 2013: 3). Conflicts over scarce natural resources such as water and pasture are common across the wider region (Gichuki 2002), and poverty rates are strikingly high, with Human Poverty Index in the area exceeding 57% against a Kenyan national HPI of just over 29% (Government of Kenya 2018).

Most residents of the area have a secondary education and undertake subsistence crop farming for a living. Reliance on subsistence crops and livestock farming is, however, highly constrained by occasional droughts and limitations related to resource-based conflicts, which might explain the high rate of poverty in the area (see Table 1).

Table 1 General socioeconomic characteristics of Tigithi Location (Survey data). General characteristics of survey respondents in Tigithi Location and their economic activities (Wachira and Cumiskey 2017)

	Percentage of population	Median age	Percentage of respondents with basic education	Percentage of respondents with secondary education	Percentage of respondents engaged in subsistence farming
Male	44	58	38	39	61
Female	56	48.5	43	35	65
Average		53.25	40	37	63

5 Findings and Discussion

5.1 2015–16 El Niño Predictions in Kenya

According to World Food Programme forecast models (WFP 2015), the 2015–16 El Niño had been forming for some time before its official declaration in March 2015, when it was forecasted to be one of the strongest in record history (Fig. 2) and to likely remain locked in for over a year. Although it was able to identify El Niño-like sea temperatures in May 2015, the Kenya Meteorological Department (KMD) did not issue an official El Niño Advisory to the public until August 2015 (Tozier de la Poterie et al. 2017). The literature indicates that the early caution by KMD was informed by a need to maximize the accuracy of prediction based on lessons learnt from other El Niño predictions, like from the 2014 event that did not materialize (Tozier de la Poterie et al. 2017) or from KMD's early warning for the 1997–98 event which "was not taken seriously and hence no mitigation/emergency response measures were put in place" (Karanja et al. 2001b) Thus, like other previous events, the 2015–16 El Niño demonstrated what uncertainties remain surrounding the phenomenon, how the credibility of forecasts affect response, and why awareness of the nature of its potential impacts can lead to different outcomes.

Indeed, even as KMD warned communities to prepare for El Niño rains, some politicians actively deprecated these advisories as lies. One Member of Parliament (MP) went so far as to threaten to sue KMD "should it fail to rain El-Niño as they say." This MP also noted: "It has been three years now the meteorological department has been lying to us that there will be heavy rains, yet farmers had been borrowing loans to prepare their lands, buying inputs and additional livestock" (The Standard Newspaper 2015a). In this statement, the MP could be referring to the 'failed' 2014 forecast for the El Niño that began to form but ended up petering out. Importantly, he is also genuinely highlighting the dilemma facing many citizens in Kenya who need to make difficult, forecast-based choices. The consequences of such choices can mean the difference between benefitting by having invested to reduce risk before an event or suffering by having invested what meagre resources one has to mitigate the impacts of an event that, like the one in 2014, eventually fails to form as forecasted. The latter scenario is, it should be understood, a lose-lose for everyone, forecasters and farmers alike.

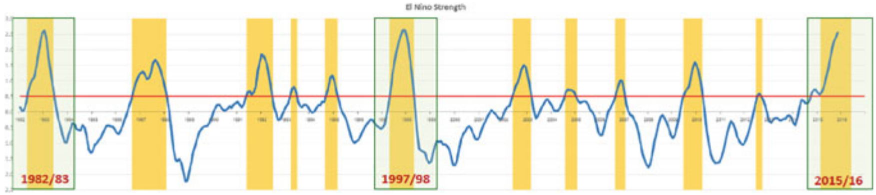


Fig. 2 Inter-tropical Pacific Sea surface temperature anomalies from 1982 to 2015. The red line indicates the El Niño threshold (WFP 2015)

KMD's monthly advisories indicate everything from definitions to global impacts. They also include detailed explanations of the current status of an El Niño's evolution as well as typical impacts of an event on Kenyan agriculture, food security and fisheries, disaster management, health, transport and public safety, water resources management, and energy generation. Early advisories for the 2015–16 event stated a 90% chance that El Niño rains would continue into early 2016 (*The Standard Newspaper* 2015b); however, a consistent message from KMD indicated that its intensity was not expected to be as extreme as in 1997. Thus, KMD advisories sought to moderate the rather alarmist misrepresentation of media coverage of the anticipated El Niño rains. Out of 47 counties in the country, 23 were deemed as high-risk and were predicted to experience severe rains throughout the period (Fig. 3).

Some Countries affected by El Niño impacts:

Nairobi	Migori
Narok	Turkana
Kwale	Busia
Garissa	Siaya
Mandera	Baringo
Wajir	Elgeyo
Samburu	Marakwet
Isiolo	Mombasa
Meru	Taita Taveta
Makueni	Lamu
Murang's	Tana River
Nakuru	

Fig. 3 Map of counties predicted to be at high risk to El Niño effects (KSFFG 2016)

Although El Niño researchers have emphasized the need to consider the potentially beneficial impacts of El Niño teleconnections (e.g. Glantz 2001b), this research has identified a need to more strongly focus on preparing for potential negative impacts, especially with regard to flooding, the damage from which tends to outweigh any beneficial impacts.

5.2 Micro-Level Understanding and Perception of the El Niño Phenomenon

Findings show that over half of the respondents (54%) (Fig. 4) understood El Niño as simply bringing heavy rains, while 28% perceived it as bringing heavy and destructive

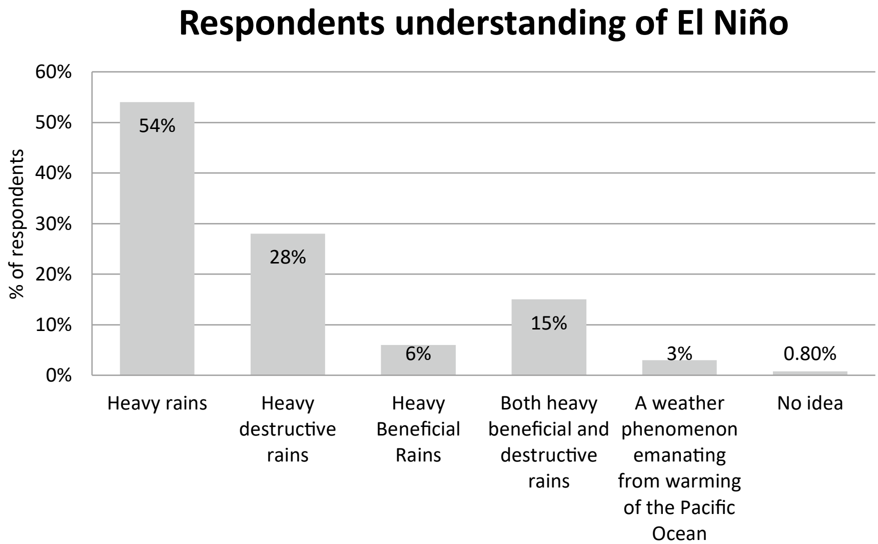


Fig. 4 Survey respondents' understandings of El Niño (Authors)

rains. Of the total, 15% of respondents perceived the rains as both heavy destructive and beneficial. Overall, 97% of the respondents associated El Niño rains with *heaviness*. Intriguingly, only 3% of respondents associated El Niño as a Pacific Ocean phenomenon that led to atypical rainfall patterns in Kenya.

Various factors play a role in shaping a population's understanding of risk to hazards like El Niño. Wachinger et al. (2013), in their research on floods, droughts, earthquakes, volcanic eruptions, wildfires, and landslides, found that personal experience with a natural hazard, trust—or lack of trust—in authorities, and knowledge of expert opinions have the most substantial impact on risk perception. In our research, 97% of respondents had recollections about past events, with 91% having had specific recollections of the 1997–98 El Niño rains that had adversely impacted many parts of Kenya. Additionally, most respondents (69%) attributed their perceptions and understandings to their own past experiences with El Niño events. Far fewer respondents attributed their perceptions and understandings to the media (24%) or to storytelling (4%). Interestingly, the impacts of formal and informal training on the respondents' perceptions were also found to be negligible, which points to a major gap in people's responses to El Niño. To be sure, a wealth of literature already exists that suggests that continued training and engagement is needed to bridge the gap and help users better understand forecasts (see, for instance, Glantz 2001a; b) (parts of this are from Wachira and Cumiskey 2017).

5.3 Micro-Level Impacts of the El Niño Rains, 2015

This study specifically sought to understand if and how 2015–16 El Niño weather impacted the Tigithi Location. The results show that 80% of respondents perceived the El Niño rains as having impacted the area. Impacts were both positive and negative, though the positive ones tended to dominate (see Fig. 5).

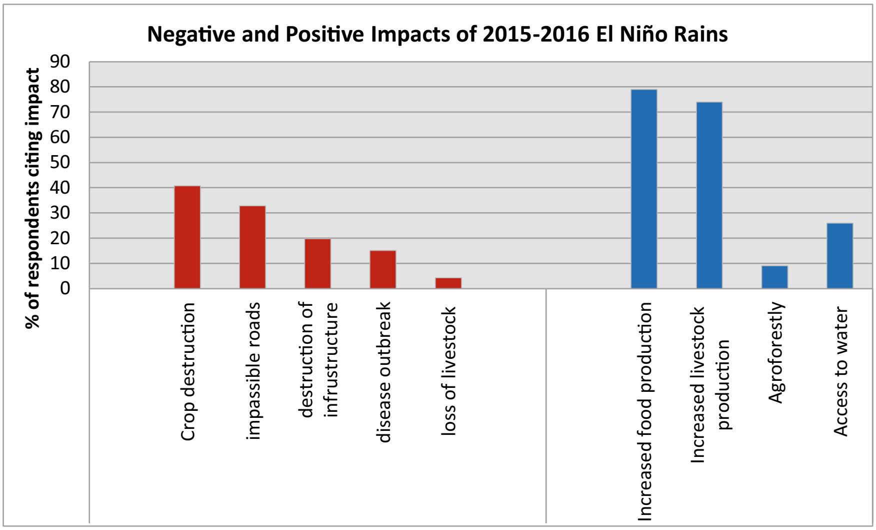


Fig. 5 Negative (Red) and positive (Blue) impacts of El Niño Rains at Tigithi location (Wachira and Cumiskey 2017)

5.3.1 Primary Positive Impacts

a. Increased Food Production

Surveys indicated that 79% of respondents reported an increase in food production due to increased rainfall. Clearly, the El Niño rains of 2015 marked a critical food security turning point for Tigithi Location residents, as a considerable number of them had been relying on food relief because of the prolonged drought. A report from Caritas Nyeri, a local NGO indicated that on average 51% of the Location's population had been receiving food aid in the years between 2005 and 2011 (Wachira 2013). This need for aid is directly attributable to the poor, erratic rains in the area that often result in extensive crop failure.

b. Increased Livestock Production

Overall, 74% of respondents reported an increase in livestock production. This increase was attributed to greater pasture availability. The area had seen five years of drought before the 2015 El Niño rains, which directly led to livestock malnutrition, low milk and beef production, and a general increase in the cost of stock rearing, further eroding people's purchasing power. The El Niño rains were, therefore, seen as beneficial, with livestock production having received a boost through an increase in adequate pasturage.

c. Improved Access to Water

Access to water tends to be a major challenge in Laikipia County—only 30% of the population has access to potable water and residents have to walk an average of 5 km for clean water (Government of Kenya 2018). In Tigithi, residents mostly rely on rivers and community water supply projects that are continually under pressure due to a combination of factors such as population increases and weak water management structures. In this study, 26% of respondents felt that the 2015–16 rains offered a short-term reprieve from these normal difficulties, as many residents were able to take advantage of the situation by, for example, harvesting rainwater.

5.3.2 Primary Negative Impacts

a. Impassable Roads/Destruction of Infrastructure

Overall, 53% of respondents reported that the El Niño rains resulted in either impassable roads (33%) or other infrastructure destruction (20%). These impacts limited residents' abilities to attend to their daily chores or transport their farm produce, erecting a significant barrier to income generation for a community heavily dependent on small-scale farming. Still, the affected communities attempted to cope with these challenges by controlling infrastructure erosion as much as possible using branches and laying gravel.

b. Crop Destruction

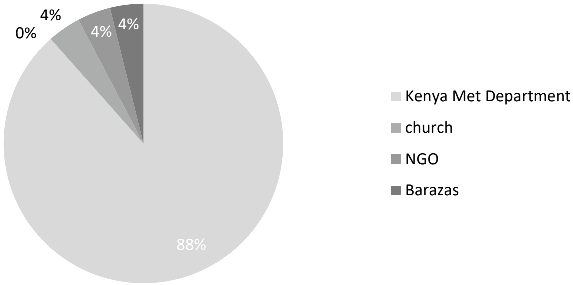
Another significant negative impact of the El Niño rains in the study area, as cited by 41% of respondents, was the destruction of crops. Crop destruction was especially pronounced with the loss of short-term crops like beans and potatoes that were submerged under the flood waters. Such destruction was experienced despite the mitigative efforts of the community, which dug furrows to drain excess water and replanted where crops had been destroyed.

5.4 Effectiveness of El Niño Early Warning Dissemination at the Local Level

5.4.1 Source of Warning

Study results indicate that 84% of respondents had received early warning information on likely El Niño weather patterns. Of those, 88% of respondents credited KMD

Fig. 6 Perceived sources of El Niño early warning messages (Authors)



with the early warning messages. As illustrated in Fig. 6, the remaining 12% believed that the early warning information had come from the church, from *barazas* (public meeting places), or from NGOs.

Notably, the County Department for Environment did not feature at all in any respondents' understanding of where early warning information had originated. This exclusion might have resulted because county government departments had at the time of the event been newly established, and many were still finding their footing within their respective communities. Furthermore, due to their lack of standing among community members, county departments may also not have as yet effectively distinguished themselves from the national government departments of which people had long known and mostly trusted for forecasting information.

The implication here is that KMD played a pivotal role in disseminating early warning information. Critical analysis of KMD early warning messages shows a cautious approach, one that struggled to deal not only with the uncertainty of the impending event but also with the important (but often overlooked) need for consistent messaging. In one of KMD's press releases, for example, acting Director James G. Kongoti wrote:

> The Kenya Meteorological Department (KMD) has noted with concern the content of information related to El Niño conditions that has been disseminated to the general public in the last few weeks. This is being done without reference to KMD, the service that is authorized to provide guidance on the current status and development of El Niño conditions and its potential impacts on the rainfall patterns in Kenya. The information is not only confusing Kenyans but also creating anxiety and panic. It is therefore imperative that technical advice be sought from KMD prior to such information being disseminated to the general public (Kenya Meteorological Department nd).

In this message, Director Kongoti affirms KMD's *de jure* responsibility for predicting and releasing public advisories about the country's weather conditions. He notably asserts KMD's mandated role in a context in which other actors such as the media had been taking a de facto role, one that had possibly been confusing to the general public.

As identified above, the fact is that KMD had strategically decided not to issue El Niño precipitation warnings early in its advisories in order to maximize the chance that they would provide accurate information to the general public. An unintended outcome of this strategic delay may have been that other actors had exploited the ensuing information gap, which then necessitated the reassertion by Director Kongoti of KMD's exclusive mandate. Further research beyond the scope of this chapter is needed to verify this proposition. The following paragraph is updated from Wachira and Cumiskey's report (2017).

Not until the onset of the OND rains did KMD's messaging become clearer in its issuance of repeated early warnings predicting that the impact of the El Niño rains of 2015–16 would not be as devastating as those of the 1997 event. Although the Kenya Red Cross had also taken a strong leadership role in monitoring the evolution of the El Niño rains, no evidence exists that it or other NGOs played a significant role in disseminating early warning messages. This outcome is perhaps because monitoring by the Kenya Red Cross was largely situational, focused on large-scale impacts that would inform its responses to any impending disaster situations. Worth highlighting, therefore, is that the Kenya Red Cross Society also relied on KMD's daily weather forecast in its planning and reporting.

5.4.2 Warning Lead Time

A very small percentage of respondents (1%) said that they first received early warning messages in 2014, but early warning information was available incrementally in the months preceding the 2015 El Niño. That said, nearly half of all respondents (47%) said that they first received early warning messages in September 2015, which means that the lead time for most of the inhabitants of the study area was one month prior to the onset of the OND short rains (Wachira and Cumiskey 2017) (Fig. 7).

The major role of a prediction system such as the one operated by KMD is to increase the lead times of early warnings to enable more timely and effective interventions. A short lead time adversely impacts the effectiveness and quality of preparedness and response, as decisions are made and resources are allocated in haste, if at all,

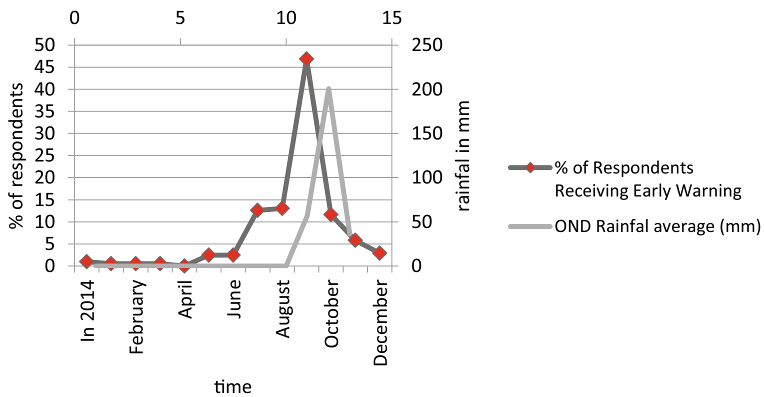


Fig. 7 Percentage of respondents receiving El Niño early warning messages over time (Authors)

due to limited actionable timeframes. This result was the case in Tigithi, where structural poverty is endemic and insufficient infrastructure is marked. Here, the short lead time resulted in insufficient short-term preparedness investments. Indeed, the study results show a positive relationship between the nature and the cost of investments, with a majority of respondents having had invested in the least costly interventions such as cropping. While these investments may have been somewhat helpful in the short-term, they were no less problematic in that they could not provide a sufficient buffer to adequately protect the area's at-risk populations from the adverse impacts of either the 2015–16 event or of future events yet to form.

5.4.3 Early Warning Communication Channels

Survey results identified local FM radio stations as the most common channels for early warning information dissemination, as indicated by 69% of respondents (Table 2).

Because FM radio stations often broadcast in the local language, they are often easy for people to understand. This relatability is further promoted by the shared local identity, as the broadcasters and listeners typically come from the same 'tribal' regions.

There is evidence, however, that in past disaster crises both positive and negative solidarity existed between local FM stations and their listeners. For instance, during the Kenya 2007–08 post-election violence, some FM stations sought either to protect or to incite their followers through coded communications. Like this, some respondents indicated that a number of FM stations chose to broadcast their own distinct El Niño early warning messages. Broadcasting of this kind can, from one point of view, be seen as a positive contribution to risk reduction through awareness and preparedness. Taken from a different viewpoint, however, such broadcasting can readily been seen to lead to misunderstandings among the general public, as such self-generated media messages are often overly simplistic (or simply erroneous) and can even be indulgently populist in nature. Indeed, upwards of 70% of respondents in this study indicated that they expected El Niño rains to be "far above normal" in 2015–16, an expectation that proved to be not only misinformed but also wholly inconsistent with KMD's official early warning messaging. This inconsistency speaks to the need

Table 2 Popular early warning dissemination channels (Wachira and Cumiskey 2017)

Channel	Popularity (%)
Local FM radio station	69
National radio station	18
NGOs	3
Newspapers	0.4
Chief's Baraza	0.8
Other	1

Table 3 Early warning messaging (Wachira and Cumiskey 2017)

Content	Rationale
Avoid sheltering under trees during rains	Sheltering under a tree during stormy rain increases lightning strike risks
Avoid using phones and other electronic devices during rains	Using electronic devices during rains increases lightning strike risk
Flood control methods, e.g. raising houses, digging trenches	Raised houses reduce flooding risk
Water harvesting	To reserve water for future use
Relocation from flood-prone areas	To avoid the risk of floods and landslides
Observe hygiene	To prevent water-borne diseases

for a collaborative approach to effective early warning messaging, an approach that is most beneficial to a local ommunity when its seamlessness safeguards quality preparedness and its streamlining ensures appropriate response actions.

5.4.4 Early Warning Message Content

Although warning messaging did include advisory actions (as highlighted in Table 3), nearly half of respondents (47%) said that advisories for people to relocate from areas prone to natural hazards (such as floods and landslides) dominated the contents of early warning messages. This advisory was incongruous with known facts about the study area, however—neither had it been pre-identified as high-risk for land- or mudslides nor did it have a history of such hazards. What this incongruity demonstrates is the difficulty of disseminating contextualized early warning information in a heterogenous society. Thus, the 2015–16 early warning messaging may not have been contextualized sufficiently enough to effectively highlight what localized impacts should have been expected or to truly benefit those who were reading or listening to them.

5.5 Community Response and Preparedness Actions

Survey results, as illustrated in Fig. 8, showed that only 46% of respondents successfully undertook investments in readiness for the 2015–16 El Niño rains. These actions were largely undertaken at the household level and tended consist only of short-term tactics meant to mitigate—or take advantage of—the effects of the enhanced OND rains. A positive relationship exists between the nature of investment and cost, with a majority of people having invested in lowest cost actions. Most respondents cited financial constraints as the main barrier leading to their having invested more in low-cost efforts than in those more robust efforts that could have helped the entire

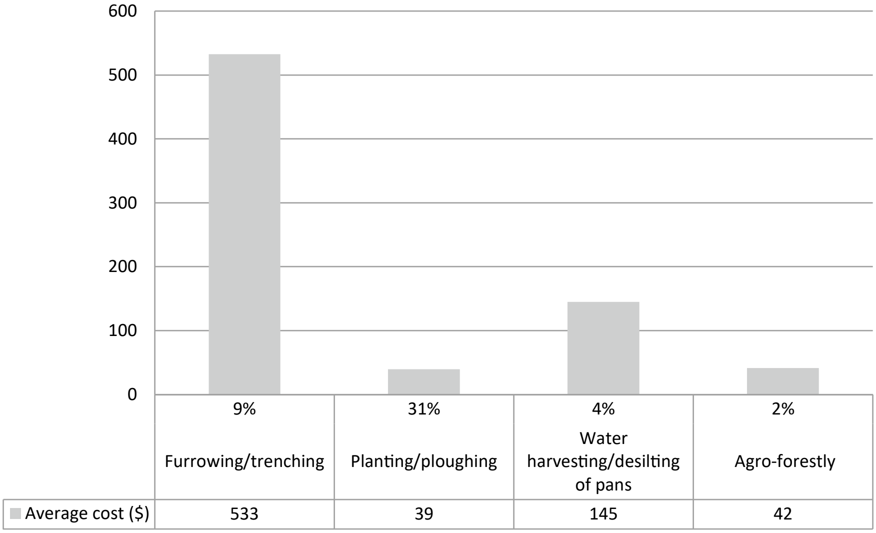


Fig. 8 Community response and preparedness actions (Wachira and Cumiskey 2017)

community mitigate the negative impacts of the El Niño rains. Even so, such investments may not have provided sufficient protection from the adverse impacts of similar hazards in the future for the most at-risk populations. Requiring further research, this supposition implies that government bodies and other agencies need to play a more pivotal role in boosting community preparedness activities if risk reduction efforts are truly to make strides in safeguarding entire populations (Wachira and Cumiskey 2017).

6 Conclusions and Recommendations

This study established that El Niño weather conditions in Tigithi Location, Laikipia County, Kenya were, on the whole, rather beneficial to the residents of the area during the 2015–16 event. In fact, the increased precipitation during the OND rains of 2015 marked a turning point to the dry weather that had characterized the area for more than five years and that had resulted in poor agricultural and livestock production, adversely impacting household food security. The extent to which the residents were able to take advantage of the enhanced rains was, however, limited by low financial capacity that forced them to make only short-term investments that were helpful but that could not provide for a long-term reduction of risk from foreseeable hazards in the area.

KMD fulfilled its mandated role in producing and broadcasting El Niño weather-related early warning information. KMD's early warning messaging tended to be cautious, implying the forecasters' struggles with the politics of uncertainty. As the onset of the OND rains neared, however, messaging became clearer, with repeated warnings emphasizing how the impacts of the El Niño rains of 2015–16 were not expected to be as severe as those of the destructive 1997 event. Nationally, though, KMD's messaging conflicted with other sources of early warning messaging, such as those generated by media outlets and politicians, neither of which can be said to have made adequate invests in either obtaining or communicating credible information. These alternative messages were broadly disseminated through local radio stations, communities' preferred mode of communication, leading to some level of confusion about the event's expected impacts.

El Niño early warning lead time was insufficiently short, with a majority of respondents claiming that they first received advisory messaging in September 2015, only a month before the start of the OND rains. In an area characterized with high poverty levels, the impact of such a short lead time resulted in only cheap, short-term preparedness investments. Indeed, the study results show a positive relationship between the nature of investment and cost, with a majority investing in the lowest cost interventions such as planting. While these investments may have been helpful in the short run, they may nonetheless prove problematic in that they will not provide a sufficient buffer to protect most at-risk populations from the adverse impacts of similar hazards in the future (Wachira and Cumiskey 2017). This study recommends the following actions in preparation for future El Niño events:

1. Close collaboration between KMD and other departments and actors to avoid conflicting early warning messages;
2. Investment in early dissemination of warning messages to provide sufficient lead times for at-risk communities to invest in preparedness measures;
3. Emphasis on both potential positive and negative impacts of El Niño to enable at-risk communities to invest in a broad range of preventive, mitigative. and adaptive strategies that can have long-term benefits; and
4. Further research to understand the interplay between the producers of early warning messaging and the channels that disseminate that messaging.

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South Africa

El Niño Impacts and Management in South Africa: Lessons Learned for an 'El Niño Ready' Nation

Marie-Ange Baudoin, Kirsty Nortje, Myra Naik, Mathieu Rouault, and Coleen Vogel

Abstract South Africa is prone to drought. The country recently experienced the combined effects of a severe drought and a strong El Niño event, which led to serious impacts on livelihood conditions and economic growth. By examining the State's response to drought over time, with a specific focus on responses to the current 2016 El Niño-related drought, we expose a number of 'sticking points' in the response to drought and the delayed action to reduce the risks to drought impacts. Complex and seemingly bureaucratic hurdles limiting action are shown to be cumbersome factors that impede and continue to frustrate effective drought response in the country. Such bureaucratic inability to enable swift and flexible responses resulted in many NGOs and civic actors stepping up to provide assistance. As demonstrated in this research, while there are response plans and key contact departments and strategies in South Africa, these have become mired down in officialdom. Some suggest the blame lies with the State itself, and its alleged poor drought risk governance that affect recovery after drought, especially in the agricultural sector. Ineffective responses are surprising given that drought is a familiar feature and given there have been several previous cases of successes in institutional response in the past.

Keywords South Africa · El Niño · Drought management

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1 Introduction

El Niño is a quasi-periodic displacement of warm sea surface waters into the central and eastern tropical Pacific Ocean, returning at least once in any ten-year period. It can last for a year. When it is forecast, societies around the globe wonder if they should prepare for its potential influences. But after El Niño peaks in intensity and begins its months-long return to neutral (average), governments and the media often quickly lose interest in the phenomenon until some years later, when the next El Niño appears.

In South Africa, El Niño most often induces severe droughts. In 2014–15 and then again in 2015–16, South Africa experienced record high temperatures and droughts, which affected its water resources and agricultural production. The observed consequences include degradation of grazing lands and vegetation, delayed production of grains, high rates of animal mortality, a significant decrease in major dam levels, a drying up of boreholes and springs, and severe veld fire damage in different parts of the country (AgriSA 2016).

Early warnings of a possible El Niño event months prior to its full formation as well as about a likely severe drought as a result did not catalyze government response. Measures to control water use were only recently set up in many provinces of the country. A similar situation was observed in surrounding countries in southern Africa, where water authorities limited water usage due to extremely low dam levels. Food shortages were already being reported and food insecurity was expected to worsen both in South Africa and at the regional scale (FAO 2015). According to the Famine Early Warning System Network (FEWS NET 2016), current food insecurity levels in southern Africa, which were already worse than usual, were projected to double in 2016–17 due to extreme regional water shortages and declines in crop yields. In South Africa, the agricultural surplus could not meet the demand, forcing the national authorities to recognize the urgent need to import five to six million metric tons of grain, a number rising to 10.9 million metric tons if regional food needs are also considered (DAFF 2016a).

IPCC reports suggest southern Africa will be particularly impacted by global climate change in the form of increasing temperatures, increasing variability in precipitation, increased flooding, and—with medium confidence—more frequent drought (IPCC 2012, 2014). A key contributor to the region's vulnerability is that a large portion of its food production is dependent on rain-fed agriculture (Hachigonta et al. 2013). Recent drought in the region negatively contributed to the impacts of the 2015–16 El Niño, and national authorities in the country qualified the drought as having been the worst since El Niño-related droughts in the early 1990s seriously affected the country (DAFF 2016). The negative effects on South Africa's food production rippled across surrounding countries that rely on imports of its surpluses. Consequently, those other governments were forced to seek international support to compensate for the serious food shortages, which resulted in reduced market availability and increased prices (RVA 2015; DAFF 2016b).

Lack of preparedness for food insecurity in South Africa contrasts distinctly with the fact that the first appearance of El Niño conditions in the tropical Pacific provided governments with the earliest possible warning of an event's likely adverse impacts on water supply and food production. As the saying goes, "To be forewarned is to be forearmed"—but only if action is taken based on early warnings. In this context, a better understanding of preparedness for and response to an El Niño is critical to enhancing future 'El Niño Readiness' in South Africa.

In Sect. 1 of this chapter, we provide an overview of South Africa, introducing its socioeconomic context and climate patterns. Section 2 focuses on El Niño. After identifying the main institutions involved in the detection of El Niño events, we analyze South Africa's sensitivity to El Niño and highlight the major El Niños that have affected the country over recent decades. We then focus on the 2015–16 El Niño event and its impacts on the country. Section 3 focuses on South African preparedness and response to El Niño-induced droughts. After providing an overview of the key institutions involved in and processes for drought management, we analyze the response to the most recent drought in the country. This section concludes with an overview of the way media have presented El Niño to the public. Section 4, finally, concludes the chapter by discussing the level of 'El Niño Readiness' in South Africa, particularly in light of past and present El Niño-related drought management strategies. Lastly, 'lessons learned' from the most recent event as well as from past El Niño events and their (mis-)management are identified, which can, hopefully, contribute to further development of proactive risk management policies and practices in South Africa.

2 Socio-Political and Environmental Context of South Africa

In this section an overview is provided of South Africa's socioeconomic context and climate patterns. This information is useful for understanding the country's administration, its main spheres of governance, and the basis of its economy. A look at South Africa's climate patterns serves to highlight the prevalence of drought in the country.

2.1 Introduction to South Africa

The Republic of South Africa is located geographically on the southern edge of the African continent. The country shares a border with Botswana, Lesotho, Mozambique, Namibia, Swaziland, and Zimbabwe. The term "Rainbow Nation" is often used to describe the South African population of about 51.77 million people. This is due to the variety of cultures, languages, and religious beliefs in the country. Although the majority of South Africans speak English, the country is multilingual—there are 11 official languages (Afrikaans, English, isiNdebele, isiXhosa, isiZulu, Sesotho sa Leboa, Sesotho, Setswana, siSwati, Tshivenda, Xitsonga) and 8 other recognized languages. The large majority of the population is African (about 79.2% of the total population), while colored (8.9%), white (8.9%), and an Indian/Asian (2.5%) populations comprise the minority.

Three recognized levels govern South Africa: National, Provincial, and Local (or Municipal). The country is divided into nine provinces; Eastern Cape, Free State, Gauteng, KwaZulu-Natal, Limpopo, Mpumalanga, Northern Cape, North West, and Western Cape (Fig. 1). The provinces vary considerably in size and include highly urbanized regions such as Gauteng as well as vast, sparsely populated arid regions such as the Northern Cape. Each province has its own legislature, premier, and executive council, and there are also three recognized capital cities within the country: Pretoria (administrative), Cape Town (legislative), and Bloemfontein (judicial) (South African Government 2015).

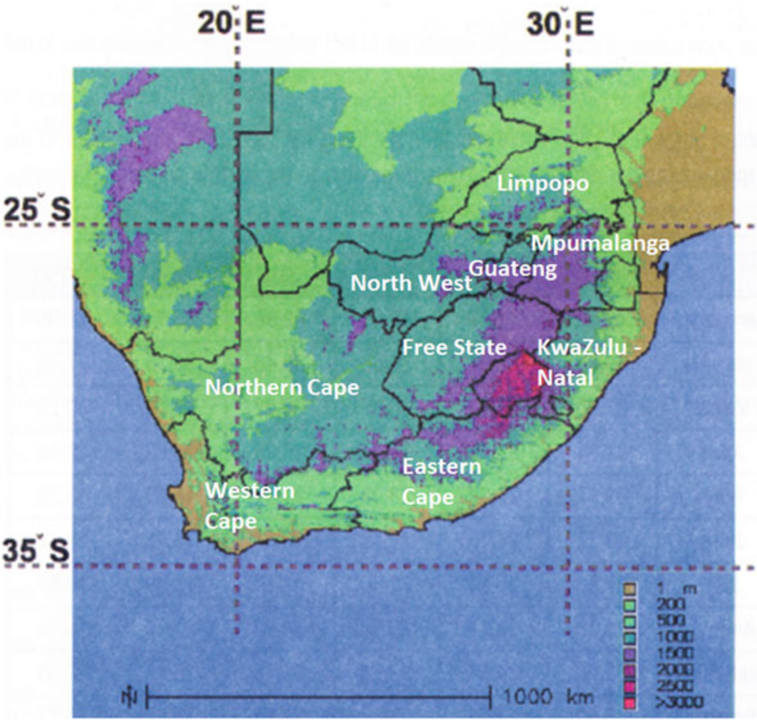

Fig. 1 Geographical location (and topography—meters above sea level) of South Africa and its Provinces (Adapted from Kruger 2004)

2.2 *Socioeconomic Context*

South Africa is the leading economy in the southern African region (RVA 2015). Table 1 presents an overview of the key economic sectors of the country. It indicates that agriculture makes a limited contribution to the national economy. Notwithstanding this limited contribution, the linkages to agricultural production are wide ranging. Good information exists about the commercial farming sector, but there is limited information about smallholder and subsistence agriculture (Statistic South Africa). Moreover, agriculture is crucial to South Africa's socioeconomic development, as it is one of the most employment-intensive sectors, involving 4.2% of South Africa's labor force (AgriSA 2016). It is also a source of income through exports within and outside of the southern African region. The agricultural sector, especially non-commercial agriculture, is, however, particularly vulnerable to climate shocks. This is because rural livelihoods in the country often depend on agriculture, which is largely rain-fed (Hachigonta et al. 2013).

Similarly, the mining sector, notwithstanding a relative decline in recent years, has traditionally occupied a principal role in the output of the South African economy (Fedderke 2002). Mineral processing and resource extraction, influencing the economy in the production of energy and electricity, are vulnerable to changes in weather and climate or extreme climate events. For instance, the South African economy is heavily reliant on coal, which contributes to the country's energy production (71%) and a large proportion (90%) of the nation's electricity (Scholvin 2014). When exceptionally heavy rainfall soaked the fuel stock of the nation's major coal-fired power plants in 2014, the ensuing energy crisis measurably affected the national economy (Worthington and Maluleke 2014). Other industries utilizing natural resources directly include the forestry and fisheries sectors.

Table 1 South Africa's key sectors: contribution to GDP growth in 2015 (Statistics South Africa)

Key sector	Contribution to GDP (%)
Agriculture, forestry, and fishing	2.4
Mining and quarrying	7.6
Manufacturing	12.6
Electricity, gas, and water	2.3
Construction	3.4
Wholesale, retail and motor trade, catering, and accommodation	13.7
Transport, storage, and communication	8.4
Finance, real estate, and business services	19.6
General government services	15.4
Personal services	5.3
Taxes, less subsidies on products	9.3

2.3 *Weather and Climate Patterns in South Africa*

South Africa experiences diverse patterns of weather and climate and is no stranger to disruptive climate anomalies such as droughts. The country's vastly different climatological regions are influenced by complex topography and ocean currents as well as high interannual variability, which pose challenges for weather prediction, seasonal forecasting, and climate projection (Archer et al. 2010) As a consequence, the country's response and ability to manage hydrometeorological hazards such as floods and droughts has been somewhat limited.

Much of South Africa receives its rainfall from December to February (DJF). Only the southwest region of the Western Cape Province, which receives frontal rainfall from the passage of mid-latitude cyclones from June to August (JJA), and a small margin along the south coast, where all-season rainfall patterns occur, differ (Tyson 1986). The southwest region and the west coast receive most of their rainfall through temperate systems in austral (SH) winter, while the rest of the country receives most of its rainfall in austral summer.

El Niño Southern Oscillation (ENSO) teleconnections play an important role in the variability of South African rainfall. El Niño and La Niña have impacts on long-term climate variability worldwide, and their influence on rainfall variability over South Africa is no different. El Niño is often associated with drier conditions (dry spells, including drought) over a large part of the summer rainfall region (Fig. 2), while La Niña is usually associated with wetter than normal conditions (including flooding) (Lindesay and Vogel 1990; Richard et al. 2000; Kruger 2004).

Extreme climatic events, particularly El Niño-related droughts, are serious concerns for the South African government, as they usually have adverse impacts on citizens and major economic sectors. For instance, five out of eight El Niño events that occurred between 1965 and 1997 decreased agricultural production and exacerbated issues of food insecurity not only in South Africa but also in several countries in the region that rely on South African food exports (Kandji et al. 2006).

3 El Niño in South Africa: Science, Detection, and Impacts

Drought is a recurrent feature of South Africa's historical climate, and previous research has shown that eight of its ten strongest droughts since 1900 happened during El Niño events. Research also indicates that El Niño can contribute to severe drought half of the time across all of southern Africa, including South Africa, which means that there is usually ample time for early warning (Rouault and Richard 2003, 2005). Such droughts often result in decreased agricultural output and exacerbate food insecurity (Kandji et al. 2006). For instance, both the strong 1982–83 El Niño episode and the moderate El Niño of 1991–92 caused extensive drought and significant socioeconomic impacts that rippled through various sectors such as livestock production, water resources, and agricultural industries (Glantz et al. 1997).

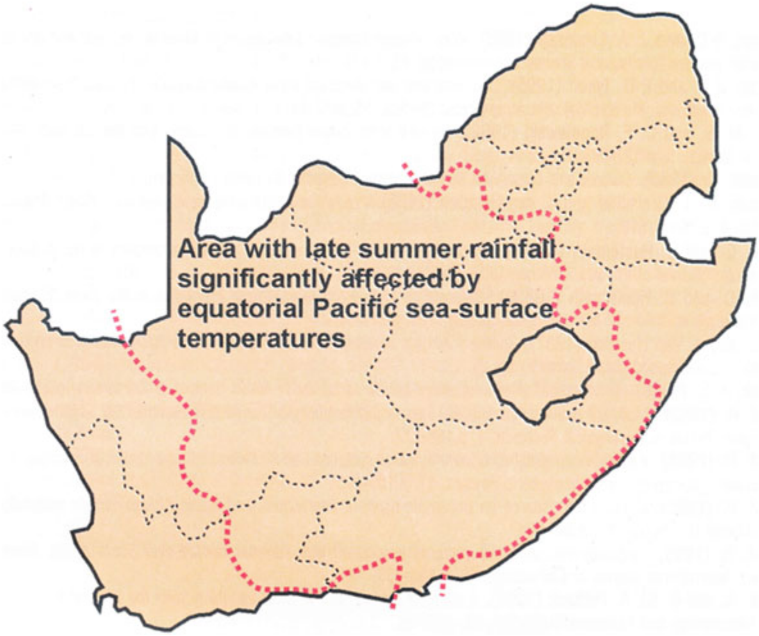

Fig. 2 Area showing significant negative correlation between equatorial Pacific SSTs (associated with El Niño) and total rainfall from January to March (Kruger 2004)

This section focuses on El Niño events in South Africa, first looking at the key institutions involved in the detection of and issuance of warnings for an event. Also critically analyzed is when these institutions issued the first warning for the 2015–16 El Niño. Then, some of the major El Niño events that have affected South Africa in recent decades are examined. Finally, the major impacts of the 2015–16 El Niño across South Africa are considered.

3.1 El Niño Detection and Warning Issuance in South Africa

South African climate modeling and weather forecasting systems have improved considerably over the past 20 years. A close partnership with the International Research Institute for Climate and Society (IRI) and the World Meteorological Organization (WMO) has had a significant impact in this regard (Landman 2014). As a result, the nation is currently the leading provider of seasonal forecasting in Africa.

The South African Weather Service (SAWS) has a key responsibility for monitoring weather and climate, including detecting and monitoring El Niño events, as well as other hydrometeorological conditions. Important to understand, however, is that SAWS's forecasting activities never specifically focus on El Niño. The service works, rather, to incorporate projected El Niño affects into forecasts that are delivered as seasonal advisories to the population (SAWS Interview 2016). These seasonal forecasts, called 'Seasonal Climate Watch' documents, are released on a regular basis, and constitute expert advisories for the coming season. These advisories are freely available to the government, users from various sectors, and the general public through various platforms and Internet portals like the South African Risk and Vulnerability Atlas (http://rava.qsens.net). More specifically, SAWS advisories include weather and seasonal climate predictions for South Africa for a period of five months. The advisories report the known facts about weather and climate patterns and include predictions for rainfall and temperature as well as ENSO conditions.

Seasonal climate watches are compiled using a number of different sources and collaboration efforts, both nationally and internationally. Although primary collaboration has been between IRI and SAWS, other key institutions have also been involved. For instance, SAWS is part of a WMO initiative to form a global framework for climate services (GFCS) and is recognized by WMO as the global center producing seasonal forecasts in the Southern African Development Community (SADC) region. Other partners include, at the national scale, the Council for Scientific and Industrial Research (CSIR), the Agricultural Research Council (ARC), the Department of Agriculture, Forestry and Fisheries (DAFF) and the Universities of Pretoria (UP) and Cape Town (UCT).

SAWS also compares its forecasting system with other international organizations, such as the Applied Centre for Climate and Earth System Science (ACCESS), and forecasting agencies like the European Centre for Medium-Range Weather Forecasts (ECMWF), the European Initiative for Climate Service Observation and Modelling (ECOMS), and various American meteorological agencies (like NOAA) to strengthen its results or to complement, correct, or confirm its own forecasts. SAWS has cross-referenced forecasts made by international centers since it first did so during the 1997–98 El Niño (Landman 2014). It does so in order to help identify what uncertainties remain within its own predictions. This range of forecast products, therefore, helps SAWS to build confidence in its own forecasts and to compile information for future advisories (SAWS Interview 2016).

As mentioned, SAWS advisories are not specifically focused on El Niño events but on seasonal projections, which can include information about El Niño when relevant. Interestingly, as explained by a key informant (Climate Scientist interview 2016), the accuracy of seasonal forecasts is generally higher during El Niño and La Niña years. That being said, there are still areas of the country and times of the year that are more predictable and those that require higher levels of forecasting skill. Such variability is taken into account when SAWS shares information with decision makers, as forecast accuracy might be high for one province, for instance, but not so strong for those surrounding it.

A SAW advisory first mentioned the detection of an El Niño event in August 2015, predicting that the El Niño would likely develop and strengthen through the summer season and into autumn. This advisory also indicated that the country was likely to face localized drought as a result of the event. Even so, the meteorological services had been aware of the formation of an El Niño event as much as nine months prior to the issuance of the warning. The event remained a topic only of internal discussion, however, and was not shared in public advisories until SAWS had strong certainty regarding the its formation (SAWS Interview 2016). This delay suggests the capacity of SAWS to detect such phenomenon very early on. It also reflects SAWS concern about providing alerts of disaster that later prove erroneous, which can happen if the media picks up on and broadcasts such information. It indicates SAWS's awareness that the issuance of an early warning for a high-impact event that does not in the end come to pass can also cause negative social impacts.

On this matter, a key informant from SAWS indicated that there is significant pressure from the government and forecast users for accurate information (SAWS Interview 2016). Adding to this pressure are two realities: the forecasting science is not perfect, and people tend to remember forecasts that were less accurate than ones that were accurate—even if accurate forecasts are more typical. But inaccuracies do happen, like in 1997 when expected El Niño impacts on southern Africa failed to materialize, resulting in a period of decreased public trust in SAWS forecasts (Landman and Mason 2001).

For this reason, SAWS tend to take extra precautions before releasing critical forecasting about the onset of an El Niño event and its potential consequences for the country (SAWS Interview 2016, Climate Scientist interview 2016). Adding to the difficulty in 2015–16 was that the country had been in drought since 2014, which further explains why SAWS wanted to be careful about attributing drought conditions to the forming El Niño event. As noted by a local forecaster, one 'cannot make decision on [the] basis of El Niño alone' (SAWS Interview 2016). especially considering the role of other regional climate drivers. Hence, information about the onset of an El Niño was only conveyed to the general public in August 2015 after the correlation between the already-formed El Niño and the ongoing drought had finally been verified.

After August 2015, seasonal advisories continuously highlighted the high likelihood of persistent dry conditions and high temperatures over most of the country due to the impending event. As SAWS advisories are distributed through multiple channels, including to the government, the August 2015 advisory can therefore be considered the first official early warning in South Africa of the formation of an El Niño.

The only outreach toward society and government that SAWS produces, the advisory is notably only presented in probabilistic terms, however, which is problematic for some users. But SAWS staff highlights that they are not mandated to go through a value chain process from production of the data/science to the end user of the information (SAWS Interview 2016). Hence, SAWS sees itself as only producing the seasonal prediction information; users are expected to monitor and interpret that information themselves.

Despite this understanding of its limited role in the end-to-end forecasting chain, misinterpretation of the probabilistic terms of a SAWS product can no less have significant impacts, especially since various sectors use SAWS products to produce more targeted advisories. This concern over interpretations and uses of climate forecasts was confirmed in an interview with a climate scientist who noted that there is often quite a gap between knowledge producers and users (Climate Scientist interview 2016). Those producing climate information often have neither the mandate nor the inclination to play the role of communicator; rather, they approach their role in terms of that one-way flow of information, where they just produce forecasts without engaging in any downstream processes related to either use or interpretation of those forecast products. This lack of integration and communication along the forecasting chain can, however, lead to significant real-world consequences.

3.2 *Past and Current El Niños*

Overall, El Niño events tend to produce drought in South Africa, especially since the late 1970s (Fauchereau et al. 2003; Richard et al. 2000, 2001). The correlation between El Niño and drought is statistically significant during the period December to March; therefore, mid-summer (SH) climate anomalies affecting South African rainfall are best predicted during ENSO warm event years.

The most severe droughts happen in South Africa during the mature phase of El Niño (Rouault and Richard 2003), when the central and eastern Pacific and the Indian Ocean are warmer than normal (Figs. 3 and 4). El Niño and La Niña also have an impact on streamflow (Landman et al. 2001; Rouault 2014; Rouault et al. 2016), vegetation (Phillippon et al. 2014), and the flux of nutrients into the ocean. They also affect wind intensity along the coast. For instance, in the upwelling system off the West Coast of South Africa known as the South Benguela current), El Niño often triggers lower than normal wind, warmer sea surface temperatures (SST), and a weaker upwelling (Rouault et al. 2010). During La Niña, in contrast, the opposite usually occurs. During an El Niño event, a 50% chance of severe drought in the summer rainfall region typically follows. Furthermore, at least one study has shown that the Western Cape is also impacted by El Niño in the winter rainfall season (Phillippon et al. 2012).

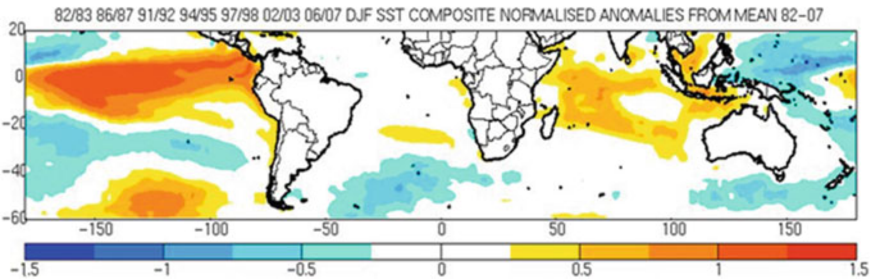

Fig. 3 Global sea surface temperature composite seasonal standardized anomalies during mature phase of El Niño in austral summer. Blue/green is colder than normal; yellow/red is warmer than normal (NOAA)

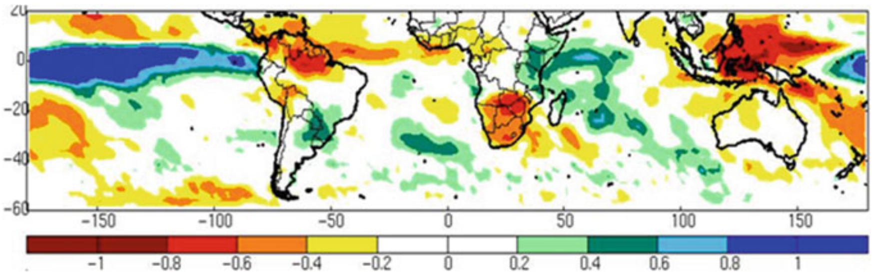

Fig. 4 Same as Fig. 3, but for rainfall Blue/green is wetter than normal; yellow/red is dryer than normal (NOAA)

Its effects having been felt for at least three years after returning to an ENSO neutral phase, the 1991–92 El Niño caused one of the most severe droughts of the last century and one of the “worst in living memory” (Glantz et al. 1997; ISDR 2002). Kandji et al. (2006) estimate that 20 million people were put at serious risk across the southern African region, and as a result of widespread food shortages, 30 million people were on the brink of famine. South Africa saw between 0.4 and 1.0% loss in economic growth and an estimated R1.2 billion reduction in agricultural GDP (Glantz et al. 1997; Kandji et al. 2006). The impacts were particularly severe in agricultural-related sectors as the country’s normal crop output was reduced by 40% (M&G 1997b). Crop production, maize in particular, reached a record low. Moreover, comparison of cereal production and imports between the 1992–93 marketing year and normal years shows a large and unprecedented commercial import of grains that exceeded five million metric tons (Holloway 2000). The country suffered a loss of R365 million in export earnings. In addition, 49,000 agriculture and 20,000 formal sector jobs were lost (Holloway 2000).

The 1997–98 El Niño effects were anticipated to be severe for South Africa, even worse than the 1992–93 drought (VOA 1997, M&G 1997a), so the government undertook a number of mitigation measures, including information campaigns (for example, to alert farmers of the potential dangers associated with the drought), stockpiling of food reserves, and efforts to address possible water shortages by, for example, by improving rainwater harvesting methods (VOA 1997). Even though the 1997–98 El Niño formed earlier than expected and reached its full-strength in October (instead of December, as is typical), the Department of Water Affairs and Forestry (DWAF) confirmed that the country’s water resources, especially its reservoirs and lakes, were adequate to cope with the expected rainfall deficit.

The 1997–98 El Niño was the first time that seasonal forecasts gave early warning of an El Niño in South Africa, specifically highlighted the increased likelihood of drought prior to the planting season (USAID 1998). It was Africa’s first experience in planning for possible drought in advance of a planting season based on a seasonal forecast (USAID 1998). Prior to this (i.e. 1991–92 and 1994–95), countries like South Africa had no experience in responding to warnings.

Even so, the 1997–98 El Niño-related drought did not unfold as severely as predicted in South Africa, with only the northeast experiencing drought. The fact that the impacts of drought on the country were not as severe as anticipated might have influenced end user perception of drought forecasting in general, rendering them less inclined to believe such forecasts in future preparedness schemes (M&G 1997a, b).

The 2002–03 El Niño was a relatively low intensity event, leading to drought in parts of South Africa but not to major drought conditions. For instance, only six of the 15 water management areas in South Africa, including areas in Limpopo, Olifants, and Swaziland, were affected by dry conditions and low streamflow during the event.

During the 2014–15 austral (SH) summer, southern Africa as a whole suffered the strongest drought since 1995. Severe drought was also experienced in 2015–16. The 2014–15 drought was the biggest contributing factor in the decline of South African GDP in 2015 and seriously depleted the country's water reserves. Although it was not considered an El Niño-related impact, some would argue that it can be considered a 'borderline weak' El Niño impact, even though the formation of an El Niño is usually not declared until that threshold has been surpassed for six months, because the Pacific Ocean for the four month period between November 2014 and February 2015 was above accepted El Niño temperature thresholds of +0.5 C on average in the Niño 3.4 region.

To be sure, the warmer than normal Pacific contributed to 2014 being the warmest year on record globally. Even so, the 2014–15 droughts were widespread in South Africa due to below normal rainfall in January and February 2015 (Monyela 2014). Over the course of 2015, the Pacific became even warmer and, despite a lack of correlation between the strength of an El Niño and the intensity and spatial extension of a drought, South Africa endured one of the biggest droughts it has ever experienced that year.

3.3 Impacts of the 2015–16 El Niño in South Africa

Agriculture and water are the most affected sectors in South Africa, with serious concerns related to the availability of water for crop production and of grazing lands for livestock.

The droughts in 2014 led to a 30% decline in South Africa's maize production for the 2014–15 harvest (OCHA 2016). The El Niño-induced drought of 2015–16 also had severe impacts on South Africa's agricultural production, which resulted from high temperatures and the fact that 2015 was the driest year on record. In this context, the Crop Estimates Committee (CEC) provided its first production forecast for the 2016 crop in January, midway through the summer growing season and a month earlier than usual (News Desk 2016). The CEC estimated that 7.44 million metric tons of maize, consisting of about 3.27 and 4.17 million metric tons of white and yellow maize, respectively, would be harvested in 2016. This amounts to a 25% decrease from the 9.94 million tonnes reaped in 2015, which even so was a harvest significantly below the norm (AgriSA 2016; Stoddard and Shabalala 2016). The CEC also reported that for the 2016 season, maize production decline by 25% from the previous year, amounting to the smallest crop since 2006. This decline was attributed directly to the drought, verifying AgriSA (2016) prediction that South Africa's maize production would continue to decline for a second consecutive year as a result of the prevailing, even if weakening, El Niño-generated conditions, which saw record-high temperatures and large deficits in seasonal rainfall between October 2015 and February 2016. According to the same source, outputs of the many other 2016 summer crops were also predicted to decline.

As a consequence, FAO (2015) estimated in 2015 that South Africa would need to import 3.5 Mi tonnes of cereal to meet domestic demand (Table 2). DAFF's estimation

Table 2 Cereal supply/demand balance for the 2015–16 market year (May/April) in South Africa (FAO 2015)

Cereal supply and utilization data	Wheat	Rice	Coarse grains	Total cereals
	Thousand tonnes			
Previous year production	1 759	3	15 551	17 313
Previous 5 years average production	1 793	3	13 440	15 236
Previous year imports	1 600	909	221	2 730
Previous 5 years average imports	1 604	1 017	245	2 866
2016/16 domestic availability	**1 700**	**2**	**11 936**	**13 638**
2015 production (rice in paddy terms)	1 700	3	11 056	12 759
2015 production (rice in milled terms)	1 700	2	11 056	12 758
Possible stock drawdown	–	–	880	880
2015/16 utilization	**3 300**	**1 102**	**12 727**	**17 129**
Food use	3 125	1 062	5 001	9 188
Non-food use	75	40	6 866	6 981
Exports or re-exports	100	–	860	960
Possible stock build-up	–	–	–	–
2015/16 import requirement	**1 600**	**1 100**	**791**	**3 491**
Anticipated commercial imports	1 600	1 100	791	3 491
Of which; received or contracted	616	90	–	716
Food aid needs	–	–	–	–
Current aid position				
Food aid pledges	–	–	–	–
Of which; delivered	–	–	–	–
Donor-financed purchases	–	–	–	–
Of which: for local use	–	–	–	–
For export	–	–	–	–
Estimated per caput consumption (kg/year)	**57**	**20**	**92**	**169**

for 2016 rose to 5–6 Mi tonnes of cereal imports, a number that approaches 11 Mi tonnes when the regional needs of Zimbabwe, Lesotho, Namibia, Botswana and Swaziland are taken into account (DAFF 2016b). South Africa is a net exporter of agricultural products, typically—in ‘normal’ years—distributing nearly one Mi tonnes of food at a value of R82.8 billion (AgriSA 2016, Vidal 2015)**.** The grain deficit was especially felt toward the second half of 2016, which made South Africa a net importer of maize and put pressure on its balance of payments (AgriSA 2016).

Finally, livestock production was also affected (DAFF 2016a), primarily because of poor veld conditions and declines in natural grazing and fodder availability (AgriSA 2016).

Because it is the largest maize supplier in the SADC region, the drop in maize crop production in South Africa had serious impacts on domestic and regional consumption and price (OCHA 2016). AgriSA (2016), for example, had estimated an 11% inflation in food prices by the end of 2016 and that the price of maize meal (pap)—a major foodstuff for many, especially poor households—would climb upwards of 47% higher. Food imports, which were required, were also affected by the depreciation of the national currency. As a result, RVA (2015) estimated that maize prices would remain above average for 2016, with additional consequences likely to result in surrounding countries that rely on South Africa for their own food imports.

Among the consequences of the price increase, OCHA (2016) estimated that the plight of the 74% of South Africa’s rural population affected by food insecurity at the beginning of 2016 would worsen with the onset of the 2015–16 El Niño event. The shortfalls in maize and cereal production (November 2015–May 2016) were severe and translated to large proportions of the population having inadequate access to food. The provinces of KwaZulu-Natal (population: 3,481,881), Eastern Cape (2,237,401), and Gauteng (2,052,802) were most affected by food insecurity at the time (OCHA 2016).

The need for significant food imports was also consequential in terms of increased pressure on transport and storage in South Africa. For instance, South Africa’s harbor and rail infrastructures struggled to cope with the increased volume of maize imports, especially as exacerbated by the El Niño-induced drought that further decimates local crops (DAFF Interview 2016b). The situation, according to an interview with a key stakeholder (Anonymous Interview 2016), showed that harbors and rail policies, due to their low carryover stock, should have adapted as soon as the earliest warning for El Niño was released. According to this informant, at the time of the interview (February 2016) South Africa had enough stock to last until the end of April, after which the Crop Estimates Committee (CEC) would need to import about 3.8 million metric tons of maize and two million metric tons of wheat within a period of 12 months. Later estimates by Grain SA suggested, however, that the country would actually need upwards of R20 billion to import the five to six million tonnes of maize required to offset the effects of the drought (Ngoepe 2016). Regardless of the actual amount, such a large import would require adequate policies and infrastructure in place to cope with and absorb the influx of imported goods.

Finally, as agriculture is labor intensive, the drought also considerably affected employment in South Africa. Although impacts on employment on maize farms were estimated to be low, it was acknowledged that other agricultural sectors could be affected. For example, cane growers expected a decline in seasonal jobs as a result of decreased production (AgriSA 2016). In addition, drought indirectly impacted upstream economic activities, such as those of input providers with less purchasing power in the agricultural sector. The depreciation of the national currency and inflationary pressures resulting from food price increases also had negative impacts on interest rates, thus increasing debt service costs for farming enterprises (AgriSA 2016). An increase in farmer debt as a result of the drought was, therefore, also expected.

4 To Be Forewarned is to Be Forearmed: How South Africa Responded to the 2015–16 El Niño-Related Droughts

South Africa was affected—possibly due to a 'failed' El Niño event—by severe droughts in 2014–15 that were only worsened by the subsequent formation of a 'super' El Niño in 2015–16. In January 2016, the Department of Agriculture, Forestry, and Fisheries (DAFF) released an official statement, acknowledging that the 2015–16 El Niño-related droughts were as serious as those that had affected the whole southern African region in the early 1990s (1992–95). The department went on to describe the situation as the worst the country had experienced in 23 years (DAFF 2016b). DAFF also recognized that impacts would last for several months after the El Niño had peaked.

Somewhat troubling in this history is that the 2015–16 El Niño had been detected months before DAFF's official warnings were released. Furthermore, at least some of the event's major consequences should have been foreseen. Lessons from past events have shown that detecting an El Niño's formation and specific characteristics is not the same as detecting either the intensity or the magnitude of its socioeconomic, ecological, and environmental impacts.

This section first identifies existing strategies and key players involved in drought management in South Africa, and then analyzes what actual responses to the 2015–16 El Niño-related droughts the South African government implemented. Finally, El Niño's impacts and how governmental responses were perceived and interpreted in the media are analyzed.

4.1 Governmental Structure, Legislation, and Processes

South Africa is prone to hydrometeorological hazards and has several key institutions that are in charge of dealing with disaster risk assessment and management. These institutions act across the three levels of government: National, Provincial, and Municipal. In addition, civil society and the private sector also engage in drought management, especially by providing technical or in-kind support. South Africa's response to disasters (including drought) is essentially guided by the Disaster Management Act (DMA) published in 2002, which passed into law following a difficult period of drought in the early 1990s (Vogel and Van Zyl 2016).

Administered by the Department of Cooperative Governance (CoG), DMA is the overarching legislation through which risk management plans are developed and implemented (CoG 2016). Currently, responsibility for drought management is shared by national, provincial, and local governments. Farming communities, private sectors, and civil society also have responsibilities. Respective roles and responsibilities for each stakeholder group with regard to preparation for and mitigation of drought are clearly delineated in the legislation. Figure 5 outlines the complex drought management structure that was defined under DMA.

Established under CoG through the Disaster Management Act, the National Disaster Management Centre (NDMC) is tasked with declaring national disasters. As such, it controls release of contingency funds from the National Treasury based on information received from various local, provincial, and national level stakeholders. Notably, NDMC also has branches at provincial and local levels to assess an ongoing disaster event at each of those scales.

NDMC tasks specifically include facilitating the coordination of a number of Joint Operation Centers (JOC) across all levels. JOCs are meant to bring numerous stakeholders together during a disaster event to assess and monitor risks in various sectors, to evaluate the status of drought, to disseminate relevant information to all stakeholders, to encourage training and use of sustainable practices among farming

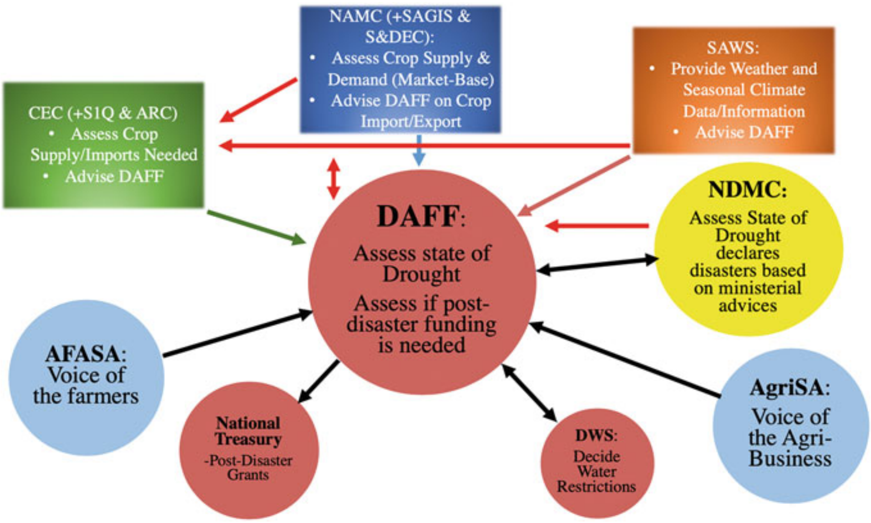

Fig. 5 National level decision-making process to release post-disaster funding Red shapes represents the drought taskforce that also includes department of health, rural development, and social development. Red arrows represent information flows (Author)

communities, and to set up food security programs that can be activated in case of drought (DA 2005).

NDMC thus officially acts as a coordinating agency, fluidly linking local, provincial, and national disaster management committees. For instance, during recent failures of seasonal rain a National Joint Drought Coordinating Committee was established to assist in national oversight and coordination of drought response across the country. Various departments contributed to the process in a number of ways (as shown below) depending on their main functions and core areas of responsibility.

The Department of Agriculture, Forestry, and Fisheries (DAFF) is a more specialized drought management agency that deals with agricultural droughts through various committees and management structures. Specifically, the Directorate of Climate Change and Disaster Management plays a key role with regard to disaster risk reduction and preparedness, including following up on El Niño events. DAFF has branches that extend out to the provincial and municipal levels where drought impacts on agriculture are assessed and implementation of national and local drought-related strategies is facilitated at local levels.

A key partner to DAFF, the Crop Estimates Committee (CEC), which is comprised of representatives from each of the nine South African provinces, is specifically concerned with future supplies of grain across the country. Three key "consortium members" on the CEC work together to produce final crop estimates based on weather forecasts and climate predictions. These key members are DAFF, the Agricultural Research Council (ARC), and SIQ (Spatial Intelligence), a private actor that assists efforts by mapping the spatial distribution of crop production. As partner of the CEC, the Agricultural Research Centre provides recommendations based on SAWS seasonal forecasts.

Providing "strategic advice to DAFF on the marketing of agricultural products" (http://www.namc.co.za), the National Agricultural Marketing Council (NAMC) works closely with industry, especially through the South African Grain information Service (SAGIS), with regard to market-related issues such as ensuring access and monitoring imports and exports. Similarly, the Supply and Demand Estimates Committee (S&DEC), a key component of NAMC, estimates the predicted level of exports and imports in the coming season and what will be processed in the local market. They are concerned with both supply and demand, whereas the CEC is mostly concerned with supply. The S&DEC releases a monthly report with a wide range of estimates. These estimates are based on information from DAFF, CEC, and various other industry stakeholders.

In collaboration with DAFF, the Department of Water and Sanitation (DWS) is responsible for managing hydrological droughts. It does so by implementing restrictions on water use (i.e. irrigation) in times of crisis and by managing water in catchment systems and reservoirs (Hassan 2010). If any department, including those working with DAFF, wishes to declare a province a disaster area, it does so through the Department of Cooperative Governance (CoG), which receives and reviews applications from provincial departments. It responds to emergency situations by activating necessary funding and protocols.

Important to the system of disaster decision making in South Africa are several nongovernmental organizations that work closely with government departments in preparation for or in times of disaster. AgriSA, a non-profit federation of agricultural organizations that includes nine Provincial Affiliations and 24 Commodity Organizations, represents collectives of individual farmers. It is involved in national and international policy, trade negotiations, land reform, farmer development, water rights, etc. and aims to promote the development and long-term sustainability of agriculture in South Africa.

Grain SA is a voluntary association of grain farmers established in 1999 to provide strategic support and services to South African grain producers with the goal of long-term sustainability. Both commercial and developing farmers are supported, as Grain SA lobbies in various forums on behalf of the grain industry. Working mainly with larger farm operations, the South African Grain Information Service (SAGIS) is a non-governmental, non-profit organization funded by the commercial grain industry trust. It aims to supply the grain industry with essential market information. For instance, SAGIS monitors and has historical records of all grain stocks on the commercial market. On the supply side, SAGIS acts as a repository of information pertaining to supply side (i.e. imports, exports, and traders) and demand side (processing and consumption) economic interests within South Africa (http://www.sagis.org.za). Information and data generated per marketing year by SAGIS is used in conjunction with information from CEC as well as the S&DEC to make decisions relating to export and import amounts (Anonymous Interview 2016).

Finally, the African Farmers' Association of South Africa (Afasa) organizes all farmer associations at the local level with the aim of promoting the development of the agricultural sector, especially focusing on better integrating black South Africans into the commercial agribusiness sector (http://afasa.za.org).

All of these organizations (along with others) are more or less actively involved in drought management in South Africa. Despite an emphasis on drought preparedness in the legislation, however, South Africa's drought management process remains essentially reactive (Fig. 6). It mostly consists of providing financial assistance to recover from drought impacts, a process that has changed little in decades (Vogel et al. 2010). In practice, funds for drought assistance must first come from the effected municipality or province, depending on the extent of the drought, and this is done only through 'reprioritizing' existing budgets. Only after local or provincial resources have been exhausted can support be requested from higher levels of governance.

At the national level, an inter-ministerial committee assesses an ongoing drought based on information from various stakeholders and institutions in different sectors (e.g. water, health, agriculture, etc.). The existing national budget will then be reallocated to respond to emergencies before, if necessary, a request to the National Treasury is made to request post-disaster funding. It is important to note that requesting funds from the National Treasury is a last resort option that can only be activated after all other options have been explored. Notably, post-disaster schemes that especially aim to enable livestock farmers to carry on their activities rather than to replace lost assets after a disaster also exist at the provincial and local levels (DA 2005).

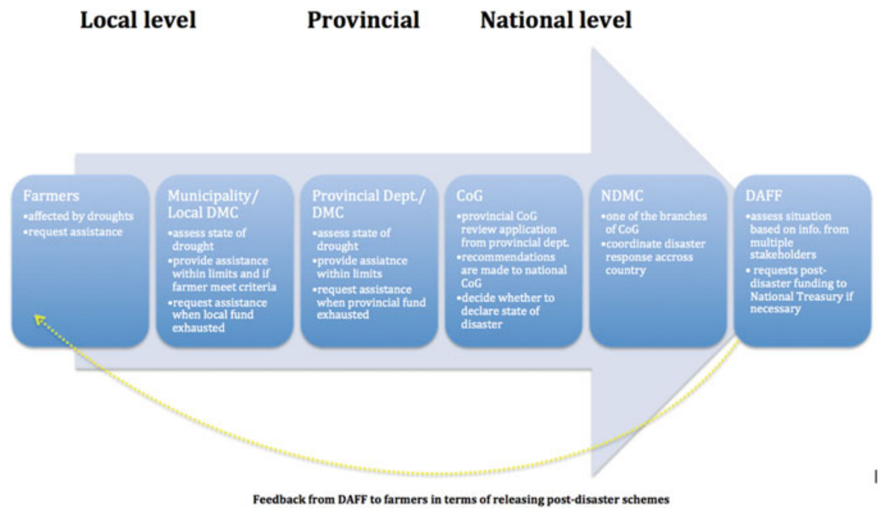

Fig. 6 Process to access post-disaster funding (DAFF 2016b)

There are several conditions to be met for farming communities to qualify for relief support during and after a drought. These include a requirement to have applied prevention and mitigation strategies (i.e. planting drought-resilient crops), to follow "good farming practices," and to use early warning information in planning. Thus, farming communities can only access recovery support if they have acted responsively and proactively to mitigate the impacts of an impending drought. Such proactive practices must be reported to the local authorities (local DMC) for eligibility.

5 Response to the 2015–16 El Niño

5.1 Response to Early Warnings

SAWS first warnings of an El Niño event were disseminated in August 2015 through various channels, including the SAWS official website, its mailing list of interested and affected stakeholders, and a variety of end users in weather and climate sensitive sectors. Various government departments, including DAFF, are on this mailing list, and thus were informed on a regular basis of the formation of an El Niño, its evolution, and its potential consequences across the country. South Africa's risk management strategy is, however, arguably more reactive than proactive. Despite the presence of a drought management plan that stresses the need for disaster risk preparedness (DA 2005), in practice little was done before the severe impacts of the El Niño-related drought were already being felt.

In terms of warnings for the agricultural sector, DAFF uses SAWS seasonal climate watch as well as FEWS NET's reports to identify the potential impacts of hydrometeorological events on agricultural production (for both crops and livestock). Advisories for the farming sector are then prepared to offer an overview of the current weather-related situation in South Africa and of what impacts the whole SADC region can expect. These reports also highlight predictions for the coming months and include recommendations for farmers related to soil choice, land preparation, crop choice, planting dates, crop and livestock management, etc. DAFF's advisories are prepared for the national level, and each province is advised to downscale and package the information according to its particular needs. But these advisories are not the only source of information farmers have available. According to Grain SA (Interview 2016), many commercial farmers use a number of Internet or mobile-based weather and seasonal forecasts, so these users were considered to have been informed of the impending threat of the forming El Niño by mid-2015.

Provinces are tasked with disseminating information about agricultural risks at the local level to relevant farming communities. It is unclear, however, whether or not these advisories are used for decision making at the local level. An interview with a key informant from DAFF indicates that most farmers, due to their limited financial resources, do not have the capacity to implement adequate strategies in response to forecasts (DAFF Interview 2016b). A possible lack of trust in climate and agricultural advisories is another barrier to the use of forecasts for decision making. The decreasing quality of forecasts and their lack of accuracy at the local level were also mentioned by an anonymous informant as a reason why farmers do not rely on them (Anonymous Interview 2016). Moreover, an informant from SAGIS indicated that farmers are overall positive and confident that the rain will come at some point, even when they are told otherwise; thus, instead of following forecast advice to modify their crop and planting habits they typically choose to wait for the rain and, as soon as it falls, plant regardless of the season (SAGIS Interview 2016).

Finally, cultural aspects must also be taken into consideration. For instance, many farmers in rural areas did not follow recommendations from DAFF to sell cattle while they were still in good health because wealth in the village is based on stock numbers (DAFF interview 2016b). This apparent lack of usability of the seasonal forecast is especially concerning because, according to an interview with an experienced climate science provider, the skill of seasonal forecasts during El Niño and La Niña years is quite significantly higher than in neutral years, so one would expect possibly higher utilization of the forecasts. Lack of use does, however, suggest that more efforts are needed for climate services to design and market useful products.

Our interview at DAFF indicated that the department received warning of an El Niño from SAWS in the second half of 2015 (DAFF Interview 2016b). Joint operational meetings from the government only commenced in about October 2015, however, indicating that it took a few weeks for these warnings to be acted upon by the government. Only then were the warnings included in DAFF's agricultural advisories, which stressed the potential long-term effects of El Niño and the expected impacts on agriculture in the country. This late warning to the agricultural sector was due to uncertainty about El Niño impacts on agriculture (Western Cape Interview 2016).

Unfortunately, by the end of the year the country had already experienced drought in 2014–15 and was experiencing water and crop deficits. While the government finally recognized the gravity of the situation, it was already too late to prepare. The late onset of rainfall in several regions translated into a lack of capacity for many farmers to plant. At this point, the government realized that SAWS forecasts were accurate, and that the late rainfall onset would result in increased food prices and food insecurity, as well as job losses (DAFF Interview 2016b).

6 Response to Drought Impacts

Due to the worsening of the drought in the context of El Niño and a lack of preparedness measures, several provinces and municipalities declared a state of disaster. It can take months after submitting an application for assistance for a province or a municipality to be recognized as being in a state of disaster, however, due to the long review process by the Drought Management Centre, not to mention other parallel bureaucratic processes. As of May 2016, seven out of the nine South African provinces (KwaZulu-Natal, North West, Free State, Limpopo, Mpumalanga, Northern Cape, and Eastern Cape) had declared a state of provincial drought disaster, and two municipalities within Western Cape Province had declared a local state of drought (Western Cape Interview 2016; see Fig. 7). These declarations were based on assessments of water availability conducted by the disaster management authority in each area.

When a province or municipality is recognized as being in a state of disaster, DAFF is able to activate the drought management plan (DA 2005) in those provinces and municipalities in order to provide in-kind support such as fodder and boreholes through grants reallocation (AgriSA 2016). It can take between two and six months to implement the drought management plan once a state of disaster has been declared, though lead time has supposedly improved in recent years (DAFF Interview 2016b). In the meantime, resources from affected municipalities and provinces are allocated—through 're-prioritizing' existing budgets—to respond to emergencies on the ground.

Re-prioritizing an existing budget—whether at the provincial or the national level—has actually been the main tool used to provide (limited) in-kind assistance during drought. For instance, DAFF reallocated funds from its 'comprehensive agricultural support programme' (CASP) toward drought relief to provinces in need for up to R205.3 million according to AgriSA (2016). In addition, Ilema Funds were re-prioritized for drought, and DAFF also worked with the Land Care Programme and the Department of Rural Development to invest (R66.4Mi) in the sustainable use of natural resources.

The same 'reallocation' process happened at the provincial and municipal levels as well. In Mpumalanga, for example, animal feed and water tanks were distributed

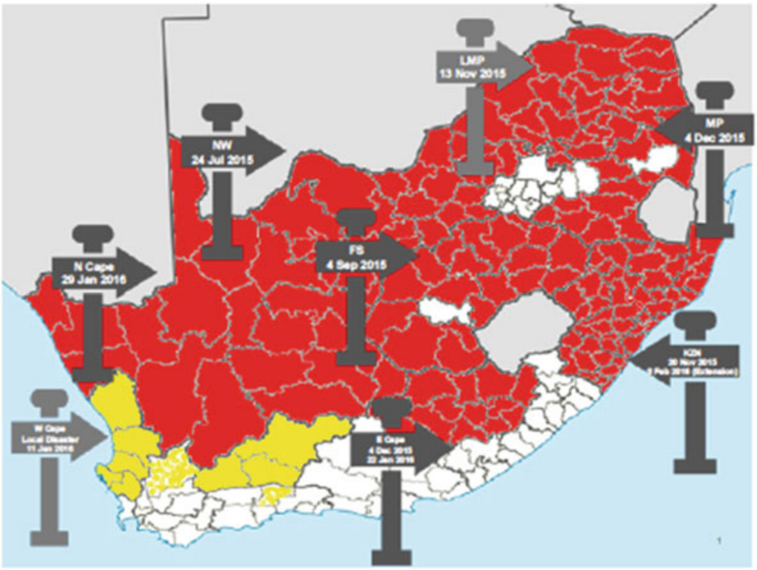

Fig. 7 Overview of areas in which drought disasters were declared in 2016 (Agri 2016)

to the vulnerable population using provincial resources (DAFF 2016b). Similar assistance schemes were also deployed in other affected provinces. In addition to governmental support, civil society and the private sector also contributed to mitigate the impacts of drought in the form of donations of bottled water, of contributions for drilling and equipping boreholes, of donations of livestock feed, etc. (Stoddard 2016). Most interventions took place too late, however, often resulting in feed being provided to cattle that were already too thin to survive (DAFF Interview 2016b).

Reprioritizing existing resources has many limitations as available funds are often insufficient. In February 2016, DAFF released a new statement indicating that, to date, the department had spent R318,726 million for drought relief through reallocation of funds. By that time, however, most provincial governments had already assessed the effects of the drought on their respective territories, and the total funding request from all provinces in a state of disaster was already at R4.1 billion. To reduce the shortfall, DAFF requested additional funds from the National Treasury in January 2016 (DAFF 2016a). Furthermore, NDMC was also able to disperse emergency grants for exceptional circumstances, but such mitigative actions, as noted, were definitely the exception rather than the rule, which was to re-prioritize existing funds.

At the local level, farmers could apply for relief support once a state of disaster had been recognized in a municipality or province. Actually, most of the funds provided by the government targeted small farmers, leaving many commercial farmers without direct support (AgriSA 2016, Grain SA Interview 2016). Even so, acquiring funds required a long, complicated process and not all small farmers qualified. The application process for relief support also often required a wait time of months as official verification of a region's drought disaster area designation slowly worked its way through the bureaucracy. Furthermore, the specific criteria (noted above) that farmers must meet in order to be eligible for post-disaster assistance might not be easily met by small-scale farmers or poor farming communities. Despite these hurdles, several "response plans" were activated across the country in 2016 to help small-scale farmers facing the impacts of drought. These included a "nutrition plan" to provide meals to the poorest farmers with no access to grants, and the activation of a "soft loan" program to aid farmers by offering low-rate loans from commercial banks (DAFF Interview 2016b).

Soft loans were also made available to commercial farmers through the Land Bank and the Industrial Development Corporation (IDC) (Grain SA Interview 2016). Large industry groups like AgriSA were also able to organize internal financial assistance programs, providing feed and fodder to farmers in need through their extensive networks. In the case of the 2014–15 drought such internal assistance programs were substantial, with up to R14 million being distributed by AgriSA alone (Grain SA 2016).

South Africa recognized the need to import millions of tonnes of cereals to compensate for production deficits and to respond to domestic and regional demand. Doing so would, however, likely put tremendous pressure on transport and stockage infrastructures. In order to mitigate these pressures, the government through CEC began importing food early in order to spread out the import burden over a longer period of time (18 rather than 12 months). This process was facilitated by existing connections between traders in South Africa and producers in the Northern Hemisphere (Anonymous Interview 2016).

7 Drought (Mis-)Management

As indicated above, under the guidance of the National Disaster Management Centre, a National Joint Drought Coordination Committee was established in October 2015 after the government understood that the forming El Niño would worsen the effects of drought across the country. This was a cross-sectorial inter-ministerial taskforce comprised of DAFF, Treasury, DWS, the Department of Social Development, the Department of Rural Development, and the Department of Health. SAWS was also invited to join the committee in order to provide input in terms of climate information and forecasts. Similar committees were also established during the 1992–93 and 2002–03 El Niño-induced droughts. The committee first convened around October 2015 and met twice weekly, later to become once weekly, in order to assess and monitor drought impacts in various sectors from local to national scales.

In addition, DAFF also convened an 'internal' multi-stakeholder taskforce on the drought. This taskforce, which included representatives of the government (e.g. DAFF), the private sector (e.g. Land Bank), and civil society (Afasa), also met twice a week, and then also eventually once a week, to analyze the state of the drought's impacts on agriculture, to monitor its progress, and to discuss potential responses

(DAFF Interview 2016b). A petition from the taskforce in January 2016 requested R11bn in funding from the National Treasury in order to administer contingency funds for disaster relief.

The Department of Cooperative Governance (CoG) also established disaster assistance schemes through the National Treasury. The funds from these schemes can only be released once a disaster has been declared by all three levels of government (National, Provincial, and Municipal). It is a last resort mechanism for internal relief funding. As a result, the country did not receive financial support from the international community, unlike neighbors such as Zimbabwe, but only technical advice from WFP and FAO. Moreover, the National Treasury had not, at the time of this writing during this El Niño, as yet released disaster grants, which also would require a declaration of national disaster. Thus, most relief support had only been provided through ‘re-prioritizing’ existing budget toward disaster assistance within the three levels of power. According to the press (March 17, 2016), one reason why the country did not declare a state of national disaster is because the National Treasury’s budget was empty; thus, requesting funding from the National Treasury would require South Africa to borrow money from international banks or other organizations in a context where its own currency had already been depreciated.

Sources also indicated that the country would not declare a national disaster over drought in the hope that ample late rain would shift the situation (February 7, 2016), despite Grain SA’s call to the government to declare disaster to enable the release of emergency relief funds from the National Treasury. As noted, the media explained the lack of financial support from National Treasury as a result of a dearth of contingency funds combined with a very low Rand value and salary increases for public officers, which had been implemented above budgeted lines. On the other hand, the government’s explanation was that the country was not yet at a stage of national disaster—not all provinces had declared a state of emergency. It is interesting to note that this statement contradicts the DMA, which states that a disaster is national if more than one province is affected, or if one affected province cannot deal with the impacts financially. As a result, current responses to drought have been using up remaining funds in any portfolio at provincial and national levels through the reallocation of funds for relief measures (March 17, 2016).

In a governmental budget speech on February 25, 2016, the government decided to allocate SA Rand 1bn in the new budget for drought relief; it was to be a first tranche over 3 years (Anonymous Interview 2016). A start, the allocation was still quite low considering the taskforce’s request for SA Rand 11bn.

In terms of coordinated response to droughts, interviews with key stakeholders in various institutions tended to confirm Vogel et al.’s (2010) observation from past drought management that the Drought Management Plan (DMP), which was activated to respond to the 2015–16 drought, was hampered by several challenges, including a lack of coordination and collaboration among key institutions and limited mainstreaming across various sectors (e.g. focus on livestock farmers through providing fodder and boreholes). The fact that so many institutions were involved in disaster management (especially—or exclusively—in assessing and monitoring risks) in South Africa, with specific responsibilities and, seemingly, limited coordination, as well as potential budget mis-management issues within the government, likely hindered the implementation of a more proactive risk reduction strategy.

8 El Niño in the Media

South Africa is a country with a free press, and the media wrote about El Niño and its impacts on the country especially after the end of 2015, when the government officially recognized the impacts of El Niño in terms of drought. Information issued by the media is sometimes used to drive political or social messages. What is certain is that doomsday views about El Niño-related risks and negative impacts dominate the press, which in 2015–16 then fed stories about what was then called the worst drought in decades. These included fear of economic recession due to declines in crop yields and rising import needs at a time when the Rand was in a deep decline, fear had grown of increased food insecurity or even famine for the most vulnerable parts of the population (especially small-holders), and risks of riots and violence had increased as food availability declined and prices rose.

The major concern was about food security. Among many others, a newspaper article from late 2015, for example (Sandner 2016), used words such as 'destruction' and 'threat of starvation' to describe the impacts of El Niño on agriculture. A number of other factors also served to exacerbate the situation. Inflation in food prices, for example, was proposed as being a result of weaknesses of the national currency as well as of competition between human consumption and livestock feeds (Karombo 2016). Risks of riots related to an expected rise in food prices—including for cereals, fruits, and vegetables—was also mentioned (Moonsamy 2016; Mwanza 2016), as were the millions of people who possibly could have gone hungry in those years (Reuters and Vice 2016; World Vision 2019).

Finally, some media reports were highly critical of the government with regard to its management and handling of the situation. They pointed to a lack of coordination between relevant departments, understaffing and inadequate financing, and a lack of responsibility for not declaring the drought a national emergency and for not providing support to victims. The ANC (African National Congress, the political party in power) and the government were accused by the media and the opposition, per Essop (2016), of being in denial—for claiming that there was no national disaster—and of 'drought mismanagement' (Stoddard 2016, News Ghana 2016). Newspapers also blamed the President's lack of urgency over this issue (Paton 2016), and highlighted South Africa's response strategy, which essentially consisted of 'waiting until the disaster has hit before making any plans' instead of proactively learning the lessons of previous disasters (Short 2016).

9 Lessons Learned for El Niño Readiness in South Africa: Insights from El Niño

South Africa is vulnerable to climate variability and change. It is also a country that has long experience dealing with droughts, experience that could be put to use to inform and improve current drought management practices (Vogel et al. 2010). Despite the adoption of a new 'Drought Management Act' at the turn of the century, however, drought management has remained strongly focused on "reactive relief responses" as opposed to longer-term, proactive drought policy measures. Reflecting a situation common across the wider southern African region, it is an approach that has long dominated drought management practices in South Africa (Vogel et al. 2010).

There are two main points to highlight regarding South Africa's response to the 2015–16 El Niño-related droughts: (1) the government did not take warnings related to the detection of an El Niño as a serious threat until the end of 2015, when the drought was already severe and dams were at a very low level; (2) no contingency funds had, as yet, been released by the National Treasury due to a lack of resources. So far, all relief support has come from the re-allocation of existing tight budgets at municipal, provincial, and national levels. Overall, there seems to be limited room for preparedness in this disaster risk management approach.

In the concluding section, a brief overview of how drought management has evolved in South Africa is provided. Then, a set of lessons that might be useful for improving future drought management practice and building 'El Niño Readiness' in the country is discussed.

9.1 Evolution of Drought Management Practices

Forecasting science in South Africa has improved since the 1990s (Unganai 1996; Landman 2014); technical support from IRI and WMO contributed to these gains. As a demonstration of such improvements, SAWS is now able to detect an El Niño's formation with a nine-month lead time. There remains, however, uncertainty with regard to the extent—in terms of spatiality, intensity, and magnitude—of drought during an El Niño year. Overcautiousness when uncertainty is high can lead to delays in the communication of information from producers through various sectors to end users, thus contributing to a lack of timely preparedness for facing and effectively coping with even foreseeable El Niño impacts. Nevertheless, even with uncertainty a very clear message of increased risk can always be passed from science producers to decision makers and end users. In the context of El Niño-related droughts, uncertainties about impacts across the country have regrettably translated into late warnings issued to relevant sectors. In addition, remaining uncertainties within relevant sectors, once they received the information, have led to even further delays before that information has been shared with relevant stakeholders and end users. This cascade of uncertainty—from the forecasters down to other sectors—has consistently contributed to an overall lack of timely preparedness to contend with El Niño impacts in South Africa. The 2015–16 event ended up being as much a casualty of this cascade as any previous event had been.

Despite delays in disseminating information about El Niño, governments and relevant sectors had been informed well-ahead of the impacts of the 2015–16 event. The existence (on paper, at least) of a proactive, inclusive drought management strategy devised from the lessons of previous similar experiences did not, however, result in a response that was much different from responses during previous events—that is, response to the 2015–16 El Niño-related droughts was again largely reactive instead of proactive.

This unlearned lesson repeats the "wait and see" pattern that is all too common in DRR, one that time and time again results in provision of emergency drought relief like delivery of livestock or grains at low cost only after such relief becomes necessary instead of having wisely built a mitigative risk preparedness strategy over time. The former approach has dominated largely since the droughts of the 1930s and early 1940s, persisting by nothing more than inertia into the 1980s and 1990s (Vogel et al. 2010). In the same way, so has the tendency persisted, to the detriment of smaller-scale farmers, to target for disaster assistance large-scale livestock and crop farmers who are perceived as forming the economic backbone of the country (Hassan 2010; Vogel et al. 2010).

At the end of the twentieth century, in response to the extensive damages associated with drought in the 1980s and 1990s, the South African government moved toward the adoption of a more proactive approach to agricultural risk management, one that emphasizes preparedness over relief support (Vogel et al. 2010; Hassan 2010; Vogel and Van Zyl 2016). This shift was adopted in parallel with democratic shifts in the South African political regime.

The government set up a National Consultative Forum on Drought in June 1994, a time when the consequences of the 1992 drought were still being felt. This forum aimed to improve relief support by considering the socioeconomic impacts of droughts on various groups (not just livestock farmers) and to facilitate cross-sectoral discussions for drought preparedness. The forum was comprised of representatives from governmental and non-governmental organizations, trade unions, and other civic organizations (Vogel 1994; Vogel et al. 2010). In the same period, attempts to develop a comprehensive national drought strategy and effective early warning system were also made. Unfortunately, the Consultative Forum was dissolved during the regime change of 1996 (shortly after its creation), and was never re-established, likely due to the fact that South Africa did not experience any significant drought (as in 1992) for many years—indeed, not until the 2015–16 El Niño event. The National Disaster Management Act of 2002 remains the key policy vehicle for managing disasters in the country.

Under the DMA (2002), the new democratic government adopted several, more traditional governmental mechanisms to manage droughts, such as the establishment of a National Disaster Management Centre in 2006. Researchers (Vogel et al. 2010; Hassan 2010, OCHA 2016), however, tend to agree that despite improvement in the legislation in terms of promoting risk preparedness, policies and practices remain largely reactive in their implementation. Vogel et al. (2010) and OCHA (2016) specifically highlight a lack of quick coordination and cooperation not only among departments concerned with drought in the South African government but also among government, military, and civil society. Such missed opportunities hamper a more proactive drought management policy, which in turn hampers effective implementation of the DMP across scales and sectors. Not only the lack of swift preparedness and more effective risk reduction approaches but also unclear mandates within the government and limited communication among all the institutions involved are barriers to El Niño readiness (DAFF Interview 2016b). None of these measures effectively incorporate the sagacious advice from a respondent at SAWS, who noted that "drought is a slow encroaching disaster, so you should prepare when the going is good" (SAWS Interview 2016).

Another main feature of past and current drought responses is that since the early 1930s they have largely been guided by natural science-based analyses of biophysical impacts with limited integration of social aspects. As a result, adopted responses tend to focus on providing food supply based on estimated needs and implementing technical solutions like drilling new boreholes instead of addressing the drivers of vulnerability, building risk preparedness, and providing relevant social support when and where needed (Vogel et al. 2010). This type of response still dominates today, as the government undertakes multiple assessments and monitors drought impacts for specific sectors like agriculture and health rather than trying to identify and address socioeconomic vulnerability to drought.

Overall, although DMA is supposed to be a proactive strategy for disaster risk management, in practice it can only be implemented as a response strategy to drought due to the long bureaucratic process involved in the declaration of a state of disaster in a given region, from assessing and monitoring progress to finally receiving support—if such support is indeed released. A late response from the government, such as providing feed for cattle when it is already too late to save them, also contributes to wasted money that could have been better used elsewhere.

9.2 Lessons Learned and Recommendations

Despite some evidence of a paradigm shift from emergency response to more holistic, disaster risk and climate risk reduction approaches since the mid-1990s, in practice the focus remains on financial relief solutions with little evidence of "on the ground" uptake of more proactive drought management approaches. The 2015–16 El Niño was no exception to this stubbornly persistent tendency.

Some lessons learned from past and current El Niño events include (updated from Baudoin 2017):

- *Timely warnings are critical to allow for the effective and efficient implementation of preparedness measures.* Due to a significant improvement in the science, detecting an El Niño event several months ahead of its teleconnected impact in Africa is now possible. Uncertainties about El Niño and its impact can, however, lead to delays in warning issuance, sometimes to a point after which adequate preparedness is no longer a viable option. Hence, improving detection and accelerating communication about El Niño with government as well as with stakeholders in climate-sensitive sectors is critical to provide time to prepare, especially since strong El Niño events could become more frequent as the atmosphere warms. Such communications include a need to release relevant information in a timely manner but also to inform stakeholders about the meaning of such information (e.g. El Niño does not necessarily mean disaster). It also includes informing stakeholders about potential "no-regret measures" that could be beneficial whether the intensity of El Niño-related impacts are severe or not.

Delayed warnings reduce time for preparedness and contribute to negative impacts. Without adequate risk communication, including warning issuance and appropriately formatted information, risk preparedness cannot be improved.

- *Raising awareness about El Niño events and their potential impacts on South Africa is critical.* Quite often, members of the scientific community refrains from releasing early information about the occurrence of an El Niño because of uncertainties surrounding its formation and its teleconnections, especially with drought. They want to avoid generating panic in society. If, however, decision-making cannot rely on the detection of an El Niño alone, it can certainly use such information to implement precautionary measures. Likewise, a misunderstanding of forecasts, a lack of trust in climate-related products, and competing cultural values and beliefs together provide some explanation for why good responses sometimes have only limited effectiveness in some climate-sensitive sectors. Developing public awareness campaigns is a way to inform actors across societies about El Niño-related risk. Such campaigns also engage actors in dialogue that can contribute to the development of trust between forecasters, policymakers, end users in climate-sensitive sectors as well as within the general population. There is a need for 'science communicators' to fill in the gap between producers and users to ensure that products are accessible, useable, and understandable so that they have maximum impact for DRR. Hence, an opportunity exists to enhance preparedness at the local level through better communication of information and ongoing dialogue.

Without clear scientific understanding of El Niño-related risks in vulnerable societies, and without outreach from forecasters or policymakers toward farmers and livestock owners, forecasts and advisories might continue to be discounted or even disregarded in decision-making. No matter how accurate it is, the detection science will not be "usable" without proper explanations and without improving outreach from climate scientists to local actors in addition to national decision makers. Such outreach should specifically focus not only on droughts but on El Niño events to ensure a clearer understanding among relevant stakeholders of their causal relationship.

- *Flexibility and diversity are critical characteristics of a risk management system.* Multiscale, multiplayer bureaucratic systems provide many barriers to risk preparedness, even for recurring hydrometeorological hazards. Moving beyond traditional bureaucratic structures is thus critical for implementing accelerated processes for risk management in order to allow for the implementation of proactive policies. Such an innovative system should combine governmental and nongovernmental representatives of various sectors, offer more flexibility in risk management, acknowledge the diversity of impacts to consider for providing support, and allow for consultation with socioeconomic groups at the grassroots level (Vogel et al. 2010). A risk management system could also include emergency plans to ensure water and food access to the most vulnerable in a society (Hassan 2010), especially given the observed lag time many stakeholders have faced before receiving assistance to recover from drought impacts.

  Having multiple stakeholders from various sectors and fields involved in drought management is important; however, bureaucratic decision-making processes that include committees with overlapping tasks and responsibilities reduce the effectiveness of even the best risk management strategies. This issue becomes acute when risk response is disaggregated between three levels of power, from the local to the national. As a result, no preparedness measures can be applied due to the long lag time for decision making between the levels of power. In such as system, relief support invariably arrives late. Without streamlining the process, preparedness measures to avoid the most severe impacts of drought or other disruptive hydrometeorological events cannot be effectively implemented.
- *Cooperation among all stakeholders involved in drought detection and management is critical.* Science-based expertise must be combined with socioeconomic and socio-cultural analysis to understand all potential impacts and to foster cooperation among sectors and governance structures to ensure development and implementation of adequate responses. Cooperative governance approaches to drought management are necessary; otherwise, drought responses remain focused on providing relief assistance instead of on tackling the root causes of vulnerability.
- *There is a need to shift from relief support to risk preparedness and, more critically, risk reduction approaches not only in legislation but also in practice.* Avoiding resource waste through better planning such as by not providing fodder to livestock that are already dying is essential. Mitigating the cost of response actions by planning ahead so as to avoid, for example, the need to purchase costly cereal imports to compensate for yield deficits is also necessary. Well-planned policy can, like this, also trigger behavioral changes. For instance, financial incentives can promote sustainable farming as well as efficient land and water management practices. Developing and implementing programs that provide subsidies for the adoption of efficient water technology can also foster water saving. Implementing higher costs for water uses in the leisure sector, as with swimming pools, before or in times of droughts could be another positive incentive to manage resources more sustainably. Incentives must be applied with caution, however, so that they do not inadvertently or disproportionately affect the poorest and most vulnerable.

> Providing relief in times of crisis usually does not trigger behavioral changes and can even contribute to locking populations into unsustainable practices. Furthermore, a call for assistance will continue to prevail among the population so long as no effective drought preparedness strategy is adopted. As a result, resources will increasingly be wasted in post-disaster assistance, especially as the impacts of natural hazards in the face of global climate change are likely to increase.

Overall, there are many lessons that can be drawn from the 2015–16—as well as from past—El Niño events in South Africa. To quote a key informant at DAFF, “You can have lessons, but implementing them depends on the political landscape.” Beyond analysis of South Africa’s response to the current El Niño, this assessment has raised questions regarding the 2002 passage of DMA. The act was adopted as a pledge from the government to avoid disasters such as the one that affected the country during the El Niño-related droughts of 1992–95. In fact, the severe droughts of 2014–16 offered the first real opportunity to fully implement the act. The results of this study suggest that implementing DMA resulted in complex multi-stakeholder and multi-scalar processes that focused on risk assessment and monitoring across sectors and provided channels for back and forth exchanges between provinces and the national level as well as between governmental departments. Overall, however, the law proved weak in terms of implementing concrete solutions and providing relief support at local levels.

Some additional, macro-scale lessons for drought management include:

(1) Declaring and detecting a drought is exceedingly difficult. Declaring a drought disaster retards swift response partly because of the slow onset of droughts and the “creeping nature of drought.” Integration of monitoring and detection remains an ongoing challenge.

(2) The 2014–16 droughts once again confirmed the need to be more proactive and responsive rather than merely reactive to impacts as they occur.

(3) Distinguishing between development challenges and problems arising as a direct result of a drought period remains a vexing problem. For example, differentiating between aging infrastructure and poor asset management, as noted in past and more recent droughts, remains a persistent problem. Developing a stronger ability to clearly discern when an issue of failed water supply arises because of a drought rather than because of aging infrastructure remains critical.

(4) Mobilizing resources and interventions in a timely manner remains critical.

(5) Governance challenges continue to affect early and effective drought interventions, notwithstanding the formation of the National Joint Drought Coordinating Committee in the mid-1990s. Although this committee could have, in theory, responded effectively to more recent events, it was dissolved and replaced with the more traditional and bureaucratic drought management structures set up under the DMA. Current challenges of coordinating multiple channels of inputs continue to promote a reactive approach to drought management in South Africa.

(6) A more equitable and detailed means of identifying *all* stakeholders in need of assistance—at both larger and smaller scales—needs to be developed.

South Africa has consistently endured drought conditions and will no doubt continue to experience drought in the future. As this chapter shows, despite some of the lessons learned much still needs to be done to ensure resilient response to foreseeable future events.

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Latin America

Central America

Lessons and Challenges from El Niño 2015–16 in Central America

Fernando Briones

Abstract El Niño Southern Oscillation (ENSO) phases affect Central American countries such as Belize, Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica, and Panama. Understanding these countries' vulnerabilities is crucial to reducing their risks. El Niño, as with other extreme hydrometeorological events, has a certain range of foreseeability. The national hydrometeorological systems and regional collaboration has played a role in prevention efforts. However, there are weaknesses that constrain the efficiency of preparedness initiatives.

Keywords El Niño · Central America · Hydrometeorological hazards · Regional cooperation · Disaster risk reduction

1 Introduction

Among other things, Central America is known for its susceptibility to major hydrometeorological disasters. One such disaster, 1998's Hurricane Mitch, was responsible for at least 5,657 deaths and more than USD$3.8 billion in damage (IADB 2005). While extreme events with excessive rain that cause flooding and flash flooding garner the most media attention, a lack of rain—meteorological drought—often causes greater damage to national economies across broader time scales. Both anomalously extreme warm and cold phases of the El Niño Southern Oscillation (ENSO) produce just such hydrometeorological hazards across Central America (Fig. 1).

The warm phase of El Niño tends to decrease rainfall, while La Niña tends to increase it across the Central American subcontinent. This chapter briefly explores how countries in Central America dealt with the 2015–16 El Niño very strong event by focusing on hydrometeorological systems and related cooperation agreements between countries. It also points out opportunities to reduce societal vulnerability for El Niño-related recurrent hydrometeorological hazards, especially flooding and drought. Most of this data comes from available literature and media reports,

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Fig. 1 Central America map (Geology.com 2007)

from conversations with staff at different National Meteorological and Hydrological Services (NMHSs), and from the Central American Integration System.

2 The Central American Context

While social diversity, natural resources, and geostrategic importance have made Central America a historically interesting region, it remains one of the poorest in the western hemisphere. Pre-Hispanic indigenous cultures in countries like Guatemala and Honduras have lived in tension since the beginning of Spanish colonization over 500 years ago. That long-standing subsistence agricultural production models based on the cultivation of large areas of land continue to exist alongside technologically imposing engineering mega-projects like the Panama Canal have resulted in a socioeconomic order almost wholly defined by its distinctive inequalities.

Today, the seven countries in the region share many cultural characteristics such as the Spanish language (except in Belize, a former British colony) but exhibit striking cultural and structural differences. While Costa Rica, for example, has enjoyed some prosperity based on its thriving tourist industry, countries like El Salvador and Nicaragua are still struggling to recover socioeconomically from armed conflicts that were at their most dire nearly 40 years ago in the mid-1980s.

Although after Hurricane Mitch progress was made in developing national-level disaster risk reduction (DRR) policies across the region (Manzilla 2008), discrepancies between each country's different levels of capacity to prepare for future events persist. In this way, political context is quite informative about levels of preparedness. Politically stable Belize, for example, has a volatile, small-size economy that is highly dependent on tourism, whereas Guatemala, which has one of the region's largest economies, consistently has to contend with high rates of poverty, violence, and inequality, not to mention the 2015 governance crisis that even further destabilized the country. Honduras, on the other hand, a low middle-income country with high violence rates and 63% of its population living in poverty, contended with a *coup d'état* in 2009 that resulted in an extended period of political instability. Different still, El Salvador has a growing but fragile economy, but is wracked by elevated levels of violence and an unsettled migrant population, while Nicaragua, according to the World Bank (2015), has macroeconomic stability but still faces many challenges related to democratic governance and the persistence of poverty. Of the seven countries within the region, Costa Rica and Panama, both of which depend on tourism and international trade related to the Panama Canal, are the most stable politically and economically, though they no less than the others exhibit severe social contrasts and rather visible levels of inequality.

The population of Central America currently consists of more than 45 million people. Guatemala is the most populous country with almost 16 million inhabitants, and Belize is the least populous with only 340,000. The most densely populated country is El Salvador, with 793 people per square mile. According to the Human Development Report (2015), Panama and Costa Rica rank highest in the UNDP's Human Development Index (HDI), occupying places 60 and 69 in world ranking, respectively. Guatemala and Honduras rank as the least developed countries in the region, at HDI positions 128 and 131, respectively.

In terms of disaster-related risks, Central America is exposed to a number of geological hazards, particularly earthquakes and volcanic eruptions. The Central American volcanic arc that runs from southern Mexico to Panama has hundreds of volcanoes, some of which, such as Pacaya and Santa Maria, both in Guatemala, are highly active. The earthquake risk is also ever present, and some modern events, such as the 1972 Managua earthquake that devastated the capital of Nicaragua, have been very destructive (Lee 2015).

Central America is also highly vulnerable to hydrometeorological hazards. This vulnerability correlates with the climate system of the region, which is characterized by great variability influenced by various phenomena such as the Pacific Decadal Oscillation (PDO), the Atlantic Multidecadal Oscillation (AMO), and ENSO in the tropical Pacific.

The El Niño phenomenon is specifically characterized by a reduction in rainfall during the middle of the rainy season (July-August), an anomalous period known in Spanish as either the "canicula" or the "veranillo" that affects the Central American Dry Corridor (Fig. 2) that runs from southern Mexico to Panama (Rojas et al. 2014). In a Central American drought update, FAO (2015) described the "dry corridor" in the following way, "the 'Dry Corridor' (Corridor Seco) of Central America is a strip

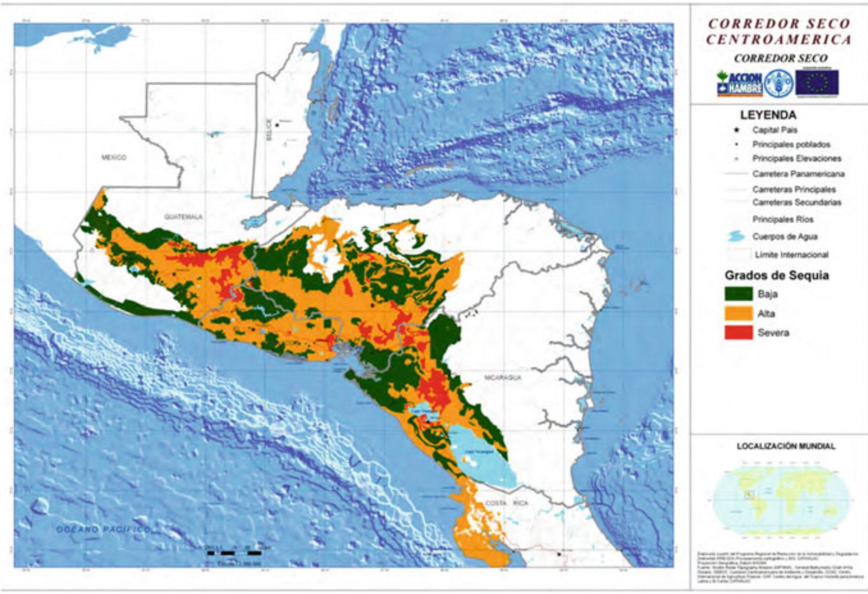

Fig. 2 Central America's Dry Corridor (ECHO FAO 2012)

of land stretching from the low areas of the pacific water shed through the foothills (0-800 meters) of Guatemala, El Salvador, Honduras, Nicaragua, and parts of Costa Rica. It is a semi-arid region characterized by recurrent droughts, which covers nearly one-third of the Central American territory."

FAO's GIEWS (2015) update reported the following observation;

> Harvesting of the 2015 main *de primera* basic grains season (May-September), which accounts on average for some 60 percent of the subregion's annual maize crop, but also rice and beans, is virtually concluded. Early estimates point to a sharply reduced *de primera* output due to the prolonged dry weather resulting from the current El Niño event, which not only delayed and reduced plantings but also affected crop development and yields negatively. This is the second consecutive year that prolonged dry weather, related to El Niño, has impacted the main *de primera* season. Most affected is the Dry Corridor…

Droughts in the region are a high-risk factor for food security, with subsistence farmers being the most vulnerable population. Contextualizing this vulnerability, the UN Food and Agriculture Organization (FAO) estimated that during the 2015–16 El Niño more than one million families dependent on subsistence agriculture lived in the Dry Corridor.

3 Contending with Hydrometeorological Hazards in Central America

As with other extreme hydrometeorological events in Central America, El Niño has a certain range of foreseeability. By working to understand and focusing their efforts on this range, NMHSs and other regional collaboration mechanisms have progressively played a role in disaster prevention efforts. Various shortcomings in this work have, however, limited the continuity and efficiency of preparedness initiatives related to the production and application of knowledge for DRR in this area. This chapter focuses specifically on the lack of credibility of NMHSs and their limitations for developing human capacity. Following the now-classic approach to social vulnerability developed by Wilches-Chaux (1993), these challenges can both be categorized as institutional vulnerabilities.

4 From Major Disasters to Prevention

The 1998 hurricane season will be remembered because of the impact of Hurricane Mitch, which made landfall in October near the end of the hurricane season. A Category 5 storm with winds reaching 178 mph (286 km/h), Mitch is considered by some to have been the most dangerous hurricane of the twentieth century. Historically speaking, Mitch is comparable to the Great Hurricane of 1780 that killed more than 20,000 people in Central America and the Caribbean. It is also comparable to the more recent Hurricane Fifi, which in 1974 resulted in 8,000 deaths in Honduras (Rappaport and Fernandez-Partagas 1995). As with Fifi, Hurricane Mitch struck Honduras hardest, killing 6,500 people and causing losses upwards of USD$4 billion in that country alone.

Hurricane Mitch triggered a movement to strengthen disaster prevention mechanisms in Central America. Evidence of this movement can be traced especially though the January 1990 launch of the UN's International Decade for Natural Disaster Reduction (IDNDR). Intergovernmental agencies that existed prior to Mitch, such as the Coordination Center for the Prevention of Natural Disasters in Central America (CEPREDENAC, in Spanish), were also caught up in this movement. CEPREDENAC, particularly, set out to strengthen institutional development with the creation of the "Strategic Framework for the Reduction of Vulnerability and Disasters in Central America." These and other initiatives that arose from this movement were supported by all governments in the region (Costea and Felicio 2005).

Even though each country has its own respective civil protection agency for prevention and risk management, the Central America Integration System (SICA, in Spanish) encourages a common agenda and regional cooperation. Similarly, although prevention and information protocols for hydrometeorological hazards operate independently through each country's respective NMHS, SICA's Regional

Water Resources Committee also organizes Climate Forums where seasonal forecasts and outlooks for the entire Central American region are produced and discussed. These cooperation mechanisms provide a means in the region by which knowledge and planning can be shared in order to ensure consistent forecasts and to facilitate informed decision making. Political and economic actors in each country are encouraged to examine with their respective NMHS staff seasonal scenarios drawn from these cooperative mechanisms.

5 El Niño in Central America

According to the United Nations Economic Commission for Latin America and the Caribbean (ECLAC, CEPAL in Spanish), El Niño events caused considerable damage in Central America over the course of the twentieth century. Estimates of the impact of El Niño-related disasters between 1972 and 2010, for example, total around USD$2.904 billion in damages and USD$1,111 billion in agricultural and forestry losses (Bello et al. 2014). To put those losses in perspective, the GDP of all of Central America in 2015, according to the World Bank, totaled only about USD$1,370.3 billion.

Although all of the countries in the Central American Dry Corridor are exposed to drought risk, Guatemala, Honduras, El Salvador, and Nicaragua have experienced the most notably damaging impacts. One reason for this is that drought especially affects maize and bean production, which are not only the basic food staples but also have cultural importance for the inhabitants of these countries. Droughts in Guatemala are particularly linked with poverty conditions that have produced social stress and famine, as in Jocotán (Chiquimula) in 2001 when 46 people died of starvation after their subsistence crop failed (Brosnan 2001). Other impacts of drought related to El Niño are the increased incidence of forest fires, as with those that affected both Nicaragua and Honduras before the start of the rainy season during the 1997–98 El Niño. The scarcity of water resources at that time also negatively impacted agriculture and tourism in both Panama and Costa Rica.

6 El Niño 2015–16: Early Forecasts and News Reports

After the 1997–98 El Niño, which was classified by NOAA (2020) as a very strong event, two other moderate events occurred in 2002–03 and 2009–10 (Brenes 2010). In both cases, the most significant hazard was a rainfall deficit across the region, which had various consequences for each of the Central American countries. Then, in early 2015, a new El Niño began to form. Preparedness mechanisms, including seasonal outlooks that had been previously discussed in regional Climate Forums, began to be distributed by each NMHS (Fig. 3). By June, forecasters had realized that this 2015 event would be one of the strongest El Niños since at least 1950.

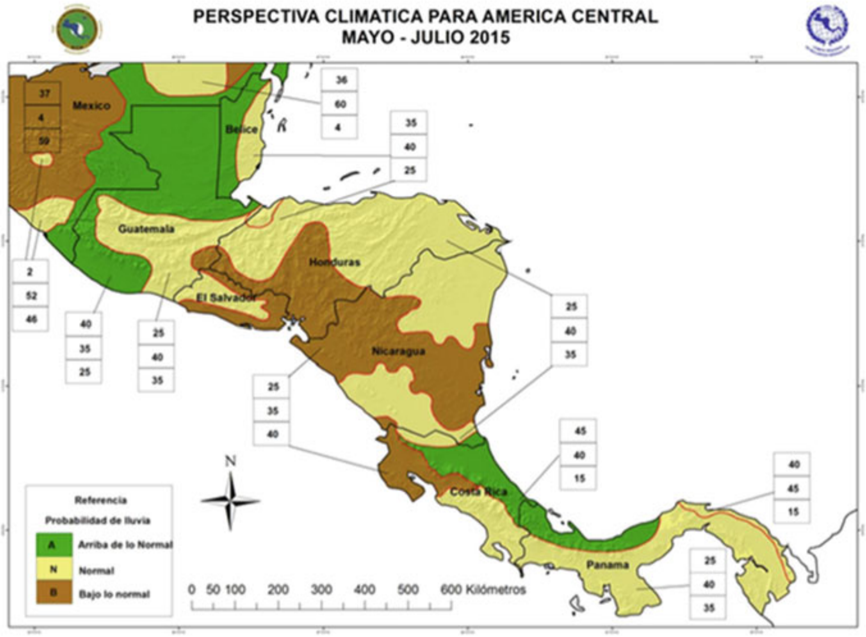

Fig. 3 Seasonal climate outlook for Central America May-June 2015 (OBSAN-R 2015)

Information about the 2015–16 event was mainly disseminated through respective NMHS websites and mail-lists. Other institutions—such as FAO, the World Health Organization (WHO), and the Inter-American Institute for Cooperation on Agriculture (IICA)—also created forecast products related to El Niño preparedness. NGOs, particularly those focused on food security such as OXFAM, Action Against Hunger, and the Famine Early Warning Systems Network (FEWS NET/USAID), played active roles in the region as well.

In fact, the first regional forecasts of a possible El Niño forming were provided by mid-2014, based on different organizations which held workshops and issued bulletins based on probabilistic models from sources such as NOAA and the International Research Institute for Climate and Society (IRI 2014). Concern about the impacts of El Niño events was prevalent across Central America, and information about its status was regularly generated and distributed, particularly among agricultural stakeholders as well as within food security agencies and meteorological services. Growing expectations of the formation of a big El Niño at the time also impelled the Central American press to increase reporting about the possibility of an event's formation.

7 El Niño Reporting on Central American Internet News Sites

In order to contextualize the prominence of El Niño as a phenomenon across Central America, the 2015 and early 2016 reporting of twelve regional online newspapers was consulted (Table 1). Articles were selected from the major news outlets of each Central American country. After having gathered over one hundred articles, 60 were determined to be representative of the basic social understanding and appraisal of El Niño forecasts, risks, preparations, and impacts. These articles also provided a glimpse of the range of actors involved in preparing for and responding to an event.

Inferences about the importance afforded to the 2015–16 El Niño in each of the seven countries of Central America can be drawn from both the number of available sources in each country and the tone of the reporting. That said, however, the size of each country can admittedly influence the number of available news sources, so size cannot be regarded as a determining indicator. Other factors do come into play. Honduras, for example, where newspapers are free, provided proportionately more information than Costa Rica, where most of the important newspapers are not free. Belize, the smallest country, provided limited El Niño coverage. In El Salvador and Guatemala, where intergovernmental agencies and humanitarian NGOs are ever-present, coverage emphasized food security. Despite some of Nicaragua's articles reporting information provided by the NMHS, in contrast, many of them focused less on local impacts and more on impacts in other countries in the region. In Panama, articles tended to cover a spectrum—from prevention to impacts—with an emphasis on water scarcity and, unsurprisingly, canal-related news.

One consistent issue found in this research was how even during ENSO neutral phase years (like 2013–14, for example) regional news outlets regularly attributed drought conditions to El Niño. Although reports from international organizations such as FAO and WMO were regularly quoted by the regional press, which maintained an active interest in El Niño during all of its phases, the tendency to re-post news from other press agencies can lead to inaccuracies that confuse lay readers. The attribution by the regional press of all drought conditions in the Central American Dry Corridor to El Niño has been especially problematic because it too simplistically characterizes drought. In fact, there is a tremendous difference between diverse types of droughts: meteorological, hydrological, and agricultural. According to Wilhite and Glantz (1985), a meteorological drought is defined by an areas amount of precipitation in comparison to some "normal" or average value and the duration of the dry period. An agricultural drought, in contrast, clarifies various aspects of meteorological or hydrological drought in terms of agricultural impacts, especially focusing on precipitation shortages, differences between actual and potential evapotranspiration, soil water deficits, reduced groundwater or reservoir levels, and so forth. Hydrological drought, differently, is associated with the effects of periods of precipitation shortfalls on surface or subsurface water supply (i.e. streamflow, reservoir and lake levels, groundwater). The point is that drought across Central America can be caused by any of these factors—alone or in combination—so simplistic representations in

Table 1 Some newspapers consulted about El Niño 2015–16 impacts in Central American countries

Belize	Severe drought in Belize during rainy season due to strong El Niño	https://amandala.com.bz/news/severe-drought-belize-rainy-season-due-strong-el-nino/
Guatemala	"El Niño" phenomenon, with greater impact	https://translate.google.com/translate?hl=en&sl=es&u=https://lahora.gt/fenomeno-el-nino-con-mayor-impacto/&prev=search&pto=aue
Guatemala	The phenomenon of El Niño 2016, as "powerful" as the worst in history	https://elperiodico.com.gt/ciencia/2016/01/03/el-fenomeno-del-nino-2016-tan-poderoso-como-el-peor-de-la-historia/
El Salvador	Unicef teme que 11 millones de menores sufran las consecuencias de El Niño	https://www.eleconomista.net/actualidad/Unicef-teme-que-11-millones-de-menores-sufran-las-consecuencias-de-El-Nino-20151110-0048.html
	El Niño más potente de los últimos 15 años hace sentir sus efectos, según la ONU	https://www.diariocolatino.com/el-nino-mas-potente-de-los-ultimos-15-anos-hace-sentir-sus-efectos-segun-la-onu/
Honduras	Fenómeno climatológical El Niño empieza a decliner	https://www.laprensa.hn/mundo/931102-410/fen%C3%B3meno-climatol%C3%B3gico-el-ni%C3%B1o-empieza-a-declinar
Nicaragua	Effects of El Niño on the 2014–15 cycle	https://www.laprensa.com.ni/2016/01/02/economia/1962529-los-efectos-de-la-sequia
	El Niño blurs the future of agriculture (El Niño empaña futuro del agro)	https://www.zamorano.edu/2015/11/11/el-nino-empana-futuro-del-agro/
Costa Rica	"Súper El Niño", la peligrosa versión del fenómeno climático que se hace cada vez más frecuente en el Pacífico	https://www.lanacion.com.ar/sociedad/super-el-nino-la-peligrosa-version-del-fenomeno-climatico-que-se-hace-cada-ve-nid2300462
Panama	ACP adquiere bombas para enfrentar el fenómeno de El Niño	https://www.laestrella.com.pa/cafe-estrella/planeta/151220/acp-bombas-adquiere-fenomeno-enfrentar

the regional press of drought in the Dry Corridor as attributable solely to El Niño tends not to explain but to misinform. Droughts in the region occur in years absent of El Niño. This becomes problematic not only because it renders the general public unaware but also because it can negatively impact how decision makers draft policy.

Examination of regional online news sources also found that the flow of information in the regional press in 2015–16 tended to follow a distinct pattern. First, the news announced the formation of an El Niño based on observations from international external sources (e.g. NOAA, WMO, FAO, IRI). Then, articles were published about possible scenarios, the usual sources having been respective NMHSs and ministries. Eventually, a few articles that contained more forecast details were published about the regional Climate Forums that were held in response to the initial observation of the El Niño's formation. Finally, articles about threat levels and specific impacts in each country were published. This kind of reporting tended to fluctuate between warnings and preparedness, even if some of the prevention plans were made for drought response, especially at the agricultural level. Near the end of the 2015–16 event, articles that informed the public about the El Niño's weakening appeared, followed by a rare few articles with political commentary about insufficient preparedness levels or various governmental actions during the event, which by then had ended.

News reporting on the 2015–16 El Niño event in the Central American press also tended to focus on each country's respective threat level. In Belize, for instance, decreasing rainfall represented a lower risk of hurricanes and some potential for increased tourism, but the press also reported negatively on the lack of rain and rising temperatures. Food security and drought risks in the agricultural sector were mentioned in Guatemala, El Salvador, Honduras, and Nicaragua. The agricultural sector is important to the economy of these countries, so they also tend to give importance to the connection between El Niño and the risk of famine as well as decreased economic expectations. In Costa Rica, where food security is not dependent on the cultivation of basic grains, water scarcities were often mentioned. In Panama, similarly, lack of rain was presented as one of the most important issues, with risks to water stocks for consumption and the low level of the Panama Canal lakes being highlighted. In fact, the Panama Canal Authority limited the navigation of large-draft ships in September 2015, a restriction that had not been implemented since the 1997–98 El Niño (Donoso et al. 2001). Intriguingly, no positive impacts from the 2015–16 El Niño were found to have been reported in the regional press.

8 The Credibility of the Region's NMHSs

One of the biggest challenges for preparedness is the timing and legitimacy of the declaration of the likely onset of an El Niño. In the past, NMHSs would rely on external sources of information, especially NOAA's Climate Prediction Center (CPC), to catalyze as well as guide the preparation of their alerts. Once an alert was issued, respective national governments would then activate their prevention protocols, hoping that the forecast they had received was accurate in both its timing and estimation of event intensity.

More recently, NMHSs and the regional Climate Forum have been able to draw from their own observations and knowledge base to better detect indicators and subsequently generate alerts as to the onset and expected intensity of El Niño events—sometimes now even before NOAA issues guidances. Although a good development overall, this recent success has led to some potential conflicts for decision making. Despite local NMHSs' successes, Central American governments are still not inclined to deploy disaster risk reduction (DRR) measures without official guidance of an event's formation from NOAA. What this means is that an NMHS's playing up of its forecasting capabilities, without the validation of a NOAA guidance, constitutes a big risk for the local agency, even if that local agency has solid evidence to support its forecast. It is a risk because any government's deployment of funds and resources for DRR is costly, both financially and politically. Without the backing of a formal guidance from NOAA, a local NMHS shoulders the entire burden for a forecast's outcome, which, if wrong, can have dire consequences for the agency—both politically and economically.

Even so, and although the capacity of each country's NMHS differs, the regional Climate Forums enable directors and technical staff to reach consensus on seasonal forecasts that provide more credible tools for decision making. This collaborative mechanism enables professionals from every country to identify and find solutions to persistent problems. Of course, each country in Central America has internal policies and rules that might limit NMHS interventions. Furthermore, political conflict can also explain why budgets often fall short or staff consistently turns over. In this regard, Central America in general requires further development of its local forecasting capacities.

9 Concluding Comments

This chapter presented a general overview of the 2015–16 event in Central America, a region with a long experience of the impacts of El Niño. Drawing from press reports found that the 2015–16 event was detected in good time; however, the preparedness capacities of each country were very uneven. In Guatemala, Honduras, El Salvador, and Nicaragua, preparedness tended to focus on response to humanitarian and food security crises, though the content of most of the Internet news articles from those countries came from third-party sources such as international organizations, which shows how limited first-hand information about impacts can be. No country's news identified El Niño's potential positive impacts, as in Costa Rica and Belize, both of which took advantage of decreased rains to increase their tourism revenues.

NMHSs have importantly become more capable of interpreting the signs of El Niño and generating forecasts based on local observations of known indicators. They have often become the first to detect the signals of a forming El Niño, despite their limited technical resources. One of the biggest remaining challenges for the region's NHMSs, however, is to be seen as credible in the eyes of their own respective governments.

This lack of decision maker confidence increases uncertainty and forces NMHSs to wait to take mitigative actions until a NOAA El Niño forecast becomes "official." It also puts into question the purpose of mechanisms such as the Climate Forums that produce seasonal outlooks to provide early estimations of an event's timing and intensity but then are so often perfunctorily dismissed. Furthermore, this lack of confidence relegates such cooperation mechanisms to a low priority by treating them not as technically sound but merely as so much political theater, thereby stripping them of their potential to trigger preventive actions at the earliest possible moment before an impending crisis. Undoubtedly, the probabilistic seasonal forecasts produced at the Climate Forums still have their limitations, but they no less constitute a considerable step forward in building regional forecasting capacity.

Moreover, important differences remain between the capacities of each NMHS. While some countries have been investing to improve their NMHSs, others hardly provide enough funding for the survival of theirs. Nevertheless, the regional integration mechanism does produce seasonal forecasts, which helps to bolster the capacities of those countries like Guatemala and Honduras that have less developed services. Notably, the well-respected Mexican Meteorological Service now also participates in the Climate Forums, further legitimizing their forecast products.

Finally, a shared feeling in our conversations with NMHS officers from different countries was that forecasts become useless when economic sectors are simply not prepared to undertake preventive measures. Even if there have been improvements among groups of farmers who can use locally produced El Niño warnings, the most vulnerable independent subsistence farmers still often neither receive nor can use the forecasts that are produced.

To reduce vulnerability, NMHSs need more trust from their governments. An ongoing challenge is to integrate the products of their expertise with national DRR preparedness initiatives. Seasonal outlooks and forecasts provide, for example, an indication of El Niño activity, but effective use of these products in decision making remains poor. As a region, Central America requires further development of its local NMHS capacities. This development should include the training of new staff and the use of scholarships and other work incentives to retain staff long-term. Turnover, because of low pay and other disincentives, has limited long-term knowledge retention and growth. Integration and knowledge-sharing platforms also remain limited, since the disparities in training and technology across Central America can be quite large. Developments since the 2015–16 El Niño, however, do show the possibility of a promising path forward.

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Cuba

Cuba and the Very Strong 2015–16 El Niño

Lino Naranjo and Janny Gonzalez Socorro

Abstract Cuba is the largest island in the Caribbean Sea. Typically, El Niño in the country produces a dramatic change in the seasonal rainfall patterns. Very rainy conditions into the winter or "dry season" and droughts in several areas in the summer or "wet-season." The 2015-16 El Niño impacts were significant in Cuba, resulting in millions of dollars in losses with severe damages in goods and important agriculture production in a very complex social and economic background. This chapter analyses the impacts of the 2015-16 El Niño in Cuba, introducing analogies to previous events and developing a view of the current Cuban capacity to provide adequate response levels for El Niño impacts, including forecast and early warnings. Some hurdles and obstacles are identified in order for Cuba to become an El Niño Ready Nation.

Keywords El Niño · Cuba · Teleconnections · Climate Impacts · Early Warning · Lesson Learned

1 Political and Economic Setting

Cuba is a sovereign state that includes the island of Cuba, as well as the Isle of Youth and several smaller archipelagos (Fig. 1). It is one of the few remaining countries in the world with a self-proclaimed Marxist-Leninist single party regime where the role of the vanguard Communist Party is enshrined in the constitution. It is a developing country with a planned economy that is dominated by tourism as well as exports of sugar, tobacco, coffee, and skilled labor. In recent years, Cuba's sugar production has suffered a significant decline, however, with the country plummeting in status from a top exporter to now being a net importer (Peter 2003; Cubatrade 2018). Cuba does, however, occupy a prominent place in some national performance metrics, such as in medical care and education.

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Fig. 1 Cuba and surrounding Islands (MapCruzin 1994)

Having anticipated significant changes in the traditional hard line of the Cuban government that would, among other things, open up the economy in the development of a more active private sector, 2015 and 2016 were years of great expectation across Cuban society. Since 2008, the ruling figure of the government had been Raúl Castro, who took over as head of state after his older brother, Fidel, abnegated power due to serious health conditions. The older Castro finally passed away in November 2016. Since the beginning of his mandate, Raúl had voiced his plan to make the Cuban economy more dynamic, a move that he claimed would also entail some distinct changes in the political structure of the government.

At the time, U.S. president Barack Obama was working to radically alter relations with Cuba, having in 2014 started to normalize ties with the island nation in what came to be known as "The Cuban thaw" (De Young et al. 2016). These overtures intended to end 54 years of hostility between countries separated by a mere 110 miles of tropical ocean. Then, on December 17, 2014, President Obama and Cuban President Raúl Castro announced a formal agreement to begin the process of normalization. On May 29, 2015 Cuba was removed from the U.S. State Department's list of Sponsors of Terrorism, and almost two months later both Cuban and U.S. "interest sections" in Havana and Washington, respectively, were upgraded to embassy status. Finally, on March 20, 2016, Obama began a three-day visit to Cuba, becoming the first U.S. president in 88 years to visit the country. Optimistically, he declared, "I have come here to bury the last remnant of the Cold War in the Americas. I have come here to extend the hand of friendship to the Cuban people" (Roberts 2016).

Unfortunately, Obama's dream was short-lived. Just a few weeks before his death in 2016, Fidel Castro voiced criticism of Obama, expressing anger over his March trip to Cuba. The older Castro also wrote a sternly worded letter admonishing Obama to read up on Cuban history, declaring "we don't need the empire to give us anything" (Associated Press 2016). Supporting his brother's critique, Raúl Castro claimed that "Cuba will continue to defend the ideas for which our people have assumed the greatest sacrifices and risks" (Granma 2015). In 2017, newly elected U.S. President Donald J. Trump began the process of reversing Obama-era policies toward Cuba.

In 2015–16, however, the Cuban economy was feeling the effects of the "Cuban thaw." For one, the Obama administration had taken executive action to ease some restrictions on U.S. citizen travel to Cuba as well as on the import and export of goods between the countries. On May 20, 2015, the Cuban government also opened a bank account in the United States, which enabled it to do non-cash business in the U.S. for the first time since the embargo began decades earlier.

This thaw in relations seemed to render the always-battered Cuban economy solvent. For example, growth in Cuban GDP increased from one percent in 2014 to 4.3% in 2015 (Frank 2015), reflecting a steep rise in tourism and a rapid expansion of domestic demand. In 2016, however, GDP growth dropped again to near zero percent due to several factors, including a decline in income from exports, a fall in oil prices, and a 50% reduction in fuel supplies from Venezuela. Cuban exports of nickel, refined oil, and sugar were also affected by a drop in prices (Chase 2016).

2 El Niño Teleconnections: Regional Impacts of El Niño

With a predominantly tropical climate consisting only of two seasons (wet and dry), Cuba is the largest island in the Caribbean Sea. Weather and climate in the region are strongly influenced by warm sea surface temperatures (SSTs), easterly winds (the Trade Winds), large tropospheric moisture content, and island topography. Tropical cyclone activity, both in the tropical Atlantic and the eastern tropical Pacific, as well as the intrusion of cold air masses (mainly in the northwest), also influence weather and climate in the region. Important to the regional distribution of precipitation is the bimodal behaviour of weather observed in Central America as well as in some areas of the Western Caribbean. Decreased precipitation during summer, known as the Mid-Summer Drought (MSD), is related to low-level wind regimes and warmer SSTs.

Typically, El Niño impacts over the region in summer are associated with an increase in low-level easterly winds and a decrease in hurricane activity over the whole Caribbean (Ballester et al. 1995). This decrease is responsible for drier conditions and drought. In some places such as Central America, El Niño droughts are more related to anomalies in rainfall distribution within the rainy season that result in agricultural declines. In winter, the most relevant pattern is the southward shift of the subtropical jet stream, which creates favorable conditions for rains from midlatitude cyclones and fronts to reach the Northern Caribbean (Cardenas and Naranjo 1997).

One of the more dramatic consequences of the 2015–16 strong El Niño was the development of extensive dry conditions and drought that spread over most of the region. During the summer, easterly winds were stronger than normal, creating anomalies over the Caribbean and Central America that brought stable and dry air masses. Additionally, intense trade winds interacting with mountainous topography generated regional patterns that resulted in near normal rains along the Caribbean coast of Central American. These same conditions, however, produced a deficit of precipitation on the Pacific coast of Central America. As a result, a sharp decline in rainfall was generalized across most of the region.

Suppressed cyclonic activity over the Caribbean Sea at the time contributed to the dry conditions over some of the islands. El Niño events also tend to suppress hurricane activity in the Atlantic Basin, including the Caribbean Sea, by generating strong westerly winds in the upper atmosphere that are capable of hindering the development of tropical storms and hurricanes by preventing energy flows that could concentrate at elevation in the air column. In the 2015 hurricane season, 11 named storms formed in the Atlantic Basin. Four of the storms became hurricanes, two of which reached major hurricane status. These numbers were only a little below the long-term average, and many of the named storms were relatively weak and short-lived. Although other factors were involved, wind anomalies typical of El Niño indicated increased wind shear aloft, a tell-tale signal of the almost complete suppression of hurricane activity over the Caribbean.

During the 2015–16 winter, the subtropical jet stream in upper levels showed an El Niño-like structure, with westerly anomalies appearing over the Gulf of Mexico and a branch of the jet stream across the region shifting to the south. This anomaly is not the same as the strong westerlies referred to in the previous paragraph. While the latter are climatic anomalies that can be observed at different levels during the summer, suppressing hurricane activity, the former is an anomaly observed in the subtropical jet stream in winter. Consequently, winter storm tracks shifted southward, bringing cloudiness and rains that alleviated some of the dry conditions over the Greater Antilles and some areas of northern Central America. At the time, five strong cold fronts affected Cuba with rains, heavy winds, and coastal flooding. On January 23, the biggest winter storm of 2016, Jonas, which ended up producing a severe blizzard in the US, caused some of the heaviest coastal flooding ever recorded in Havana (Granma 2016).

The 2015–16 El Niño had its own uniqueness in terms of impacts in the region. For example, anomalies in circulation patterns in 2015 were stronger than those observed during the very strong 1997–98 "El Niño of the Century," and dry conditions were more extensive and longer lasting. Several countries in Central America and the Eastern Caribbean experienced some of the worst drought conditions they had ever seen, a developing trend that is slowly increasing the vulnerability of their respective populations. Soon after, the 2015–16 El Niño was identified as one of the three strongest events since at least 1950.

3 Impacts in Cuba

Cuban weather conditions associated with El Niño tend to be very rainy and sometimes stormier between the months of January and April (Meulenert 1991). During 1997–98, the three months after the dry month of October were rainy in the west and center of the country. Strong winds and high temperatures in December of 1997 led to losses in potatoes and tomatoes, among other crops (Naranjo 2001). A weak El Niño does not cause, in general, significant changes in the rainfall and temperature patterns in Cuba. Moderate or strong events, however, can lead to severe storms, persistent rains, and coastal flooding, including saltwater intrusion into low-lying areas of the western region's northern coast, mainly in the Malecón area of Havana. But not all El Niño events produce the same effects because the full scope of impacts is also influenced by other factors associated with atmospheric and oceanic circulations.

The 2015–16 El Niño resulted in millions of dollars in losses to Cuban agriculture, affecting crops such as sugarcane, tobacco, rice, coffee, and vegetables. Nearly 90,000 metric tons of rice were lost in 2015, for example, because of water shortages. Droughts added further losses in vegetable and grain crops, while winter rainfall additionally affected sugar and tobacco harvests (Cubahora 2016).

On January 17, 2016, a cold front reached western Cuba with rain and strong winds having been recorded at the Casa Blanca meteorological station. Peak winds of 95 km/hr were recorded at dawn and were accompanied by coastal flooding in the afternoon in areas on the north coast, including in Havana's Malecón. This front was preceded by several rainy days in Havana. On January 22, another cold front reached the western region of the country, resulting in strong winds and coastal flooding, including sea water inundation in Havana's Vedado neighborhood, which is several blocks inland from the coast.

4 Forecasting El Niño

In the 1990s, researchers of the Cuban Meteorological Service (INSTMET) worked to define a new El Niño index based on observed impacts across Cuba (Cardenas and Naranjo 2000). Currently, however, INSTMET operational predictions still rely on NOAA forecasts deduced from the Oceanic Niño Index (ONI). What this means is that an official first advisory of a possible El Niño event forming is released from the Institute of Meteorology only after an event has officially been declared by NOAA. El Niño onset forecasts are also importantly used in the development of hurricane season outlooks for the tropical Atlantic and the Gulf of Mexico because of the anomalies generated there.

Climatic considerations of El Niño tend to serve as a basis for monthly and seasonal forecasts. In the case of the winter season, strong pre-frontal lines tend to generate severe local storms (in Spanish, TLS). As Cuba is not in El Niño's "ground zero" area, however, the effects on the Caribbean region and Cuba specifically depend more on the development of teleconnection patterns and, as a consequence, are usually delayed approximately six months from an event's formation.

The Institute of Meteorology's Climate Center is responsible for providing predictions about everything related to monthly and seasonal climate conditions. Additionally, once an El Niño event has formed, the center is responsible for providing predictions about expected conditions spanning three-month intervals.

5 Suggested Analogue El Niño Years Noted During the 2015–16 Event

Historical analogues of potential impacts of El Niño events are dependent on the expected level of intensity of a forming El Niño, which can range from weak to very strong. If an event is weak, it generally does not cause significant changes in atmospheric circulations, and therefore, large changes are not expected in Cuba's rainfall and temperature patterns. If they are moderate or strong, on the other hand, the analogue events of 1982–83 and 1997–98 in particular are analyzed for signs of what impacts might be expected, as these were very strong events. Such impactful events have in the past led to severe storms, persistent rains, and coastal flooding by sea water intrusion into low-lying areas along the north coast of the western region, where storm surges have reached up to 500 m inland.

In the 1982–83 and 1997–98 strong El Niño events, extreme weather anomalies were observed between January and April in Cuba. Adverse weather especially occurred between January and March 1983, when damages were comparable only to those of 1963's devastating Hurricane Flora. The 1982–83 El Niño rainfall, for example, exceeded three to five times the monthly historical record, with even higher values falling in some areas. It was the most humid and rainiest winter for 50 years, and few monthly precipitation records remained standing in the western part of the country.

Other meteorological phenomena of great interest were also recorded during the same period in 1983. Among them were strong winds that exceeded 30 m/s (and in some places reached 69 m/s), hailstorms, and tornadoes. The most severe weather during that period occurred when intense extratropical lows formed over the Gulf of Mexico on four separate occasions: January 20, February 16, February 27–28, and March 16–17.

The persistent severe weather in Cuba was, however, primarily caused by the development of extratropical cyclones over the Gulf of Mexico and the southern United States. Their frequency during this period was extraordinary—in an average year, Cuba is affected by just five extratropical cyclones, but during the strong El Niño of 1983 it was affected by no fewer than 18 of them.

6 Early Warning

Within Cuban society, a traditionally shared cultural framing tended to consider severe weather only in relation to hurricanes during the known hurricane season. This perspective prevailed for decades, and consequently, Cuban society did not have a strong awareness of the risks associated with El Niño-related winter storms. This lack of awareness made the society vulnerable.

In general, Cuba's preparedness plans are designed to focus on key weather episodes such as strong winds, heavy rains, and coastal flooding. Predictability is crucial for defining the scope of these plans. Coastal flooding conditions, for example, can be predicted two or three days in advance, making possible the mobilization of action plans to protect life and property. Warning systems, therefore, are designed to give a 72 h or more lead time in advance of an event, so authorities know what type of hazard to expect, its projected magnitude, and the area it will likely affect.

Depending on the event, however, an alert with a lead time of only 48 h, accompanied by a Special Report sent to authorities and broadcast to the general public, may only be possible while an event is still in its formative phase or even just a few hours before its expected impact. Nevertheless, warnings of short-term phenomena such as severe local storms still demand immediacy in prediction in order to be of use. For example, a fast-moving squall line can only be predicted a few hours ahead of time. Actions for such storms are mainly focused on mitigation.

In any case, warnings released to the media tend to become more frequent within 72 h of a potential hazard. National TV and radio stations broadcast live from the Forecast Center in the INSMET. Local TV and radio stations do the same in the Provincial Meteorological Centers and with the Civil Defense system.

7 El Niño Information and Forecasts

El Niño information and forecasts come from Climate Outlooks prepared by Cuban specialists from the Climate Center of the Institute of Meteorology; however, such forecasts are basically just adaptations of NOAA outlooks and predictions tailored to Cuban concerns and interests. The information does importantly serve as a basis for extended range (weekly to seasonal) forecasting of El Niño's impacts on Cuba. As a rule, first impacts tend to appear about six months after the formation of an event in the tropical Pacific Ocean. El Niño information is additionally used to develop a seasonal Cuban forecast for the hurricane season (Ballester et al. 2014).

8 First Indicators of the 2015–16 El Niño

In March 2015, NOAA's Climate Prediction Center (CPC) confirmed the formation of weak El Niño conditions in the tropical Pacific. By July, these conditions were forecast to intensify into a strong event that would peak in the fall and winter of 2015. CPC estimated a greater than 90% chance that El Niño would continue through the 2015–16 winter and a more than 80% chance that it would last into the following spring.

In mid-November, NOAA reported that the sea surface temperature anomaly in the Niño 3.4 region for the 3-month running mean average for August to October 2015 was the second warmest on record. Only 1997 SSTs were warmer. Consequently, in Cuba the first mention of a possible El Niño event came in October 2015 in the Climate Outlook for the period November 2015 to April 2016, which was issued by the Climate Center of the Institute of Meteorology. The Outlook read:

> In November, the dry season normally begins in Cuba, which runs until April. During that season, approximately 20 percent of the annual rainfall is recorded. Climate behaviour during the current dry season will be influenced by the strong El Niño-Southern Oscillation (ENSO) 2015-2016, however, which continues developing in the central-eastern Pacific Ocean.

Previously, in August 2015, CPC had reported that this El Niño could be one of the strongest on record because monthly SST anomalies in the Niño 3.4 region were already slightly higher than 1997 values, the warmest ever recorded in the modern era.

9 Government and the NMHS

Cuba has a totalitarian, one-party government that controls the media, organizations, and agencies, so civil society in general and individuals specifically are usually not able to take or coordinate actions on their own. The safety mechanisms in Cuba are driven by the National government and the Civil Defense. In order to strengthen the capacities of the country and the territories to face high intensity earthquakes, tidal waves, hurricanes, droughts, and health disasters, a nationwide training exercise called "METEORO" is carried out annually, simulating preparation for and coping with extreme events. This training exercise takes place just before the hurricane season, and actions are organized between the Civil Defense system and INSMET to prepare for the possibility of having to face dangerous weather phenomena such as strong local storms, coastal flooding by seawater inundation, and other hydrometeorological hazards.

For 50 years since the creation of INSMET, technological advances have been driven by investments from the national government in the interests of better forecasts and research on weather events and phenomena. The Cuban government has managed to implement these advances despite the decades-long U.S. embargo. Also, NGOs and UN agencies such as FAO and UNESCO have helped financially to support research projects with state-of-the-art equipment. Investment in forecasting technologies by the national government began in 1963, when Hurricane Flora devastated the eastern region of Cuba.

INSMET also has Provincial Forecasting Groups with staff that are dedicated to climate study and monitoring. Thus, impacts and vulnerabilities are studied according to each province's specific conditions. Results are analyzed and forecasts are issued out of INSMET headquarters.

10 Inter-agencies Involved in El Niño Forecasting and Response

Cooperation among relevant agencies in Cuba tends to be high. Many institutions related to science and the environment take part in efforts to strengthen results, especially when those results could be useful in forecasting severe events at short- and mid-term time scales.

The Cuban Civil Defence system is composed of all the forces and resources of society and the state and functions to protect people and property, social infrastructure, the economy, and natural resources from disaster events and climate change consequences.

The Centers for Risk Reduction Management (CGRR) are designed to provide local governments with estimates and monitoring of the risks associated with events that threaten their respective territories by managing actions to reduce vulnerability and exposure. CGRR provide the foundation for disaster risk reduction efforts at the local level, which are linked to the sustainable development of each respective municipality (UNDP 2015). CGRR may involve state or non-state agencies, supervisory institutions, entities working with hazardous substances, or centers of environmental studies. Each is responsible for the following:

- Update annually plans for disaster risk reduction;
- Plan response and recovery measures by modelling situations according to risk levels; and
- Use all mass media for public guidance and information broadcasts.

11 Media Coverage

The media in Cuba is fully controlled by the government, which is the owner of their facilities. The general population relies on public services, which provide information, with people generally paying close attention to the news. In an El Niño event, the media is responsible for reporting to the population measures taken by respective provincial governments, events predicted by specialists at the Institute of Meteorology, and news about other countries. Agents of the media tend to visit areas impacted by hazard events and broadcast their reports to the entire nation as they occur, though coverage is mainly available in the western region of Cuba and especially in the capital, Havana, where vulnerability tends to be greatest. The media provide an effective link between the forecast center and the community and exerts a strong influence on the way the special reports or weather notes are received by their audiences.

12 Hurdles and Obstacles

Even today, real social risk perception about El Niño in Cuban society tends to be quite low. Events are not like fast-developing cyclones, tropical waves, or cold fronts. Neither are they relatively short episodes or phenomena visible in satellite images. El Niño events do not themselves even occur in the Caribbean Sea or even in the Atlantic Ocean. Over the past 70 years, the most severe El Niño events have also appeared at time intervals (14–17 years) that are far too long for most people to remember very well.

The Cuban national government grants funding for research aimed at the understanding and prevention of hazards and disasters associated with severe weather events such as tropical cyclones, strong cold fronts, coastal flooding, and severe storms. The latter two events are closely related to El Niño extremes. Because those events can evolve rapidly, effective planning for their inevitable return demands immediacy in the forecast and short-term action and infrastructure for rapid response. A good first step is the RSS channel, which was opened on the INSMET website; it is, however, still insufficient to reach the majority of the population, especially those not living in the major cities. This is especially true since Internet access in Cuba is limited and its cost is prohibitively expensive for most Cubans, which has hindered the development of alternative ways to broadcast information and create advanced warning systems.

13 El Niño-Related Surprises in Cuba

In Cuba, the hottest year since 1951 was 2015, which tracks with how out of the 15 hottest years ever recorded on the island 10 correspond with El Niño events. The November-December months were also rainier than normal that year, mainly in the western and central parts of the country. During that period, the island recorded a national precipitation average of 179 mm, which is 158% higher than the historical average for that period. Despite these facts, the summer of 2015 was dry, and the vast majority of reservoirs remained only half-full. Thus, the rain events in the winter did not significantly avert water shortages in western and central regions.

As the newspaper Granma (July 25, 2015) explained: “The main impact of ENSO on Cuban weather usually occurs between January and April of the year after its first appearance, generally when rainfall totals exceed the normal values for that season. Also, it sometimes increases the episodes of heavy rainfall, severe local storms, and coastal flooding. Likewise, in certain moments, there has been a marked decline in rainfall in the period from August to October, as in 1972, 1982 and 1997" during El Niño year + 0, the year of formation of the event.

14 Lessons Learned from El Niño Events

- To increase risk perception, long-lasting efforts should be implemented to build capacity and increase awareness about the extreme El Niño and La Niña phases of ENSO.
- Agricultural associations should plan local-level strategies using El Niño forecasts. Although NGOs do not have direct influence on policy, they can increase local awareness.
- Media, which have a strong influence on the information people receive, provide an effective link between the Forecast Center and local communities.

In Cuba, the adverse effects of El Niño can significantly damage infrastructure in its large cities (mainly Havana) due to population growth and poor maintenance. Consequently, vulnerability has risen among the population, and the disastrous effects have become more noticeable.

Formally, Cuba had adequate mechanisms to deals with lessons identified from previous events:

- A highly professional Meteorological Service with a strong capacity to understand El Niño and its consequences and to improve the current prediction system, and
- Well-defined mechanisms in government institutions to control the behavior of each part of the warning system to mitigate disaster and to manage post-disaster recovery efforts.

The true picture is, however, not so idyllic. Serious resource shortages and bureaucratic sluggishness are significant obstacles to overcome. The nature of the government in Cuba—where everything tends to be under political control and where critical comments considered to be against the political system and actions suspected of exposing weaknesses in government, civil society, or the country are forbidden—jeopardizes improved projections about the future that will unavoidably depend on new technologies and broader, more open participation of the entire society.

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Ecuador

Ecuador and the 2015–16 El Niño

Maria del Pilar Cornejo-Rodriguez

Abstract In response to Ecuador being a multi-hazard-prone country, changes in the Ecuadorian Constitution in 2008 included Risk Management as a state policy. This was put into practice through the creation of the National Secretary of Risk Management (SGR). Between 2009 and 2018, it was a state secretariat (it was later changed to a service). From 2009 to 2020, Ecuador changed from being a response country to a prevention one. This led the SGR to establish an interconnected system between weather and climate forecast providing services and those responsible for developing hazard scenarios, such as those for El Niño/Southern Oscillation (ENSO) extremes, which in the Ecuadorian case are related to extreme rainfall events, floods, landslides, and increasing sea level at the coastline. Also considering the losses due to flooding in 2008–09, the Ecuadorian government sought to reduce flood impacts by structural (e.g., flood control) systems and nonstructural measurements means (e.g., contingency plans for floods with the multilateral bank system). These disaster risk reduction actions taken between 2009 and 2015 led to a threefold decrease in El Niño losses during 2015–16. After changes made in the SGR in 2017, Ecuador could no longer be considered an El Niño Ready Nation.

Keywords ENSO · Disaster risk reduction · Floods · Risk management · Ecuador · Emergency operation committee

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Editor's Note: The author of this paper served from 2009 through November 2015 as the head of the national Secretariat for Risk Management (SGR) in the Office of the President and was in charge of disaster risk reduction (DRR). She was involved in government planning of the three phases for El Niño action and was in charge of the first phase, which consisted of identifying, planning, and executing actions and policies to mitigate the negative effects of El Niño but also to enable people to take advantage of the positive effects. She was not directly involved in the 2015–16 El Niño or the 2016 earthquake.

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1 Setting

Ecuador, with a population in 2016 of 16.6 million, is located on the Pacific coast of South America. The country is affected by several hydrometeorological and geologic hazards. For example, in 2016 alone, Ecuador was affected by the following (World Vision 2016):

- January 2016: Torrential rain, floods, and landslides from El Niño conditions affected many impoverished families in Manabí province.
- April 16: Magnitude 7.8 earthquake struck northern Ecuador.
- May 19 & July 10: Severe aftershocks in the same area set back recovery efforts.
- July: Outbreak of Zika virus, likely worsened by flooding and people living outside after the quake; 80% of cases were in Manabí.

During the 2014–16 period, then President Rafael Correa was in the midst of his last term (ending in May 2017) and elections were held in February 2016. At the time, the national Secretariat for Risk Management (SGR) in the Office of the President was in charge of disaster risk reduction (DRR) and operated in accordance with the 2008 Ecuadorian Constitution. Notably, as of 2018, SGR was changed from a state secretariat to a service and is now called the National Service for Risk and Emergencies. The national decentralized risk management system, composed of the risk management units of all public and private institutions from local, regional, and national levels, was also involved with DRR in the 2014–16 period.

Since 2010, Ecuador has been a part of Agroseguro, an association of insurance companies subsidized by the government that offers crop insurance, to which 240,370 farmers had subscribed by 2016. It covers damages by climatic and biological phenomena such as droughts, floods, frost, fires, hailstorms, strong winds, uncontrollable pests, diseases, landslides, and excess humidity. Additionally, livestock and fishing insurances are provided by the government (Ministerio de Agricultura y Ganaderia 2016).

Ecuador's water sector was then managed by the National Secretariat of Water (SENAGUA), which later merged with the Environment Secretariat. The national secretariat was responsible for guaranteeing access to adequate, quality water resources through policies, plans, and strategies for integrated management. In 2015, SENAGUA published a list of its megaprojects for flood control and irrigation, which are represented in Fig. 1. Notice that the geographic location of these projects corresponds to the "chronic" flooding locations on the Ecuadorian coastal plains (e.g. red areas in Fig. 2, which are usually flooded under extreme rainfall events, including those related to El Niño).

SGR (2015a) had a regulatory framework and procedures stipulated in the manual of the Risk Management Committee (RMC), which was published in September 2015. It has since that time been replaced by a new framework and procedures that are only for emergencies. The original manual had three strategic objectives: (i) to mitigate and reduce the level of risks to natural and/or human-induced hazards, (ii) to increase social and institutional capacities for risk management, and (iii) to

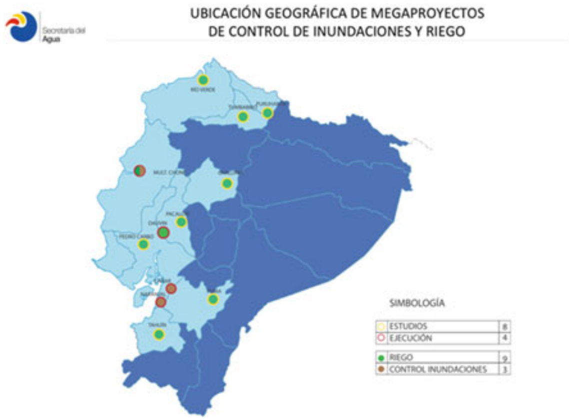


Fig. 1 Infrastructure under construction (red circle) or planned (yellow circle) during 2015 for flood control (brown shaded circles) and irrigation (green shaded circles) (SENAGUA 2015)

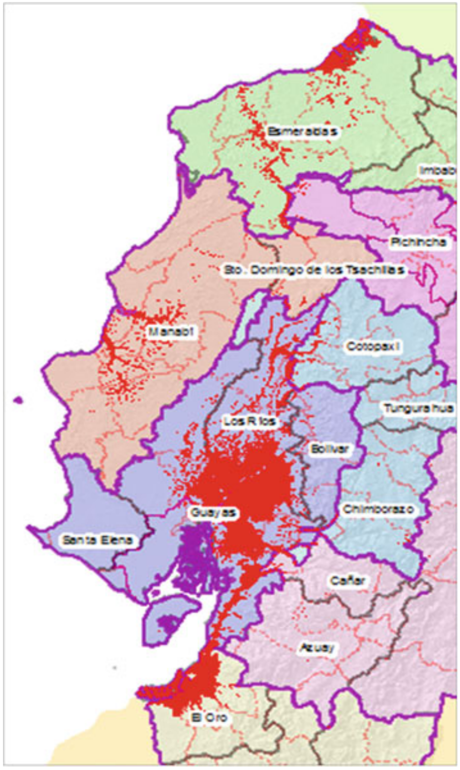


Fig. 2 Coastal plains (red areas) where flooding tended to occur during extreme El Niño events (1972–73, 1982–83, and 1997–98) and during the 2008 rainy season (Secretaria de Gestion de Riesgos 2015)

Fig. 3 Technical working groups (SGR 2015a,2015b)

increase the effectiveness of actions in response to the needs of populations affected by disasters or emergencies.

The RMC manual explained the different alert levels, the responsibilities of institutions, and the command structure at each level (local, regional, and national). It also clearly established a Risk Committee (CDR), which was to meet at least quarterly at the provincial level to assess the regional situation in relationship to any forecasted hazard. Complementing the CDR was the Emergency Operations Committee (COE), which was to be activated in response to specific threats. COE could be activated at the local, provincial, or national level, depending on the type of hazard being forecasted. Both committees operated under the mechanism of the plenary and technical working groups (Fig. 3). The plenary was responsible for inter-institutional coordination, and the technical working groups focused on specific issues and coordinated and integrated with the technical capacities of private and public sectors as needed. The role of SGR was to advise different government levels on hazard alerts based on thresholds assessed through monitoring carried out by national and international institutions.

If there was a foreseeable threatening hydrometeorological hazard, emergency situations and states of emergency could be declared, depending on the hazard's expected severity. The declaration of an emergency situation had a triggering effect, as it immediately activated processes for a humanitarian response and the authorization to make contracts for goods, works, and services that could be of value during the emergency. States of emergency, on the other hand, could only be declared by the country's president, and all response actions were the responsibility of SGR, which, according to the constitution, would "act in coordination with the decentralized autonomous governments and with civil society." SGR also had the support

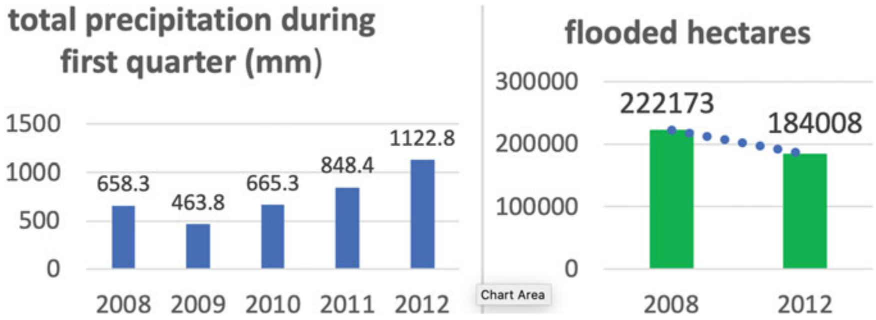


Fig. 4 A measure of resilience building in Ecuador between 2008 and 2012 (SGR 2014a)

of the Armed Forces and other agencies necessary for population protection and response actions.

This model for DRR proved adequate for Ecuador's conditions. Figure 4, for example, specifically shows an increase in resilience to flooding between 2008 and 2012. Evidence for this increased resilience comes from data on precipitation, which in 2012 was 1.7 times greater than it was in 2008 even as the overall flooded area was reduced by 17%. Greater resilience is also indicated by the sharp decrease in economic losses from flooding over that same period—from approximately USD$3 billion during the extreme rainy season of 2008 to around only USD$200 million in 2012.

As noted at the outset, Ecuador is prone to several natural hazards, such as floods, earthquakes, volcanic eruptions, and severe events related to the extremes (El Niño and La Niña) of the El Niño/Southern Oscillation (ENSO). El Niño events, such as in 1982–83 and 1997–98, tend to produce extreme rainfall and flooding in Ecuador, with losses exceeding a billion US dollars. In response to the devastation of the 1997–98 "El Niño of the century," the National Committee (EC) for the Regional Study of the El Niño Phenomenon (ERFEN-EC) was created in March 2001 by presidential decree and was based in Guayaquil. ERFEN-EC usually had monthly meetings, though their frequency increased if there were any El Niño alerts. The committee alerted SGR about the formation of any extreme ENSO event. ERFEN-EC's members were the Navy Oceanographic Institute (INOCAR), the National Institute for Fisheries (INP), the National Institute for Hydrology and Meteorology (INAMHI), the Polytechnic University (ESPOL), the Deputy director for Civil Aviation (SDAC), and SGR.

In 2003, the International Center for Research on the El Niño Phenomenon (CIIFEN), sponsored by the World Meteorological Organization (WMO), the Government of Ecuador, the International Strategy for Disaster Reduction (ISDR), and subsequently the Government of Spain, was created in Guayaquil by the UN General Assembly. CIIFEN provides climate and oceanic services and develops products at the regional level. Other services provided include the CIIFEN Bulletin, Impacts of El Niño/La Niña in the Eastern Pacific, Bulletin of the Ocean, Analysis of the Eastern Pacific, and the Regional Climate Center (CRC) for Western South

America. In addition, CIIFEN organizes, coordinates, and holds community workshops, scientific trainings, and validation and dissemination exercises in different Latin American countries. All information on newsletters, climate services, programs are described on the CIIFEN (2017) website.

Regarding early warnings for extreme climate, hydrological, and meteorological events, INOCAR and INAMHI issue reports on existing conditions and predictions for discussion at ERFEN-EC or CIIFEN. ERFEN-EC also monitors data such as that provided by NOAA's Oceanic Niño Index, or ONI, NOAA's primary—but not its only—indicator for monitoring El Niño and La Niña. NOAA considers El Niño conditions to have formed when both ONI is +0.5 °C or higher for at least five consecutive months *and* there is an atmospheric response to that anomalous SST warming, indicating the east-central tropical Pacific region known as Niño 3.4 is significantly warmer than normal. La Niña conditions exist when the ONI three-month running mean value is -0.5 °C or lower, indicating the region has become anomalously cooler than average. ONI values for the past 25 years are shown in Fig. 5.

Ecuador has established the necessary steps to cope with any event, at national to local levels, with a structure that integrates the actions of all governmental secretariats

1995	1.0	0.7	0.5	0.3	0.1	0.0	-0.2	-0.5	-0.8	-1.0	-1.0	-1.0
1996	-0.9	-0.8	-0.6	-0.4	-0.3	-0.3	-0.3	-0.3	-0.4	-0.4	-0.4	-0.5
1997	-0.5	-0.4	-0.1	0.3	0.8	1.2	1.6	1.9	2.1	2.3	2.4	2.4
1998	2.2	1.9	1.4	1.0	0.5	-0.1	-0.8	-1.1	-1.3	-1.4	-1.5	-1.6
1999	-1.5	-1.3	-1.1	-1.0	-1.0	-1.0	-1.1	-1.1	-1.2	-1.3	-1.5	-1.7
Year	**DJF**	**JFM**	**FMA**	**MAM**	**AMJ**	**MJJ**	**JJA**	**JAS**	**ASO**	**SON**	**OND**	**NDJ**
2000	-1.7	-1.4	-1.1	-0.8	-0.7	-0.6	-0.6	-0.5	-0.5	-0.6	-0.7	-0.7
2001	-0.7	-0.5	-0.4	-0.3	-0.3	-0.1	-0.1	-0.1	-0.2	-0.3	-0.3	-0.3
2002	-0.1	0.0	0.1	0.2	0.4	0.7	0.8	0.9	1.0	1.2	1.3	1.1
2003	0.9	0.6	0.4	0.0	-0.3	-0.2	0.1	0.2	0.3	0.3	0.4	0.4
2004	0.4	0.3	0.2	0.2	0.2	0.3	0.5	0.6	0.7	0.7	0.7	0.7
2005	0.6	0.6	0.4	0.4	0.3	0.1	-0.1	-0.1	-0.1	-0.3	-0.6	-0.8
2006	-0.8	-0.7	-0.5	-0.3	0.0	0.0	0.1	0.3	0.5	0.7	0.9	0.9
2007	0.7	0.3	0.0	-0.2	-0.3	-0.4	-0.5	-0.8	-1.1	-1.4	-1.5	-1.6
2008	-1.6	-1.4	-1.2	-0.9	-0.8	-0.5	-0.4	-0.3	-0.3	-0.4	-0.6	-0.7
2009	-0.8	-0.7	-0.5	-0.2	0.1	0.4	0.5	0.5	0.7	1.0	1.3	1.6
Year	**DJF**	**JFM**	**FMA**	**MAM**	**AMJ**	**MJJ**	**JJA**	**JAS**	**ASO**	**SON**	**OND**	**NDJ**
2010	1.5	1.3	0.9	0.4	-0.1	-0.6	-1.0	-1.4	-1.6	-1.7	-1.7	-1.6
2011	-1.4	-1.1	-0.8	-0.6	-0.5	-0.4	-0.5	-0.7	-0.9	-1.1	-1.1	-1.0
2012	-0.8	-0.6	-0.5	-0.4	-0.2	0.1	0.3	0.3	0.3	0.2	0.0	-0.2
2013	-0.4	-0.3	-0.2	-0.2	-0.3	-0.3	-0.4	-0.4	-0.3	-0.2	-0.2	-0.3
2014	-0.4	-0.4	-0.2	0.1	0.3	0.2	0.1	0.0	0.2	0.4	0.6	0.7
2015	0.6	0.6	0.6	0.8	1.0	1.2	1.5	1.8	2.1	2.4	2.5	2.6
2016	2.5	2.2	1.7	1.0	0.5	0.0	-0.3	-0.6	-0.7	-0.7	-0.7	-0.6
2017	-0.3	-0.1	0.1	0.3	0.4	0.4	0.2	-0.1	-0.4	-0.7	-0.9	-1.0
2018	-0.9	-0.8	-0.6	-0.4	-0.1	0.1	0.1	0.2	0.4	0.7	0.9	0.8
2019	0.8	0.8	0.8	0.7	0.6	0.5	0.3	0.1	0.1	0.3	0.5	0.5
Year	**DJF**	**JFM**	**FMA**	**MAM**	**AMJ**	**MJJ**	**JJA**	**JAS**	**ASO**	**SON**	**OND**	**NDJ**
2020	0.5	0.6	0.5	0.3	0.0							

Fig. 5 El Niño/La Niña values from the ONI index. Red and blue signify warm and cold events, respectively. Abbreviations signify 3-month running means. DJF = December, January, February (NOAA 2020)

for DRR as well as for each municipalities' DRR agendas. A national assessment about implementation of the Hyogo Framework for Action was carried out in Ecuador during 2014 (SGR 2014b) for the 2008–2013 period. It showed that by the end of 2012, Ecuador could be considered an El Niño Ready Nation (ENRN). In 2014 and early 2015, Ecuador was also actively participating as a member of the Bureau for the Sendai Framework of Action Conference on DRR, which was held in March 2015 as part of the United Nations DRR agenda.

2 The 2015–16 El Niño Event

Beginning in March 2014, many local newspapers published articles about the lessons learned from past El Niño events (Fig. 6).

Then, in November 2014, the Third International Conference of the Scientific Committee on the El Niño Phenomenon was organized by CIIFEN and inaugurated by the Secretariat of Risk Management. The main goal of the conference was to strengthen El Niño research in order to better prepare countries that tend to be adversely impacted socioeconomically. Participants from various national and international agencies attended the meeting, including NOAA, IPSL/Ocean Institute of France, the Catalan Institute of Climate Sciences, WMO, the Australian Marine and Atmospheric Research Center, Universidad de Concepción de Chile, and ESPOL.

Later, in 2014, the September-November (SON) three-month running mean value of the ONI started to increase, reaching the +0.5 °C threshold in the November-January (NDJ) period (Fig. 5). By the end of 2014 and in early 2015, the DJF and JFM ONI values continued above +0.5 °C. These values prompted forecasters to believe they were witnessing the formation of an El Niño event. After the January-March period, however, the ONI three-month running mean value remained near

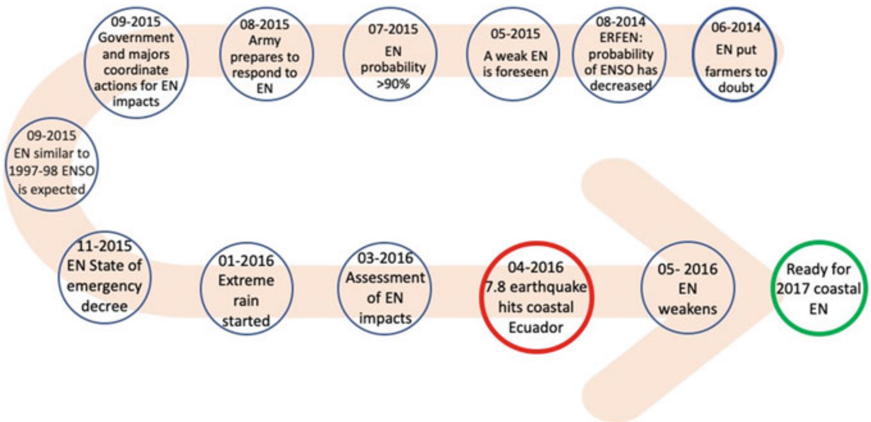
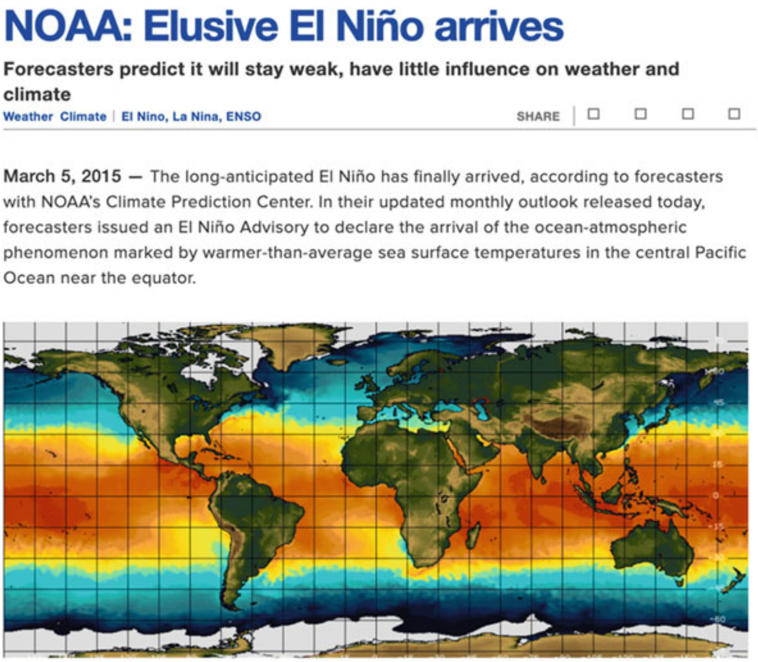


Fig. 6 Summary of major headlines/milestones about El Niño, June 2014–2016 (Pilar 2020)


NOAA: Elusive El Niño arrives

Forecasters predict it will stay weak, have little influence on weather and climate

Weather Climate | El Nino, La Nina, ENSO SHARE

March 5, 2015 — The long-anticipated El Niño has finally arrived, according to forecasters with NOAA's Climate Prediction Center. In their updated monthly outlook released today, forecasters issued an El Niño Advisory to declare the arrival of the ocean-atmospheric phenomenon marked by warmer-than-average sea surface temperatures in the central Pacific Ocean near the equator.

Fig. 7 News about El Niño arriving (NOAA 2015)

average, technically in ENSO neutral conditions. For a couple of months, nothing was reported in the news until March 2015, when NOAA announced the formation of an El Niño (Fig. 7) and forecasted that it would be weak and have little influence on the climate.

The fact that an El Niño was forecast was taken, in Ecuador, as alarming news and warnings were issued for various climate-sensitive socioeconomic sectors, especially agriculture, because of the lessons learned from previous events, particularly the 1997–98 El Niño. Since the intensity of an El Niño event is difficult to forecast, SGR decided that it was better to play it "safer now rather than be sorry later" (La Republica 2015a).

In July 2015, the Secretary for Risk Management called for a meeting with several ministerial members as well as with the INAMHI and several governors to prepare for a strong event.

In September 2015, the Ecuadorian government announced that it had secured loans from the Inter-American Development Bank (IDB), CAF (Development Bank of Latin America), and the World Bank that reached USD$850 million to respond to the concurrent emergencies of the Cotopaxi volcanic eruption near Quito and the impacts of the El Niño event. One month later, the government implemented a three-phase plan to address the effects of El Niño, which by then had a high probability of affecting the country by the end of the year. The first phase consisted of identifying, planning, and executing actions and policies to mitigate the negative effects of El Niño but also to enable people to take advantage of the positive effects. It was planned to last until December 2015. In planning, a qualitative approach known as "forecasting by analogy" (Glantz 1988) was used to ready the country for the most likely impacts based on the historical El Niño record. The second phase was planned to last through May 2016, during which contingency plans would be carried out. The final phase focused on revitalizing adversely impacted social, economic, and production sectors (La Republica 2015b).

By November 2015, a "Yellow Alert" declaration for 17 out of the 24 provinces in Ecuador was signed by SGR (El Universo 2015). The SGR secretary noted that raising this alert would enable city mayors to take adequate readiness actions for reducing likely El Niño impacts. The secretary also adopted the INAMHI forecast, which predicted that rainfall associated with the El Niño would start by the end of December 2015. The alert was followed by a State of Emergency decree by the president that enabled the government to allocate necessary resources to cope with El Niño's foreseeable impacts.

The rainy season started in January 2016 with heavy rainfall over short time periods in some coastal cities. Although it weakened in February, in March and April the season fully developed with some negative impacts. Likely because Ecuador had made itself an El Niño Ready Nation, the impacts of those rains were less damaging than the rains during the very strong 1997–98 event.

In mid-April, Ecuador was hit by a major earthquake that registered as 7.8 on the Richter scale and caused upwards of 600 fatalities. Later assessments by the Ministry of Foreign Affairs found that although the earthquake had been catastrophic in terms of human loss, the event had only a 3% impact on GDP, a small percentage compared to the 1997–98 El Niño event, which had had a 14% impact. Because of the earthquake, a complete assessment of the losses from the 2015–16 El Niño was not possible. Some impact data, however, were available through the media (Garcia 2016) and are shown in Table 1 along with, for comparison, some of the impacts from the 1997–98 El Niño.

Table 1 shows quite clearly that the 2015–16 El Niño had much less of an impact than the 1997–98 event. At some point, the intensity of the event in Ecuador did not compare at all with what was happening worldwide. In terms of precipitation, however, one can see what Rasmusson and Carpenter (1982) have called "canonical El Niño behavior" in the Guayaquil time series (Fig. 8), with a first peak early in

Table 1 Data from the 2015–2016 and 1997–98 respective rainy season impacts (CAF 2000)

Impact	2015–2016 ENSO	1997–1998 ENSO
Flood events	106	Over 200
People affected	14,464	63,896
Number of deaths	15	292
Livelihoods lost	337	29,655
Houses affected	7,767	10,225
Crops losses (hectares)	86	683,630

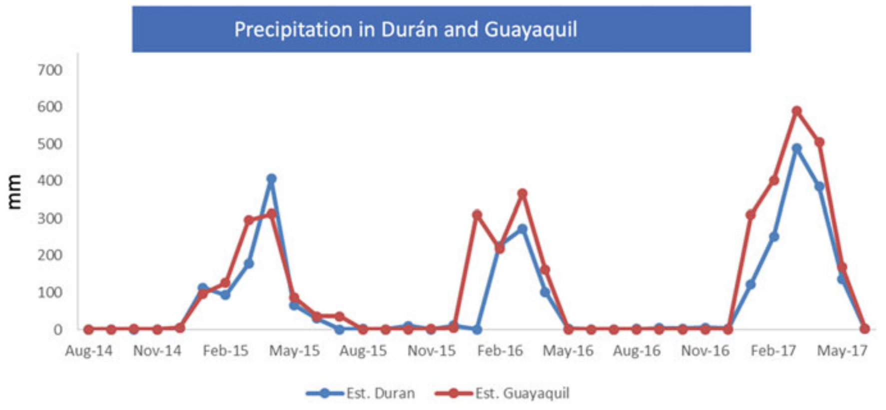


Fig. 8 Precipitation in Durán (2°10′24″S 79°49′52″O) and Guayaquil (2°11′00″S 79°53′00″O), 2014–2017. Data provided by INAMHI (2020) (INAMHI, Graph creation by author.)

January 2016 followed by a second peak that coincided with the March seasonal maximum.

Figure 8 shows that despite the anticipated heavy rainfall during the 2015–16 "Godzilla El Niño" (Corral 2015; Rossi 2016), the "Coastal Niño" of 2017 (Ramirez and Briones 2017) brought more rainfall to Ecuador, almost doubling the average amount in Guayaquil. Neither the 2015–16 El Niño nor the 2017 "Coastal Niño," however, heavily impacted Ecuador's socioeconomic sectors, likely because of the disaster risk reduction policies that had been implemented after 2009. Such DRR policies included but were not limited to megaprojects for flood and irrigation control located in flood-prone areas, implementation of early warning systems, and establishment of institutional structures focused on minimizing losses through smart investment. Economic losses in Ecuador were around USD$7–10 million during the 2017 Coastal El Niño, whereas across the border in Peru losses were estimated to be as high as USD$600 million**.**

Despite the gains outlined in this chapter, due to changes in the institutional policies of SGR since 2016 along with the compounding influences of the Covid-19 pandemic of 2020, Ecuador can no longer be considered an El Niño Ready Nation.

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The Panama Canal

The 2015–2016 El Niño

Gisell Aguilar and Lino Naranjo

Abstract The Panama Canal is a human-made, 48 mile (77 km) long waterway in Central America. Cutting across the Isthmus of Panama, it connects the Atlantic and Pacific Oceans and is an important channel for international maritime trade. Typically, El Niño in Panama produces drought with major problems to the economies of the region, including impacts on water resources and energy, farming, fisheries, and Human Health. Particularly, the Panama Canal area copes with severe water shortage and occasional suspension of the shipping operations into the waterway. The 2015-16 El Niño had major impacts on the country's main economic sectors. The Panamanian government had to draw up a strategic plan for the country's water sectors, including the Panama Canal Authority, to maintain both ship transit activity and urban drinking water supplies. The rainfall deficit was accompanied by abnormal temperatures that remained 2–3 °C above average throughout the event. This chapter analyses the impacts of the 2015-16 El Niño in Panama and specifically in the Canal de Panama area, introducing analogies to previous events and developing a view of the current country's capacity to provide adequate response levels for El Niño impacts, including forecast, early warnings, and the role of the media. Some lessons were identified, including those from previous events and already integrated into the current canal operations.

Keywords Panama canal · El Niño · Drought · Early warning · Vulnerability · Lessons learned

1 Setting

As luck would have it, a researcher was visiting Panama during the 2015–16 El Niño event and wrote her observations about the country's water situation at the time.

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The opening paragraph of her work provides an excellent snapshot of the setting for Panama Canal operations:

> "In 2014, Panama was the fifth rainiest country in the world (World Bank, 2016). In August 2015, with the annual rainy season months overdue, the Panamanian government declared a state of emergency in reaction to an El Niño-related drought that had affected much of the country. Most of the domestic and international attention was focused on the central part of the isthmus: a narrow, urbanized strip of land that is home to some two million Panamanians and is also the site of the Panama Canal." (Carse 2017: 888)

The Panama Canal is a human-made, 48 mile (77 km) long waterway in Central America (Fig. 1). Cutting across the Isthmus of Panama, it connects the Atlantic and Pacific Oceans and is an important channel for international maritime trade. More specifically, in 2019 the Panama Canal Authority reported in the *Hellenic Shipping News* that:

> The main routes using the Panama Canal by cargo tonnage in FY19 include between the U.S. East Coast and Asia, followed by the U.S. East Coast and the West Coast of South America, Europe and the West Coast of South America, the U.S. East Coast and the West Coast of Central America, and the U.S. intercoastal route. The main users of the waterway during FY19 were the United States, China, Japan, Chile and Mexico.

Since its completion, annual traffic though the canal has consistently risen, from roughly 1,000 ships in 1914, its first year of operation, to more than 815,000 in 2012. The annual number of transiting vessels has only further increased since 2012, earning the Panama Canal designation as one of the seven wonders of the modern world. Laurels aside, the canal is also incredibly important to the socioeconomic stability of Panama, with one author having recently described it as "one of the engines of the country's economy" (Cervera 2018).

The Watershed of the Panama Canal (CHCP) drains 5,379 million cubic meters of water per year, supplying not only canal operations but also the urban areas of Panama City and Colon, which together account for about half of Panama's total

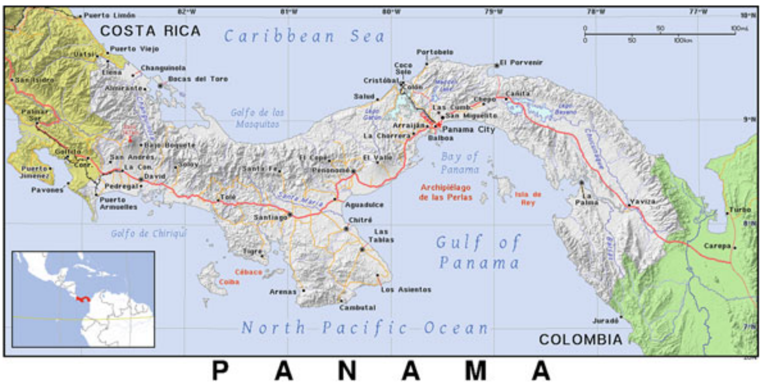

Fig. 1 The canal cuts across the Isthmus of Panama, the narrowest part of its namesake country (Macky 2014)

population. The CHCP also provides water resources for other, often competing needs like electricity generation and irrigation (Cervera 2018). It is the most important hydrological resource on the isthmus.

The CHCP has, however, at various times shown vulnerability to climate hazards. Two of the events that exposed its vulnerability had to do with ENSO's warm (El Niño) and cold (La Niña) extremes, which occurred in 1997–98 and 2010, respectively. The effects of these events in Panama were drought during the warm ENSO extreme and excess rainfall during the cold extreme. Both extremes resulted in loss of life and livelihoods, damage to infrastructure, decreased health and food security, and economic instability across Panama. The provinces of Panama and Colon also had to contend with diminished drinking water supplies. In the latter case, the Panama Canal Authority was forced to temporarily suspend canal operations (UPI 2010).

An important point in the history of the canal came in 2006, when Panamanians approved a referendum to expand the waterway, doubling its capacity in order to enable far larger ships to transit through it. Work began in 2007 to increase the size of Gatun Lake and to build two new sets of locks in order to accommodate ships carrying up to 14,000 containers of freight, a tripling of the size limit of ships previous to the expansion. Sixteen massive steel gates, each weighing an average of 3,100 tons, were built in Italy, and shipped to Panama for installation in the new locks. Nine years and USD$5.2 billion later, the expansion project was completed, and the expanded canal began commercial operations in late June 2016.

Although the Panama Canal Authority has claimed that the expansion to the waterway would not harm the environment or local communities, many issues have to be taken into account in order to piece together this puzzle. One of these issues involves the link between El Niño's impacts on the canal's water quality, quantity, and availability.

2 The Strength of El Niño Teleconnections in Panama

Panama's climate has two distinct seasons, a rainy season (mid-April to mid-December) and a dry season (mid-December until mid-April). El Niño has notable impacts on these seasons, primarily having to do with alterations to regional precipitation patterns. Specifically, Panama is known to be affected by winter drought during El Niño years due to the large-scale subsidence and orographic effects that the central eastern and western Caribbean experience at these times. What happens is that the intense anomalous convection over the eastern Pacific generates an increase in the intensity of atmospheric circulations over the Caribbean Sea, which in turn inhibits deep convection and hinders expected winter rains.

In addition, with the intensification of trade winds over the Caribbean in the summer during El Niño years, more rain tends to fall on the Caribbean coast of Panama, even as precipitation deficits tend to dry out the country's central highlands and Pacific coast. The intensity and duration of the deficit of rainfall in the country is highly correlated with the intensity of the El Niño event.

El Niño tends to cause major problems to the economies of the region, including Panama. Several socioeconomic sectors are especially affected, including water resources and energy, natural resources, farming, fisheries, and human health (CATHALAC 1995). According to data released by both government agencies and private researchers, for example, the productive sectors of Panama's economy experienced losses topping USD$50 million during the very strong El Niño of 1997–98.

3 Forecasting El Niño

The Hydrometeorology Department of the National Electric Transmission Company S.A. (ETESA, in Spanish) is the acting national weather agency in Panama. According to information provided to government and some economic sectors at the beginning of 2015, ETESA predicated that Panama would be affected by the then newly forming El Niño, which it noted would likely be a weak event.

The Panama Canal Authority (ACP, in Spanish) generates its own internal, non-public forecasts, which allows the agency to optimize water use. A part of this capability is a state-of-the-art rainfall and river forecasting system that was implemented in 2000 to assist in daily operations (Georgakakos and Sperfslage 2005). Precise forecasts of precipitation, inflows, and elevations of the canal's reservoirs ensure an adequate water depth for ships that transit through the canal every year. The system is the result of an agreement, signed in August 1996, between the Panama Canal Commission and NOAA's National Weather Service Office of Hydrology (NWS/OH) (Kane et al. 2001).

3.1 Previous El Niño Years

To compare the impacts of the 2015–16 El Niño event on the Panama Canal with those of the 1997–98 event, which has since become an informal baseline for such comparisons, it is necessary to recognize that the country's social conditions have changed as Panama's population has since the turn of the century become increasingly concentrated in urban areas. In addition, the Panama Canal Authority learned the lessons of both the 1982–83 and especially of the 1997–98 strong El Niño events. In terms of rainfall amounts, the 2015–16 event was much like the 1997–98; fortunately, however, the impacts of the latter event were very different from those of the former.

4 Early Warning

The World Bank (2010) noted that "Panama has improved its legal and institutional framework for disaster risk management (DRM). The authority for Panama's DRM National Platform stems from 2005's Law No. 7, Resolution 28, which established the National Civil Protection System (SINAPROC). SINAPROC, as Panama's highest-ranking authority on natural and human-made catastrophes, is responsible for coordinating DRM in Panama. As such, it is also charged with coordinating responses to the negative impacts of disasters on human lives, goods, and society."

As the leading DRM authority in Panama, SINAPROC maintains responsibility for both the National Emergencies Plan and the National Risk Management Plan. The mandate of the National Emergencies Plan is to define roles, responsibilities, and general procedures for institutional preparedness and response; to establish an inventory of resources; and to coordinate operational activities and assessments in order to safeguard life, protect property, and restore normalcy as soon as possible after the onset of a hazard event. The role of the National Risk Management Plan is to guide risk reduction activities and to prepare for emergencies and disaster recovery efforts. These measures are intended to improve safety in the face of various risks while also to greatly reduce material losses and social consequences from disasters.

Since June 2015, the Water Center for the Humid Tropics of Latin America and the Caribbean (CATHALAC) has helped the Panamanian government make decisions in areas relevant to its expertise. It has, for example, developed climate bulletins that update forecasts of El Niño events. It has also analyzed the outputs of climate models such as the Global Forecast System (GFS), which can extrapolate for from three to six months out both rain and temperature predictions for Panama, creating forecast products that serve the needs of the government as well as various economic sectors. This information is updated every month and published online at www.servir.net.

In the summer of 2015, the Panama Canal Authority issued an early warning about possible draft restrictions for vessels passing though the canal. These restrictions were foreseeable due to the known potential negative impacts of El Niño events, which (as noted above) tend to cause a drop in seasonal rainfall over the CHCP. Officials at ACP sought to provide shipping companies with a five-week lead time to prepare before implementing the emergency draft restrictions. ACP had learned from 1997–98 that El Niño events can cause serious reductions of rainfall, which can significantly lower the water levels of the reservoirs that are essential to normal canal operations. With a five-week lead time, shipping companies would have enough time to adjust their cargos to meet the emergency draft restriction.

5 The Source of Panama's El Niño Information and Forecasts

In March 2015, NOAA's Climate Prediction Center (CPC) confirmed the formation of weak El Niño conditions. Based on this information, the Hydrometeorology Center of ETESA issued information on its website and TV interviews page. By July, those early weak conditions were predicated to intensify into the fall and winter. CPC estimated a greater than 90% chance that strong El Niño conditions would form during the 2015 winter, and a more than 80% chance that they would last into the following spring. Basing its assessment on the anomalously warmer-than-normal waters measured in the eastern Pacific, a month later CPC reported that the 2015 El Niño had become one of the strongest on record. By this time, however, Panama was already quite aware of the event's strength, having already suffered through the country's driest June in 84 years.

5.1 Formation of the 2015–16 El Niño

From the beginning of 2015 there had been news coverage, based on TV interviews from representatives of Hydromet ETESA, of a possible El Niño event soon to form. Early indications were of the formation of a weak event, but this assessment changed in June when it was first predicted that the event would be very strong, with its intensity forecasted to peak at the end of 2015. This change in the forecast was coincident with the experience of the very dry June in Panama, which alarmed the population and concerned government officials.

6 2015–16 El Niño Impacts on Panama

Not all El Niño events produce the same impacts in Panama because impacts tend to be highly dependent on each event's particular intensity. Weak and even moderate events may have little or no noticeable adverse effects in Panama, while strong events can be devastating. According to data from the Smithsonian Tropical Research Institute (Tropicos 2015), El Niño events have over the last 90 years typically had little or no significant effect on Panama's annual rainfall (Fig. 2), which could at least partially explain the low priority that El Niño forecasts had been given in the past.

That relaxed attitude toward forecasts changed after the 1997–98 "El Niño of the Century," however, when drought wrought havoc across the country. Furthermore, the 2015 El Niño was also coincident with already ongoing drought conditions: Rainfall in 2013 and again in 2014 had been below the long-term average. The 2015 El Niño only served to exacerbate the existing rainfall deficit, which led to a significant water crisis. Tropicos, reporting on the crisis, claimed:

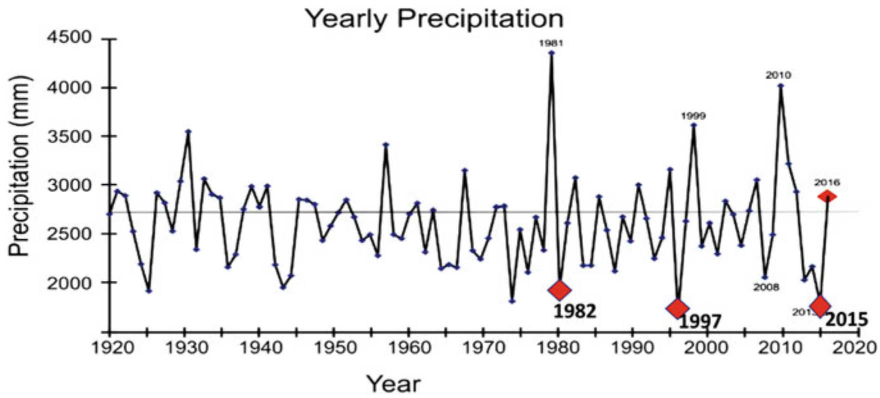

Fig. 2 Total rainfall in Barro Colorado Island, Panama Canal (from http://www.stri.si.edu/)

> "It is hard to imagine an impending drought at the height of the rainy season, as daily cloudbursts flood the streets of Panama City. But come April next year [2016], the capital's taps may be running dry and ships transiting the Panama Canal may have to shed cargo to meet draft restrictions. This is the work of El Niño…. El Niño is already setting records in Panama …. [W]e know 2015 is central Panama's direst years on record through September." (2015)

The 2015 El Niño had major impacts on the country's main economic sectors. The Panamanian government had to draw up a strategic plan for the country's water sectors, including the Panama Canal Authority, in order to maintain both ship transit activity and urban drinking water supplies.

Although during both the 1982–83 and 1997–98 events changes in rainfall patterns were not seen until the last three or four months of the year, the onset of adverse impacts during the 2015–16 El Niño came near the beginning of Panama's rainy season, which had a late start in 2015 anyway. Adding to the adversity, the primary producer of rainfall across Panamanian territory, the Inter-tropical Convergence Zone (ITCZ), shifted further to the south than normal and remained weak compared to historical averages. This weakened shift of the ITCZ worsened the already dire rainfall deficit across much of the country. This rainfall deficit was accompanied by abnormal temperatures that remained 2–3 °C above average throughout the event.

Still, impacts to canal operations turned out to be relatively minor as compared with the impacts of the 1997–98 El Niño event. In mid-August of 2015, rainfall finally appeared over the CHCP region, and on August 28 the Canal Authority suspended all planned restrictions on vessels passing through the canal (http://www.prensa.com/economia/). Although the level of Gatun Lake was still below normal for that time of year, there had been enough rainfall over the canal itself. The Canal Authority assured companies that water saving measures had been implemented and that work had also been done to deepen navigation channels.

7 Regional Impacts of El Niño

In September 2011, CATHALAC released a study focused on an evaluation of the actual vulnerability of human and natural systems in the Panama Canal Watershed for the period 1970–2010. This study, commissioned by the Panama Canal Authority, provided a better understanding of the spatial and temporal distribution of rainfall at different scales (monthly, seasonally, and annually), which enabled a better characterization of the foremost climate threats, particularly those cause droughts and floods, in the watershed. The study also included vulnerability assessments in 50 sub-basins and townships in the watershed in order to identify communities most vulnerable to climate change and variability.

Based on NOAA's classification of ENSO extremes, the study found that the formation of 13 El Niño and 12 La Niña events had affected the Panama Canal Watershed between 1971 and 2010. It noted that these extreme phases of ENSO are generally associated with water stress or a very pronounced dry season. It also highlighted that the annual precipitation amounts of these extremes varied depending on the geographic location of each of the tributary sub-basins.

During the "rainy season" (May to December), seasonal precipitation decreases east to west and north to south in the Panama Canal Watershed. This means that most rain accumulates in eastern (3000 to 3900 mms, or 118 to 153 in.) and northeastern (2600 to 3200 mms, or 102 to 125 in.) areas. The Pacific Trans-Isthmus Corridor, bounded by the sub-basins of Chilibre and Chilibrillo, shows annual precipitation values of 2100 to 2300 mms (82 to 90 in.). The southern part of the Watershed is driest, averaging only 1700 to 1900 mms (66 to 74 in.) in the Miraflores Lake sub-basin. The entire southern part of the Alajuela, Gatun, and western Panama regions are bounded by rainfall isohyets of annual total rainfall between 1900 and 2000 mm (75 to 79 in.).

During the "dry season" (January to April), the spatial distribution of precipitation maintains similar patterns as observed in the distribution of total annual precipitation, where the eastern part of the watershed receives the most rain, with an average value ranging from 300 to 500 mms (12 to 20 in.). The southern and western areas show similar seasonal rainfall amounts—ranging from 50 to 100 mms (2 to 4 inches)—from the sub-basins of Chilibre and Chilibrillo, passing through Miraflores Lake and the entire region of west Panama to the Quebrada Grande sub-basin.

Although El Niño's influence is associated with the reduction of rainfall (monthly and annually), in some cases the rainy season may well surpass the historical record of rainfall. This has happened in 1976, 1982, and 1997. Knowing this history can be useful for the management of reservoirs during future El Niño and La Niña events, especially in the context of climate change.

8 Government and the NMHS

Although there are some agencies that plan activities on weather and climate, ETESA acts as the official national weather agency in Panama. ETESA was created by Law N.6 of February 3, 1997, a result of the privatization of the electric power sector that was previously managed by the former Institute of Hydraulic Resources and Electrification (IRHE). Law N.6 delegated to ETESA the management of all national hydrometeorological functions, which includes the National Hydromet Network that consists of 165 meteorological and 72 hydrometric stations.

ETESA operates and maintains a meteorological and hydrological observation network, processes data, and makes data products available to all socioeconomic sectors. The Hydromet Department of the National Electric Transmission Company has the mission of helping to guarantee the security and protection of human lives, the environment, agriculture, hydrologic resources, electric energy, marine resources, aerial and maritime navigation, ground transportation, construction, industry, health, recreational activities, tourism, the climate, and the hydrological assets of the country's sub-regions.

ETESA represents Panama in the World Meteorological Organization (WMO) and all other international organizations related to hydrological and meteorological activities. Two important functions of ETESA are to maintain permanent links with regional meteorological centers, sharing meteorological products and data within the World Meteorological Surveillance Program (VMM), and maintaining international relationships with regional meteorology and hydrology organizations such as the Economic Commission for Latin America (ECLA), the United Nations Environment Program (UNEP), the Organization of American States (OAS) and the Central American Integration System (SICA, in Spanish).

9 Inter-Agencies Involved with El Niño Forecasts and Impacts

For hydrology and meteorology, ETESA officially has a responsibility to report and investigate all information related to El Niño events and their impacts. Other entities such as the Smithsonian Tropical Research Institute and CATHALAC also develop their own forecasts and conduct their own research about the various aspects of event impacts. Results and information from these institutions are published on their respective websites, as are specific forecasts that are released upon request by either the Ministry of Environment or the Presidency.

Because of the strong impacts of the 2015–16 El Niño, Panama's Ministry of Environment (MiAmbiente) declared a state of emergency to deal with the event. This declaration mobilized the "High Level Water Safety Committee," which involved the ministries of Environment, Water, Health, Agriculture, Public Works, SINAPROC (the civil protection system), and other national entities such as the

Panama Canal Authority and CATHALAC. The Government of Panama (2016) developed a National Water Security Plan for 2015–2050 with short-, medium-, and long-term goals. Of these, Cervera (2018: 333) wrote:

> "The Ministry of Environment published in 2010 the National Integrated Water Resources Management Plan 2010–2030 with the objective of guiding actions towards the best use, protection and conservation of the natural resource. However, through the passing of an extensive drought event on 2015 that caused alarm at national level due to shortages of water and energy, a new plan was devised to address the issues thus the 'National Water Security Plan 2015–2050: Water for all' was born."

More specifically, Cervera reported how El Niño has served as a stimulus for policymaking:

> "In 2015, the El Niño phenomenon produced the occurrence of one of the largest water crises in recent years, affecting heavily the provinces of Herrera and Los Santos in the *Arco Seco* and provoking alarm nationwide due to the low level of reservoirs, used for electric power generation and human consumption. The situation placed in the focus of the media and citizenship, the management capacity of the resource by the state and the Ministry of the Environment.
>
> As a result of this problem, the Cabinet Council approved the Cabinet Resolution No. 84 of August 11th, 2015, which declared a state of emergency for 60 days, as well as established a High Level Commission with representatives of all competent ministries, to prepare and present a 'National Water Security Plan 2015–2050: Water for all'." (336)

Measures in the water security plan sought to address the competing uses of finite water resources, to achieve a prevention strategy, and to establish a call-to-action for the efficient management of water resources in the context of climate change.

9.1 Media Coverage

Panama is a country where in general the news media, both electronic and print, tends to be sensationalistic as well as reactive. They tend to pay attention to disastrous weather or climate anomalies once in progress. Because of bias toward sensational headlines (Fig. 3) and news stories, media tends to focus on societal problems and government attempts to address them. It often seeks explanations for actions, controversies, or mistakes.

Carse, noting the role of the media, observed that:

> "Panama's drought was characterized as a national emergency, but what kind of emergency was it? In media and political accounts, droughts are often presented as meteorological events: extended dry periods in which lower-than-expected precipitation levels are associated with atmospheric disruptions like El Niño phenomena. Drought discourse in Panama was no different." (2017: 889)

During the 2015–16 El Niño, the media consistently reported on the millions of dollars in expenditures by the government and the Panama Canal Authority to avoid a national water shortage crisis. It also highlighted the restrictions on vessel draft

News Headlines: Panama Canal 2015-16 & El Niño Impacts

- **Panama Canal to Place Limits on Shipping Due to El Niño Drought (N. Feeley, TIME, 11 Aug 2015)**
- **Americas hit hard by El Niño (UNDRR, 27 Nov 2015)**
- Drought Affects Panama Canal Shipping (VOA, 2 May 2019)
- Panama Canal drought, linked to El Niño, highlights climate fears (The Hindu, 1 May 2019)
- An infrastructural event: making Sense of Panama's drought (A. Carse, Water Alternatives (2017)
- Panama Canal faces uncertainties from drought (Youtube, CGNT, 27 June 2016)
- **Panama Canal reduces slots for ships due to droughts and levies 'freshwater' charge (Japan Times, 1 Jan 2020)**

Fig. 3 Headlines from various news articles (compiled by Glantz)

because of severe drought. It was reported in mid-March in *The* Guardian (2016), for example, that:

> The Panama Canal is to impose new depth restrictions on ships due to drought that has left water levels falling in lakes that form part of the waterway between the Atlantic and Pacific Oceans. Ships seeking to cross the waterway must comply with a maximum draught of 39 feet (11.89m) beginning on 18 April, authorities have said. The 'temporary and preventive measures' are connected to local climate impacts of El Niño, the seasonal weather phenomenon that has caused a drought in the canal's watershed and will be implemented in six-inch (15cm) depth increments to be announced at least four weeks in advance.

This is just another example of the media's perception in Panama that El Niños are synonymous with drought and disaster.

10 Hurdles and Obstacles

In a general sense, the 2015–16 El Niño event was, at the time, considered more intense than the 1997–98 event. By the 2015–16 event, however, ACP had undertaken better strategic and tactical preparations for water resource management and was in a position to take timely actions to maintain operations. Unfortunately, the need for preparation was not viewed similarly by other economic sectors in Panama. These other sectors often refused to take action to prepare for this foreseeable, recurring quasiperiodic event. Their refusal was compounded by a lack of serious scientific research and poor dissemination of El Niño information by the media and other sources. It led to unnecessary loss of life and livelihood.

10.1 Lessons Learned from Past and Current El Niño Events

Based on lessons learned from responses to the impacts of the 1997–98 El Niño event, the Panama Canal Authority developed operational actions for the conservation of water resources in the watershed. Two of these actions were taken in late 2015, when ACP stopped the generation of electricity at the Lake Gatun hydroelectric power station and discontinued the use of the hydraulic assistance system in the operation of the channel's locks. Interestingly, similar actions were taken during the 2018–19 El Niño as well. Other measures were also designed to save water for canal operations, including the decision to transit more than one ship in a lock at a time. In addition to these operational activities, the Panama Canal has an active plan for the protection of forests and for reforestation as well as plans for projects to deepen the main navigation channel to improve water management.

The Panama Canal has become a case study for sustainable and efficient water use. Its expansion has aimed to be a model for how to adapt to climate change and reduce disaster risk. ACP issued a report on June 18, 2016 ensuring that it maintains strict surveillance of water resources and of those events that might generate significant water deficits. It also noted that it continues to work to develop robust strategies for the use of water, to emphasize the expansion of the canal, to establish crisis plans to respond to possible damage to the canal and its watershed, and to create contingencies to address risks as they arise.

11 Lessons identified, with Emphasis on those Learned and Integrated into Current Operations

ACP is expected to maintain the high-level "Committee on Water Security" and to comply with its goals, which are to provide:

- Universal access to quality water and basic sanitation, meeting the Sustainable Development Goals of the United Nations;
- Water for inclusive economic growth, through which Panama not only continues to grow but that that growth reaches everyone;
- Timely risk management related to water in order to prevent and be prepared for changing weather and its effects on the availability and quality of water; and
- Fifty-two healthy watersheds, which ensure the availability and improved quality of "raw" water for everyone.

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In Memoriam

Gisell Aguilar Oro (1975–2017). A prominent Cuban meteorologist born July 31, 1975, Gisell received her bachelor's degree in Meteorology at the Havana University in 1998. Since started her career as a weather forecaster in the Cuban Institute of Meteorology and soon was presenting daily weather forecasts for Cuban TV. She became known as the "weather woman."; her sympathy, knowledge, and her way of communication made her an icon for the public.

As a researcher, she was the PI for a Cuban study of Local Severe Storms. In 2007 she received a PhD in Meteorology, developing a forecast system for local systems in Cuba.

In 2015, Gisell Aguilar is missed as anGisell received a research position in Panama at CATHALAC (Water Center for the Humid Tropics of Latin America and the Caribbean) where she designed courses and research activities such as the use of numerical weather prediction for rainfall forecasting for watersheds. During Hurricane Otto (November 2016), She performed outstanding work, helping the government cope with that hazard. Having contracted a rare disease, Gisell continued her life's work until the day she passed away on June 22, 2017. Gisell Aguilar is missed as an excellent colleague, friend and a stellar Young Scientist filled with compassion, commitment and dedication and determination.

El Niño Ready Cities (ENRCs)

The City of San Diego, California

Alicia M. Kinoshita, Tracy Nishikawa, and Christina Stewart

Abstract The 2015–16 El Niño was forecast to be the strongest event in recorded history. In southern California, United States, El Niño events typically result in warmer summers and winters, with above normal precipitation and frequent storms occurring primarily between December and March. San Diego, California is a large urban city, where heavy precipitation and flooding occurred during the 1982-83 and 1997-98 El Niño events. These analogue years were considered as the strongest events of the twentieth century, which influenced expectations for strong El Niño events such as 2015-16. Using the 2015-16 El Niño event, we investigated the city of San Diego's preparation activities and steps to prepare storm-related infrastructure, develop emergency protocols, establish communication and coordination efforts, and encourage public outreach and awareness. San Diego public agencies were cognizant of the 2015-16 El Niño event and anticipated above-average precipitation and potential related impacts, as indicated by a media analysis; however, the amount of rainfall received in the San Diego region was greatly overestimated. Important lessons learned towards an El Niño Ready City include a need for communication and established emergency plans for quicker response times to emergency situations; collaboration and communication between different agencies; and up-to-date information, data, and forecasts. Uncertain forecasts continue to complicate pre-planned mitigation strategies and procedures and a challenge remains to develop readiness capacities for long-term periods even if El Niño signals are weak or not present.

Keywords San Diego · El Niño · Lessons learned · El Niño Ready City

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1 Political and Economic Setting

By 2050, an estimated 68% of the global population is projected to live in urban areas (United Nations 2018). Natural disasters in cities can be expensive and jeopardize development at local, regional, and, in some cases, national levels. Large cities have assumed a significant role in disaster risk reduction (DRR), with increased levels of autonomy to decide their own development agendas, to work directly with their local communities, and to develop their own policy practices. The city of San Diego (City) is on the Pacific coast of California in the United States (Fig. 1). San Diego County, in which the City is located, has a population of 3.3 million residents, and the City itself has 1.36 million residents (United States Census 2018; Fig. 2).

San Diego is the eighth-largest city in the United States and the second-largest in California. Economic development in the region has increased rapidly over the past few decades, especially within the 100-year floodplain of the San Diego River. For example, rapid expansion along the river has included residential, mixed-use, hotel, retail, commercial, and educational projects (City of San Diego 2016b). Water infrastructure within the 100-year floodplain includes more than 5,314 km (3,302 miles) of water lines, 49 pumping plants, 90 plus pressure zones, and more than 757 million liters (200 million gallons) of potable water storage capacity in 32 standpipes, elevated tanks, and concrete and steel reservoirs (National University System Institute for Policy Research 2015; City of San Diego 2016c).

Fig. 1 Location of San Diego, California (author)

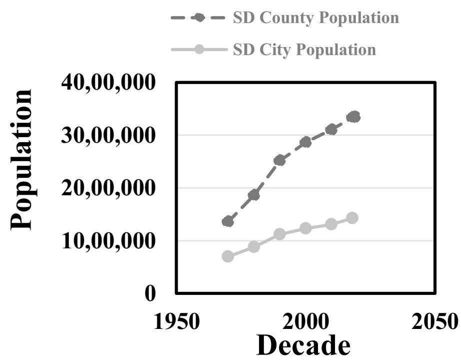

Fig. 2 Populations in San Diego County and City (U.S. Census 2018)

2 Strength of El Niño Teleconnections in San Diego

El Niño is characterized by the aperiodic warming of sea surface temperatures (SSTs) along the equator in the central and eastern tropical Pacific. An event occurs approximately every two to seven years. For southern California and the City, an El Niño event typically results in warmer summers and wetter winters, with above normal precipitation and frequent storms occurring primarily between December and March. These expected impacts can contribute to coastal erosion and flooding, which can be accelerated during storm events. Previous El Niño events associated with heavy precipitation and flooding in southern California happened in 1982–83 and 1997–98.

3 Forecasting El Niño

Most of the research and climate predictions concerning El Niño in San Diego County are available from the San Diego National Weather Service (SDNWS) and the Scripps Institute of Oceanography (SIO), which is located at the University of California, San Diego (UCSD). These centers provide guidance to San Diego County and city policymakers for decisions related to El Niño preparation and management. The San Diego National Weather Service tracks the current status of El Niño events and reports monthly updates on El Niño conditions (https://www.climate.gov/enso).

In addition to the SDNWS web page, both SDNWS and SIO provide secondary sources of information, such as social media primarily targeting the at large public. For example, accounts on popular social media platforms such as Facebook (www.facebook.com/NWSSanDiego) and Twitter (twitter.com/NWSSanDiego/) are updated daily. The SDNWS YouTube channel (www.youtube.com/user/NWSSanDiego) and Weather-Ready Nation site (www.nws.noaa.gov/com/weatherreadynation/) also provide public education for weather preparations.

The Scripps Institute of Oceanography focuses on climate impacts such as receding shorelines and flooding caused by storm waves and increased precipitation (Scripps Institute of Oceanography 2016a). Furthermore, SIO uses an experimental forecast model (Pierce 2000) to predict the ENSO extremes of El Niño and La Niña, to summarize El Niño patterns, and to identify oceanographic phenomena of concern (i.e. high sea levels, warmer oceans, etc.) for the City (Scripps Institute of Oceanography 2016b).

Agencies and research institutes such as SDNWS and SIO use climate models that forecast anomalous strong warming of SSTs in a region along the equator known as Niño 3.4. These models are used to forecast El Niño events and to provide warnings to public agencies and local communities. Forecasting such events, however, is often portrayed as a temperamental science. This portrayal may stem from the fact that some event years result in no major or visibly devastating impacts like excess precipitation or flooding.

Even more anomalous are those event years that are very weak or that do not develop into mature El Niños at all. An example of this anomalous circumstance came was in June 2014, when SIO was one of several forecast centers that predicted a strong El Niño for the winter of 2014–2015 (Scripps Institute of Oceanography 2014). At the time, NOAA also predicted a 70% probability of an El Niño developing in July 2014. By November, however, the probability of an event had dropped to 58% (NWS and CPC 2015). In the end, the forecasted 2014 El Niño did not develop. Unfortunately, neither did its anticipated precipitation, which planners had hoped would help refill reservoirs that had been depleted after multiple years of drought in California. This example lends credence to what has been described as the largest El Niño uncertainty—forecasting the local storms that are often associated with an event, such as those that brought heavy precipitation in 1982–83 and 1997–98 (Scripps Institution of Oceanography 2014).

4 Previous Analogue Years Noted During the 2015–2016 Event

Previous El Niño years associated with heavy precipitation and flooding in Southern California included 1982–83 and 1997–98, which were considered by scientists as the strongest events of the twentieth century. Both events had increased precipitation and flooding in the City, particularly along the San Diego River and its tributaries. In water year (WY) 1983 (October 1, 1982 to September 30, 1983) and WY 1998 the City received 26.44 cm and 25.15 cm of rain, respectively. In WY 2016, the City received 30.25 cm of rain, which is 115% of the average (San Diego County Water Authority 2016). While the totals are similar, the instances of flooding are attributed to the intensity and frequency of the storms.

5 Early Warning

Understanding the processes that drive ENSO extremes is an important component of forecasting the warnings that provide critical information to policymakers and their coastal constituents (Allan and Komar 2006). The SDNWS, the City's primary source for El Niño forecasts and warnings, constantly monitors the weather and sends updates to public agencies and the public at large. This information is received four times a day in a grid format that can be readily retrieved and interpreted. The SDNWS uses the Global Forecast System (GFS), other U.S. models, and the European Centre for Medium-Range Weather Forecasts (ECMWF) to predict winter storms and hurricanes (Alex Tardy, SDNWS, personal communication 2016). The European Weather Agency predictions supplement and support the U.S. NWS model predictions. Private sources, such as AccuWeather, are typically contracted by local San Diego television news stations to broadcast forecasted weather events.

6 First Indicators of the 2015–2016 El Niño

The NOAA Climate Prediction Center (CPC) issued an El Niño Advisory in March 2015 (L'Heureux 2016; Stockdale et al. 2017). At the time, the 2015–16 El Niño was forecast to be the strongest event in recorded history, with the potential for a greater impact than either the 1982–83 or 1997–98 events, both of which were referred to in their respective times as the "El Niño of the Century" (Nash 1997).

6.1 Regional Impacts of El Niño

For southern California, El Niño impacts are generally greater, with a stronger chance of excessively wet conditions, in the late northern hemisphere winter than in early winter (Seager et al. 2015). Expected impacts include destructive storms, mudslides, flooding, ecosystem changes, and transformations of local beaches. Most long-range forecast models predicted larger amounts of precipitation for the 2015–16 El Niño than the City received in either 1982–83 or 1997–98. Monroe (2017) notes, however, that the difference in model precipitation predictability and actual precipitation amounts was due to "tropical sea-surface temperature anomalies." This means that some of the total amount of precipitation anticipated in southern California in 2015–16 was actually displaced to northern California because the El Niño-strengthened jet stream traversed primarily across northern California and the Pacific Northwest rather than across Southern California (Swain 2016). Such unexpected weakening indicates a need for more regional metrics of El Niño events to understand the diverse expressions possible of events of similar magnitudes (Jacox et al. 2016).

In southern California, beach transformation from the 2015–16 El Niño varied widely, from erosion to accretion (Young et al. 2018). For example, 27% of the shoreline accreted, while beaches adjacent to estuaries eroded. Approximately 12% of cliffs experienced erosion and those that did had a markedly smaller retreat than historical values. Some coastal erosion and damage was limited by the timing of high tides and large waves, the direction of northerly swells, and the low rainfall. Overall, the coastal transformation from the 2015–16 El Niño were more comparable to the 2009–10 event than to previous strong events like 1997–98.

7 Impacts in San Diego County and City

Historically, the San Diego County coastal areas of Oceanside, Encinitas, Cardiff, Solana Beach, Del Mar, La Jolla, Pacific Beach, and Mission Beach have been impacted by the high sea levels typically associated with El Niño events (Fig. 3). Based on this history, the City had granted 23 El Niño-related emergency permits to increase financial resources and expedite maintenance of storm infrastructure and preparation for storm-related damages following the 1982–83 and 1997–98 events (Hansch et al. 1998). During the 1982–83 El Niño, for instance, storms caused heavy erosion and left beaches vulnerable to subsequent storms (National Resource Council 1984). Other impacts included decreased storm-drain capacity, building

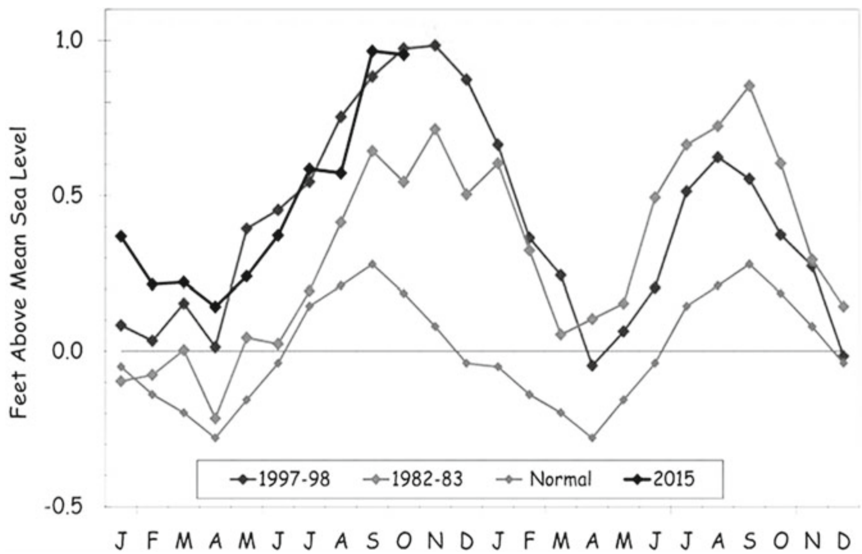

Fig. 3 Monthly mean sea levels for the 1982–83 & 1997–98 El Niños, La Jolla, California (Doherty 2015)

Fig. 4 **A** Avenida del Rio in Fashion Valley. **B** Alvarado Creek, a tributary of the San Diego River (author)

and beach closures, beach erosion, boardwalk damage, infrastructure damage, emergency permits, and multiple emergency responses (Hansch et al. 1998). Damage assessments following El Niño storms in California had already caused an estimated USD$804 million (1997–98) and USD$204 million (1982–83) in economic losses (National University System Institute for Policy Research 2015). Economic impacts specific to the City were not available; however, the overall cost of the 2015–16 El Niño for the Storm Water Division of the City's Department of Transportation and Storm Water was approximately USD$1.2 million. This amount specifically supported personnel costs for pump station maintenance and repair, structural inspections, and cleaning.

8 2015–2016 El Niño Event Impacts

Visible impacts from the 2015–16 El Niño storms included flooding and coastal damage. Flooding in the City occurred in anticipated flood zones such as Mission Valley and Sorrento Valley as well as in higher mesa areas such as Kearny Mesa. Flooding also occurred across roads that had been built directly over the San Diego River (Fig. 4A) and in urban channels (Fig. 4B). Coastal damage included erosion and sinkholes as well as highway damage in La Jolla, Del Mar, and the Torrey Pines area. As of June 2016, the overall cost of the 2015–16 El Niño for the Storm Water Division of the City's Department of Transportation and Storm Water was approximately USD$1.2 million.

9 Government and the NMHS

Federal agencies such as NOAA and NWS provide both the county and the City with weather prediction and forecasts, which guide and inform homeowners, businesses, and nongovernmental organizations (NGOs) for El Niño preparations. Additionally, several disaster-related groups (i.e. DHS, police, emergency services) in San

Diego City and County are registered as "ambassadors" in the NOAA Weather-Ready Nation (WRN) national program.

10 Inter-Agencies Involved in El Niño Forecasts and Impacts

The San Diego County Office of Emergency Services (OES), San Diego City Department of Transportation and Storm Water, and San Diego City Lifeguard Services are primarily responsible for El Niño preparedness (Fig. 5). Additional City agencies and departments that participate in El Niño preparations include Administrative Services, Environmental Services, Financial Services, Fire-Rescue, Public Works, Police, and Public Utilities. The city of San Diego Police Homeless Outreach Team (HOT) also provides storm and flood warnings to people experiencing homelessness, who are living along the San Diego River (The City of San Diego 2016a).

Nongovernmental organizations, such as the San Diego and Imperial Counties' chapter of the American Red Cross (Red Cross) and the Alpha Project, a human services organization in San Diego, use NWS data for El Niño preparation and planning. During emergencies, the Red Cross provides food and shelter, 24-h response to local emergencies, and other services across an approximately 25,900 square kilometer (10,000 square mile) area in two counties (American Red Cross 2016). The Alpha Project primarily serves those experiencing homelessness in San Diego by providing affordable housing, residential substance abuse treatment, and basic and emergency services (Alpha Project 2015).

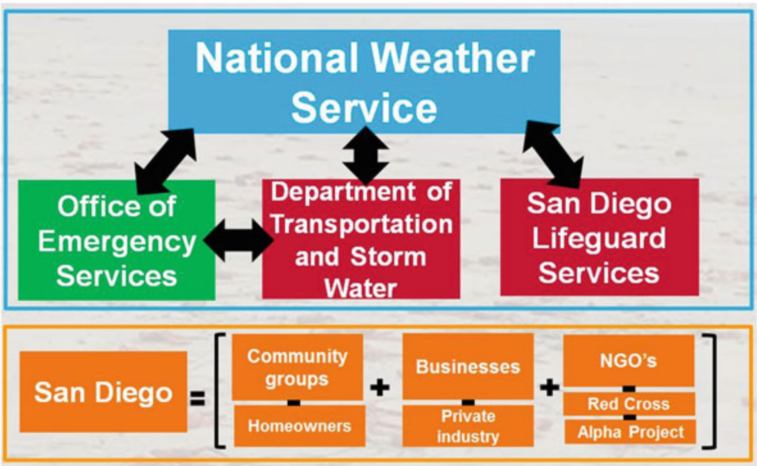

Fig. 5 General inter-agency structure for El Niño preparation in the city of San Diego (author)

Preparation for El Niño-related storms is financially supported by the City and additional funding for specific mitigation activities is allocated accordingly. For example, the City declared a state of emergency in November 2015, which allowed faster access to state and federal funding (Alvarez 2015). To prepare for El Niño storms and impacts, county and city agencies developed plans in the event of an emergency such as flooding to improve preparation and response times. Local agencies were also involved in ensuring the City and its residents were prepared with resources, education, and outreach services. During the 2015–16 El Niño, the various city and county departments coordinated mitigation and preparation activities such as simulating practice exercises in the case of an emergency and educating the public about the potential impacts of an event. The City distributed sandbags to local residents and businesses to prevent flood damage, cleaned and cleared 11 high-priority storm channels, and developed flood-rescue procedures (Gomez 2015).

County and city departments took additional precautions to mitigate the potential impacts of foreseeable El Niño storms. For example, the San Diego Lifeguard Department and River Rescue Team developed flood-rescue plans for specific areas in San Diego that are historically flood prone. Using geospatial methods, the Lifeguard Department incorporated maps of the 100-year flood zones and created eight flood plans to guide rescue actions for areas such as Sorrento Valley, Mission Valley, the San Diego River, and the Tijuana River.

In previous El Niño years, challenges arose from inter-agency communication and coordination, resulting in slower response times and less efficient mitigation actions. For the 2015–16 event, agencies emphasized the importance of collaboration, took specific actions toward establishing lines of communication throughout the event, and addressed critical needs with the most recent and up-to-date information and data to provide adequate lead time for preparative actions. There were also numerous workshops, meetings, and education and outreach activities available in San Diego, which focused on El Niño preparation for both local agencies and the public.

11 Media Coverage

El Niño warnings were widely disseminated to the public through media outlets such as television and radio news, city of San Diego websites, social media (e.g. Facebook, Twitter, and YouTube), and mobile alert messages for cellphones. A media search was conducted to study media perceptions of the 2015–16 El Niño in comparison with the 1982–83 and 1997–98 events (Fig. 6). Media outputs (e.g. online news articles, websites, printed news, and transcripts) within the City were divided into four groups by decade, from 1980 through 2016. Search results indicated that throughout the four decades, the number of maintenance-related articles (114) surpassed the number of preparation-related articles (97). Preparation and maintenance activities include steps taken to repair storm-related infrastructure, develop emergency protocols, establish communication and coordination efforts, and encourage public outreach and awareness. These numbers correspond with interviews with San Diego county and city

News Headlines: (San Diego and El Niño 2015-16)

- **City Council declares State of Emergency in advance of El Niño storms**
- San Diego Leaders Call For State of Emergency To Clear Storm Channels
- Beach Erosion, Not Rain Was This El Niño's Major Impact
- Did forecasters overestimate El Nino rains?
- El Niño 2015-2016
- Homeless Along San Diego River Warned Of El Niño
- Coming El Niño Has Emergency Officials Preparing, Researchers Watching Closely
- Godzilla El Niño left Southern California mostly high and dry
- Scientists Say We Could Be Heading Into 'Godzilla El Niño'
- EL NINO: 'The Great Wet Hope' is dead

Fig. 6 Headlines from news articles about the 2015–16 El Niño, one of the three strongest in 70 years (compiled by author)

public agencies, which were concerned with potential El Niño-related impacts and were proactively engaged in preparation and maintenance activities.

Heightened publicity showed the increased importance and awareness over time of El Niño events and consequences; the media analysis tended, however, to heavily emphasize the costs and damages associated with El Niño. Overall, "cost" had the highest total number of articles (457), followed by "repairs" (120), and then "losses" (86). Finally, the media analysis indicated a focus on El Niño-related weather and its implications for the City, as evidenced by the total number of articles related to weather across four decades. The tone of the media coverage was generally factual, as indicated by the number of weather and forecast articles. The media also focused on the immediate impacts to community activities. "Cost" is the fifth highest subcategory, indicating the emphasis on the City's El Niño storm preparation, impacts, and costs to the City and its citizens.

12 Barriers and Challenges

Some barriers and challenges for the City were identified after the 2015–16 El Niño.

- The City must declare a state of emergency to procure permits and support to expedite maintenance of storm infrastructure. The environmental permitting processes necessary to clear storm channels impeded prompt action for El Niño preparedness. Under normal circumstances, permitting can take one to two years (City News Service 2015).

- Weather forecasting for the 2015–16 El Niño event proved challenging, especially with regard to storm events (Hoell et al. 2016). The amount of precipitation that the San Diego region received ended up being overestimated (Robbins 2016). Much of the total amount of precipitation anticipated in southern California was displaced because the El Niño-strengthened jet stream ended up traversing primarily across northern California and the Pacific Northwest (Swain 2016).
- Despite challenges, the City's agencies were prepared and acted effectively using the developed response plans. Agencies also noted that storm preparation was an ongoing process not limited to El Niño events.

13 El Niño-Related Surprises in the City

The amount of rainfall that the San Diego region received was greatly overestimated (Robbins 2016). Expectations were likely based on rainfall amounts from the previous two major events.

14 Lessons Learned from El Niño Events

Some important lessons have been learned from past events.

- Interviews with representatives from key agencies revealed that there was less interagency communication and collaboration during previous El Niño events than during the 2015–16 event. In general, better communication and established emergency plans resulted in quicker response times to emergency situations.
- Improving both efficiency and response time to emergency situations, collaboration and communication between different agencies were vital for ensuring that the City was El Niño ready.
- Pre-planning and practice for foreseeable flooding events are important and provide preparation and coordination among city agencies in cases of emergency.
- The most recent and up-to-date information and data are needed to keep agencies informed. Such timely information provides adequate lead time for preparation.
- Forecasts of El Niño are not always correct (e.g., most recently the failed 2014 El Niño forecast). This uncertainty complicates pre-planned mitigation strategies and procedures (Chen et al. 2004; Chen and Cane 2008; Glantz 2015).

15 Lessons Identified: How Past Lessons have been Used in Future Planning

In previous El Niño years, challenges arose from poor inter-agency communication and coordination, resulting in slower response times and inefficient mitigative actions. During the 2015–16 El Niño event, deeper collaboration between agencies was emphasized, with specific steps to establish lines of communication throughout the event. Numerous workshops, meetings, and education and outreach activities focused on El Niño preparations were also made available to agencies and the general public in the San Diego area.

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Correction to: El Niño Ready Nations and Disaster Risk Reduction

Michael H. Glantz

Correction to:
M. H. Glantz (ed.), *El Niño Ready Nations and Disaster Risk Reduction*, Disaster Studies and Management,
https://doi.org/10.1007/978-3-030-86503-0

The original version of the book was published with incorrect figure 1 in chapter "China", and incorrect abstract lines are updated in chapter "Kenya—Local" and in the Epilogue, figures placement has been updated after the figure citation.

The chapters and book have been updated with the changes.

The updated version of the book can be found at
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Epilogue

Crosscutting Themes of the El Niño Ready Nations Case Studies

Each of the country studies in this volume has exposed issues of concern as examined by its respective researcher. The Consortium for Capacity Building (CCB) clustered several, but not all, of these concerns into the following six crosscutting themes, each of which highlights challenges faced by decision makers in policymaking as well as by researchers in forecasting El Niño events: (1) El Niño's characteristics; (2) Forecasts; (3) National meteorological and hydrological services (NMHSs); (4) Governance; (5) Awareness; (6) Media, including social networks.

The challenges posed by each of these crosscutting themes must be successfully addressed if the singular overarching goal of El Niño Readiness is to be achieved at national to local levels (Fig. 1). Though each of the six themes is general in nature, together they encompass many of the basic needs of societies as well as the foreseeable opportunities, either strategic or tactical, for country-appropriate responses to El Niño forecasts and events. The discussions of each theme that follow include recommendations and questions that must be addressed, if the goal of global El Niño Readiness is to be achieved before the next very strong event comes along.

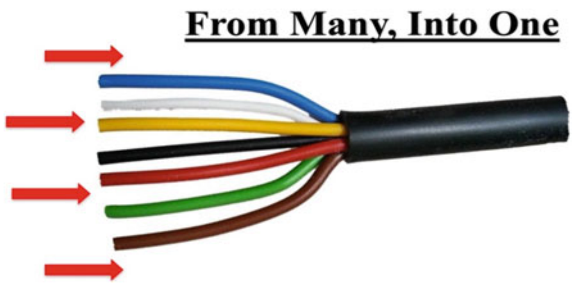

Fig. 1 Illustrates that many themes can flow into one cohesive idea or plan (*Source:* Auprotec Hella Fahrzeugleitung)

M. H. Glantz (ed.), *El Niño Ready Nations and Disaster Risk Reduction*, Disaster Studies and Management, https://doi.org/10.1007/978-3-030-86503-0

El Niño's Characteristics

What needs to be better understood is that pinning down the characteristics of the El Niño phenomenon remains quite problematic for decision makers, scientists, and forecasters. Currently, when civil society hears about an El Niño event what is typically heard tends to be limited to the expected formation of an event or the projected devastation of its impacts somewhere on the globe. That this is what is usually heard by the public creates an incongruence between what is actually known about the El Niño phenomenon and what information about it is broadcast in electronic and print media, which too often today appears in overly sensationalized "doom and gloom" headlines.

The problem with the incongruence that arises in this typical situation is that it tends to disregard the essential reality that forecasting El Niño is still partly an activity of science and partly a form of art. Mysteries remain, that is, in understanding the phenomenon, many of which have to do with the various characteristics of El Niño events.

To resolve this incongruence between what is known and what is generally understood, more incisive attempts must be made to draw public attention to answers to more useful, more germane questions about the phenomenon. Such questions might include, for instance: What makes the current El Niño forecast trustworthy? Why are projections about its likely intensity or the location of its impacts credible? What makes the impacts that are beginning to appear in different places, as interviews with scientists have suggested, attributable to the forming of an El Niño event?

The point is that a close look at El Niño as an isolated phenomenon reveals various uncertainties in terms of air-sea interactions in the equatorial Pacific. Uncertainties about an event's characteristics are also introduced by the influences of other surrounding air-sea oscillations. Together, these various characteristics interact, sometimes in (as of now) seemingly arbitrary ways, to determine the societal and environmental impacts that will emerge during a particular El Niño event.

The uncertainties that continue to surround El Niño characteristics can also affect decision makers' perceptions about when, or even whether, to focus more on tactical preparations for a specific event or more on strategic responses to the long-term possibilities of recurrence. Some variables affecting such decisions include:

- That El Niño's uncertain return period of two to seven years means, for example, that an elected government can likely expect only having to contend with the impacts of one event during its tenure;
- That the effects of other atmospheric and oceanic oscillations can influence El Niño's characteristics, as, for example, when the Indian Ocean Dipole (IOD) and the Pacific Decadal Oscillation (PDO) interfere with the accurate forecasting of El Niño's formation and its teleconnected impacts, making tactical preparations more politically problematic;
- That ongoing local and regional social, economic, environmental, and political factors at the time of an El Niño's formation can influence the extent and location

of impacts, as when sectarian unrest leads to a withholding of food assistance to vulnerable populations resulting in a famine after an El Niño-induced drought;

- That the range of possible El Niño intensities is quite wide (from borderline weak, to moderate, to strong, to very strong), and researchers currently have difficulty, save for the very strong events, forecasting how intense each event might become;
- That strong and very strong events capture media attention worldwide, while more minor El Niños, which can still have significant impacts, tend to receive considerably less media attention, public concern, or government attempts at preparation or readiness;
- That just as physical scientists refer to "flavors of El Niño," it is now time for other scientists to identify and categorize "flavors of El Niño's impacts";
- That difficulty remains in indisputably attributing to specific El Niño events with a range of intensities causal relationships to what are believed to be the teleconnected effects—like droughts or floods—of those respective events in different areas around the world;
- That research challenges remain in forecasting the strengths of the various teleconnections for each emerging El Niño event;
- That scientific uncertainty continues to exist about what exactly "kicks off" a basin-wide El Niño event, especially considering the notable El Niño forecasting failures that have occurred since near the end of the twentieth century (i.e., in 1997, 2012, and 2014);
- That, though a limited time series supports a projection of the recurrence of a very strong event every 15 years or so, few very strong El Niño events have as yet been directly observed;
- That both media outlets and the scientific community have seemingly over-focused on strong and very strong El Niño events, a consequence of which is a gap in the general understanding and appreciation of the risks created by events of lesser intensity. Even weak events can have societal and environmental consequences;
- That there is value in distinguishing—especially for increased understanding by the public and policymakers—between El Niño as a discrete *event*, as determined by the physical characteristics of ENSO, and as an ongoing *episode* with distinct phases that can have social and environmental impacts that continue for months, or sometimes even years, after the geophysical event itself has ended; and
- That forecasting the possible onset of an El Niño is not the same as forecasting its locked-in phase, which is the threshold beyond which the forecasted event will definitely run its full course (see Glantz and Ramirez 2020).

Further Thoughts about El Niño Characteristics

The suggested return period (~15 years) of very strong-to-extraordinary events might suggest to policymakers that they need only prepare for the big events, believing that smaller events are less destructive and, therefore, less worrisome. This belief should be understood as erroneous, based not on sound science but more on researcher and media tendencies to overemphasize major events, like those in 1982–83, 1997–98, and, most recently, what has been called “The Godzilla of El Niños” in 2015–16.

- Societal preparations for a specific El Niño will depend on its anticipated intensity (Fig. 2) and anticipated societal impacts. Which specific countries will suffer, however, depends on each country’s history with previous events and the projected intensities and timings of future events, as well as an understanding that the forecast of El Niño is no longer a probability but is a reality once it has entered its “locked in” phase.
- Researchers and forecasters must be more forthcoming with the public and policymakers about the state of what might be thought of as the scientific “knowns, unknowns, and surprises” about ENSO, especially with regard to forecasting its warm and cold extremes.
- El Niño has numerous second and third order “downstream” effects that merit serious attention, which means that with respect to the physical characteristics of El Niño’s teleconnections, “out of sight *should not be* out of mind.”
- Because the strength of known teleconnections can vary from one event to the next, relying only on the last event or the biggest previous one as a guide to what impacts to expect in preparing for the next El Niño is a highly risky strategy. Planners should consider at least a few past events in formulating tactical responses for a range of foreseeable possible impacts on both society and the ecosystems on which it depends.
- Individuals, socioeconomic sectors, and NGOs live and operate by the expected flow of the seasons, which makes the forecast of the timing of an El Niño event extremely important. El Niño tends to disrupt expected seasonal flow as well as seasonal climate.

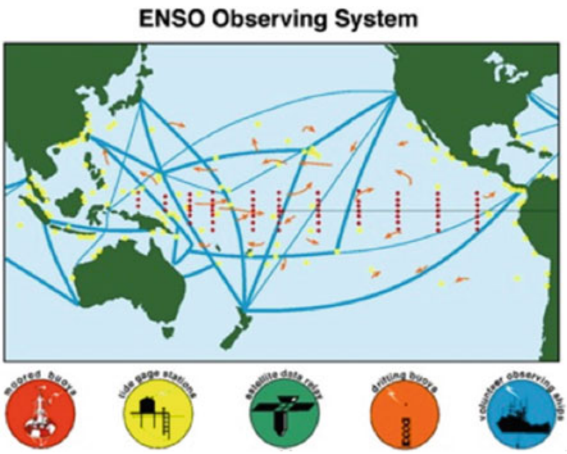

Fig. 2 ENSO observing system (Biologyeducation.com)

In sum, natural variance in the characteristics of the El Niño phenomenon is part of the problem faced by planners with regard to accurate and timely forecasts, early warnings, optimal disaster risk reduction readiness, and appropriate societal responses.

Forecasts

El Niño information typically reaches the general public by way of media articles about forecasts of an event's intensity and less so its life cycle (Fig. 3). People respond to such information in different ways—to act or not to act, that is the question civil society as well as decision makers must answer.

All forecasts, however, are based not on what *will* be but on what *will probably* be as a quantitative expression of the likelihood of occurrence. Forecasts always come with an unstated "buyer beware" warning. As such, it is imperative:

- That the scientific community make explicit the distinction between forecasting an El Niño event's formation, forecasting the event's "locked in" phase, and forecasting an event's likely behavior during its life cycle (see Glantz and Ramirez 2020);
- That, at the time a forecast is released, the public understands that many decisions must be made in response not only to that forecast but also to the cascade of secondary and tertiary impacts that are expected to follow, especially those that will likely affect routine activities and livelihoods. For example, a secondary effect of the formation of an El Niño event is reduced fishing, which means growing food insecurity can be expected because of both higher food prices and higher unemployment (not only in the fishery but also in other associated, "downstream" industries such as boat builders and motor and fishing gear manufacturers);
- That forecasters and governments periodically re-evaluate their so-called "best practices" for disseminating El Niño forecasts to the public, which will, for some governments, require changes to regulations about how and when official "early warnings for hydrometeorological hazards" can be passed to the media for general broadcasting;

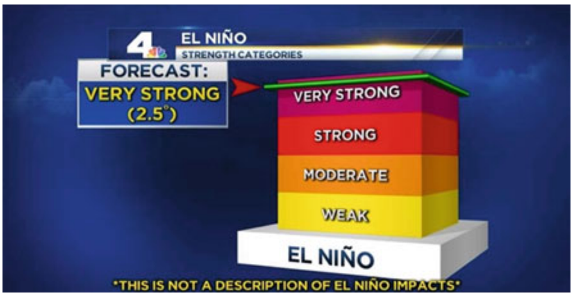

Fig. 3 Example Figure of a scale of El Niño Intensity broadcast to the public (NBC Los Angeles)

- That the public and policymakers understand that no "canonical forecast" exists to precisely determine the exact timing of the formation of an El Niño event, or of its decay;
- That scientists continue to improve techniques for identifying the attributes of teleconnected local and regional hydrometeorological anomalies, especially for events of different intensities;
- That governments invest in more effective methods to track and measure their respective El Niño-related socioeconomic impacts;
- That policymakers support research that identifies relationships between El Niño events and chronic socioeconomic problems, particularly those underlying problems that have essentially negated what would otherwise have been effective responses to past El Niño forecasts and impacts; and
- That El Niño readiness is tailored to address hidden or neglected societal weaknesses that will likely worsen as atmospheric and oceanic chemistries continue to change—resulting in greater social, economic, and environmental uncertainties—as a result of human-induced global warming.

National Meteorological and Hydrological Services (NMHSs)

NMHSs are central players worldwide when it comes to monitoring ENSO's warm extremes and teleconnected hydrometeorological impacts. While various NMHSs *may* have the necessary technological tools and personnel to directly monitor sea surface temperatures (SSTs) in the tropical Pacific, many do not. Even though an NMHS may not have modernized to its desired level, it should at least have the personnel, training, and equipment it needs to track and follow up on an El Niño forecast it has received from any of the reliable regional or international hydrometeorological research and forecast centers (Fig. 4).

That said, to be effective a sufficiently modern NMHS must have:

- The ability to meet the increasingly common expectation, if not government mandate, to not only conduct scientific research and applications but also to create products and services that directly engage the at large public;

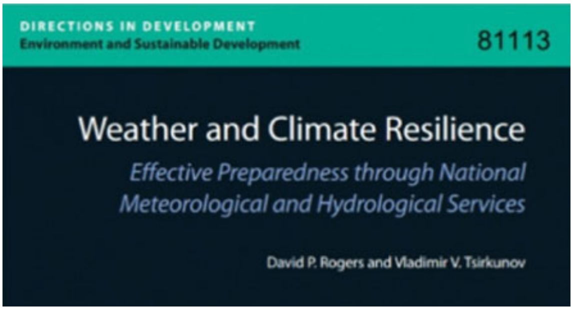

Fig. 4 "Weather and Climate Resilience" was a workshop that evaluated NMHSs capacity around the world (https://openknowledge.worldbank.org/handle/10986/15932)

- Sufficient funding directly given to it to train personnel as capable scientists and as science communicators and outreach facilitators in order to effectively interface with the users of their expanding services;
- Enhanced political standing with various government agencies to inform if not influence climate, water, and weather policy discussions that often involve national security;
- Stable, apolitical links to NOAA, a U.S. government service that provides critically important El Niño forecasts to countries around the world. To be sure, many foreign governments and their hydrometeorological services rely on NOAA forecasts in their decision-making processes, particularly once the probabilistic forecast of an El Niño's formation has been issued; and
- Strong relationships with local media and NGOs, so as to explore innovative ways to reach all at-risk populations with warnings and other DRR interventions.

The point is that, as the adage goes, "an ounce of prevention is worth a pound of cure," which suggests that even seemingly modest efforts to modernize NMHSs can significantly improve the expected outcomes of vulnerable populations to the deleterious impacts that El Niño events can have.

Governance

Governance issues are central to effective DRR activities in the same way that they are central to sustainable development planning.

"Governance," a term first used in the fourteenth century, is generally defined as "the act or manner of governing." The country case studies in this volume identified various aspects of governance that can either favorably or adversely affect El Niño-related decision making and impacts.

DRR activities can build societal resilience to hydrometeorological hazards, which are most often shared experiences. A focus on this shared nature of experience should lead to sustained sufficient funding and political will as well as moral support for ensuring timely hydrometeorological forecasts, well-developed early warning systems, expedited forecast dissemination, strengthened hydrometeorological capabilities, expanded tactical or strategic readiness, shared lessons learned and best practices, and so forth.

Governments determine when to plan and to act, whether to react or to pro-act, how to react or pro-act, and whether to allocate funds appropriate to the nature of different threats, both spatially and temporally (Fig. 5). They can proactively make funds available for strategic El Niño preparedness in advance, or they can reactively provide funds after-the-fact for disaster response and recovery.

Suggestions for improving the governance of DRR-related issues include:

- Framing El Niño-related governance decisions in terms of strategic and tactical responses;

Fig. 5 Good governance characteristics and values. Adapted from UNESCAP

- Identifying and evaluating government regulations that directly or indirectly impede effective responses to or preparations for foreseeable impacts of an El Niño event, especially in known El Niño hotspots;
- Fostering collaborations between both in-country agencies and their counterparts in neighboring countries *that share the same weather systems* in order to compare and share regional response tactics and lessons learned from their past responses;
- Appointing at the national level of El Niño hotspot governments an "ENSO Czar" to facilitate collaboration among government agencies, not just for El Niño but also for the La Niña and Neutral phases of the ENSO cycle;
- Examining the possibility of setting up a national-level "Standing Working Group on El Niño"—or, more broadly, "on ENSO"—especially in hotspot countries;
- Mitigating, if not avoiding entirely, societal disruptions that are likely to occur due to El Niño impacts by encouraging inter-agency collaboration *in advance of* the formation of an event;
- Implementing lessons learned from past El Niño events, a measure that is usually dependent on the political landscape, the continuity of which has been known to be affected by transfers of power that often redirect government priorities and interests to new or at least different policy directives for El Niño-related issues;
- Placing El Niño on a government's list of strategic threats; and
- Developing an El Niño national action plan to bolster response effectiveness to El Niño forecasts and impacts, as many countries already have to contend with, for example, droughts, fires, disease outbreaks, and floods.

Awareness

Generating societal awareness about El Niño should be an on-going process that requires constant reinforcement and revision as new scientific information becomes available. So-called awareness-raising activities, however, often turn out to have been little more than a one-time education or training workshop in different locations. Such efforts, while admirable and important, are not enough to develop, let alone sustain, higher levels of awareness about aperiodic natural occurrences such as are ENSO's extremes (Fig. 6).

Awareness of obstacles to accessing knowledge about El Niño is a necessity because El Niño is a potentially life- and livelihood-threatening hydrometeorological hazards-spawner. As a quasiperiodic event, however, it is not a constant annual concern to governments or civil society, so it usually falls outside the policymaker's and the public's one- or two-year attention span. At the least, policymakers and community-level decision makers, along with the "attentive public," merit special, prioritized attention in awareness-raising processes.

The concept of the "attentive public" has evolved since it was first coined in the 1920s. Today, it refers to the segment of the citizenry that closely follows public affairs on a wide range of issues. It can also refer to people who closely follow only a specific issue.

The following ideas might help raise awareness of the nuances involved in forecasting and responding to ENSO extremes:

- Using the two to seven years between El Niño events to create better understanding as well as awareness of the phenomenon and to remind society about the impacts of and responses to previous events;
- Considering whether an explicit distinction between "DRR" (Disaster Risk Reduction) and "drr" (disaster response and recovery) usefully raises awareness, educates citizens at large, trains direct stakeholders, and develops pre-and post-disaster coordination plans;
- Targeting audiences for awareness raising, an imperative that will vary from country to country;
- Deciding whether everyone in a given society needs to be made aware of all the scientific details behind the El Niño phenomenon to understand that the formation of an event will have impacts on society and that taking precautions before an event's formation makes sense. This decision, of course, requires trust in government agencies as well as in NMHSs and the forecasts they produce;

Fig. 6 Levels of awareness (Nischwitzgroup.com)

- Demonstrating to governments and societies clearly and repeatedly on a continual basis the value of El Niño and ENSO knowledge and information;
- Practicing readiness exercises to reinforce broad awareness of, as well as concern and preparedness for, the havoc an El Niño event could foreseeably wreak on a society and its sustainable development prospects.

Media, Including Social Networking

People tend to focus on the last big climate, water, or weather disaster, whether it was a drought, a flood, a heatwave, a vector-borne disease outbreak, a hurricane, or a severe storm. The same holds true for the media. Looking back to the last big disaster of the same type, however, may not provide the best insight about likely impacts for an upcoming event. Science reporters, like the public and policymakers, must look at more than just the last El Niño, for example, to provide their readers or listeners with a glimpse at the range of possible impacts that could accompany the next event (Fig. 7).

Media must:

- Recognize the special role they have in informing the public through daily broadcasts;
- Consider developing strategies and tactics to be able to sustain awareness-raising campaigns so as to more effectively disseminate El Niño information, especially for outreach to at-risk countries and communities;
- Understand their public service and early warning responsibilities to inform the public about El Niño as one phase of the naturally occurring, all-encompassing ENSO cycle;

Fig. 7 Various sources for media-based reporting (Brusselmedia.be).

- Urge funding agencies to support "media awareness and education needs" workshops to discuss how best to report on El Niño as part of the broader ENSO cycle;
- Recognize that social media are increasingly important conduits for educating people of all ages, with special attention on youth and young professionals, about how they can assist with early warnings for hydrometeorological anomalies (Fig. 8);
- Explore ways that social media can be used for awareness-raising, such as through education and training, and for informing government agencies and traditional media outlets about the local consequences of El Niño events in real time;
- Encourage professionals to use social media to create awareness about and discuss the impacts of El Niño as an event that, either positively or negatively, disrupts expected seasonal weather patterns and, more generally, seasonality in a changing climate;
- Appraise social media's capacity to complement traditional media in order to increase the average person's ability to undertake a wider range of informed responses (beyond mere reaction to an alert) to reports of the formation and ensuing life cycle of an El Niño event and its often prolonged impacts;
- Meet the differing needs of various distinct target audiences, regardless of region or socioeconomic status;

Fig. 8 Various Social Media portals (Kalifeh Media Group)

- Provide positive guidance rather than sensationalized headlines and stories about disastrous impacts so as to be more useful to the at large public.

Life on a Warmer Planet

Just how global warming is likely to affect climate impacts around the globe is at this point still quite uncertain, with many conflicting views offering a wide variety of possible futures, from the inconvenient to the intolerable. The selected La Niña headlines in Fig. 9, for example, illustrate just some of these possibilities as understood

La Niña and Global Warming

- Global warming doubles risk of extreme La Niña event, research shows
- La Niña Events May Spike with Climate Change
- La Niña–like Mean-State Response to Global Warming and Potential Oceanic Roles
- Can the response to global warming be La Niña-like?
- Frequency of extreme El Niño and La Niña events under global warming
- Tropical Pacific trends under global warming: El Niño-like or La Niña-like?
- La Nina to make global warming more intense

Fig. 9 Headlines about La Niña and Global Warming, selected. (Glantz 2020)

now, in 2020.

At the risk of oversimplification, two dominant but opposing views have emerged. One claims that worldwide climates, from regional to local levels, will be more like those now observed during El Niño extreme events, while the other claims that climates will be more like those observed during current La Niña events. The reality of what the future will be has yet to resolve the issue. Even so, different climate models have now been parameterized based on what different assumptions modelers have made of how the ENSO phases (warm, cold, and neutral) might behave with warmer atmospheres and oceans. Using the same basic geophysical data, different modelers have drawn equally plausible but radically different conclusions, demonstrating nicely just how the answer to a question is nearly always embedded within the assumptions that undergird the basic logic of that question.

In a study comparing the outputs of five different models (Kohyama 2017a), for example, four supported the hypothesis that the consequences of global warming for the world's climate subsystems would be more like El Niño than La Niña. If these outputs were to be validated over time, either by enhanced modeling products or by empirical observations (or both), such a finding would have immense cross-cutting value for decision makers in at-risk countries, economic sectors, communities, and humanitarian organizations. Such validation would enable the development of more appropriate—not to mention more sustainable—DRR activities, a goal that becomes increasingly urgent as the impacts of climate change appear with greater and greater intensity even now, decades earlier than had been expected just a few short years ago.

It must be asked, however, what of the fifth model Kohyama examined in his comparative study, the prestigious Geophysical Fluid Dynamics Laboratory (GFDL-ESM2M) model output at Princeton University that did not support the hypothesis that the consequences of global warming for the world's climate subsystems would be more like El Niño? Instead, the GFDL model indicates that global warming's impact on ENSO would likely be similar to those climates occurring during a La Niña event.

Lian et al. (2018) captured the essence of these two opposing views as follows:

> Many state-of-the-art climate models project that the tropical Pacific Sea Surface Temperature (SST) response to the greenhouse gas (GHG) forcing would be an 'El Niño-like' pattern, meaning that the eastern equatorial Pacific warms faster than anywhere else in the tropical Pacific" . . . It is clear that the available observations suggest that the global warming in the recent past tends to induce a 'La Niña-like' rather than 'El Niño-like' mean-state change in the tropical Pacific.

Kohyama (2017b) notes that, "based on the NEWS [Nonlinear ENSO Warming Suppression] mechanism, this physical explanation for the termination of extreme El Niños supports the notion that the response to global warming could be La Niña-like."

For the past 50 years, the El Niño extreme has received the lion's share of attention about ENSO from policymakers and media outlets. This historical disparity has, however, begun to shift in favor of La Niña; how La Niña, as ENSO's cold extreme, might be affected by climate change is of growing interest to researchers. Policymakers should also be concerned because of the potentially devastating impacts known to be associated with La Niña events. For example, a record-setting number of named hurricanes and tropical storms occurred in the Atlantic Ocean and Gulf of Mexico as a result of the 2020 La Niña. Initial estimates along the US Gulf Coast alone have come in at tens of billions of dollars in material losses and at least a score of deaths directly attributable to these 2020 storms, which at the time of writing now total an unprecedented 31 named events.

But a closer look at the history of the ENSO cold extreme shows that, at least for some countries, the impacts of a La Niña can be even more severe than those of an El Niño (Glantz 2002). What these data suggest is that a comprehensive review of the global consequences of La Niña events over time, a project that will prove invaluable to researchers and policymakers alike especially if the results of the outlier GFDL-ESM2M model output prove to have been correct, is now warranted.

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