Climate Change Adaptation of Urban Dwellers: A Case Study in Lima, Peru

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ABSTRACT

Given climate change projections and the insufficient global mitigation efforts, scholars have increasingly investigated adaptation options for social and ecological systems. Climate change scholars have engaged in examining what drives societies to adapt, predominantly by theorizing the determinants and resources that enhance the capacities to adapt, and assessing the emerging governance of adaptation. Research findings show that governments face numerous constraints for adaptation, including social barriers as individuals contest policies that challenge their own beliefs or their social expectations. However, the understanding of what motivates individuals to adapt remains limited and fragmented, even more so across urban contexts of developing countries. The adaptation of urban dwellers has remained at the margins of the adaptation literature. To put adaptation policies into action in urban areas, governments need to comprehend how urbanites are responding to climate change threats and what drives them to adapt. This requires a conceptualization of urban dwellers' agency within the normative structures of their socio-urban milieus. My dissertation examines urbanites' adaptation to climate change in the Global South context, examining the normative and behavioral aspects of adapting. The aim of this thesis is to identify, characterize, and evaluate urban adaptation to climate change threats to water security in Lima, Peru.

First, I evaluate the scientific assessment of adaptive capacity in urban areas of developing countries. I identify key gaps in the literature, including a narrow focus on the range and types of adaptive capacity; limited assessment of the multilevel determinants, place-based processes, and urban determinants that shape adaptive capacity; and a lack of consideration of adaptive capacity interactions between social entities and with regard to climate sensitivity and exposure of a given area. Second, I carry out a case study in Lima, Peru building on the case of residents' responses to the extreme events brought by the 2017 El Niño Costero, which is used as a temporal analogue. The case study involved seven months of fieldwork in Lima, where I conducted over 130 in-depth interviews with residents, policymakers, and stakeholders, and 400 surveys with dwellers. For this study, I advanced a conceptual approach to understanding adaptive capacity as a process that looked at both the behavioral and the institutional factors shaping adaptive capacity. The interrelation of residents' cognitive processes with evolving social norms lead to strategies for

dealing with climate change in line with coping, sustainability, morality, technology, and laissezfaire approaches. The findings shed light on the diversity of adaptative strategies within an urban milieu and highlight the need to understand the multiple paths that lead to adaptive behavior. Building on the qualitative results of the case study, I developed a survey instrument and then used regression analyses to identify the significant socioeconomic, socio-institutional, and psychological determinants of individuals' intentional and non-intentional adaptive behavior. Findings show that education, extended water availability, climate change concern, and cultural environmental values are significant determinants.

Throughout the dissertation, I reflect on the socio-environmental inequalities that structure how dwellers experience climatic hazards and perceive climatic risks, the persistence of gender norms in mediating coping and adapting responses, the established and emergent social norms in regards to water-use and how these are affected by social trust, the dynamics between urban social groups and its effects in responding to climate change, and the importance of residents and authorities relationship in framing adaptation paths. I further discuss the limits of conceptualizing and measuring adaptive capacity and behavior only through a socio-economic lens, the problematic assumption that the sole experience with extreme climatic events leads to increased adaptation, and the need to contextualize the use of psychological distance to climate change to the realities of individuals in the Global South.

RÉSUMÉ

Compte tenu des projections du changement climatique et de l'insuffisance des efforts mondiaux d'atténuation de ce dernier, les chercheurs étudient de plus en plus les options d'adaptation des systèmes sociaux et écologiques. La recherche a examiné ce qui pousse les sociétés à s'adapter, principalement en théorisant les déterminants et les ressources qui améliorent les capacités d'adaptation, et en évaluant la gouvernance émergente de l'adaptation. Les résultats de ces travaux montrent que les gouvernements sont confrontés à de nombreuses contraintes d'adaptation, y compris des barrières sociales lorsque les individus contestent les politiques qui remettent en question leurs croyances ou leurs attentes sociales. Cependant, la compréhension de ce qui incite les individus à s'adapter reste limitée et fragmentée, et ce, de façon plus marquée dans les contextes urbains des pays en développement. La question de l'adaptation des citadins demeure marginale dans la recherche sur l'adaptation. Pour mettre en œuvre les politiques d'adaptation dans les zones urbaines, les gouvernements doivent comprendre comment les citadins réagissent aux menaces du changement climatique et sur ce qui les pousse à s'adapter. Cela nécessite une conceptualisation de leur action au sein des structures normatives de leurs milieux socio-urbains. Cette thèse se penche sur l'adaptation des citadins au changement climatique dans le contexte du Sud Global, en examinant les aspects normatifs et comportementaux de l'adaptation. L'objectif est d'identifier, de caractériser et d'évaluer l'adaptation urbaine face aux menaces que posent le changement climatique sur la sécurité de l'eau à Lima, au Pérou.

Premièrement, la thèse examine l'évaluation scientifique de la capacité d'adaptation dans les zones urbaines des pays en développement. Des lacunes clés sont ainsi identifiées dans la recherche existante, y compris une focalisation étroite sur la gamme et les types de capacités d'adaptation; une évaluation limitée des déterminants multi-niveaux, processus locaux et déterminants urbains qui façonnent la capacité d'adaptation; et un manque de prise en compte des interactions de capacité d'adaptation entre les entités sociales au regard de la sensibilité et de l'exposition d'une zone donnée. Deuxièmement, une étude de cas a été mené à Lima, au Pérou, en se basant sur les réponses des résidents aux événements climatiques extrêmes provoqués par le phénomène El Niño Costero de 2017, utilisée ici comme analogue temporel. L'étude de cas a impliqué sept mois de travail sur le terrain à Lima, où ont été effectué plus de 130 entretiens approfondis avec des résidents, des décideurs et des parties prenantes, et une enquête auprès de

400 habitants. Pour cette étude, il est proposé une approche théorique pour comprendre la capacité d'adaptation en tant que processus. Cette approche examine à la fois les facteurs comportementaux et institutionnels qui façonnent la capacité d'adaptation. La corrélation entre les processus cognitifs des résidents et l'évolution des normes sociales conduit à l'adoption de cinq types de stratégies d'adaptation correspondant à des approche associée à la capacité de faire face (*coping*), à la durabilité, la moralité, la technologie et au laissez-faire. Les résultats révèle la diversité des stratégies adaptatives en milieu urbain et mettent en évidence la nécessité de comprendre les multiples voies menant au comportement adaptatif. En se fondant sur les résultats qualitatifs de l'étude de cas, une enquête a été développé. Elle a été utilisé lors des analyses de régression pour identifier les déterminants socio-économiques, socio-institutionnels et psychologiques significatifs du comportement adaptatif, intentionnel et non intentionnel. Les résultats montrent que l'éducation, la disponibilité accrue de l'eau, les préoccupations liées au changement climatique et les valeurs environnementales culturelles sont des déterminants importants.

La thèse aborde les inégalités socio-environnementales qui structurent la façon dont les habitants vivent les aléas climatiques et perçoivent les risques climatiques; la persistance des normes de genre qui influencent les réponses d'adaptation; les normes sociales établies et émergentes en matière d'utilisation de l'eau et comment celles-ci sont affectées par la confiance sociale; la dynamique entre les groupes sociaux urbains et ses effets sur la réponse au changement climatique; et l'importance des relations entre les habitants et les autorités dans la définition des avenues d'adaptation. Cette thèse traite en outre des limites de la conceptualisation et de la mesure de la capacité et du comportement d'adaptation uniquement à travers une approche socio-économique; de la supposition selon laquelle la seule expérience des événements climatiques extrêmes conduit à une adaptation accrue; et de la nécessité de contextualiser l'utilisation de la distance psychologique au changement climatique afin de tenir compte des réalités des individus vivant dans le Sud Global.

RESUMEN

A la luz de las proyecciones del cambio climático y los insuficientes esfuerzos globales de mitigación, los investigadores han explorado cada vez más las opciones de adaptación para los sistemas sociales y ecológicos. Por ello, la investigación académica en cambio climático se ha enfocado en examinar lo que conduce a las sociedades a adaptarse, principalmente teorizando cuáles son los determinantes y recursos ligados a la capacidad de adaptación y evaluando la gobernanza de la adaptación emergente. Las investigaciones han demostrado que los gobiernos enfrentan muchas limitaciones para ejercer y fomentar la adaptación, incluyendo barreras sociales, ya que los individuos no responden como se espera a las políticas que desafían sus creencias o sus expectativas sociales. El conocimiento sobre lo que incentiva a las personas a adaptarse sigue siendo limitado y fragmentado, más aún en los contextos urbanos de los países en desarrollo. Hasta este momento, la adaptación de las poblaciones urbanas se ha mantenido al margen de la investigación sobre adaptación. No obstante, para implementar políticas de adaptación en áreas urbanas, los gobiernos necesitan comprender cómo los habitantes de las ciudades responden a las amenazas del cambio climático y qué los impulsa a adaptarse. Para ello, se necesita una conceptualización sobre la agencia de los pobladores dentro de las estructuras normativas de los entornos socio-urbanos. Tomando en cuenta las dimensiones normativas y conductuales, la tesis examina la adaptación de los residentes urbanos al cambio climático en el contexto del Sur Global. Su objetivo es identificar, caracterizar y evaluar la adaptación urbana a las amenazas del cambio climático sobre la seguridad hídrica en Lima, Perú.

En primer lugar, la tesis evalúa los estudios científicos sobre la capacidad de adaptación en áreas urbanas de países en desarrollo. Los resultados muestran sustanciales vacíos en la literatura, incluyendo un enfoque limitado en el rango y los tipos de capacidad adaptativa considerados; una evaluación limitada de los determinantes de multinivel urbanos y de los procesos locales que moldean la capacidad de adaptación; y, por último, una falta de análisis de las dinámicas de la capacidad adaptativa, entre entidades sociales, y en relación con la sensibilidad y la exposición de un área determinada. En segundo lugar, la tesis desarrolla un estudio de caso en Lima, Perú. Dicho estudio se basa en las respuestas de los limeños a los eventos extremos causados por El Niño Costero de 2017, el cual se utiliza como un análogo temporal. El estudio de caso implicó siete meses de trabajo de campo en Lima, donde se realizó más de 130 entrevistas en profundidad con

residentes, formuladores de políticas y stakeholders, y 400 encuestas a residentes de la ciudad. Para este estudio, se desarrolló un marco teórico para entender la capacidad adaptativa como un proceso, analizando los factores conductuales e institucionales que median la capacidad de adaptación. La interrelación entre los procesos cognitivos de los residentes y las normas sociales, establecidas y emergentes, conduce a cinco tipos de estrategias de adaptación: afrontamiento, sostenibilidad, moralidad, tecnología y laissez-faire. Los resultados demuestran la diversidad de estrategias adaptativas dentro del entorno urbano y, por ende, la necesidad de comprender las múltiples vías que conducen al comportamiento adaptativo. En tercer lugar, tomando en cuenta los resultados cualitativos previos, se desarrolló una encuesta y se efectuó un análisis de regresión, con el objetivo de identificar los determinantes socio-económicos, socio-institucionales y psicológicos del comportamiento adaptativo, intencional y no intencional. Los resultados muestran que la educación, una mayor disponibilidad de agua, la preocupación sobre el riesgo del cambio climático y los valores culturales ambientales son determinantes significativos.

La tesis toma en consideración las desigualdades socio-ambientales que estructuran la forma en que los habitantes experimentan las amenazas climáticas y perciben los riesgos climáticos, la persistencia de las normas de género que median las respuestas de afrontamiento y adaptación, las normas sociales establecidas y emergentes sobre el uso del agua y cómo éstas se ven afectadas por la confianza social, la dinámica entre los grupos sociales urbanos y sus efectos en la respuesta al cambio climático, y la relación entre los pobladores urbanos y sus autoridades, la cual demarca los posibles caminos para la adaptación. Además, la tesis discute las limitaciones de conceptualizar y medir la capacidad de adaptación y el comportamiento adaptativos sólo a través de un enfoque socioeconómico, el supuesto discutible de que el mero hecho de experimentar eventos climáticos extremos conduce a una mayor adaptación y la necesidad de contextualizar el uso de la distancia psicológica al cambio climático con las realidades de los ciudadanos de países en desarrollo.

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FORMAT OF THE THESIS

This doctoral thesis is submitted following the manuscript format, with three papers suitable for journal publication. This format is approved by McGill University and its Faculty of Graduate and Postdoctoral Studies.

The chapters of this thesis are submitted in the format in which they were submitted for publication, each chapter with its own reference list. The chapters are integrated into a cohesive dissertation with connecting texts that describe the links between the different chapters. At the end of the manuscript, a comprehensive reference list is provided, which includes all the references cited throughout the document, as well as the supplementary materials mentioned in each chapter.

AUTHOR CONTRIBUTIONS

This thesis includes three manuscripts that are either published or in review. These manuscripts were written with co-authors, whose contributions are as follows.

Chapter 2: "*Adaptive capacity in urban areas of developing countries*" by Camila Flórez Bossio (primary author), James Ford and Danielle Labbé

Camila Flórez Bossio led the conceptual development of the manuscript, data collection, data analysis, and manuscript preparation. James Ford contributed feedback throughout the research development stage, and provided comments on the preparation of the manuscript. Danielle Labbé provided feedback during the development of the article and reviewed and commented on the manuscript.

Chapter 3: "*Urban Dwellers' Adaptive Capacity as a Socio-psychological Process: Insights from Lima, Peru*" by Camila Flórez Bossio (primary author), Danielle Labbé and James Ford Camila Flórez Bossio led the conceptual development of the manuscript, data collection, data analysis, and manuscript preparation. Danielle Labbé and James Ford contributed feedback throughout the research development stage, and reviewed and commented on the manuscript.

Chapter 4: "What Motivates Urban Dwellers to Adapt to Water Insecurity? An Empirical Study in Lima, Peru" by Camila Flórez Bossio (primary author), Oliver Coomes and James Ford Camila Flórez Bossio led the conceptual development of the manuscript, data collection, data analysis, and manuscript preparation. Oliver Coomes contributed feedback throughout the research development stage and during data analysis, and provided comments on the preparation of the manuscript. James Ford provided guidance and feedback during the development of the article and reviewed and commented on the manuscript.

PUBLICATION DETAILS

Chapter 2: "Adaptive capacity in urban areas of developing countries" is published in *Climatic Change*. It can be found at:

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Chapter 3: "Urban Dwellers' Adaptive Capacity as a Socio-psychological Process: Insights from Lima, Peru" is under review at Climate Risk Management (August 2020).

Chapter 4: "What Motivates Urban Dwellers to Adapt to Water Insecurity? An Empirical Study in Lima, Peru" is under review at Environmental Science and Policy (March 2021).

CHAPTER 1: Introduction

1.1 Background

The world is experiencing the impacts of climate change, having already warmed by 1°C above pre-industrial levels and continuing to increase by 0.2°C per decade (Allen et al., 2018). Following the recognition that more is needed than mitigation efforts, a large body of literature emerged in the 2000s to address the adaptation of social and ecological systems (Bassett & Fogelman, 2013; Ford et al., 2018; Ribot, 2011). Adaptation refers to the actions to reduce the vulnerability¹ of a system (social or ecological) to the impacts of climate change (Smit & Wandel, 2006). Scholars have developed theoretical approaches to examine the nature of vulnerability and identify adaptation options and paths. Adaptation has often been operationaled through the concept of 'adaptive capacity', understood as the result of a sum of resources possessed by a social entity to adapt to the effects and consequences of climate change (Heinrichs et al., 2013). This operationalization has been useful to measure and compare different degrees of preparedness for adaptation, but has limited power in explaining how adaptive practices emerge from the sum of resources (Adger & Vincent, 2005; Mortreux & Barnett, 2017; Toole et al., 2016). A limited and fragmented understanding of what fosters individuals to adapt to climate change remains (Bechtoldt et al., 2020), even more so across urban contexts of developing countries.

This dissertation contributes to the adaptation literature by examining the normative and behavioral aspects of adapting to climate change, and using a temporal analogue² to do so. The aim is to identify, characterize, and evaluate urban adaptation to climate change threats to water security in Lima, Peru, enhancing the understanding of individual-level adaptation within a sociourban context of the Global South, and advancing a theoretical framework that integrates the agency of urbanites with their socio-normative context. The thesis relies on a mixed-method research design, drawing on qualitative document analysis, semi-structured interviews, and surveys to examine urbanites' adaptive capacity and behavior.

In this introductory chapter, I describe the background for my thesis regarding the importance of studying climate change adaptation in urban areas, particularly of urbanites in the Global South. Then, I describe the research context in Lima, explaining the relevance of studying adaptation in

¹ Vulnerability refers to the susceptibility to harm.

² Temporal analogue refers to the use of past or present past sensitivity and adaptation to climatic variations change and extremes to provide insights for vulnerability to climate change (Ford et al., 2010; Magalhães & Glantz, 1992)

this city. This is followed by the research problem, aim, questions, and objectives of the thesis. Then, I present the background literature review synthesizing the current state of research on water security, and adaptation to climate change. Further, I describe the methodological considerations that guide the research design. Finally, I provide an overview of the remaining chapters in the thesis and their relationship to the research questions raised.

1.1.1 Climate change and urban areas

The latest IPCC report (Revi et al., 2014, p. 538) states that "much of key and emerging global climate risks are concentrated in urban areas", where more than half of the world population lives. Although the increasing urban population across the world means greater opportunities for adaptation due to the economic, political, and cultural resources that it enhances, it also means that risks are more concentrated if they are not acted on (Allen et al., 2018). As urban areas concentrate populations and infrastructure, they have increased exposure and sensitivity to potential climate-related hazards (Birkmann et al., 2010; Pelling, 1999; Wilbanks et al., 2007). Climate change-related risks to urban areas include rising sea levels and storm surges, heat stress, extreme precipitation, inland and coastal flooding, landslides, drought, increased aridity, water scarcity, and air pollution (Field et al., 2012; Revi et al., 2014a). A common thread of the identified risks is the threat they pose to water security.

Water security denotes accessible and sufficient good quality water for social, economic, and cultural uses, while sustaining ecosystem functions (de Loë et al., 2007), and within an acceptable level of water-related risks to social and ecological systems (Grey & Sadoff, 2007). Water security in developing countries is an ongoing challenge. Many cities struggle to deliver even basic services to their residents, especially those living in informal settlements. Scholars have identified that current patterns of urbanization and environmental change affect water security. This happens through land-use changes coupled with urban social practices and the associated transformations of ecosystems and hydrological systems (Romero-Lankao & Gnatz, 2016). Then, as urban areas in developing countries continue growing, demand and competition for limited water resources increases, and climate change is likely to make these pressures worse. Climate change brings extreme climatic events and unpredictable rainfall patterns that can lead to more frequent and intense droughts and inland floods, compromising water quantity and quality (Kashyap, 2004; WWAP, 2019). The use of unsafe water exacerbates malnutrition, leads to infectious diseases, and

it is already a main global health risk factor responsible of responsible for 1.2 million deaths each year (Murray et al., 2020). Thus, climate change threats to water security can have enormous consequences on human health and well-being (UN-Habitat & WWAP, 2010; WHO & UNICEF, 2012; WWAP, 2019). At the same time, slow and extreme water-related hazards affect citizens' livelihoods, economic development, by undermining the production of agricultural and industrial goods, and damaging essential city infrastructure that allows the well-functioning of urban life (Damania et al., 2017; Rosenzweig et al., 2018a; Satterthwaite et al., 2007; UN-Habitat, 2011; Wilbanks et al., 2007; WWAP, 2019).

A high proportion of the world's population most affected by extreme weather events is concentrated in urban areas, and of these, the majority live in low and middle-income countries (IFRC, 2010; UNISDR, 2009, 2011). The main differences between urban areas in the Global North and the Global South are the governmental capacities to respond to climatic risks, and the existing infrastructure and services that affect how dwellers experience climate change (Allen et al., 2018). In urban areas located in the Global North, infrastructure and basic services are provided across urban social groups, and safeguards are set to prevent dwellers from settling in high-risk areas (Allen et al., 2018). In contrast, urban areas located in the Global South tend to have a large deficit in infrastructure and service provision, and the distribution and quality of services significantly vary between income groups (Mitlin & Satterthwaite, 2013). Hence, it is in the Global South where urban dwellers are disproportionately vulnerable to climate change (Allen et al., 2018).

1.1.2 Current research on urban adaptation

Following climate change projections, scholarly interest rose in the last decade to examine climate risks to urban areas (Meerow & Mitchell, 2017; Rosenzweig et al., 2018a). Scholars have primarily focused on urban areas' exposure to climatic events, assessing how the geographical characteristics of urban areas make residents vulnerable to climate change impacts (Inostroza et al., 2016; Leichenko, 2011; Zhu et al., 2014). To a lesser degree, scholars have examined the underlying socioeconomic structures and institutional factors that shape the vulnerability of urban populations (Romero-Lankao & Qin, 2011), evaluating dwellers' livelihood strategies, housing conditions, and neighborhood services (Ajibade & McBean, 2014; Lwasa, 2010; Moser & Satterthwaite, 2008; Pelling, 1999, 2003). This research has shed light on the exposure of urban

settlements to climate change and explained the contextual vulnerabilities of urban social groups, but it has paid little attention to the process of urban adaptation. Empirical research that does address urban adaptation predominantly focuses on the public sphere by examining adaptation governance. This focus may be due to the fact that governments are responsible of ensuring city services to residents, and urbanites have been mainly considered as recipients of adaptation plans in regards to such services.

Researchers have examined multiple themes of relevance to climate change adaptation in urban areas, including the integration of adaptation in development and urban planning policies, the internal and external factors shaping urban public responses, the institutional changes and strategies used in adaptation planning, the role and responsibility of urban authorities in facilitating adaptation, the governmental institutional capacity to reduce the vulnerability of the urban poor, the interaction between public and private adaptive capacity, and the engagement of civic organizations in designing adaptation plans (Anguelovski et al., 2014; Carmin et al., 2012; Dodman & Satterthwaite, 2008; Hughes & Sarzynski, 2015). Across these research themes, scholars emphasize the critical role of local governments in promoting climate change adaptation by managing and improving services, protecting vulnerable sectors, sharing knowledge of risks, and coordinating with relevant organizations (Carmin et al., 2012; Dodman & Satterthwaite, 2008; Hunt & Watkiss, 2011; Jerneck & Olsson, 2008; Revi et al., 2014a; Sanchez-Rodriguez, 2009). However, research findings show that local governments face numerous constraints for adaptation, including knowledge and understanding barriers, regulatory barriers, capacity constraints, and social barriers, which include institutional and behavioral ones (Baker et al., 2012; Jones, 2010; Lehmann et al., 2015; Measham et al., 2011).

The social barriers identified in the literature shed light on the challenges of adaptation policymaking. As seen in other non-urban realms, individuals do not always respond as expected to policy measures (Beratan, 2007; Eakin et al., 2016b; Hamilton et al., 2018; Truelove et al., 2015). Citizens contest policies that challenge their own beliefs or their social expectations. To put adaptation policies into action, governments need to comprehend how citizens adapt to change and uncertainty and what shapes their ability to respond to hazards (Bechtoldt et al., 2020; Fatti & Patel, 2013). Thus, advancing urban adaptation to climate change requires an in-depth understanding of what drives urbanites to adapt (Brink & Wamsler, 2019; Helm et al., 2018). It is

also important to consider that not all adaptive responses to climate change will be governmentally planned. Adaptation scholars understand that societies have inherent capacities to adapt to climate change and that these are bounded by individuals' ability to act together (Adger et al., 2004). Both private and public actors will deal with increased climate variability, either with anticipatory or reactive responses. Although the international climate science community recognizes that cities and their residents have already begun to experience the effects of climate change, research on how urbanites adapt is still in its infancy. Understanding how dwellers cope with fast and slow climatic events, changing their habits and lifestyles to adapt to the new climatic conditions is critical. Only then, it will be possible to design adaptation policies that respond to the myriad of residents' needs, and that successfully incentivizes the uptake of adaptation responses.

An understanding of adaptation is needed across urban regions, as adapting to climate change is a context-contingent process (Leichenko, 2011; Romero-Lankao et al., 2014; Shi et al., 2016). Urban areas will not be affected the same way because changes will not occur gradually or at consistent rates of change across cities and towns (Bader et al., 2018). Although more than a third of the world's population lives in urban areas of low and middle-income countries, and these urban areas have the highest population growth rates, the vulnerability and adaptation of urbanites of the Global South have received little attention compared to the attention paid to rural populations (Birkmann et al., 2010; Garschagen & Kraas, 2011; Satterthwaite et al., 2007). The vulnerability of rural and urban populations differ considerably as only rural livelihoods rely directly on nature, while urbanites have non-natural resource-based livelihood strategies (Tacoli & Satterthwaite, 2014). Then, if urbanites do not directly depend on nature for their livelihoods, what explains their vulnerability? Urban areas in developing countries usually have inherently vulnerable populations due to place-based processes (e.g., socio-spatial inequalities, settlements in high risk areas, livelihoods within informal economy) that increase the sensitivities and decrease their populations' adaptive capacity (Anguelovski et al., 2014; Carmin et al., 2012; Pelling, 2003; Satterthwaite et al., 2007). The IPCC report concludes that dwellers' adaptive capacity depends on the provision and quality of public services, the capacity for investments and land use management, and the health and safety standards of infrastructure (Revi et al., 2014a). Accordingly, adaptation is intrinsically linked to the development progress of nations (Sanchez-Rodriguez, 2009). As scholars recognize the vulnerability of developing countries, adaptation research should not disregard the agency of its residents, who are vulnerable to climate change, but can also take actions in response to the risks.

1.2 Study Context: Lima, Peru

This section describes the relevance of Lima, Peru, as a case study for urban adaptation. First, I review the history of Lima from a socio-urban perspective, highlighting the city's relationship with water, and then I describe current climate change threats to water security in the city.

1.2.1 Lima's Socio-Urban Development

Lima is situated in the valleys of the Chillon, Rimac, and Lurin River, with a history of settlement reaching back more than 11,000 years (Rostworowski, 1978), and today is a mega-city of approximately 10 million people spread over a territory of 2,819 km² (INEI, 2015). Lima's initial population was scattered in low-density settlements. This began to change around 1750 BC when the population started converting the desert into productive valleys irrigated by water canals (Del Busto, 1986; Williams León, 1986). The canals were maintained by the Pre-Incan civilizations and the Inca Empire through the fifteenth century (Córdova Aguilar, 1989). Lima's designation as the capital of the Viceroyalty of Peru in 1535 impacted its design and growth, evolving to a chess grid pattern with its urban core been surrounded by a wall (Ortiz de Zevallos, 1986). Only when the wall was taken down in the nineteenth century did the city expand onto surrounding agricultural lands (Williams León, 1986). Through the twentieth century, the expansion of water pipelines and the opening of irrigated parks became important elements of urban modernization for the growing population (Ioris, 2016).

In the early years of the twentieth century, 140,000 inhabitants lived in Lima (Córdova Aguilar, 1989). This figure increased dramatically from the 1950s until the 1970s due to a massive inmigration from other provinces to the capital (5% average annual growth rate) changing the pace of socio-urban development (Matos Mar, 1986, 2012). The in-migration process required an intense and rapid expansion of all the urban services (i.e., energy, water, transport, education). However, the expansion of the services was slow, leading to unplanned self-built settlements around the urban core through the occupation of private and public lands (Zolezzi & Calderón, 1985). Since the 1960s, private and public organizations organized new formal urban settlements, yet informal settlements continued to develop without governmental support (Durand, 2015). Urban growth was not homogenous, with significant differences between districts due to their urbanization process (Calderón Cockburn, 2017), which enhanced social segregation in Lima (Cotler, 2007; Matos Mar, 2012). This started to shift during the 1990s, when socio-economic characteristics and ways of grouping the population did not conform large homogenous areas anymore (Fernández de Córdova et al., 2016).

In the twenty-first century, the joint areas of Lima and Callao, two distinct regional administrative entities, comprised the metropolitan city of Lima (see Figure 1). Further, the metropolitan city was divided into 50 districts, each with its own municipality³. Lima is usually described as having four geographic subregions -- Lima Norte, Lima Sur, Lima Este, Lima Centro (see Figure 2). The metropolis has evolved into a polycentric city that has multiple centers in addition to the historical center. These sub-centers are focused on either financial, industrial, combined industrial-commercial, or only commercial centers (Fernández de Córdova, 2012). Today, the social composition of districts is heterogenous with scattered degrees of diversity in terms of migrant origin, socio-occupational categories, and per capita income (Fernández de Córdova, 2012). However, income inequality is still reflected with a gradient of the highest income in Lima Centro, towards a decrease to middle and medium-low incomes in the peripheries (Lima Este, Lima Sur, Lima Norte) (Fernández de Córdova et al., 2016). Moreover, neighborhoods' population densities are considerably different. In a general trend, the lower-income districts have high density whereas higher-income districts have low density. Nevertheless, there is an evident densification of central areas (high-, middle- and low-income districts) (Fernández de Córdova et al., 2016). A couple of districts of Lima Sur and Lima Este remain with low densities as these districts include large recreational and agricultural areas, respectively.

As mentioned above, Lima is home to approximately 10 million people, which is 33% of the national population and is growing at a rate of 1.5% per year (INEI, 2016). Since 2003, policies promoting affordable housing for different socioeconomic strata have triggered a revitalization of the real estate market (Fernández-Maldonado & Bredenoord, 2010). The city has changed its horizontal expansion to a vertical expansion process, changing the urban fabric. However, the lack of land for urbanization for low-income groups and the low investment in this sector continues to

³ For a detailed description of each district see Matos Mar (2012).

lead people to construct their homes in floodplains and high-risk areas (Durand, 2015) while public services continue to lag behind the expansion of the city (Durand, 2015; Fernández-Maldonado, 2008; Ioris, 2016; Mesclier et al., 2015). In 2017, 10% of dwellers lacked access to the water supply network⁴. These people are compelled to buy water from water trucks, or use water wells and public fountains (Barde & Lehmann, 2014; Mesclier et al., 2015). The deficient expansion of city services is incommensurable with Lima's economic development; it produces more than 40% of the national GDP (INEI, 2020). Again, district municipality services significantly differ between high-, middle- and low-income districts (Fernández de Córdova et al., 2012), notably in terms of water provision.

The urban processes described above have transformed the city's territory and its society profoundly. Martuccelli (2015) synthesizes Lima's social transformation as the result of parallel structural changes. The intense urban expansion, the Andean immigration, the political party system collapse, the political violence between the 1980s and 2000s, and the neoliberal economic turn have led to a new urban sociability based on popular culture, and a new individualism reigns in social interactions. In this fragmented urban milieu, dwellers face multiple risks in their day-to-day, from political instability to water insecurity. Climate change poses new threats to the city, challenging the social fabric to address current sensitivities shaped by socio-environmental inequalities and to enhance resilience city-wide.

⁴ This figure was provided by a water utility representative during an interview in July 2017.





Source: Durand - L'Espace géographique, 2015 (Mesclier et al., 2015)





Source: INEI (2014)

1.2.2 Lima's Water Security Under a Changing Climate

Although Lima lies on the Chillón, Rímac, and Lurin basins, the city has scarce water resources. Almost the entire water supply depends on the meltwater of the Andean glaciers and the precipitation from upper watersheds. The Rímac River provides 69% of the surface water supply, with a flow of 17 m^3 /s in the dry season (May-November) and 45 m^3 /s in the rainy season (December – April). The Chillón River has an average annual flow of 7.8 m^3 /s, with a very strong seasonal variability, from 17.5 m^3 /s in rainy periods to 3 m^3 /s in the dry season. The Lurin River is the smallest in the basin with an average annual flow of 4.5 m^3 /s, 11.4 m^3 /s in the wet season, and 1 m^3 /s in the dry season. The city also has groundwater stored in two aquifers: Chillón-Rímac and the Lurín aquifers. The three rivers provide 83% of the city's water supply, and the 17% remaining is obtained from the aquifers (Aquafondo, 2016).

Lima is considered to have chronic water scarcity. A given area is considered to be waterstressed when the availability of freshwater per capita is between 1,000 and 1,700 m³, and waterscarce when the availability is below 1,000 m³. Currently, the total annual per capita water availability of Chillón, Rímac, and Lurín basins' is 125 m³ (Aquafondo, 2016). Moreover, the city's water supply is endangered because the upper watersheds have receding aquifers and degraded catchments, due to illegal mining practices, over-extraction of groundwater, and untreated wastewater (Observatorio del Agua, 2019).

In this water-scarce and endangered water context, the groups within the growing population compete for water (GIZ, 2014; 2015). The levels of consumption within the city vary largely across districts, and perceptions on the availability and price of water are polarized between rich and poor districts' residents (LIWA, n.d.). Contrasting perceptions of water scarcity among residents are related to the fact that low-income districts that do not have water service pay higher prices per gallon of water; and the middle class, who do have water service, are less concerned about water scarcity, water pollution or global warming (World Bank, 2015). According to a World Bank study (2015), the Peruvian water utility (Sedapal) would not be able to achieve water reliability in 2040 if demand exceeds approximately 920 Mm3, regardless of future flows. While the current flow is 855 Mm3, for 2040 the highest plausible demand is of 1,800 Mm3. However, if future flows decrease, as estimated by the IPCC, Sedapal may not be able to ensure water reliability even if

future demand were less than current demand. Hence, long-term climate change impacts may leave the city under perpetual water stress (World Bank, 2015).

Climate change is a major threat to the city's water security because it leads to changes in the melting cycle of the Andes, as well as changes in rainfall patterns in the upper watersheds (Thompson et al., 2017; Vuille et al., 2008). In this region, future temperature and precipitation changes are uncertain; so, with rainfall possibly increasing or decreasing, droughts may also become more severe and more common (Pachauri et al., 2015). Three climate change scenarios have been developed for Lima in 2040 (Calvo, 2012; Miranda Sara & Baud, 2014). All scenarios suggest a temperature rise of approximately two degrees Celsius. The first scenario shows an increase of 6% of annual rainfall and increased river flows, which would increase overflows, landslides, mudslides and floods, all of which could be aggravated by extreme meteorological conditions of a higher frequency ENSO events. The second scenario shows a decrease of 9.6% in annual rainfall with a colder climate similar to La Nina phenomenon, which would lead to the presence of more extreme and permanent droughts (13.72% decrease of water flow), with impacts on water access and energy production. The third scenario entails the combination of the first and second scenarios, which would lead to permanent drought conditions with extreme events of intense rainfall. Local experts consider that the most plausible climate change scenario for Lima in 2040 is one leading to a permanent drought with extreme and intense rainfall events (Calvo, 2012; Miranda Sara et al., 2017).

1.3 Research problem

The literature on climate change adaptation literature expanded rapidly in the 2000s, developing conceptual and methodological approaches to examine the vulnerability and adaptation of social entities (Bassett & Fogelman, 2013; Ribot, 2011). Although scholars have long acknowledged the dynamic nature of human-environment interactions, research has primarily focused on describing the current state of vulnerability, neglecting how vulnerability and adaptability evolve over time (Fawcett et al., 2017; Ford et al., 2018; Magnan et al., 2016; Minx et al., 2017; Wise et al., 2014). There is a need for process-oriented approaches that explain adaptation (Wise et al., 2014). Examining adaptation should benefit from theoretical approaches that are developed beyond environmental studies, which can provide an in-depth understanding of human behavior. However, studies continue to frame vulnerability from disciplinary specializations (Ford et al., 2018),

undermining the development of more comprehensive understandings of vulnerability (Castree et al., 2014; Murphy, 2011). Further, studies that combine quantitative and qualitative approaches within an integrated methodology are missing in the literature (Ford et al., 2018).

Despite the importance of climate change adaptation and the number of urban people at risk, research on vulnerability and adaptation of urban populations in developing countries has received little attention compared to the vulnerability of rural populations (Birkmann et al., 2010; Garschagen & Kraas, 2011; Satterthwaite et al., 2007). However, urbanite adaptation cannot be analyzed and explained on the basis of research undertaken in rural areas. Reliance on nature in rural areas may have an influence on perceptions of environmental risk and thus peoples' responses to such risks. Previous research has shown clear differences between rural and urban populations in environmental attitudes and actions (Berenguer et al., 2005; Huddart-Kennedy et al., 2009). These differences may then influence how rural and urban populations respond differently to climate change. The specific determinants of urban populations' adaptability have not been addressed yet.

The growing trend of research on urban areas has primarily focused on exposure to climate risks resulting from urbanization. The sensitivity and adaptive capacity to climate change are insufficiently represented in urban research, and their understanding is limited (Garschagen & Romero-Lankao, 2015). While existing research connects weak adaptive capacity with increased vulnerability, understanding what fosters adaptive capacity across developing countries' urban contexts is limited and fragmented. There is a need to understand how socio-cultural and urban processes shape urban adaptive capacity in developing world contexts. A comparison of adaptive capacity across urban contexts would allow a better understanding of urban adaptation, and aggregating knowledge for scientific policy advice.

Further, the existing empirical research on urban adaptation is strongly oriented towards policy and governance questions at the city scale, examining governments' capacities for adaptation and evaluating adaptation planning (Meerow & Mitchell, 2017; Rosenzweig et al., 2018a). This scholarship has raised significant questions, but we should not disregard the equal necessity to examine urban adaptation at the individual level, as has been approached in climate change rural studies (Beratan, 2007; Eakin et al., 2016b; Hamilton et al., 2018; Truelove et al., 2015). Addressing individual-level adaptive capacity underscores urbanites' agency in dealing with climate change, instead of assigning dwellers a merely passive role in the process of adaptation. Such knowledge is also needed to understand urbanites' responses to government-led adaptation plans and interventions, and ultimately improve adaptation policies' effectiveness and enhance the adoption of positive autonomous adaptive actions (Brink & Wamsler, 2019; Helm et al., 2018).

The understanding of what motivates urban dwellers to adapt is limited. There is a need to examine how adaptive capacity translates into actions and practices that increase resilience (Mortreux & Barnett, 2017). It is crucial to investigate if the theoretical underpinnings of adaptive capacity drive behavior and to what degree such behavior is intentional. The emerging line of research on the psychological antecedents of individuals' adaptive behavior (Bradley et al., 2020; Clayton et al., 2015; Cologna & Siegrist, 2020; Domingos et al., 2018; Reser et al., 2012), mostly focuses on urban areas located in the Global North (Amoah & Addoah, 2020; Carman & Zint, 2020; González-Hernández et al., 2019; Zander et al., 2019). Reviewing Carman & Zint (2020)'s systematic review of adaptive behavior database, from seventy-five studies assessed, I identify only forty empirical studies at the individual level (i.e., excluding studies only assessing households and those that only assess policy support). From those empirical studies, eight focus on developing countries, yet none of these have been conducted in Latin America. How can we explain that residents of the Global South, who already face multiple risks (Arku et al., 2017; Jabeen et al., 2010; Pelling & Wisner, 2012), undertake to adapt to climate change?

1.4 Research aim, questions, and objectives

This study responds to the research gaps outlined above by examining how urban areas of developing countries deal with climate change threats. The aim of this research is to identify, characterize, and evaluate urban adaptation to climate change threats to water security in Lima, Peru. The following three research questions guide the thesis.

1. How is the capacity to adapt to the effects of climate change in urban areas of developing countries being assessed in the scientific literature?

2. What characterizes the capacity of Lima residents to adapt to climate-related risks to water security?

3. To what extent, and how, do socio-economic, socio-institutional, and psychological determinants explain adaptive behavior of Lima residents?

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The thesis addresses each research question and is structured around the following four objectives.

Objective 1. To examine and evaluate the scientific assessment of urban capacity to adapt to climate change in developing countries.

Objective 2. To develop a theoretical framework to understand climate change adaptation of urbanites in developing countries.

Objective 3. To identify and characterize the capacity of urban residents to adapt to climate threats to water security in Lima.

Objective 4. To examine the relationship between socioeconomic, socio-institutional, and psychological determinants of adaptive behavior.

1.5 Background Literature Review

In this section, I summarize the relevant literature that this thesis builds upon. First, I describe the evolving concept of 'water security.' Second, I describe the core theoretical understandings of adaptation to climate change. And third, I review the environmental behavior and new institutionalism approaches to frame individual-level adaptation in the urban milieu. I provide a systematic literature review on urban adaptive capacity in Chapter 2.

1.5.1 Water security

In the quest to govern water, the concept of water security emerged. Broadly, water security refers to the goal of ensuring "an acceptable level of water-related risks to humans and ecosystems, coupled with the availability of water of sufficient quantity and quality to support livelihoods, national security, human health, and ecosystem services" (Bakker, 2012, p. 914). Even though the concept is considered to be complex, dynamic, and contested (Allan et al., 2013; Bakker, 2012), water managers, policymakers, and scientists seem to have a general notion of what water security, or its counterpart water insecurity, means (Lankford et al., 2013).

During the last two decades, water security has received increased attention in the academic and policy realms (Bakker, 2012). Currently, research on water security involves using a conceptual framework to understand and manage the trade-offs in the use of water, and water risks (Allan et al., 2013; Lankford et al., 2013). The analysis of water security evolved to produce many framings (e.g., national security, human-centered, integrated human-environment framings)

(Mollinga, 2008; Pahl-Wostl & Knieper, 2014). The common assumption is that water security is an overarching objective in water management and governance (Zeitoun et al., 2016), shifting the emphasis in the water scholarship from a process (water management) to a goal (Varady et al., 2016).

The water security framework has been extensively used to assess the sufficiency of water supply, ensure potable water and drinking water infrastructure, evaluate the links between water and human needs, and in discerning the balance between human and ecosystem water demands (Cook & Bakker, 2012). Despite the large number of resources used in research on water security and efforts to implement the concept on the ground, 2.4 billion persons in the world remain without access to sufficient quality water (WHO & UNICEF, 2015). Persistent problems remain in sustaining improved water access (Loftus, 2015), and human pressures have driven freshwater ecosystems to be the most endangered ecosystems in the world (Naiman & Dudgeon, 2011). Scholars further argue that under a human-centered framing of water security, human water security has only been achieved at the environment's expense with long-term negative consequences (Bogardi et al., 2012; Pahl-Wostl et al., 2013). Following this framing, management strategies for water security tolerate the "degradation of ecosystems and then applying costly remediation strategies (if at all) after the damage has been done" (Bogardi et al., 2012, p. 39). In this context, climate change brings another layer of complexity to manage water. It undermines the foundational assumption of stationarity (i.e., the predictable variability of water) that water managers use to plan and design water systems (Milly et al., 2008). A human-centered approach is limited in dealing with interdependencies of the social and physical processes that affect water security and in dealing with uncertainties that come with climate change.

Against this background, alternative water security approaches emerged to include a broader set of concerns and objectives, such as environmental, equity, and democratic ones (Mollinga, 2008; Pahl-Wostl & Knieper, 2014). This shift in thinking to an integrated framing of water security led to a new conceptualization of water as a life support system by considering the links between water and land, and water and ecosystems (Falkenmark, 2001). Then, water security denotes the accessible and sufficient good quality water for social, economic, and cultural uses, adequate water to sustain and enhance ecosystem functions (de Loë et al., 2007) coupled with an acceptable level of water-related risks to social and ecological systems (Grey & Sadoff, 2007). Alternative definitions also start considering complexity and uncertainty, such as "the sustainable availability of adequate quantities and qualities of water for resilient societies and ecosystems in the face of uncertain global change" (Scott et al., 2013, p. 281). This integrated humanenvironment framing of water security incorporates the understanding that human actions, deliberate or inadvertent, can undermine an ecosystem's natural resilience to hydroclimatic variability (Garrick & Hall, 2014).

Essential to the integrated framing of water security is the assumption that there are two urgent needs: to satisfy human water demands and to secure biodiversity and ecosystem services (Bogardi et al., 2012). Further, the integrated framing involves explicitly identifying the full set of waterrelated risks that confront all actors in a given area for whom risk is potentially intolerable in analyzing water security (Garrick & Hall, 2014). Thus, the integrated analysis requires tolerable trade-offs to ensure a level of water security in a system. As Garrick & Hall (2014, p.620) explain, "[t]rade-offs can materialize at multiple scales, which renders problematic the question of the appropriate scale of assessment and decision making.". Most studies have traditionally operationalized water security at the national, regional, or large watershed levels (Cook & Bakker, 2012), often overlooking people's perceptions about water security (Gerlak & Mukhtarov, 2015; Huang et al., 2015). As de Loë (2007) suggests, the achievement of water security depends on the decisions made by many actors, from individual water users to governments at all levels. Choosing alternative analytical scales (e.g., individual, district) to understand water security is valuable as water occupies multiple and overlapping socioecological scales (Bolin et al., 2008; Budds & Hinojosa, 2012; Cohen & Davidson, 2011; Garrick & Hall, 2014). Therefore, according to Zeitoun et al. (2016), integrated framings of water security will result in policy recommendations that are more context-specific and better respond to local hydroclimate and social conditions, which in turn limits its generalizability and produces findings that are not politically expedient.

1.5.2 Adapting to climate change

Overall, vulnerability science aims to identify and understand the factors that put social systems at risk, analyzing where, how, and why people are affected by climate change (Cutter et al., 2003; Ford et al., 2018; McDowell et al., 2016; Räsänen et al., 2016; Wang et al., 2014). Three main conceptual approaches are used to assess vulnerability. First, biophysical vulnerability approaches, rooted in the natural sciences, understand vulnerability as an outcome of exposure to climatic

hazards. Second, social vulnerability approaches, coming from the social sciences, understand vulnerability as inherent and contextual to a system where climate change is only one of the multiple stressors. Third, integrative approaches that combine the (biophysical) exposure to climatic hazards with the (social) characteristics of systems (Bennett et al., 2016; Burton et al., 2002; O'Brien et al., 2007). Increasingly, scholars have raised concerns that vulnerability research takes place in disciplinary silos, leading to incomplete understandings of the nature and drivers of vulnerability, and to a lack of progress in accumulating knowledge on climate solutions – including adaptation and mitigation options (Ford et al., 2018; Minx et al., 2017; Wise et al., 2014).

The conceptualization of vulnerability influences how adaptation is understood (Eriksen et al., 2015b; O'Brien et al., 2007) and thus the adaptations proposed. Research has largely focused on identifying and assessing adaptation options (Biagini et al., 2014; O'Brien, 2012; Webber, 2016). Scholars evaluate the effectiveness of adaptation options (e.g., cost-benefit, trade-offs, winners and losers) (Singh et al., 2020), and the likelihood that adaptation options will take place (e.g., political leadership, availability of usable science, funding) (Araos et al., 2017; Ford & King, 2015). Recently, the assessments of adaptation have been enriched by critical adaptation research that increasingly examines the limits, thresholds, constraints, barriers, and frontiers of adaptation, considering social, cultural, economic, and political aspects (Webber, 2016). Critical scholars question adaptation research for ignoring the socio-environmental and socio-political processes that mediate adaptation, and the way that individuals are conceived as 'recipients of adaptation,' rather than active agents in the adaptation process (Eriksen et al., 2015a; Eriksen et al., 2015b; Nightingale, 2014; Ribot, 2011). Thus, scholars underscore the need for 'transformational adaptation' instead of 'incremental adaptation,' which shall address the root causes of vulnerabilities to climate change, rather than only responding to climatic exposures (O'Brien et al., 2007; Pelling, 2011). Likewise, scholars recognize that adaptation takes place in contexts of existing social relations, rather than in a political vacuum (Eriksen et al., 2015b; Wise et al., 2014). Has research responded to these calls?

To understand the process of adaptation, the concept of adaptive capacity has been widely used (Adger, 2006; Engle, 2011; Ribot, 2014). This concept broadly refers to the ability of a system (social or ecological) to perceive, cope with, prepare for, and adapt to the effects and consequences of climate change, including climate variability and extremes (Brooks & Adger, 2005; Füssel,

2007; Grothmann & Patt, 2005; Hinkel, 2011; Plummer & Armitage, 2010; Smit & Wandel, 2006). Since the 2000s, this notion has acquired a pivotal position in the adaptation literature, as it is used across the disaster risk, vulnerability, and resilience literatures (O'Brien & Selboe, 2015; Romero-Lankao & Qin, 2011). The cross-disciplinary use of adaptive capacity makes it a useful entry point to critically examine how adaptation is currently conceptualized, defined, and operationalized across disciplines and regions (Engle, 2011), and assess the social, cultural, economic, and political dimensions that influence the process of adaptation.

Overall, adaptive capacity has often been operationalized as a broad set of resources and determinants possessed by a social entity (i.e., individual, community, city) (Heinrichs et al., 2013). While this conceptualization provides a straightforward way to measure and compare adaptive capacity (Brooks et al., 2005; Eakin et al., 2014), it has been criticized for its failure to capture how adaptive practices emerge from the sum of resources. In other words, it leaves unanswered the critical question of how capacity becomes action (Adger & Vincent, 2005; Mortreux & Barnett, 2017; Toole et al., 2016). In response to this gap, an alternative conceptualization of adaptive capacity, on which this thesis builds, focuses on the process of adaptation by examining the attributes that enable social entities to adapt (Mortreux & Barnett, 2017). This allows studying adaptation as a process, rather than a sum of resources, and thus linking adaptive capacity to actual behavior. The key aspect of the alternative approaches lies on the interpretation of the process of adaptation. However, there is still a lack of evidence of adaptation as a dependent variable and a lack of theories explaining the relationship between adaptive capacity and adaptation (Mortreux & Barnett, 2017). This can be addressed by building on theoretical models that explain human behavior, with the caveat that a single model will likely be insufficient to explain the full extent of adaptive behavior (Gifford et al., 2011).

To date, most assessments of adaptive capacity continue to account for resources and determinants. Still, the theoretical development of adaptive capacity has been considerable. Adaptive capacity is conceived as contextual because it varies over time and across and within localities, among social groups and individuals. Hence, adaptive capacity is thought in three levels: coping, adapting, and transforming. Coping refers to the ability to deal directly with in-the-moment and short-term climate threats with concrete actions and using existing resources (Few, 2003; Yohe & Tol, 2002). Adapting describes longer-term efforts to adjust to and prepare for potential climate

change opportunities and risks, including actions to facilitate learning processes (Qin et al., 2015; Smit & Wandel, 2006). Transforming refers to the ability to change structural conditions that are no longer desirable, because they sustain the vulnerability of the system, and increase resilience (O'Brien, 2012; Revi et al., 2014b). Likewise, scholars distinguish between adaptive capacity at the individual, social, and institutional levels. Studies focusing at the institutional level understand adaptive capacity as the governmental ability to address local vulnerabilities and facilitate resilience by guiding decision-making and providing incentives for other actors to adapt (Dodman & Satterthwaite, 2008; Hughes & Sarzynski, 2015). In contrast, studies at the social and individual levels understand adaptive capacity as the ability of a community, household, or individual to directly deal with climatic threats (Grothmann et al., 2013; Moser & Satterthwaite, 2008). How then can the individual ability to deal with climate change be assessed?

1.5.3. Behavioral and Normative Underpinnings for Understanding Adaptation

To examine individual-level adaptation, I build on environmental behavior and new institutionalism literatures. Integrating behavioral with normative factors facilitates the examination of individual-level adaptation within the socio-normative context of the urban milieu.

Environmental behavior research focuses on the role that cognitive and affective processes play in shaping a wide range of environmental behaviors (De Groot & Steg, 2008; Kaplan, 2000). Scholars examine the cognitive, affective, and experiential factors that explain pro-environmental behavior, such as risk perception, perceived self-efficacy, perceived controllability, experience with hazards, climate change awareness, and more recently, the psychological distance to climate change (Gifford et al., 2011; Lange & Dewitte, 2019; Steg et al., 2016). Pro-environmental behavior usually covers desired sustainable practices that enhance low-carbon lifestyles (de Leeuw et al., 2015; Lin, 2013; Poortinga et al., 2004; Steg & Vlek, 2009) which is closely aligned to climate change mitigation responses (Gifford et al., 2011). Research examining the cognitive and affective processes that explain adaptive behavior has been less extensive, but with noteworthy findings.

Adaptation studies that do include behavioral considerations have mainly been influenced by two behavioral theories: the theory of planned behavior and the protection motivation theory. The theory of planned behavior explains behavioral intentions as a function of the weighted sum of a person's attitudes, his/her subjective social norms, and the perceived behavioral control (Ajzen, 2002). The attitudes refer to a person's expectation that some behavior will have certain effects, and their valuation of these effects. The subjective norms refer to a person's belief that others have some expectation relating to the behavior. The perceived behavioral control refers to people's perceptions of their ability to perform a given behavior. Behavioral intention refers to a person's motivation to perform a target behavior; the theory argues that intentions are the key proximal determinant of actual behavior (Ajzen, 1991). This argument is further used in the adaptation literature. Some scholars further argue that intentions are considered a good predictor of future behavior in unstable conditions such as those brought about by climate change (Kuruppu & Liverman, 2011). The theory of planned behavior has been influential in climate change adaptation studies that investigate the attitudes of farmers and their behavioral control over adaptation responses (Arbuckle et al., 2013; Faisal et al., 2020; Feola et al., 2015; Masud et al., 2016; Niles et al., 2016; Zamasiya et al., 2017; Zhang et al., 2020). It has been applied to a lesser degree in other fields such as tourism (Pröbstl-Haider & Haider, 2013) and the general population (Masud et al., 2016). However, the theory of planned behavior was thought to work following the principle of correspondence of constructs where each component (i.e., intention, attitude, norms, and perceived behavioral control) is assessed in relation to the same action, target, context, and time (Conner, 2020). Hence, the theory is conceived to analyze specific adaptation responses instead of evaluating individuals' general adaptive behavior, meaning a regular uptake of actions and practices to deal with climate risks that extend in time and space, which specific adaptation responses do not. Moreover, adaptation intentions do not always result in actual adaptive actions; according to Grothmann and Patt (2005), this can be explained by an individual's perceived adaptive capacity.

To understand adaptive behavior, Grothmann and Patt (2005) advance Rogers' (1975) protection motivation theory. This theory explains behavior by examining risk appraisal (i.e., perceived vulnerability and severity) and coping appraisal (i.e., self-efficacy, response efficacy, and action costs) (Rogers, 1975). Grothmann and Patt (2005) extend this theory with the sociocognitive model of private proactive adaptation (MPPACC). The MPPACC examines risk perception, which expresses the perceived probability of being exposed to climate change impacts and the appraisal of how harmful it would be, and the perceived adaptive capacity, as the ability of actors to deal with climate change themselves with the resources available (Grothmann & Patt,
2005). The authors show that explaining adaptation through risk perception and perceived adaptive capacity is more effective than through socio-economic measures, which are often the main component of mainstream adaptive capacity assessments (Mortreux & Barnett, 2017). The MPACC has been frequently used by authors focusing on individual-level adaptation (mostly in rural settings focusing on farmers' behavior and flood preventive behavior). However, studies that examine these constructs in relation to adaptive behavior provide mixed results on the significance of risk perception and perceived adaptive capacity in explaining behavior (Akompab et al., 2013; Bamberg et al., 2017; Blennow & Persson, 2009; Frank et al., 2011; Jain et al., 2015; Koerth et al., 2013; Liu et al., 2013; Reser et al., 2012). While some studies confirm the significance of these constructs, other studies do not find risk perception or perceived adaptive capacity to be influential. Mixed results may be related to the fact that empirical studies building on this approach have ignored the roles of social norms in mediating risk perceptions and adaptive capacity (Lo, 2013), and they have focused on the factors leading to conscious behavior.

The broader behavioral scholarship sheds light on the fact that individual reactions to external stimuli are not the mere result of rationalized thought processes. Instead, they involve multiple mental heuristics that individuals use when evaluating situations and making decisions about how to respond, often leading to cognitive biases that affect individuals' behavior (Kahneman & Tversky, 1979). Kunreuther (1996) found that individuals underestimate the likelihood of being affected by disaster events and therefore tend to underreact. At the same time, risk perception is influenced by recent or common events that are more cognitively available (i.e., the availability heuristic) (Clayton et al., 2015; Kahneman & Tversky, 1979). Thus, researchers continue to examine the determinants and mediators of risk perception. These factors include experience with previous hazards, holistic affect, climate change awareness, knowledge, and concern, as well as values and worldviews (Deng et al., 2017; Dessai et al., 2004; Lee et al., 2015; Steg & Sievers, 2000; Weber, 2010; Whitmarsh, 2008) and only recently, social norms (van der Linden, 2015). Although, behavioral scientists agree that the social and geographical context, and place-based identities are important to respond to risks (Alló & Loureiro, 2014; Clayton et al., 2015; Grothmann & Patt, 2005; Lo, 2013; Reser & Swim, 2011; van der Linden, 2015; van Valkengoed & Steg, 2019; Weber, 2010), the integration of normative dimensions with behavioral ones in examining climate change adaptation is weak. The study of individual adaptive behavior within local norms, and their interaction with broader social, political, and economic processes is essential.

New institutionalism offers a theoretical approach to examine social norms within broader social processes while focusing on individual behavior. This school of thought challenges methodological individualism by considering that human behavior is mediated by social institutions broadly defined as rules, norms, and beliefs (Ostrom, 1990; Scott, 2001). The main assumption is that individuals do not make decisions and act based on the highest expected utility alone, or solely on collective rational argumentation, but based on what is appropriate in a certain institutional setting (Ostrom 2005). From this theoretical perspective, institutions consist of cultural-cognitive, normative, and regulative norms that, together with associated activities and resources, provide stability and meaning to social life (Ostrom, 1990; Scott, 2001, 2010). Institutions provide information about other people's likely behavior and the incentives and disincentives attached to different courses of action (Lowndes, 2002); preferences are considered as the stable properties of actors (Scott 2010). The way individuals act is framed by institutional factors that affect our expectations about the behavior of others and the expectations of others regarding our behavior (Ostrom 2005). In contrast to classical institutionalism, neo-institutionalists put more emphasis on rules (instead of organizations), informal institutions (instead of formal ones), and dynamics (instead of stability). Most neo-institutionalists try to find a balance between agency and structure (Giddens, 1984).

Different branches of new institutionalism have developed (Hall & Taylor, 1996): rational choice institutionalism (i.e., focuses on the rules that shape the structure of situations where individuals ought to choose strategies or preferences), historical institutionalism (i.e., emphasizes the historical evolution and stability of institutions), sociological institutionalism (i.e., emphasizes the role of culture) and discursive institutionalism (i.e., analyzes the role of ideas and narratives in institutional change). In this thesis, I build upon rational choice institutionalism, as this strand facilitates questioning whether and how institutions enable or constrain actors from dealing with new circumstances and uncertainty (Bisaro et al., 2018; Matthews & Sydneysmith, 2010; Oberlack, 2017). Through this theoretical lens, it is possible to analyze how formal and informal norms structure the situation where urbanites ought to take adaptive actions (i.e., what the neo-

institutionalists call 'action situation') and identify the evolving role of institutions as new ones emerge.

Currently, adaptation studies, specially those examining adaptive capacity, that account for institutions' role tend to define them relatively narrowly as organizations rather than rules and norms (Grothmann et al., 2013). Some studies do pay attention to norms, though mostly to formal ones at the community and governmental levels, especially in managing natural resources (Bakker, 2012; Bettini et al., 2015; Brown et al., 2009; de Loë et al., 2007; Kashyap, 2004; van de Meene et al., 2011). Integrating informal norms in the analysis allows examining individuals' social cognition (i.e., cognitive process of perceiving and acting upon information about how others act in given situations). In a meta-analysis of adaptive behavior, van Valkengoed and Steg (2019) find that perceived descriptive norms are positively associated with adaptive behavior. However, this was based on a small number of studies available.

1.6.4 Urbanite adaptation: an analytical framework

I develop an analytical framework to examine urbanite adaptation building on recent literature on adaptation, environmental behavior, and new institutionalism (see Figure 3). The framework underscores individual agency and the role of social norms. I conceptualize cities as socio-urban settings (A) consisting of: i) characteristics that condition the everyday practices of residents in relation to a given public good (e.g., water) such as public infrastructure availability and management; and, ii) the socio-natural processes that take place in the urban space and its hinterland, such as the processes of urbanization that configure exposure to environmental events. These socio-urban settings are at the same time shaped by broader multilevel processes (i.e., national, regional, global) that indirectly structure the way in which individuals behave and interact. I assume that these broader multilevel processes are present and contextualized in the socio-urban characteristics and processes identified as relevant in the analysis, however I do not examine the broader processes *per se*.

Figure 3 - Urbanite Adaptation Process



Multilevel processes influencing urban milieu

I then borrow the concept of 'action situation' from neo-institutionalism to structure the analysis of how individuals cope with climate threats to their water security. 'Action situations' are social spaces with specific institutional arrangements where individuals interact, for example with the aim of solving a problem (here climate-driven water insecurity). I identify and categorize the institutional and behavioral factors that jointly structure individual actions and strategies to adapt to climate change. In dealing with climate change impacts, two main action situations are relevant for urban residents, I call them the "coping" and "adapting" arenas⁵, two levels in the range of adaptive capacity conceptualized in the adaptation literature⁶. In the face of imminent risk, individuals take actions in the coping arena (B) bounded by current social norms and using personal heuristics to minimize potential damages. These actions interact with those taken by other

⁵ "Coping" refers to the ability to deal directly with in-the-moment and short-term climate threats with concrete actions and using existing resources (Few, 2003; Yohe & Tol, 2002). "Adapting" describes longer-term efforts to adjust to and prepare for potential climate change opportunities and risks, including actions to facilitate learning processes (Qin et al., 2015; Smit & Wandel, 2006).

⁶ I acknowledge that the range of adaptive capacity can lead to transformations as in changes to structural conditions that are no longer desirable as they sustain the vulnerability of the system with the aim of increasing resilience (O'Brien, 2012). However, I purposefully excluded "transforming" from the adaptive capacity range in light of the limited transformative practices of urban adaptation at the individual level in the Global South (Florez Bossio et al., 2019).

urban residents, social groups, and the authorities. The actions and dynamics happening in the coping arena both influence and are influenced by those occurring in the adapting arena (D). The resulting coping-adapting interactions (C) are key to understand the evolving process of adaptation. They can indeed enhance or limit the objective and perceived capacity of individuals in dealing with climatic events. Within the adapting arena, social norms remain relevant, but individuals may as well challenge certain institutions in dealing with climate change, which in turn influences individual cognitive and affective processes⁷. Together, the evolving social norms and behavioral processes are called socio-psychological processes. These processes shape individual longer-term strategies to deal with the uncertainty and climate change; that is their adaptive behavior. Adaptive behavior refers to personal actions and practices that reduce the possible harm of climate change, which may bring additional benefits to households, the community, or the environment (Carman & Zint, 2020). It is important to clarify that one adaptation action does not mean an individual is acting in a comprehensive manner to deal with climate change threats. Thus, adaptive behavior includes a set of actions and practices that enhance resilience, considering local risks and climatic threats over the mid- and long-term; therefore, the extent of adaptive behavior is greater in time and space than specific adaptation responses.

1.6 Methodology

This section describes the methodological design of the research reported in this dissertation. I start by explaining how Lima's climate extremes serve as temporal analogue for this research. Then, I present the mixed-method approach I relied upon, which is followed by an overview of the qualitative and quantitative methods used, and a description of data integration. Lastly, I describe the ethical considerations that guide my thesis.

1.6.1 Lima's Climate Extremes as Temporal Analogue

To study urban adaptation to climate change, climate extremes (drought and ENSO) are used as a temporal analogue. ENSO is a climate phenomenon that occurs irregularly at two- to sevenyear intervals, it does not have a regular cycle, nor is predictable (Brown, 2014; Cobb et al., 2003; National Geographic, 2017). In climate change research, temporal analogues use past and present

⁷ It is important to note that the cognitive and affective processes are also relevant in the process of coping, however methodologically we cannot study these after the climate extremes occurred as individuals tend to rationalize and justify their past actions as the most appropriate.

experiences and responses to climatic variability and extremes to provide insights on current and future vulnerability (Ford et al., 2010; Glantz, 1991; McLeman & Hunter, 2010). ENSO produces widespread and severe changes in the climate, increasing rainfall drastically, which contributes to coastal flooding, mudslides, water pollution, and increased water-borne diseases. Therefore, the research uses urban dwellers' experiences with ENSO, and their coping and adapting strategies to the climatic hazards. The occurrence of ENSO has a long history in Peru. From the mid-sixth century, there are records that the Peruvian pre-Incan cultures (Moche and Caral) were dealing with the phenomenon, which influenced their collapse (Fagan, 2009). Although there is a long experience in dealing with ENSO, there are great variations in this phenomenon (Takahashi & Martinez, 2017a). One of the variations (internationally called *ENSO 1+2*, in Peru named *El Niño Costero*) occurred in 2017 in Peru and Ecuador's coasts (see Figure 4). The last time this type of ENSO occurred was in 1925 (Takahashi & Martinez, 2017b). This ENSO type is characterized by fast heating of the surface ocean water and slow trade winds, which together cause extreme rainfall.

Figure 4 - El Niño Costero (1+2) in Comparison with the Global Niño (3.4)



Source: IGP (2019)

From December 2016 to March 2017, Lima dealt with climatic extremes, first droughts and then *El Niño Costero*. In December 2016, Lima went through a drought, which translated into water shortages for one to three days, several times during the month. In early 2017, the city had anomalies in the maximum and minimum temperature (see Figure 5), with 5 degrees as the highest increase above the average from 1999 to 2016. During February and March 2017, the rainfall increased exponentially due to the *El Niño Costero* with anomalies between 1500 to 2000% above normal (see Figure 5). The increased rainfall and mudslides flooded several Peruvian cities,

including Lima. These hazards affected the city's water provision after treatment systems were clogged, energy provision as hydroelectric turbines were also clogged, and public and private infrastructure damaged. Residents also experienced food shortages due to the mudslides that affected the main highways used for transporting goods, and water-borne vector diseases (e.g., dengue) due to the floodings.





Source: SENAMHI (2017)



Figure 6 - ENSO 2017 in Peru, Anomalies in Precipitation

Source: SENAMHI (2017)

Lima is an ideal case for study of adaptation to climate-driven water insecurity because of its current water scarcity; the experience with climate extremes; the climate change threats to the city's water security; water consumption patterns and population vulnerabilities; and, the policy windows available to work on soft measures at the city level.

1.6.2 Mixed Methods Design

This study relies on a mixed methods design to respond to the research questions, drawing interpretations based on the integration of quantitative and qualitative data. Specifically, I use the Concurrent Nested Mixed Model Design, where quantitative data is embedded in the qualitative analysis (see Figure 6, right side scheme) (Creswell et al., 2003). This design has two phases, one with qualitative questions and data collection and analysis techniques, and the second one with quantitative questions, data collection, and analysis techniques. The inferences are made based on

the results of each phase, putting them together to form meta-inferences at the end of the study (Creswell et al., 2003).

Figure 7 - Mixed Method Concurrent Nested Designs





Source: John Hopkins Bloomberg School of Public Health (2017)

The combination of qualitative and quantitative methods enables a comprehensive view of urban adaptation. Qualitative methods allow in-depth understanding of individuals' experiences, while quantitative methods provide an opportunity for the generalization of perspectives. Furthermore, the initial exploration with individuals in the first phase allows quantitative variables to be selected that fit the local culture in the second phase (Creswell, 2015). The qualitative and quantitative methods used to collect data depend on the study scale and information source. A summary of the methods is presented in Table 1. The next subsections cover each method in more detail.

1.6.2.1 Systematic Literature Review

To respond to the first research question, I used a systematic literature review. A systematic literature review is a summary and evaluation of the state of knowledge of a given topic that defines a review strategy, explicitly identifies inclusion criteria, and aims to assess a large amount of literature (Berrang-Ford et al., 2015). As such, this method allows synthesizing and evaluating scientific articles dealing with urban adaptive capacity. Through the systematic literature review, I identified and examined research published between 2000 and 2017 that assesses urban adaptive capacity to climate change in developing countries. To evaluate the scientific literature, I developed a framework that focuses on key components of urban adaptive capacity in three dimensions: the characterization of adaptive capacity. Following the inclusion criteria for the analysis, 38 articles underwent a thorough full text review in Chapter 2.

Method	Data	Study	What?	Fieldwork	Source	Analysis	Research
	Collection	Scale		phase		method	Questions
	Method						
Qualitative	Systematic	Urban	Adaptive	Not	Peer-	Conceptual	1
	Review	areas	capacity	applicable	reviewed	model	
					articles	rubric	
	Semi-	Individual	Adaptive	1	Urban	Thematic	2
	structured		capacity		dwellers	coding	
	interviews						
		District	Institutional	Not	Authorities	Thematic	2 & 3
		& City	Arrangements	applicable		coding	
	Qualitative	District	Institutional	Not	Policy	Thematic	2 & 3
	Document	& City	Arrangements	applicable	documents	coding	
	Analysis						
Quantitative	Survey	Individual	Adaptive	2	Urban	Regression	3
			Behavior		dwellers	Analysis	

Table 1 – Overview of Methods used and its Relation to the Research Questions

1.6.2.2 Qualitative Document Analysis

In the first step in responding to the second research question, I used qualitative document analysis (QDA). This method aims to rigorously and systematically analyze the contents of written documents (Wach & Ward, 2013). QDA is usually used in political science to analyze public policies. I review climate change and water management policy documents at the city and national levels (n=12). By reviewing these documents, I identified and characterized the formal institutional arrangements (such as laws, regulations) that frame the process of adaptation in Lima. The goal was to understand the different governance structures and formal institutions that influence urban residents' capacity to adapt. Dwellers are directly affected by water and adaptation governance, and their perceptions of these governance arrangements are important as they consider in responding to climatic events.

1.6.2.3 Semi-Structured Interviews

In the second step, I interviewed urban dwellers, and policymakers and stakeholders. Interviews are used to investigate complex behaviors and motivations, look for diversity of opinions and experiences, aiming to fill a knowledge gap (Hay, 2010). I used semi-structured interviews, which establishes a predetermined order of questions and ensures flexibility to the informant's way of addressing the issues raised by the researcher. The interviews (n=115 residents) were used to investigate the attributes, determinants, and dynamics of adaptive capacity, and its relationship with adaptive behavior. The interviews with dwellers were done through purposeful sampling to include residents with diverse characteristics (e.g., gender, age, location, profession) until reaching saturation. Further, building on the results of QDA, interviews with stakeholders and policymakers (n=15) examined the formal structures and processes underpinning the management of climate risks to water security in Lima. Interviews with policymakers used a snowball sampling technique to cover the three levels of government (i.e., district, city, national) working on climate change adaptation, risk management, and urban planning in Lima. Interview transcripts were coded deductively following the theoretical approach presented in Chapter 3, and inductively to account for emergent themes. The analysis considered the characteristics of adaptive capacity, including objective and subjective adaptive capacity (Grothmann & Patt, 2005), and the range of the adaptive capacity as coping (Few, 2003; Yohe & Tol, 2002), adapting (Qin et al., 2015; Smit & Wandel, 2006; Yohe, 2001), and transforming (O'Brien, 2012; Revi et al., 2014b) (these notions are defined and reviewed in Chapter 2). In the analysis, I further considered the determinants that mediate the adaptive capacity of urban residents, including multilevel, place-based, and institutional factors, as well as the dynamics of adaptive capacity between urban groups (Romero-Lankao et al., 2014; Wilhelmi & Hayden, 2010).

1.6.2.4 Surveys

To respond to the third research question, I undertook a survey as the means to acquire information about the characteristics, behaviors, and attitudes of a population by administering an instrument comprised of structured questions to a sample population (Cloke et al., 2004; McLafferty, 2003). The survey was employed in four Lima districts, which were selected based on their different urban development paths and aiming to represent different locations of the city; different socioeconomic groups account for various sensitivities to water insecurity. Multistage sampling was used for each district. I randomly selected three zones of 1km² in each district (i.e.,

random area sampling); and subsequently randomly selected three public spaces in each zone from a list of public spaces identified in Googlemaps (e.g., parks, plazas, bus stops, markets). Participants were randomly selected in these public spaces. Additionally, the sampling was stratified for gender to have an equal number of men and women. In total, 400 participants were surveyed, 100 per district.

The survey was used to examine the socio-economic, socio-institutional, and psychological determinants with adaptive behavior. Adaptive behavior was measured with an index of adaptive actions and practices aimed at reducing the harm of climate change impacts. I developed two main indices: the Intentional Adaptive Behavior Index (IAB Index) that assesses intentional actions and practices in response to climate change; and the General Adaptive Behavior Index (GAB Index), which measures general actions and practices that enhance individuals' resilience to climatic threats to water security. The GAB index includes structural, knowledge, consumption, planning, and environmental-friendly actions and practices. Additionally, I analyzed the five GAB index themes as separate thematic indices. The analysis of the data started with a descriptive statistical analysis, followed by multiple regression analyses.

1.6.4 Integrating Mixed Method Results

In the thesis, I integrated the data at three stages. First, I used parallel sampling. During Phase 1, data was collected from residents across Lima. After analyzing the results of Phase 1, on Phase 2 data was collected using different people from the same population (i.e., Lima residents from four selected districts). Second, I integrated data through building from findings on Phase 1 to design data collection of Phase 2. Specifically, the results from the semi-structured interviews and QDA were used to inform the selection of determinants to explain adaptive behavior. The final stage of data integration took place using all results to build a narrative to understand urban adaptation in Lima. The narrative approach of integrating findings can be implemented by reporting results together thematically, separately in the same document, or individually in different documents. I present the results of each phase in different Chapters (2-4) and have reported the similarities and differences of the empirical findings in the concluding Chapter (5).

1.6.5 Ethical Considerations

The main principle guiding research is doing no harm to individuals and communities, which refers to both physical and psychological harm (Berg, 2012). The consequences of research are

considered in the research design and during the fieldwork to assess the ongoing relationship with participants, fully implementing the no harm principle. Accordingly, I follow McGill University's research ethics and compliance, and undertake the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans to consider best practices on research. As a first step, I visited Lima during summer 2017 to meet with local stakeholders, community leaders, and affiliated organizations to validate the research's aim and objectives, and identify the risks that communities face from the research and ways in which those risks can be managed. Then, during the data collection, all participants receive an 'informed consent' form (Berg, 2012; Dowling, 2016). The consent form explains the research's goal, the potential risks, the expected time commitment, and the ethical principles of research, such as guarantees of confidentiality and anonymity (Berg, 2012; Dowling, 2016). Further, doing research requires a full consideration of the relationship and implications of research to the research participants. My relationship with the participants involves managing the local expectations of the research and its results. Then, I emphasize the extent to which I could support the communities in communicating their needs to the 'powerful', as has been exemplified in the literature (MacKenzie et al., 2015). The results of this thesis are synthesized for Lima policymakers in two policy briefs. I also develop a series of comic strips that portrays the research findings for laypeople in Lima (Flórez Bossio, 2020).

1.7 Thesis Outline

I have written this dissertation as a series of manuscripts, with each manuscript addressing the above stated research questions. In Chapter 2, I answer the first research question by evaluating the assessment of adaptive capacity in urban areas of developing countries through a systematic literature review. The manuscript for the systematic review was published in 2019 in the journal, *Climatic Change*. The literature review is followed by two empirical manuscripts. Chapter 3 answers the second research question by identifying and characterizing the capacity to adapt of urban dwellers' in Lima, Peru, following an extreme climatic event in 2017. This manuscript was been submitted to the journal, *Climate Risk Management* in August 2020. Chapter 4 answers the third research question by examining the socioeconomic, socio-institutional, and psychological determinants of adaptive behavior of Lima residents. This manuscript is ready for submission. The concluding chapter discusses the major contributions of this thesis, compares the empirical findings of the studies in Lima, and sets forth recommendations for future research.

Preface to Chapter 2

In response to the limited and fragmented understanding of what fosters adaptation across urban contexts, Chapter 2 provides a synthesis and critical evaluation of the urban adaptation literature, and examines the first research question: How is the capacity to adapt to the effects of climate change in urban areas of developing countries being assessed in the scientific literature? The study contributes to the adaptation scholarship with a conceptual framework that assesses the characteristics, external factors, and dynamics of urban adaptive capacity. I argue that studies of urban adaptation have taken a narrow conceptualization of adaptive capacity, and demonstrate the mismatch between theoretical debates on adaptive capacity dynamics and empirical assessments. The findings underscore the need for research that focuses on understanding adaptive capacity as the processes that leads to adaptive practices, as well as, the need to contextualize adaptation studies to urban realities.

This chapter was published in *Climatic Change* in July 2019 (Flórez Bossio et al. 2019). The format has been modified to be consistent within the thesis. All references cited in Chapter 2 appear at the end of the chapter. All online resources referred to in Chapter 2 appears in the Appendix at the end of the thesis.

CHAPTER 2: Adaptive Capacity in Urban Areas of Developing Countries

Abstract

Urban areas of developing countries face increasing risks due to climate change. This paper systematically identifies and examines research published between 2000 and 2017 that assesses urban adaptive capacity to climate change in developing countries. To critically examine this literature, we developed a conceptual framework of urban adaptive capacity. The framework focuses on key components of urban adaptive capacity in three dimensions: the characterization of adaptive capacity, the external factors mediating adaptive capacity, and the dynamics of adaptive capacity. The study sheds light on the spatial and scalar interactions of individuals, communities, and authorities' adaptive capacities within urban areas and highlights the importance of governance and social institutions in shaping urban adaptive capacity. The work also finds shortcomings in the current assessment of urban adaptive capacity, with key gaps including a narrow focus on the range and types of adaptive capacity; limited assessment of the multilevel determinants, place-based processes, and urban determinants that shape adaptive capacity; and a lack of consideration of adaptive capacity interactions between social entities and with regard to climate sensitivity and exposure of a given area, including the potential for maladaptation. Addressing these research gaps would contribute to generate knowledge that can adequately support adaptation planning of urban areas in developing countries.

2.1 Introduction

The saliency of the risks posed by climate change to urban areas of the developing world and their populations has increased considerably since the turn of the century. This has been matched by increasing scholarly interest in the opportunities and constraints for adaptation (Revi et al. 2014). The last two decades witnessed a steady rise in the number of empirical studies on these issues that now cover a large part of what is sometimes called the Global South (Rosenzweig et al., 2018b). These studies, however, tend to focus on different dimensions of adaptation, rendering comparisons, let alone generalizations, of findings across urban contexts and scales difficult.

This paper tackles this challenge through a synthesis and evaluation of recent scientific publications on adaptive capacity (hereafter "AC") in urban areas of developing countries. At the most general level, we define AC as the ability of a system, region, community, household, or an individual to perceive, cope with, prepare for, and adapt to disturbances and uncertain social-ecological conditions (Hinkel, 2011; Plummer & Armitage, 2010; Smit & Wandel, 2006). Since the turn of the century, this notion has acquired a pivotal position in the urban adaptation literature. It is now mobilized by research on disaster risk, vulnerability, and resilience—the three areas of investigation at the core of this scholarship (O'Brien & Selboe, 2015; Romero-Lankao & Qin, 2011). All three bodies of work use the concept of AC, making it a useful entry point to critically examine how urban adaptation is currently conceptualized, defined, and operationalized across disciplines and regions (Engle, 2011).

Urban areas display specific characteristics which, according to the literature, not only shape but adversely sharpen climate change impacts on these areas. These specificities include: the spatial concentration of population and infrastructure; urban cores' dependency on their hinterlands and related center-periphery governance mismatches; the role cities play within larger socio-economic systems as hubs of political and economic power; the distinct urban livelihoods that condition population dynamics; and the propensity for social fragmentation (Birkmann et al., 2010; Lehmann et al., 2015; Revi et al., 2014b; Rosenzweig et al., 2018b). The situation is even more critical in developing countries, where economic, social, and institutional challenges exacerbate local sensitivities and decrease urban populations' capacities to adapt (Anguelovski et al., 2014; De Coninck et al., 2018; Hunt & Watkiss, 2011; Satterthwaite et al., 2007). The need to better understand AC, including ways to facilitate AC in these challenging urban contexts, is pressing. Most importantly, while existing research concurs to connect weak AC with increased vulnerability, we still have a limited and fragmented understanding of what fosters AC across urban contexts of developing countries. This situation may be related to a narrow conceptualization of AC in the larger (non-specifically urban) literature.

As Mortreux and Barnett (2017) explain, conceptualizations of AC to climate change can be organized according to two generations. The first generation, rooted in Sens's capabilities theory, apprehends AC as a broad set of resources or capitals (e.g., financial assets) and the determinants to access them (e.g. education). While this conceptualization provides a straightforward way to measure and compare AC (Brooks et al., 2005; Eakin et al., 2014), it has been criticized for its failure to capture how adaptive practices emerge from the sum of resources. In other words, it leaves unanswered the critical question of how capacity becomes action (Adger & Vincent, 2005; Mortreux & Barnett, 2017; Toole et al., 2016). The second generation of AC conceptualization, on which this study builds, seeks to fill this gap by focusing on the process of adaptation and by examining the attributes that enable social entities to adapt, thus extending the analysis to include psycho-social and institutional dimensions (e.g., place attachment) (Grothmann & Patt, 2005; Nelson et al., 2007). This latter conceptualization gives rise to two key questions that underpin this critical literature review: What do we know about the ways in which socio-cultural and urban processes shape urban AC in developing world contexts? and, how do internal dynamics of AC evolve in these urban settings?

This study uses these two questions to examine how urban AC to climate change in developing countries has been characterized and assessed in studies published between 2000 and 2017. While adaptation literature has a long history (Smit and Wandel 2006), it was not until 2000 that adaptation re-emerged as central component of climate policy. As the climate change adaptation literature boomed in the 2000s (Bassett & Fogelman, 2013; Ribot, 2011), it interfaced with calls for greater conceptual and methodological consolidation of the climate vulnerability scholarship (Crane et al., 2017; Ford et al., 2018). By focusing on the 2000–2017 period, this systematic literature review of empirical research on urban AC contributes to take stock of scholarly responses to this call. It does so by examining recent empirical research in light of the theoretical advances in adaptation that stemmed from the important conjuncture in the research outlined above.

To this end, this study formulates a novel conceptual framework which seeks to capture how studies published since the early 2000s assess key dimensions of AC in urban settings, shedding light on the characteristics, external factors, and dynamics of AC. This framework supports the identification and discussion of four emergent research patterns within empirical studies of urban AC in developing countries: 1) AC's variability across and within scales, 2) the relevancy of objective and subjective approaches to AC, 3) the importance of both governance and social institutions for AC; and 4) the limited attention paid to urban determinants in explanations of AC. Finally, we call for a better integration of theoretical debates about adaptation in empirical assessments of urban AC. More specifically, studies need to move beyond treatments of AC as static in time and space and to address the relationships between coping, adaptation, and transformation.

2.2 Conceptual framework

The construction of the conceptual framework presented in this section was the first step in this study (see Methodology section). In the absence of a pre-existing framework, we adopted Jabareen (2009) qualitative method, which although not specifically tailored for systematic literature review, supports the building of conceptual frameworks to study phenomena linked to multiple scholarships (such as urban AC in the developing world). This involved a broad survey of the adaptation literature, from its foundation to now, and selective forays into the resilience and disaster risk scholarship. In a first phase, this survey involved mapping the most cited scientific papers on climate change adaptation and served to identify contributions discussing the state and frontiers of the adaptation literature. In a second phase, we identified and categorized what we called the "theorized determinants of AC" for diverse settings and scales, and contextualized them to urban settings taking into consideration the characteristics of socio-urban systems. In doing so, and in contradistinction to some conceptualizations of AC, we integrated linked concepts from the scholarships to depict different stages in the adaptation thinking (e.g., coping, adapting, and transforming). Finally, we grouped these determinants under three broad theoretical dimensions that we call: *adaptive capacity characterization*, external factors, and *adaptive capacity dynamics*. The dimensions, their determinants, and the ways they relate to each other are schematized in Figure 8. The resulting conceptual framework is described in more details below.





2.2.1 Adaptive capacity characterization

The first dimension is at the core of our conceptual framework as it delineates researchers' conception of the nature and extent of the AC of the urban social entity studied.⁸ It translates into the first general question that we asked when examining each paper included in this systematic literature review: *What does this study understand adaptive capacity to be?* The determinants of AC grouped under this dimension allow us to systematize answers to this first question by examining what each study considers to be: the attributes composing AC; the agents putting it into action; the type of ability that these agents have; and the range of the capacity to adapt.

Urban AC attributes concerns the definition of adaptive capacity to climate change used in different studies. These definitions vary depending on the scholarship and object of study. They

⁸ Some authors refer to AC characterization determinants as endogenous variables of AC.

may be framed solely in response to climate change threats or to multiple threats with a special focus on climate change. Overall, these definitions refer either to: 1) a broad set of resources (e.g., financial resources) accessible to an individual or social entity to be employed when adapting (Engle, 2011; Heinrichs et al., 2013); 2) a series of determinants and processes that enable the ability of an area, community, or individual to ad(Mortreux & Barnett, 2017)apt (e.g., social learning) (Adger et al., 2004; Smit & Wandel, 2006); or 3) the ability to perceive and avoid or lessen the negative consequences of climate hazards (e.g., risk perception) (Grothmann & Patt, 2005). Looking at the definitions of urban AC and the attributed relation to key concepts in the studies' contexts reveals the literature understandings of AC as: the ways in which individuals and groups mobilize the resources available to them; the factors that enable human responses in urban areas; and the ability of urban actors to perceive and avoid climate change impacts.

Adaptive capacity cannot exist in a vacuum or be separated from the actor(s) that has the ability and resources to deal with climate change. As such, a second determinant that characterized how AC is mobilized in the literature concerns the agents to whom studies ascribe the capacity to act in the adaptation process. We call this determinant *adaptive capacity agency* and divide it into individual, social, and institutional agency (Grothmann et al., 2013; Moser & Satterthwaite, 2008). Individual agency refers to urban dwellers' ability to manage threats at the individual or household level. Social agency denotes the ability of groups of people or households and of civil society organizations to deal with threats at the community level. And institutional agency refers to the ability of urban political authorities to address vulnerabilities and facilitate resilience by guiding decision-making and providing incentives for actors to act in certain ways in an urban system (Dodman & Satterthwaite, 2008; Hughes & Sarzynski, 2015).

The way AC is used in the literature is further characterized by whether the concept is conceived of as an objective or as a subjective ability to deal with climate change. We refer to this determinant as the *adaptive capacity type*. Objective AC refers to the ability of an individual or social group to deal with climate change, employing the resources available within the given factors that enhance or diminish their AC (Grothmann & Patt, 2005). In this view, AC can be accounted for and measured towards the understanding of vulnerability and resilience. Alternatively, AC can be conceived of as a subjective ability concerned with the perceived ability of actors to deal with climate change given the resources available and prevailing social norms. The distinction is important because actors are not always aware of their objective ability scope, which they may under- or overestimate (Gifford et al., 2011; Grothmann & Patt, 2005). Subjective AC may be influenced by cognitive mechanisms (e.g., illusion of control), perceptions of risk, previous experience, and social norms (Clayton et al., 2015; Grothmann et al., 2013). This suggests that AC depends partially on each actor's perspective and can differ among actors evolving in the same urban milieu (Fuchs et al., 2017).

We call the last determinant of AC characterization *adaptive capacity range*. It concerns the way in which studies understand agents' ability to deal with extremes and manage the sensitivities of the system at stake. We organize studies' *AC range* in three levels: coping, adapting, and transforming. Coping refers to the ability to deal directly with in-the-moment and short-term climate threats with concrete actions and using existing resources (Few, 2003; Yohe & Tol, 2002). Adapting describes longer-term efforts to adjust to and prepare for potential climate change opportunities and risks, including actions to facilitate learning processes (Qin et al., 2015; Smit & Wandel, 2006). Transforming refers to the ability to change structural conditions that are no longer desirable as they sustain the vulnerability of the system and change these conditions with the aim of increasing resilience (O'Brien, 2012; Revi et al., 2014b). Transformations, such as the formulation of alternative urban development paths (Revi et al., 2014b), opens a range of novel policy options through non-linear changes (Fazey et al., 2018; Pelling et al., 2015). All three levels of AC can coexist. The same urban household may, for instance, adopt a mix of coping, adapting, or transforming strategies to deal the different risks it faces or with regard to different sector paths (e.g., water infrastructure or market choices).

2.2.2 External factors shaping adaptive capacity

The second dimension in our conceptual framework concerns the factors, external to agents' character and internal logics, which directly shape the circumstances in which the process of adapting takes place and, incidentally, agents' broader decision structures.⁹ As with the first dimension, this translates into a general question: *What factors do studies of urban AC identify as the structural shapers of adaptive capacity?* To systematize answers to this question, we

⁹ Some authors refer to this as the exogenous variables of AC.

differentiate between processes and institutions (though recognizing that they are interconnected). In the case of processes, we further distinguish between multi-level and place-based processes.

Processes occurring at the global, national, regional, and local levels shape actors' ability to deal with climate change. We refer to this determinant as *multilevel processes*. Studies may identify processes such as globalization, urbanization, decentralization, trade agreements, and international conflicts (Leichenko & O'Brien, 2008; Sanchez-Rodriguez, 2015). These processes often occur at multiple scales concomitantly and have a particular dynamic in a given urban area, which together condition the AC of urban dwellers and their authorities.

In contrast, and although they are rarely entirely disconnected from processes occurring at different scales, *place-based processes* mainly occur due to specific place traits of the urban system under analysis. These more localized social, economic, political, or ecological processes influence the vulnerability of people in that particular place (Cutter et al., 2008) and shape how actors respond to hazards and thus influence urban AC (Krellenberg et al., 2014; Romero-Lankao et al., 2014). Studies may analyze place-based processes such as urban sprawl, gentrification, mobility patterns, place identity, socio-environmental fragmentation, and socio-spatial inequalities.

Finally, the determinant concerning the formal and informal norms that evolve from social interactions and guide actors' behavior and collective action is called *institutions* (Ostrom, 2014). Institutions can either facilitate or constrain adaptive actions (Bisaro et al., 2018). To schematize the studies' assessment of institution we build on Ostrom's (2005) classification of institutions relevant to socio-environmental contexts, including position, boundary, choice, aggregation, information, scope, and payoff rules.

2.2.3 Adaptive capacity dynamics

The last dimension in our conceptual framework concerns the constant time-space interactions between social entities and their socio-natural context which mediates how AC is practiced in a given moment and its effects over time. It leads to a third general question: *How do studies observe changes in AC change over time and space?*

A first determinant of the *AC dynamics* dimension relates to how studies consider certain vulnerable populations in relation to the broader social setting in which they are situated and how they see this setting as affecting their AC. Specific population groups, such as the elderly, children,

women, marginalized communities, and indigenous populations may be more negatively affected by external shocks given their inherent vulnerabilities and have been recognized as being particularly vulnerable to the effects of climate change (Bunce & Ford, 2015; Gencer, 2013; Romero-Lankao et al., 2014). These groups tend to have higher levels of sensitivity and lower levels of AC to climate change. The assessment of *vulnerable urban populations* groups involves examining the conditions that drive their vulnerability in a given urban setting, and how these conditions mediate their AC.

Climate change research findings also show that the impacts of disasters are experienced differently according to individuals and social contexts which are rarely homogenous across or within urban communities (Leichenko, 2011; Shi et al., 2016). Further, the AC of a given area is relative in terms of the spatial distribution of people and their capacities (Lemos et al., 2013). We call this determinant *differentiated urban AC*. Studies' assessment of urban dweller groups may be disaggregated according to demographic and spatial determinants such as income, profession, age, gender, social group, geographic area, and length of settlement.

As discussed earlier, adaptation can further take place at different scales, and different agents have the capacity to implement adaptation measures. As such, the *AC interaction* determinant regards the examination of the dynamic relation between the AC of different entities, considering that the AC of an individual or group can mediate the AC of another individual or group (Romero-Lankao et al., 2014; Wilhelmi & Hayden, 2010). Also, we also look into studies' consideration of tradeoffs between specific capacities (e.g., climate risk insurance) and generic capacities (e.g., income diversification) (Eakin et al., 2014).

Scholars have also underlined that one of the main challenges with climate change is that it is a continuous change process (Chelleri et al., 2015). Adapting to climate change means dealing with changing conditions that require continuous societal adjustments (from habits to laws) over time. The *AC time frame* determinant involves the examination of AC attributes that can transform over time because changing social or individual conditions may affect the extent to which individuals or groups can withstand and adapt to shocks (Ford et al., 2013; Leichenko & O'Brien, 2002). Further, AC put in practice (as adaptation) can lock in risks and the future capacity of cities to respond to climatic events (Ürge-Vorsatz et al., 2018).

Finally, analyzing the relationship of *AC*, *exposure and sensitivity* is important to better understand the interactions between society and the environment and thus for meeting the needs of both systems along sustainable trajectories (Kates et al., 2001; Turner et al., 2003). Hence, exposure and sensitivities can shape urban AC and, conversely, the AC of urban social entities can shape future exposure and sensitivities of the urban area. At the same time, these interactions are mediated by the type of hazard and correspondingly how the hazard is shaped by the given urban setting and development.

2.3 Methodology

Developing the conceptual framework presented above was the first of six steps in the procedure outlined by Berrang-Ford et al. (2015) and which we followed to develop the present systematic literature review (Online Resource 1). Secondly, we selected the keywords to identify papers dealing with urban AC, these were: ("climat* change" OR "global warming") AND TOPIC: ("adaptive capacity" OR "coping strategies" OR "coping capacity" OR "adaptation capacity") AND TOPIC: (urban OR cities OR city OR metropolitan). Thirdly, we used these keywords in the Web of Science platform to systematically collect all relevant scientific articles in English and Spanish¹⁰ published between 2000 and 2017, which resulted in 341 publications. After retaining only original research articles, the citation information of 289 articles was downloaded into a bibliography manager software (EndNote). Fourthly, we reviewed each article with a finer set of inclusion criteria, so as to retain only those articles presenting empirical research relevant to urban AC in developing countries (Table 2). We began applying these finer inclusion criteria by reading the articles' abstracts, which resulted in the exclusion of 185 articles. The remaining 104 articles were assessed in their entirety against the inclusion criteria listed above and also in terms of their quality. In this regard, we excluded those papers that failed to explicitly present conceptual and methodological approaches. This left us with 38 articles that underwent a thorough full text review (Online Resource 2). Most articles excluded either did not focus on a developing country or on urban areas, or did not have AC to climate change as their primary focus. Only a handful of articles were excluded due to quality issues (Online Resource 3). Fifthly, data was extracted to a table by reviewing each article with a conceptual framework rubric (Online Resource 4). The rubric contained 20 questions (both open- and closed-ended) organized around

¹⁰ The two languages spoken by the lead author.

the three dimensions of AC presented in the conceptual framework. Finally, we analyzed the questionnaire results based on the three dimensions of AC and by looking for trends according to year of publication and region studied.

Inclusion	Exclusion
Published from Jan 1, 2000 to December 31, 2017	Research published before Jan 1, 2000 or after
	December 31, 2017
Published in English or Spanish	Published in a language other than English or
	Spanish
Focuses on developing countries	Focuses on developed countries
Focuses on urban settings	Focuses on rural settings only or on both rural and
	urban settings.
Focuses on contemporary climate change	Focuses on prehistoric climate change
	Focuses on multiple general stressors without
	tackling climate change
Examines human AC	Research focuses on ecological AC or
	infrastructural AC
Substantial focus on adaptive capacity	Adaptive capacity definition and/or attributes are
Adaptive capacity definition and/or attributes are	not explicitly outlined
explicitly outlined	
Empirical articles	Opinion or conceptual articles
Methodology is explicitly outlined, including	Methodology is implicit or does not explicitly
assessment criteria	outline assessment criteria

Table 2 - Summary of Review Parameters

2.4 Results

2.4.1 General research trends

All 38 articles retained for full review were published in English¹¹ from 2009 on, with the majority published between 2013 and 2017 (Online Resource 5). This trend mirrors a broadening of vulnerability research that has evolved from mainly looking at climate impacts and possible adaptation options towards assessing barriers to adaptation and examining social capacities to deal with changes and uncertainty (Ford et al., 2018).

In total, this review covers studies looking at 32 urban areas in 21 countries, two regions with 85 cities, and one global study on urban areas (Online Resource 6). The studies are situated in Africa (n=9), Latin America and the Caribbean (LAC) (n=11), and Asia (n=17). Approximately half of this corpus focuses on only five countries (i.e., Chile, Ghana, India, Philippines, and South Africa). Further, the majority of urban areas studied (82%) are located in middle-income

¹¹ None of the articles in Spanish originally identified were retained for review.

countries,¹² including both upper-middle income (one-third) and lower-middle income (twothirds) countries. Only one urban area is located in a low-income country (Dakar, Senegal) and the few remaining urban areas studied are located in high-income countries. The urban areas studied include small cities of 200,000 or less people (n=5), medium cities of 200,000 to 1 million (n=6), large cities of 1-10 million (n=16), and mega cities of 10 million or more (n=5). A third of the articles analyze AC at the city scale (n=13) and most of the remaining articles are framed at the district or sub-district (or neighborhood) scale (n=10). A lower frequency of articles narrow the research at the community (n=5), household (n=6), or individual levels (n=3) as their primary scale of analysis.

The studies reviewed rely on a mix of qualitative, quantitative, and spatial methods. More than half use only one of these three methods: qualitative (n=13), quantitative (n=8), or spatial (n=3) methods. Nevertheless, the distribution of study designs shows an increase in the use of mixed methods (n=14) over time, especially with regard to mixed qualitative and quantitative methods (n=11). Studies using spatial analysis are the least common (n=6), and this holds whether this method is used alone or as part of a mixed method strategy.

The studies reviewed include single case studies (n=29), comparative case studies (n=6) including four south–south and two north–south¹³ urban areas comparisons, territorial studies (n=2), and one global study (n=1). Comparative case studies examine in-depth two or more urban areas within one country or region (e.g., comparing two cities in LAC), and territorial studies assess many cities within one country area (e.g., 65 cities in southern China).

The majority of studies frame the analysis of AC in responding to climatic stressors or hazards (e.g., urban heat), focusing less on the possible impacts of those stressors (e.g., health impacts). More than half of the studies (n=22) consider multiple climatic stressors, while fewer articles focus on only one climatic stressor (n=11) or otherwise define their analysis as motivated by the threat of climate change generally (n=5). Researchers design their studies to focus mostly on floods, droughts, urban heat, sea-level rise, and water scarcity.

¹² Country income levels were drawn from the UN World Economic Situation and Prospects 2017, based on the per capita Gross National Income (GNI) in September 2016.

¹³ We assessed only the approach on the developing country information of the north-south studies.

Most of the articles reviewed were published in journals within the environmental sciences and studies disciplines (n=27). A smaller number of studies were published by journals at the interface of urban and environmental studies, and/or planning and development (n=5), by geography-focused journals (n=3) or other disciplines (n=3) such as women studies.

2.4.2 Adaptive capacity characteristics

The literature characterizes urban AC in multiple ways. The methodological approach discussions in over two-fifth of the studies reviewed (n=16) do not provide an explicit explanation of what constitutes AC, limiting comparison possibilities. In these studies, adaptation practices are generally understood to be determined by AC levels (low/high) and these tend to be assessed using key determinants. Conversely, studies featuring explicit AC definitions (n=22) tend to apprehend urban AC as the result of resources and determinants that structure agents' ability to respond to climate variability and climate change. A less common understanding of urban AC apprehends it as processes leading to adaptation actions.

The resources and determinants most often used to describe AC are financial (income and assets), informational, technological, access to basic services, and social capital. Other determinants utilized by studies are knowledge, education, experience with previous hazards, awareness, risk perception, infrastructure, social networks, warning systems, and to a lesser extent innovation, governance, political participation, legal structure, self-efficacy, and leadership. For instance, in a study of AC in San Salvador, El Salvador, Wamsler et al. (2012) found a significant correlation between past disaster impacts and the use of coping strategies, showing that previous experiences can determine AC. Some studies further highlight determinants of AC significant to developing contexts, such as poverty and deprivation. A study in Accra, Ghana, for instance reported that while 97% of the urban traders it surveyed reported that climate change negatively impacted their livelihoods, a majority of respondents were unable to meet their basic needs, let alone adopt coping strategies to respond to climate change (Arku et al., 2017).

In the majority of studies (n=29), scholars did not refer to specific urban attributes when characterizing urban AC. Instead, they used standard AC attributes such as income and knowledge. Urban attributes call attention to the settlement's characteristics (e.g., density, size), the systems that facilitate social urban life (e.g., urban governance settings, flux of resources from the hinterlands), and social-urban dynamics (e.g., social fragmentation). In the few cases (n=9) where

studies did refer to urban attributes, these included infrastructure (e.g., urban water supply), household location, property characteristics (e.g., ownership, insurance), land use regulation processes (e.g., informal settlements, urban governance), and stability and security of the urban areas. These cases illustrated the importance of considering urban attributes, for instance city size as demonstrated by a comparative study of three Indonesian cities (Handayani et al., 2017).

The studies reviewed analyze AC agency from a mix of individual, social, and institutional stances. Half of them focus on only one type of agency (individual or governmental) while the other half takes a broader perspective and include two or more types. Individual agency is the type most often considered (n=26), closely followed by institutional (n=22) and, somewhat later, by communities' social agency (n=11). Studies looking at all three types of agency tend to frame AC as an objective ability to deal with climate change. Overall, less than a third of studies (n=11) discuss the subjective AC of an actor or social group. Studies that do consider the subjectivities of AC mostly do so as a supplement to the analysis of objective AC. The combination of objective and subjective AC is typically done by combining resources and determinants that compose AC with climate change awareness and risk perceptions, and to a lesser extent with self-efficacy perceptions. These studies' findings show that subjective factors influence adaptation decisions. For example, in Taichung, Taiwan, the community members' risk perceptions and appraisals of their abilities to access resources and perform adaptation successfully have been shown to be key determinants of residents' willingness to take adaptive actions (Hung et al., 2016).

Regarding the range of AC, more than a third of the studies reviewed focus only on the ability to deal with short-term climate threats through concrete actions (e.g., moving furniture one floor up during floods), which corresponds to the coping level (n=15). Around half of the studies reviewed analyze AC in a medium time frame by considering the ability to adjust and prepare in advance for climate impacts; this includes studies that exclusively assess the adapting level, and studies that combined the coping and adapting levels (n=17). Few studies examine longer-term strategies that aim to change structural conditions in urban areas, the transformability level (n=6), and when they do, they do so at a primarily theoretical level. An exception to this trend is Schaer (2015), whose study in Dakar explores the effect of past maladaptation as a determinant of present coping and adaptation levels of AC and discusses the timing of coping and adaptation strategies and whether they support permanent transformations.

2.4.3 External factors shaping urban adaptive capacity

The majority of articles reviewed consider external factors that mediate urban AC (n=30). This consideration ranges from the description of processes that contextualize AC to analyses of how these processes empower (or undermine) the AC of urban actors. Several of the articles reviewed include urban vulnerability assessments that explicitly consider AC (n=17), along with exposure and sensitivity (as is common practice in the scholarship). In these cases, the external factors that shape AC are analyzed as factors shaping vulnerability and therefore AC.

Research concerned with multi-level processes tends to identify global and national processes that affect local urban circumstances. A third of the studies reviewed take into account multilevel processes (n=12). This literature frequently highlights decentralization, urban growth, and economic growth and transformation as factors directly influencing AC. For example, in Nadi, decentralization of early warning systems was shown to enhance AC, but at the same time national political instability eroded international finance, which decreased AC (Chandra & Gaganis, 2016). In a global-level study, Garschagen and Romero-Lankao (2015) demonstrate that countries with rapid urbanization and economic transformation face significant challenges with respect to the lack of capacities and sensitivities, while urbanization can also be a main driver for enhancing AC. Other multilevel processes identified include migration, national political instability, institutional national fragmentation, historical processes following post-colonialism, and neoliberal reforms.

More than half of the peer-reviewed articles (n=22) describe place-based processes that influence how actors respond to climate hazards. These processes include the informality of settlements, employment, poverty, forced evictions, social segregation and marginalization, provision of city services, increased mobility, and population density. The most common place-based process, addressed in 39% of the articles reviewed (n=15), is urban spatial expansion through informal settlements. Studies concerned with this process are looking at an informal settlement or at the way informality influences the local capacities to adapt to climate change. As exemplified in Lagos, Nigeria, communities living on informal settlements are marginalized by being classified as "outside" of the city and hence excluded from the city's regulatory and planning systems for dealing with climate hazards (Ajibade & McBean, 2014). Likewise in relation to informal settlements, in San Salvador researchers found that the increasing ease of mobility leads households to default on their obligations to relatives and neighbors, as the different income levels

foster individualistic behavior that result in opting out of mutual and hierarchical arrangements that could support adaptation (Wamsler & Lawson, 2012).

The documentation of institutions (i.e., rules and social norms) affecting urban AC is elaborated in much more detail than the multilevel and place-based processes. The institutions identified as shaping urban AC correspond to position, boundary, choice, aggregation, and information rule types, following Ostrom's classification (Table 3). Regarding the influence of governance institutions on institutional capacity (e.g., governmental), the literature reviewed highlights the roles and responsibilities of policymakers and stakeholders, the flexibility or rigidity of institutional procedures, leadership, elitism, turnover, and flow of information. Frick-Trzebitzky (2017) demonstrated the importance of informal institutions for adaptation in Accra, where the role of the chief contributed to or impeded adaptation to urban flooding, depending on the chief's own rationalities and institutional context.

Type of Rule	In a given situation, the rule regulates:	Institutions mediating AC
Position	Positions	Roles and responsibilities, leadership, gender roles, chieftaincy structures
Boundary	Participants	Elitism, turnover
Choice	Actions	Flexibility/rigidity Distrust
Aggregation	Control	Tenure security
Information	Sending or receiving information	Flow of information
Payoff	Cost/benefits	
Scope	Outcomes	

Table 3 - Classification of Institutions mediating Adaptive Capacity

Considering the influence of institutions on social and individual AC, several studies (n=9) found that tenure security mediates households' AC. In Korail, for example, a large informal settlement in Dhaka, Bangladesh, Jabeen et al. (2010) found inhabitants unwilling to invest in improving their living conditions because of tenure insecurity, despite the fact that some have lived there for as long as 20 years. Similarly, in urban communities in Lagos, while the authorities enforce evictions and demolitions on account of flood prevention and urban development, the inhabitants expressed a reluctance to invest in quality housing because they feared these forced actions from the authorities (Ajibade & McBean, 2014).

Further, several studies mention that urban dwellers distrust local authorities (n=8), which can impact the capacity to respond and adjust the urban system to climate change. For example, in Ekurhuleni, South Africa, the relationship between local governments and residents has historically been distrustful, thus shaping the risk perceptions of the latter and prompting them to pool ideas as well as financial resources to combat floods on their own rather than to rely on the government (Fatti & Patel, 2013), which shows the importance of local political interactions in shaping AC.

2.4.4. Adaptive capacity dynamics

The literature often disaggregates the AC of different urban dwellers groups (n=12). This is mainly done by contrasting low-income to high-income groups, low-risk to high-risk groups (measured by their exposure and/or sensitivities), and geographic areas. For example, Wamsler et al. (2012) showed a relationship between households' level of education and risk level in San Salvador and Rio de Janeiro. Their study explained the lower risks faced by people with higher levels of education because they are more likely to be responsive to disaster warnings and alerts, to accept and use institutional support, and to move to a more secure area. Further, the study shows that formal education seems to be of special importance for determining women's risk level. The urban dwellers differences in AC have also been assessed in relation to the capacity of other actors to foster adaptation (i.e., authorities).

Where only the most vulnerable populations are identified (n=16), the literature focuses mostly on one vulnerable group (e.g., urban poor) or alternatively disaggregates results and identifies particular phenomena related to a vulnerable group (e.g., women). For example, in Dakar, the most vulnerable population groups are excluded from taking part in local decision-making and thus are negatively affected by the undesirable impact of adaptation initiatives (Schaer, 2015). Moreover, while a majority of studies (n=34) did not include gender considerations to characterize AC, those that did had noteworthy results. For example, studies in Delhi, India, shed light on the decisionmaking process of households in which social gender relations undermine women's adaptation decisions (Saini et al., 2015).

Six articles engage with the dynamics of AC, from considering the interaction of a person's own capacities to the individuals' capacities within the social groups. For example, in Mexico City

there are tradeoffs between specific and generic capacities at the household level. Households' efforts to adapt in conditions of marginality can come at the expense of households' investment in other aspects of human welfare, reinforcing poverty traps and leading to inequity in the burden of risk management (Eakin et al., 2016a). Also, a study in Malolos, Philippines, shows that some children, especially those from poor families, experience helplessness and exasperation in performing individual-level adaptations in the absence of corresponding long-term action from their community (Berse, 2017). The literature also highlights the importance of studying the internal dynamics of AC at multiple scales. For example, in Paramaribo, Suriname, and Georgetown, Guyana, households perform most of the preventative actions, and during floods households often act collectively within their localities without contacting the authorities (Linnekamp et al., 2011).

Only four articles examine time when studying urban AC. Regarding changes of AC over time, in Concepción, Chile, researchers concluded that all the municipalities in the area increased their level of AC between 1992 and 2002. In most municipalities, knowledge was the most important determinant of this increase. However, the relative differences in AC between rich and poor municipalities did not change significantly over the studied period, which is explained by economic conditions, location, and inequalities rising from urban sprawl (Araya-Munoz et al., 2016).

Some researchers reflected on the relationship between AC and exposure and sensitivity to climate change, showing the strong connections to the broader vulnerability research. For example, in Nadi, it was suggested that the presence of multiple exposures, of physical, social, economic, and political factors reinforced, transformed, or weakened the existing patterns of local people's AC, highlighting the importance of contextual vulnerability (Chandra and Gaganis 2016). From a metalevel perspective, scholars propose that understanding the content of AC and how it interacts with exposure and sensitivity during different periods will be an important basis for responding to unexpected climatic events (Berse, 2017; Hung et al., 2016; Sales, 2009).

2.5 Discussion

This paper systematically examined how urban adaptive capacity (AC) to climate change in developing countries is being framed and assessed in the peer-reviewed literature. In doing so, we

responded to calls for more research across urban contexts in a globalized world facing climate change (Huyssen, 2008), while remaining cognizant of ongoing debates about comparability stemming from differences in methodological and theoretical approach (see Robinson, 2011). The 38 studies on AC to climate change in urban settings of the developing world analyzed in this paper are but a small fraction of the broader urban adaptation literature, with 1,957 articles on this theme published during the 2000–2017 period.¹⁴ The articles retained in this study were all published from 2009 on, signaling the relatively recent—yet significant—rise of scholarly interest in the question of urban AC in the developing world. Moreover, research on urban AC in this context tends to focus on a rather limited number of countries and their urban areas. This uneven geographic distribution means many countries of the Global South are "off the map" in existing urban AC research, and this despite the fact that they are expected to be significantly impacted by future climate change. There is need to research urban areas in all developing regions, including Sub-Saharan Africa, Arab states, South and East Asia, Central and South America, the Caribbean and the Pacific states. The conceptual framework presented in this paper can assist further research to characterize and examine urban AC in developing countries, especially those "off the map."

This review also identified four emergent patterns within urban AC research and sheds light on the mismatch between theoretical debates on AC dynamics and empirical assessments. Firstly, the results support previous claims that AC varies across urban scales (Moser & Satterthwaite, 2008; Romero-Lankao et al., 2014), including individuals, households, communities, districts, and city levels. Moreover, urban AC consistently varies within scales, such as between urban sub-groups and geographic locations within urban areas. Hence, it is important to contextualize and map AC as suggested by broader vulnerability researchers (Dunford et al., 2015; Lemos et al., 2013; Waters & Adger, 2017). Secondly, the review showed that objective resources and processes mediate AC in urban areas and that subjective AC can directly influence the resulting adaptive practices. Articles that use an integrated framing of both objective and subjective AC in urban settings provide more nuanced results than those focusing only on one type of AC. Thirdly, the role of governance and social institutions is key to understanding the agency of actors in their path to adaptive actions. As such, our review supports previous studies concluding that governance institutions shape institutional and individual urban AC (as a two-fold capacity) (Hughes &

¹⁴ According to a Web of Science query for the 2000–2017 period using the following keywords: TOPIC: (urban OR cities OR metropolitan) AND TOPIC: (adaptation) AND TOPIC: ("climat* change" OR "global warming").

Sarzynski, 2015; Wamsler & Brink, 2014b), also illustrating that social institutions are critical in shaping individual, social, and institutional urban AC in developing countries. Fourthly, most articles fail to include specific urban determinants in their analysis and questions remain as to how and why these determinants can have different impacts in urban areas globally. In addition, it would be appropriate to explore possible interdependencies between the urban determinants and multilevel and place-based processes, which together affect urban AC.

The treatment of AC dynamics in the scholarship is found to be marginal with regard to the interactions of AC over time, between and within urban groups' capacities, and with urban exposure and sensitivities. These gaps point to a rather narrow understanding of AC as static in time and space, and non-reciprocal between social entities. Although some studies did consider differentiated AC in a given urban area, analyses of how these reinforce or diminish one another is weak. While it has been largely agreed that adaptation actions will unavoidably produce winners and losers (even with no-regret options) (Eriksen et al., 2011; O'Brien & Leichenko, 2003; Sovacool et al., 2015), there is limited consideration on the effects of how AC in a given moment by a specific social group or in response to certain exposure can affect AC elsewhere. Research needs to more strongly emphasize the dynamics of urban AC, including potential for maladaptation, as has been addressed in the context of land-use measures and adaption planning (Anguelovski et al., 2016). Further, considering that one third of the studies reviewed only focus on the coping level of AC, there is need to promote analysis that links coping, adapting, and transforming levels of AC. This is particularly important when considering that coping responses of individuals and social entities can generate undesirable outcomes for communities in the longterm, as has been studied in rural and national settings (Fazey et al., 2010; Fazey et al., 2016). The treatment of urban AC in research as a short-term ability to deal with shocks can translate into an equivocal analysis of vulnerability to climate change and support maladaptation of urban areas and their communities. Altogether, we can observe a mismatch between theoretical papers addressing the adaptability and transformability of urban areas (Hordijk et al., 2014; Pelling et al., 2015; Rosenzweig et al., 2018b; Solecki et al., 2017; Ziervogel et al., 2016) and the limited empirical papers that sought to study these processes on the ground. Studying the dynamics of urban AC has methodological challenges such as designing approaches that account for multiple AC paths within urban milieus in changing socio-natural contexts. Likewise, taking longer study time-frames (i.e., 10 years and longer) is a challenge but then again it would allow to see the effects of AC in other

entities and places. Despite these challenges, there is need to strengthen and link empirical work to the current theoretical debates on climate change adaptation in and beyond urban areas, especially the growing body of research dealing with the political nature of adaptation (Chu, 2016; Chu et al., 2017; Eriksen et al., 2015b; Meerow & Mitchell, 2017), historical processes framing adaptation (Adamson et al., 2018), and the role of values in defining adaptation practices (O'Brien & Wolf, 2010).

Ultimately, this review of urban AC literature raises a key question: How should we explain the process of adaptation? Using the concept of AC is useful to address the ability of urban social systems to deal with climate change. However, using this concept should not restrict the analysis to a sum of characteristics that may or may not indicate possible adaptations. As Mortreux and Barnett (2017) warned, the first generation of AC research (what they define as the sum of capitals) has been unable to explain how adaptation is practiced across diverse contexts and scales. Thus, there is need for research that focuses on understanding existing adaptation processes (Mortreux & Barnett, 2017). Embracing the second generation of AC by adopting an understanding of urban AC as the adaptation process that leads to adaptive practices and outcomes in specific socio-urban settings would be valuable. In this paper, such an understanding allowed us to better integrate the socio-cultural and urban processes that shape urban AC in the analysis and to inquire how the dynamics of AC evolve. At the same time, the understanding of urban AC as a process requires engaging with broader literatures concerned with urban space, such as urban planning, urban sociology, geography, and history. All of these disciplines can contribute to equip scholarship on urban AC with a better and more in-depth understanding of the psychological, cultural, and political processes it seeks to explain.

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Preface to Chapter 3

The literature review in Chapter 2 reveals that the urban adaptation literature has had a narrow conceptualization of adaptive capacity as static in time and space, underscoring the need to understand adaptation as a process. The literature review also showed that urban adaptation literature has scarcely investigated individual level adaptation. However, the adaptation of urban areas requires all actors to be involved in the process, despite the responsibility that authorities have in steering its governance. Taking into consideration these results, in Chapter 3, I bring together the adaptation literature with new institutionalism and environmental behavior scholarships to develop a theoretical approach that conceptualizes the adaptation process of urbanites, considering dwellers' agency within the normative structures of their socio-urban milieus. This approach is used to examine the Lima dwellers' responses to the extreme events brought by the 2017 El Niño Costero, which is used as a temporal analogue. Accordingly, I address the second research question: What characterizes the capacity to adapt of Lima residents to climate-related risks to water security?

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CHAPTER 3: Urban Dwellers' Adaptive Capacity as a Socio-psychological Process:

Insights from Lima, Peru

Abstract

This study examines the adaptive capacity of urban dwellers in the face of a changing climate. It builds on the case of Lima residents' responses to the extreme events brought by the 2017 El Niño Costero, used here as a temporal analogue. Our novel, process-oriented approach to framing adaptive capacity integrates elements from both environmental behavior and new institutionalism literatures. Based on interviews with Lima residents, policymakers, and stakeholders as well as on a qualitative document analysis of national and city policies we identify and characterize the sociopsychological processes that are critical to understanding why individuals adopt (or not) different adaptive strategies. We show how governance and social institutions (from municipal regulations to gender roles) influenced residents' perceived vulnerability and how this, in turn, structured their coping actions during the El Niño Costero episode. We further demonstrate that ways in which individuals deploy coping mechanisms structure their future adapting paths through practices that privilege the status quo as individuals defer risks in time and space. In this context, the interrelation of residents' cognitive processes with evolving social norms lead to five strategies for dealing with climate change. The discussion reflects on the need to address institutionalized social inequalities that permeate Lima's daily urban life in order to enhance the adaptive capacity of the most vulnerable, and on the relationship between residents and authorities on the pathway to urban resilience.

3.1 Introduction

In already challenging urban contexts for water security, climate change threatens to exacerbate extreme climatic events and unpredictable rainfall patterns that can lead to more frequent and intense droughts and floods (Rosenzweig et al., 2018a; Rosenzweig et al., 2011). This could compromise water quantity and quality, directly affecting urban populations' livelihoods and infrastructure (e.g., housing, sewage systems, transport systems, energy systems) (Kashyap, 2004). Climate threats to water security can have significant consequences on human health and wellbeing, safety, the environment, economic growth, and local development (Satterthwaite et al., 2007; UN-Habitat, 2011; WHO & UNICEF, 2012; Wilbanks et al., 2007). These concerns are especially salient in urban areas of developing countries experiencing demographic growth. Climate change is likely to add pressure to an already mounting demand and competition for limited water resources. Cities such as Lima, Peru, where 10% of the population is still unserved by the public water network, could soon be under perpetual water stress, undermining water provision reliability (World Bank, 2015).

In the last decade, researchers have increasingly studied the vulnerability of urban areas to climate change and assessed their adaptation plans (Meerow & Mitchell, 2017; Rosenzweig et al., 2018a). This scholarship has, however, remained focused on exposure to climate risks resulting from urbanization, giving only limited attention to urban societies' sensitivities and capacities to adapt to climate change (Flórez Bossio et al., 2019; Garschagen & Romero-Lankao, 2015). When studies do address the adaptation of urban areas, scholars predominantly analyze policy and governance issues at the city scale, leaving largely unattended the question of urban populations' response to government-led adaptation plans, policies, and interventions. A deeper understanding of urban adaptation at the individual level is needed to understand these responses and ultimately improve the effectiveness of policies and influence citizens to adopt positive autonomous adaptive actions (Brink & Wamsler, 2019; Helm et al., 2018).

Empirical studies of adaptation processes in non-urban settings show that social barriers, experienced at the individual level, play an important role in constraining the effectiveness of local government's adaptation policies (Baker et al., 2012; Jones, 2010; Lehmann et al., 2015; Measham et al., 2011). The findings indicate that residents can—and sometimes do— respond negatively to policies devised by governments to respond to climate change hazards. But in contrast to studies on climate change in rural contexts and to the broader social-ecological systems literature (Beratan,

2007; Eakin et al., 2016b; Hamilton et al., 2018; Truelove et al., 2015), individual-scale analyses of institutional and behavioral barriers are still lacking from urban adaptation research (with few exceptions such as Brink & Wamsler, 2019; Liang et al., 2017).

This paper begins to fill this gap through a city-wide case study of Lima residents' adaptive capacity to climate change. At the most general level, adaptive capacity refers to the ability of a system (social or ecological), region, community, household, or individual to perceive, cope with, prepare for, and adapt to the effects and consequences of climate change, including climate variability and extremes (Brooks & Adger, 2005; Ford & Smit, 2004; Grothmann & Patt, 2005; Hinkel, 2011; Plummer & Armitage, 2010; Smit & Wandel, 2006). This study further emphasizes the contextual nature of adaptive capacity, understood as varying across and within localities, among social groups and individuals, and over time (Leichenko, 2011; Romero-Lankao et al., 2014; Shi et al., 2016). In so doing, it supports a process-oriented analysis focused on areas wherein individual-level socio-psychological dynamics intersect with broader socio-normative dynamics in the process of adaptation (Bunce & Ford, 2015; Flórez Bossio et al., 2019).

In this study, we use this process-orientated approach to document and analyze the adaptive capacities of Lima's urban residents in the face of an extreme climatic event that happened between February and April 2017 during the El Niño Southern Oscillation (ENSO). This climate phenomenon occurs irregularly, at two- to seven-year intervals, producing widespread and severe changes in climatic conditions. During these episodes, drastic rainfall increases contribute to coastal flooding, mudslides, water pollution, and increased water-borne diseases (Brown, 2014; Cobb et al., 2003). Although this phenomenon has repeatedly affected the north of Peru, in 2017 an unusual event known as *El Niño Costero* severely affected the country's north and central coast, including the Peruvian capital's water security. These climatic events were in many ways consistent with climate change scenarios formulated for Lima, where the most plausible scenario foresees permanent droughts with extreme ENSO events and intense rainfall (Calvo, 2012; Miranda Sara et al., 2017). We use this period as a "temporal analogue," an approach that studies present experiences with climatic phenomena as a means to gain understanding of future vulnerability and responses (Ford et al., 2010).

In what follows, we bring insights from environmental behavior and new institutionalism to study individuals' adaptive capacity. Our analysis relies on over a hundred interviews with Lima residents documenting their experiences during the climate extremes of 2017, and their current strategies for dealing with climate change threats to their water security. This is complemented by an analysis of governance and social institutions that structure individuals' responses through interviews with policymakers and stakeholders, and a review of relevant policy documents.

3.2 Conceptualizing the adaptive capacity of urban dwellers

Our conceptualization of urban dwellers' adaptive capacity to climate change draws on insights from environmental behavior and new institutionalism studies. At the crossroads of psychology and behavioral economics, environmental behavior research puts attention to the role that cognitive and affective processes play in shaping a wide range of environmental behaviors (De Groot & Steg, 2008; Kaplan, 2000). Empirical studies have focused on individuals' attitudes, motivations, and values that lead to conscious behavioral intentions (Sheeran, 2002). Yet, the literature sheds light on the fact that individuals' reactions to external stimuli are not the mere result of rationalized thought processes. Instead, they involve multiple mental heuristics that individuals use when evaluating situations and making decisions about how to respond, which often lead to cognitive biases that affect individuals' behavior (Kahneman & Tversky, 1979). In this view, environmental behavior literature provides for an in-depth understanding of cognitive and affective processes that facilitate or prevent individuals from seeking the most appropriate forms of adaptation (Grothmann & Patt, 2005; Helm et al., 2018; Jones & Tanner, 2015; Truelove et al., 2015; van der Linden, 2015).

Regarding climate change, scholars have identified relevant heuristics and biases (called behavioral barriers) that can lead people to maladapt, whereby an adaptation action does not succeed in reducing vulnerability but instead increases it, for example, by downplaying the severity of a threat or giving only the illusion of control over it (Clayton et al., 2015; Gifford et al., 2011; Grothmann & Patt, 2005; Magnan et al., 2016). Studies examining the role of behavioral barriers in adaptation processes tend to assume the existence of a direct link between cognitive processes and adaptation actions, frequently operationalized between risk perception and intended adaptations (Lo, 2013). Such assumptions are problematic, especially in view of the growing number of empirical studies highlighting a range of factors that mediate the relation beween risk perception and adaptation. These mediating factors concern other psychological processes (e.g., self-efficacy and controllability beliefs) (Grothmann & Patt, 2005; Jones & Tanner, 2015; Kuruppu & Liverman, 2011) as well as social norms (e.g., gender norms) upheld by local socio-

cultural institutions (Adger, 2003; Brooks & Adger, 2005; Thorn et al., 2015; van der Linden, 2015).

Such findings point to the importance of approaching adaptive behavior as inherently situated and contextual. This, in turn, calls for greater attention to the broader social, political, and economic processes happening at the urban scale, as these shape the local institutional contexts where individuals will adapt. New institutionalism provides a useful lens in this regard. This school of thought challenges methodological individualism by considering that human behavior is mediated by social institutions broadly defined as rules, norms, and beliefs (Ostrom, 1990; Scott, 2001). From this perspective, institutions consist of cultural-cognitive, normative, and regulative norms that, together with associated activities and resources, provide stability and meaning to social life (Ostrom, 1990; Scott, 2001, 2010). Echoing insights from the environmental behavior scholarship, neo-institutional scholars argue that individuals do not make decisions (or act according to them) based solely on their highest utility expectations or on processes of collective argumentation. Instead, individuals take into account both the consequences and the appropriateness of intended actions, while being enabled and constrained by the formal and informal norms that organize all forms of repetitive and structured social interactions (Ostrom, 2005). While there are different strands of new institutionalism, we build upon rational choice institutionalism, which examines how institutions shape the structure of situations in which individuals or groups then elaborate strategies when pursuing their preferences (Ostrom, 2007; Scott, 2010). This strand argues that institutions, given their determinant structuring role, are essentially providing individuals with information about the likely behavior of other people or organizations, and about the incentives and disincentives attached to different courses of action (Lowndes, 2002; Ostrom, 2007; Scott, 2010).

These insights are echoed in climate change research concerned with the ways in which institutions facilitate or constrain actors from dealing with new circumstances and uncertainty related to a changing climate (Bisaro et al., 2018; Matthews & Sydneysmith, 2010; Oberlack, 2017). However, adaptation studies that account for the role of institutions tend to define them relatively narrowly as organizations rather than rules and norms (Grothmann et al., 2013). Deeper-level institutions that shape cognition are especially missing the adaptation literature. And yet, as demonstrated in the discussion of the environmental behavior scholarship, social cognition—understood as the cognitive process of perceiving and acting upon information about how others

act in given situations—brings a fuller understanding of how individuals deal with changes and uncertain contexts.

In this study, we bring together the insights from environmental behavior and new institutionalism schools. While new institutionalism enables the identification and characterization of institutions in the urban space, the environmental behavior literature sheds light on urban dwellers' cognitive and affective processes within that institutional context. These ideas are central to this study as we approach the diversity of behavioral strategies that emerged within Lima's socio-urban institutional context.

3.3 Methodological approach

The aim of our study is to investigate the capacity of Lima's urban residents to adapt to climate threats to water security using a temporal analogue approach. This approach relies on past and present experiences and responses to climatic variability and extremes as a way to understand current and future vulnerability processes (Ford et al., 2010; Glantz, 1991; McLeman & Hunter, 2010).

The temporal analogue used in this study is an ENSO event, called El Niño Costero, which occurred between February and April 2017. This ENSO event differed from the El Niño basinwide phenomenon because it was spatially confined along the coasts of Peru and Ecuador (IGP, 2017), as opposed to involving the El Niño-related expansion of warm waters coming from the western and central equatorial Pacific (Ramírez & Briones, 2017). Hence, El Niño Costero is a different and rare kind of El Niño, the previous one dating back to 1925 (Takahashi & Martínez, 2017a). It represents a particularly valuable temporal analogue for the study of urban adaptive capacities in Lima because the climate extremes that the city endured in 2017 are similar to those projected by climate change scenarios for the city (see Section 3.4). Preceding El Niño Costero, Lima had endured a drought in December 2016 and maximum and minimum temperature anomalies (up to 5-degree increases) in early 2017. During that same year, El Niño Costero led to exponential rainfall increases in February and March (SENAMHI, 2017).

As explained above, individuals are the unit of analysis of this study. Following the conceptual approach discussed earlier, we combined various data sources to examine the institutional and socio-psychological determinants and processes shaping Lima residents' adaptive capacity. First, we performed a qualitative document analysis (QDA) of policy documents (n=12) concerned with

climate change and water management. These documents were identified by reviewing the most recent compendium of Peruvian environmental laws, the websites of the Ministry of the Environment and Lima Metropolitan Municipality, and searching for decrees published in the official Peruvian newspaper "El Peruano". We coded each policy document using MAXQDA 2018. We reviewed national- and city-level policies in order to identify and characterize the formal institutional arrangements (such as laws, regulations) that frame the process of adaptation in Lima. This provided a portrait of the different governance structures and formal institutions that influence urban residents' capacity to adapt.

Second, we rely on data from semi-structured interviews conducted with key stakeholders (n=15) and residents of Lima (n=115) from July 2017 to May 2018. Building on the results of QDA, interviews with stakeholders and policymakers further examined the formal structures and processes underpinning the management of climate risks to water security in Lima, which influences individuals' responses to climatic threats (see questionnaire in Appendix B). We initially mapped the governmental organizations involved in climate change adaptation and risk management in Lima, as well as the non-governmental organizations that had participated in climate change consultation processes. After identifying the first key informants, we used a snowball sampling technique to further recruit national, city, and district policymakers and other stakeholders working on climate change, risk management, and urban planning. While these interviews were meant to gain knowledge of the governance structures shaping individual adaptation, they also shed light on the perspectives of policymakers themselves as individuals taking public adaptation decisions. Interviews with urban residents focused on their daily experiences with water in the city and during the 2017 climate extremes, and on their knowledge and perceptions about climate change (see questionnaire in Appendix B). Through these interviews, we explored residents' capacity to deal with threats by discussing how they perceive their own water (in)security and incentives or constraints to adapting and by documenting their adaptive practices before, during, and after the ENSO-related extreme events. We used a purposeful sampling to include residents with diverse characteristics (e.g., age, location, occupation, socioeconomic status). To this end, we recruited participants among users of 25 key public spaces selected across the city (i.e., plazas, parks, commercial centres, markets, transport stations). To ensure the inclusion of a diversity of people in our sample, the main investigator (CFB) and two local research assistants conducted recruitment at these different public spaces at

different times of the day (mornings, afternoons, and evenings) and week (weekdays and weekends). We reached saturation¹⁵ after interviewing 115 urban residents (see Table 4), between the ages 18 and 80, living in 37 districts distributed across the city's five main zones: North Lima (n=5/8), South Lima (n=8/11), Central Lima (n=13/15), East Lima (n=6/9), and Callao (5/7).¹⁶ All interviews were conducted in Spanish and transcribed. The main investigator coded the interview transcripts using MAXQDA 2018.

Following the conceptual approach presented above, the stakeholder interviews were coded deductively focusing on the governmental policy approaches and legal structures in place. For coding residents' interviews, we used constructs such as self-efficacy, perceived risks, perceived vulnerability, as well as social cognition in relation to neighbors, city residents and authorities' responses. All interviews were also coded inductively to account for emergent themes. The main investigator then cross-referenced themes with residents' attributes (i.e., gender, age group, district) to identify relevant coded themes for these groupings.

3.4. Study area: Metropolitan Lima

Lima's metropolitan area has two distinct regional administrative territories: Lima and Callao (hereafter "Lima"). Together, these two territories are divided into 50 districts, each with its own municipality, conventionally grouped into five zones: North Lima, South Lima, Central Lima, East Lima, and Callao. Overall, the area is home to approximately 10 million inhabitants (INEI, 2015), growing at 1.5% per year (INEI, 2016).

Historically, Lima has been a highly socially segregated city (Fernández de Córdova et al., 2016; Ioris, 2016). In the 1990s, however, this started to shift, such that the city's many socioeconomic profiles and population groupings are now less likely to be consolidated in distinct homogenous areas (Fernández de Córdova et al., 2016). The social composition of districts is heterogeneous, with scattered degrees of diversity in terms of migrant origin, socio-occupational categories, and per capita income (Fernández de Córdova, 2012). However, what can be observed is that income and environment inequalities augment as one moves out of Central Lima towards the peripheries (Fernández de Córdova et al., 2016). The lack of land for urbanization has led people to construct their homes in floodplains and in other high-risk areas (Calderón Cockburn,

¹⁵ We define saturation as the point when no new information was observed in the data during its collection.

¹⁶ Interviews were conducted by the main investigator (CFB) and two local research assistants. All interviews were conducted in Spanish and transcribed.

2017), while public services have failed to keep up with the pace of expansion (Fernández-Maldonado, 2008; Ioris, 2016; Matos Mar, 2012). To this day, 10% of the population is still unserved by the public water network.¹⁷

Gender	Participants Interviewed
Male	46
Female	69
Age	
18-30	46
31-50	40
51-80	29

Table 4 - Demographics of Residents Interviewed

Lima is under permanent water stress. With only 9 mm of precipitation per year in the city, the water supply depends almost entirely on precipitation in the upper watersheds and on glacial meltwater from the Andes. Water shortages, wide rainfall variation due to ENSO, and competition for water between sectors and user groups severely affect the city's quantity and quality of water (GIZ, 2014; World Bank, 2015). Nonetheless, Lima's water consumption is high. On a daily basis, the Lima population uses approximately 66 gallons of water per capita, well above the average of 40 gallons for other large cities in South America (The Nature Conservancy, n.d.). Levels of consumption, however, vary largely across districts and there are polarized perceptions on the availability and price of water between rich and poor districts (LIWA, n.d.). According to an estimate of a World Bank study (2015), the Peruvian water utility—Sedapal—will be unable to ensure water reliability¹⁸ by 2040 should the demand by then exceed 920 Mm³, regardless of future flows. With the current flow being 855 Mm³, the highest plausible demand in 2040 would be 1,800 Mm³. However, should future flows decrease, as estimated by the IPCC, Sedapal may be unable to ensure water reliability even if future demand were to fall to today's level. It has been argued

¹⁷ This figure was provided by an anonymous representative from Lima's water utility during an interview in July 2017.

¹⁸ Water reliability was defined as meeting 90% of demand 90% of the time, measured monthly.

that long-term climate change impacts may leave the city under perpetual water stress (World Bank, 2015).

Climate change is a major threat to the city's water security because it leads to the accelerated melting of the glaciers in the Andes as well as changes in rainfall patterns in the upper watersheds (Thompson et al., 2017; Vuille et al., 2008). In this region, future temperature and precipitation changes are uncertain; so, with rainfall possibly increasing or decreasing, droughts may also become more severe and more common (Pachauri et al., 2015). Local experts consider that the most plausible climate change scenario for Lima in 2040 is one leading to permanent droughts with extreme events and intense rainfall (Calvo, 2012; Miranda Sara et al., 2017).

3.5 Results

The conceptual approach presented above facilitated gathering information on the institutional and behavioral factors that influence adaptive capacity. In this section, we present the findings organized in four subsections about: 1) the socio-urban setting in which individuals experienced El Niño Costero; 2) the coping mechanisms used by dwellers to deal with imminent climate extremes, and the way these mechanisms were bounded by social norms; 3) the interactions between these coping mechanisms and adapting to climate change; and 4) the socio-psychological processes leading to individuals' (non)adaptive strategies for dealing with climate change.

3.5.1. Socio-urban setting

Interviews with residents, stakeholders, and policymakers showed that individuals were significantly affected by the climate extremes of 2016–2017, mainly by El Niño Costero. The rainfall anomalies, an increase between 1500 and 2000% compared to previous years, led to flash floods and flooding that affected citywide water provision, with water treatment systems getting clogged and having to be shut down. Subsequently, the lack of water led to increased costs of alternative sources (e.g., bottled water, water trucks) and overall social stress about securing water for one's personal intake. Residents reported experiencing strong negative emotions (i.e., fear, anger, sadness, anxiety, annoyance) in responding to the lack of water. Flooding and mudslides had direct impacts only on the communities settled in river banks, namely by flooding homes, damaging public urban infrastructure, and contributing to water-borne diseases such as dengue.¹⁹

¹⁹ According to PAHO (2017), there were 87 cases in the Lima region as a consequence of El Niño Costero.

Nevertheless, flooding and mudslides affected all Lima residents indirectly in the form of moderate food shortages (due to damaged roads) and, to a lesser degree, of electricity shortages (due to the clogged hydroelectric plants). Residents reported that upon realizing the scale of the physical and economic consequences of El Niño Costero they had negative feelings (i.e., hopelessness, helplessness, insecurity, apathy) when thinking about the future of Lima or their own wellbeing were a similar event to happen again.

The way residents experienced and responded to these climatic hazards was mediated by the city's water management, which perpetuated everyday inequalities, and moderated by the location of individuals' households and their residential water infrastructure. Dwellers' experiences of water (in)security were directly related to Lima's water management institutions. Interviews with residents indicated that the distribution of water is regularly uneven between and within districts. As stakeholders explained, Lima's water utility, SEDAPAL, provides and distributes water using economic efficiency principles that in practical terms mean that areas of the city that pay a higher water tariff receive water 24/7, whereas areas of the city that pay a lower tariff receive water only for limited hours per day or certain days of the week.²⁰ Nonetheless, the latter are still better off than the ten percent of Lima residents who are not connected to the system at all and who must obtain water from other sources. Further, stakeholders and policymakers questioned the unjustified sequence in which areas of the city recovered the water service during El Niño Costero, and thus criticized the management principles that seemed to be reinforcing the systemic inequalities of water provision.

Moreover, residents showed to have very little knowledge about the governance of their water. Interviewees repeatedly expressed their realization, during El Niño Costero, that residents in other parts of the city had daily water limitations or that they were surprised that residents in established or wealthier areas were also affected by the lack of water. This points to an overall limited knowledge about Lima's water management's rules and procedures, which is nurtured by weak public communication and discussion about Lima's current and future water situation considering climate change. Thus, the water governance institutions structured residents' perceptions of water and related risks, such that different population groups had different views based on their

²⁰ Sedapal has since changed its water tariff structure.

perception of access and distribution of water in the city, and their own vulnerability to climate risks.

Nevertheless, while access to a secure water source was shown to be critical, interviews with residents revealed that individuals' objective and perceived vulnerability was also moderated by the water infrastructure they had set up in their homes. Individuals who had a water tank in their households had access to water for a longer time (between 1 to 3 days longer) than households who did not. As a woman interviewed from the San Martin de Porres district mentioned: "Honestly, in my house, built of concrete, we weren't very affected because we have a water tank (...) So uh, let's say we didn't have a lot of difficulties. But I actually saw my neighbors [struggling], right? We gave them water; but we also saw a sea of people looking for water." Individuals equipped with water wells likewise had an alternative water source in times of water shortages. Respondents with water wells were mostly located in the eastern districts of the city, an area dominated by agricultural spaces within the metropolis and with ongoing establishment of new informal settlements. As stakeholders highlighted, it has taken the water utility up to 20 years to set up public water services for new dwellers, and even then water shortages are recurrent. Hence, many residents have taken the initiative to install water tanks or construct water dwells on their own accord as a way to ensure water availability. However, residents under conditions of tenure insecurity, alongside low incomes, reported being unable to afford water tanks and to instead use large barrels for storing water on a regular basis. While this practice also allowed them to save water during El Niño Costero, it could not do much to abate the feeling of powerlessness among this group of the population during the extreme events.

The location of households—be it with regard to neighborhood or elevation (low- or highterrain area)—is likewise a key moderating factor in how Lima's residents are affected by water shortages and mudslides. Water pressure is weaker in the upper hills when public water reservoirs haven't been installed and where many of the low-income families that recently migrated to Lima have settled. Moreover, citywide, respondents reported that households occupying the lower levels of buildings have stronger and steadier water provision than those in the higher levels. These differences were accentuated during the climatic events. Regarding mudslides, households' proximity to rivers or streams is likewise a critical factor, insofar as it exposes them to destruction and flooding. Even though current policies set rules and incentives to evacuate at-risk homes, interviews with stakeholders and residents suggested that individuals' decisions to remain in atrisk areas are explained primarily by their affective and economic investment in their properties. Residents in households at risk reported feeling unsettled about the prospect of relocating to proposed alternative areas, as those locations tended to be more difficult to access or to lack public services, which would exacerbate their conditions of marginality. At the same time, these individuals showed confidence in the capability of the new built infrastructure to effectively channel mudslides over the long term.

3.5.2. Coping mechanisms in dealing with climate risks

Residents reported perceiving that Lima was completely running out of water during El Niño Costero, which generated a shared feeling of distress across the city. Given Lima's widespread previous experiences²¹ with brief or lengthy water limitations, residents already had a know-how in reconfiguring their water-use practices when hit by El Niño Costero. These coping mechanisms, implemented at both the household and the individual level, were influenced by larger societal coping dynamics regulated by governance and social institutions.

Residents took actions that affected all members of the household. These actions included preventive measures (e.g., storing water after having been informed by the authorities of imminent water shortages or protecting the house with cement bags) or behavioral changes (e.g., use of disposable dishes to avoid the use of water). Interviews with residents revealed that individuals relied mostly on ties with family and work relations (bonding and bridging ties) to implement these actions, and less on those with neighbors. Indeed, the population had hardly been socially organized prior to the climatic events and lacked the built trust for working together. As a resident from the Barranco district stated "Mostly [neighborhood] organizations are in informal settlements; but in [more advanced] towns like us, there aren't associations; everyone lives on their own and that's all." These weak social ties thus acted as a barrier for neighbors to take locally coordinated coping measures, and even contributed to the emergence of conflicts between neighbors seeking to secure water for their households. However, residents from areas that had been developed only recently, or that were still in the process of developing, reported having

²¹ Most adults in Lima have experienced water scarcity in their day-to-day life, either by migrating to an area of Lima without water connections, by recurrent water shortages during the 1980s and 90s internal conflict, or by the common daily water restrictions in a number of districts.

stronger ties with their neighbors, mainly because they continued working together to obtain land recognitions and public services.

Interviews with stakeholders and residents demonstrated that social ties further moderated people's previous experiences with extreme events in the city. At the individual level, interviews in the Chosica district showed that residents who had already experienced mudslides and flooding were prepared to take individual coping actions (e.g., move furniture to the second floor) but also relied on neighbors' contingency plans (e.g., mudslide alert system) in contrast to the population that hadn't had previous experiences with extreme climatic events. Yet, unexperienced residents in the Punta Hermosa district, who didn't have emergency plans, proved capable of rapidly organizing themselves to protect the most vulnerable (e.g., securing children in school buildings and providing living resources for over a month), which can be attributed to the strong social ties in this particular neighborhood. Thus, while previous experiences positively influence residents in ensuring emergency plans, social cohesion is able to compensate for a lack of experience and facilitate coping mechanisms between neighbors.

We also found that residents' coping strategies at both the household and individual level were structured by gender roles prevalent in Lima. The woman's role in the household was key in the process of organizing alternative water practices, with families relying heavily on women as household protectors. However, women in traditional male-headed households reported that their decision-making power was limited because men would take the final monetary or infrastructural decisions. At the individual level, women's reported coping actions were focused on changing their own behavior to reduce water consumption by decreasing their personal water intake, altering their diet, changing personal cleaning practices, recycling water, and using water available in locations outside of their homes (e.g., gym). In contrast, most men stated that rather than changing their behavior to reduce their water consumption, they sought alternative water sources elsewhere in ways that tended to require economic resources and physical strength (e.g., fetching water outside of the city). The actions of men complied with their roles as providers of their families. Interestingly, the gendered differences in coping actions between men and women were less pronounced among the youth (aged between 18-25), who did not report much difficulty in changing their water consumption habits and who saw themselves as being "adaptable" to water restrictions for a limited number of days. This adaptability occurred in spite of the youth having

limited access to water, as educational institutions, who offer a source of water, were closed during times of water shortage.

3.5.3. Interactions between coping mechanisms and adapting to climate change

Interviews with residents, stakeholders, and policymakers suggested that coping with El Niño Costero led to an increased understanding of the value of water and the associated risks of water insecurity, and that the social coping dynamics have structured emergent social norms about wateruse practices. However, coping actions and dynamics have also strongly privileged the status quo, narrowing the overall scope of individuals' capacity to adapt to climate change.

The majority of residents interviewed reported that due to El Niño Costero, they had a new or greater appreciation of water resources for their daily life and for Lima as a whole. As a resident from Comas acknowledged, "We realized that there is need for water; without water you can't do anything. At least without electricity we can light a candle, right? But without water you can't do anything, right?" In addition, residents frequently reflected on their overall dependence on nature for their wellbeing and the damage done by society to the environment. These new considerations shed light on the underlying disconnection between urban lifestyles and the daily reliance on ecosystem services in the city. Dwellers are detached from the process of collection and distribution of water, and in many cases individuals even displayed lack of knowledge about Lima's water sources. The climatic events have thus served to close this gap, making residents more aware of water's value and the possible risks to water security of Lima.

Interviews showed that individual coping actions in reducing water consumption were often incorporated (predominantly by women, 79%) into their daily life after the water shortage was over, up until one year later.²² The continuation of water-saving practices was enhanced by emergent social norms on preserving water. Several interviewees recognized that they themselves, or people they knew, had outspokenly criticized the misuse of water of others, not only within their own inner social circle but also with strangers in the city. Despite the emerging social norms around water, half of the interviewees who reported adjusting their water consumption behaviors only did so for several weeks to a month, reporting difficulties in changing their own habits, with the discomfort this meant for their daily life, or the perceived lack of need to continue saving water

²² Interviews were taken one year later after El Niño Costero.

once water availability is back to normal. In addition, many individuals who considered themselves as having attained a certain level of efficiency in using water (in comparison with "others") no longer saw the need to pursue further improvements over the medium or long term.

In the same way, residents who reported having enough water in their household water tanks during El Niño Costero²³ mentioned that they did not feel vulnerable regarding the prospect of water shortages occurring in the near future, and thus lacked incentives to incorporate long-term water-sustainable practices. Therefore, while the tanks were an effective means to cope, they also transferred costs in time and led residents to misconstrue their future ability to deal with dangerous climate change risks to their water security. In addition, interviews revealed that those individuals who had coped by decreasing their personal water intake were also more cognizant of the fact that the absence of drinking water, or not using water for an extended period of time, would lead to hygiene and health issues. Interviews also revealed that coping actions transferred costs in space as residents had searched for water in the city surroundings, but that they could not maintain this practice on a daily basis due to time and cost constraints over the long term.

3.5.4. Socio-psychological processes leading to individuals' (non)adaptive strategies

One year after El Niño Costero, Lima residents had developed distinct strategies for dealing with climate change, which are structured by five socio-psychological processes. These processes entail the conjunction of social norms and rules with individual-level cognitive and affective mechanisms for dealing with climate change. Hence, in a city heading towards a population of 10 million people, we observe that these processes appear and mix depending on personal characteristics and backgrounds (Table 5).

First, interviews revealed that most residents are aware of climate change, yet mostly understand it as a global process with impacts at the global and national levels (i.e., threats to polar bears or melting glaciers). Most interviewees thought that climate change may affect ENSO, often recalling the intensity of El Niño Costero of the year before. Interestingly, however, interviews showed that residents hardly made the association that climate change will have a direct impact on their own city, Lima. This disassociation may be explained by the interviewees' lack of knowledge about Lima's water sources as well as by a cognitive dissonance they were experiencing by having knowledge of climate change risks while nonetheless believing that nature is inherently

²³ This is a subset of the group of residents who had water infrastructure in their homes.

unpredictable and hence "natural events" are unmanageable. As one interviewee said, "For example, the frequent rain or thunders that happened in Lima, we aren't used to it. So we can't be prepared in the face of nature, because it's unknown what nature has laid out for us. And I believe that neither scientists nor Senamhi²⁴ can [deal] with nature. (...) Climate change can worsen El Niño for us; we're polluting the environment (...)." Residents' inconsistent beliefs about climate change and nature lead them to channel their attention and efforts to taking environment-friendly actions and conservation initiatives tackling the global threat to nature, which is at the same time incentivized by the climate change governance in Lima. QDA and interviews with policymakers indicated that current policies and projects in Lima feature mitigation strategies more so than adaptation ones, which, while contributing to reducing GHG emissions, will not directly reduce residents' vulnerability. At the same time, interviews with policymakers revealed their personal beliefs and expectations about residents' behavior. Policymakers repeatedly mentioned that residents ought to 'behave well' in socio-environmental terms, supporting the global fight against climate change. In turn, they deemed themselves responsible to raise individuals' awareness about current global environmental challenges, but little was mentioned about communicating local risks.

Second, interviews with residents and stakeholders indicate that since El Niño Costero, many residents have an increased recognition that the city is vulnerable to climatic extreme events. Residents interviewed perceive that Lima is not prepared for climatic changes, be they changes in temperature or rainfall, including the impacts thereof on water availability and public and private infrastructure. In addition, they are not convinced that the three levels of government in the urban space are dealing with climate risks or even planning on doing so, which is mediated by widespread mistrust in authorities, enhanced by current corruption cases. Yet, despite residents' recognition of the city's vulnerability, they do not feel directly vulnerable to climatic events. Individuals' perceived personal impacts were generally framed in comparison to more disadvantaged people (e.g., people who lost their house), vulnerable groups (e.g., children, elderly), or higher-risk areas (e.g., cities in the north of Peru). At the same time, individuals minimize their possible exposure to such events (e.g., mudslide will not affect my house by the riverbank) and trust that their current

²⁴ Senamhi is the National Meteorology and Hydrology Service of Peru.

resources could ease impacts (e.g., if I have a job, I will have the financial resources). These framings demonstrate residents' widespread optimism bias regarding the sensitivity and exposure to climate change. Therefore, residents' increased risk perception of Lima's vulnerability has not translated into an increased sense of personal vulnerability or an increased preparedness or adaptive actions for dealing with the impacts at the individual level; instead, it entails a laissez-faire strategy in terms of adapting to climate change.

Cognitive & affective processes		Institutions			Individuals' strategies for dealing with climate change
Туре	Descriptors	Cultural-cognitive level	Normative level	Regulatory level	
Cognitive dissonance	 Anthropogenic climate change is happening Climate change may affect ENSO Climate change is melting glaciers Nature is unpredictable Lima is not threatened by climate change 	 Limitations on acquiring knowledge about nature 	1. Social expectations on contributing to socio- ecological wellbeing	 National climate change mitigation policies. Municipal incentives for sustainable household practices 	Environment-friendly strategy: recycle
Optimism bias	Lima is vulnerable to climate change But I'm less likely to be exposed to disasters I'm not vulnerable to climate change	 Peruvians having ancestral knowledge in dealing with El Niño Economic resources allow individuals to thrive through difficult times 	 It is fair and just that people who are more disadvantaged get support Lack of governmental practices Distrust of authorities 	 National and city regulations forbid settling in risk-prone areas 	Laissez-faire strategy: continue living close to river banks
Faith-in- technology bias	1. Lima is vulnerable to climate change 2. I'm concerned about climatic threats to my personal wellbeing 3. Technological innovations can decrease my vulnerability	 Technology is very advanced to protect urban residents Urban development requires investment in water infrastructure Individual construal of self as independent 	 Increasing the water supply for Lima is good Men in households should secure and provide resources 	 Incentives for sustainable buildings, such as water-smart technologies 	Technological strategy: invest in household water infrastructure
Low perceived controllability	 Nature cannot be managed, nor can climate change My response actions will not be sufficient to increase my own resilience 	 Belonging to religious group and associated faith in god's will Limitations on acquiring knowledge about nature 	 Citizen's role in society is to behave well God's role is to protect humans and manage nature 		Moral strategy: pray more
Authoritative bias	 Authorities have the skills and technical knowledge to adapt to climate change Authorities are less likely to make mistakes 	1. Individual construal of self as interdependent	 Authorities have a parental role in taking care of citizens The citizen's role is to abide by guidelines set by authorities during crises Absent governmental practices 	 Hierarchical governance arrangements. Lack of regulatory norms or incentives to adapt at the individual level 	Coping strategy: In the face of lack of support during crises, reduce personal water intake

Table 5 - Examples of socio-psychological processes leading to (non)adaptive strategies

Third, while the above cognitive mechanisms for dealing with climate change were recurrent, some respondents (authorities, stakeholders, and residents) did show concern about the threats that climate change poses to Lima and the need to act. In these cases, respondents vocalized strong interest in technological strategies that facilitate sustaining the water supply for Lima and that help

protect communities from the environmental hazards. At the city level, in the water sector, authorities are keen on investing to expand the water sources that provide water to Lima, through water transfers from further water basins (e.g., Cañete River) and salinization plants in areas without reliable water supply (i.e., currently under construction in the Santa Maria del Mar district). Policymakers have worked on measures to increase the water supply, though demandside measures to reduce water consumption have yet to be considered. At the individual level, residents had or were in the process of installing water tanks in their homes, to increase their water storage capacity during droughts, as well as water-efficient fixtures (e.g., toilets, faucets). Similarly, in dealing with mudslides and flash floods, local authorities facilitated the installation of debris flow barriers (mallas) in the steep valleys above population centers of the Chosica-Lurigancho district. The installation of the *mallas* followed the failed attempt to relocate residents located in a zone declared as being of immitigable risk (Mechler, 2017). Interviewees in this district supported the installation of more *mallas* as they were successful in protecting the area during the 2017 flashfloods. During the interviews, residents reported feeling content and safe thanks to the mallas. This sense of security may lead to further settlement in this area, which would put the population at risk in the long term.

Fourth, yet a further set of residents interviewed showed a low external locus of control regarding climate change and related events (i.e., ENSO). The low controllability in the climate threats is transferred to a low efficacy in reducing their own vulnerability and/or adapting to new conditions (i.e., their self-adaptive capacity). Overall, this sentiment exacerbates a feeling of despair among individuals in dealing with "natural events." Several of the interviewees, mostly senior adults and elderly, also linked their perceptions of low controllability of climatic events to their religious beliefs, such that only god could reduce the risk or impacts. For example, one resident from Chosica said, "But what can be done with nature? No one can take responsibility for that. We must request God to prevent anything worse from happening to us. We need to behave well with him so that he won't hassle us." Based on these beliefs, adaptation strategies are best delegated to a higher force who is trusted to take care of people and prevent climatic threats from happening. In that sense, respondents say that there is a need to pray more often, to appease god, or to call on Limeños to improve their daily behavior so that god will stop punishing them with climatic hazards. Similarly, some residents in the Cieneguilla district, in keeping with ancestral

beliefs and traditions, put offerings in the riverbanks with the hope that this will calm the forces of nature in the coming seasons.

Fifth, residents were asked to ponder on the governmental and individual responsibilities in adapting to climate change. Beliefs about governmental responsibility, in conjunctions with the perceived impacts, mediate current adaptive strategies. While some residents think that the authorities should bear greater responsibility in the adaptation process, others think it is a shared responsibility. In the former case, residents associate the authorities' responsibility with the notion of a paternal state that takes care of citizens. In the latter case, residents advocate that society should take action, collectively, considering the limits of governmental support. In both cases, residents expect their authorities to provide them with the relevant information before making adaptive decisions. When these expectations were not met, they reported feeling the need to act on their own, to compensate, which usually resulted in coping strategies. Such strategies appeared to hinge more strongly on residents' economic capacity (e.g., to acquire materials necessary for coping) rather than on adapting their behaviors (e.g., changing daily water habits), which would be more beneficial in the long term for the city as a whole.

3.6 Discussion

The extreme climatic events that affected Lima in 2016–2017 have led to an increased recognition that Lima is vulnerable to climate change. The overwhelming perception that Lima is not prepared for climatic changes, with variation in either temperature and/or rainfall, or the impacts thereof on water availability and public and private infrastructure has opened the political agenda for climate change adaptation, and has encouraged residents to consider their water security prospects in light of the threat. With our case study, we have examined urban dwellers' adaptive capacity in Lima using an unusual ENSO event as a temporal analogue. Our methodological approach allowed us to examine individual responses to abrupt climatic events affecting water security, and to understand dwellers' adaptive strategies in light of further climate change uncertainties for their city. Further, our study responds to the lack of clarity on whether people who take coping actions to decrease their vulnerability to current climate variability are also developing their capacity to adapt to climate change (Schaer, 2015). For this, we advanced a conceptual approach to understanding adaptive capacity as a process that looked at both the behavioral and the institutional factors shaping adaptive capacity in the urban milieu. This approach can be used to analyze other urban areas, considering that the socio-psychological

processes that emerge in the analysis constitute deeper-level factors that are contextually and culturally relevant.

Current attempts to understand the process of urban adaptation have mostly focused on adaptation governance, looking at planning and policy implementation, often overlooking dwellers' interests, experiences, and beliefs. It is frequently assumed that residents form a homogenous group (Brink & Wamsler, 2019) that will positively respond to adaptation plans. In Lima, we observed that authorities share the belief that residents need to "behave better" and that they trust that focusing their policy efforts on raising awareness about environmental problems will incentivize people to act more sustainably. Two main problems arise from not considering individual-level characteristics and associated dynamics in urban adaptation. First, studies show that increased awareness about climate change alone will not increase adaptive behavior, given the mental and affective mechanisms that mediate adaptation (Clayton et al., 2015; Gifford et al., 2011); and in many cases the targeted behavioral change goes counter to cultural and personal beliefs and values (Hulme, 2009; Jooste et al., 2018; O'Brien & Wolf, 2010). In our study, we have shown the importance of socio-psychological processes as part of the process of adaptation. Even though most Lima residents have knowledge about climate change and have experienced firsthand impacts of the climatic events in 2017, individual perceptions and cognitions, together with the social institutions found in Lima, delineate existing adaptive strategies. We find that cognitive dissonance, optimism bias, technological paradigms, locus of control, and authoritative beliefs shape Lima residents' adaptive strategies. These psychological processes are influenced by: gender roles, social ties, religious norms, urban lifestyles and a related disconnection from nature, paternalism, absent government practices, and hierarchical and collaborative ideals of governance. These social institutions structure individuals' interactions with their families, neighbors, coworkers, and strangers, which manifests in individuals expecting certain coping responses and adaptive strategies from these actors in the urban milieu, and in adjusting their own behavior to the expectations (i.e., social cognition). One year after El Niño Costero, we observed that residents support and/or take on strategies for dealing (or not) with climate change in line with coping, sustainability, morality, technology, and laissez-faire approaches. Based on the distinct sociopsychological processes leading to these strategies, adaptation governance needs to consider individuals as the complex human beings they are by designing policies and measures that appropriately incentivize adaptive behavior.

The second problem, stemming from a lack of attention to individual-level factors, is the assumption that residents are a homogenous group when designing adaptation policies, which disguises systemic inequalities. We have challenged this misconception by looking into the diversity of experiences and beliefs that shape how each individual understands and deals with climate change threats throughout Lima. Our findings portray residents' diversity in terms of the settings in which they find themselves (e.g., availability of water infrastructure) and of the social interactions that moderate their coping actions (e.g., intrahousehold dynamics), both of which influence the adapting scope (e.g., water valuation). A main consideration that follows our results is that current inequality in water access and distribution, as well as the unequal support of local governments in responding to climatic threats, directly undermine residents' capacity of coping with climate change impacts on their water security. Currently, the experience of daily water use differs greatly within the city, and will gradually get worse with the increasing climate change impacts. With El Niño Costero, residents had to overcome the impacts on their water security, as it affected most residents' finances and daily routines while also giving rise to numerous physical and mental health issues. While acute physical health issues were limited to those directly affected, mental health issues prevailed across Lima, albeit more so by those who already felt too disempowered to change their living conditions, given their marginality. However, mental health impacts have received little attention in climate change literature (Cunsolo & Ellis, 2018; Fritze et al., 2008; Gifford & Gifford, 2016) and more research is needed to understand how the degree of distress related to systemic inequalities alters coping actions and overall adaptive behavior in urban areas. This is important as urban adaptation plans often fail to incorporate poverty and other social systemic exclusions established in cities, which can contribute to greater inequalities (Dodman et al., 2019). Thus, considering the contextual factors that shape individuals' adaptive capacity in the city would help policymakers to better respond to specific group needs in urban areas.

Finally, we conclude that studying the relationship between residents and authorities is fundamental. Authorities establish policies that structure the adaptation scope of residents. And residents' actions affect not only their personal safety but also overall public adaptation (Brink & Wamsler, 2018; Wamsler & Brink, 2014a). As we've seen in Lima, authorities' disregard of climate scenarios for policymaking and their enthusiasm for technological measures to solve Lima's current water stress situation seems to obstruct considerations about incentivizing demand-side measures to reduce residential water consumption for the long term. This is not to say that the

adaptation responsibilities should burden residents, but that a comprehensive outlook should be cultivated on the possibilities of reducing the impacts of climate change and on fostering adaptive behavior of individuals, one that builds urban social resilience on a broader scale. Lima residents have now experienced and coped with a period of water insecurity in their daily lives, have gained new knowledge about climate extremes, and are expecting—to varying degrees—their authorities to step up to the challenge in an environment of mistrust. The current processes of individualization and disintegration of social organizations found in Lima is likely to undermine adaptive capacity (Cinner et al., 2018), and mere exposure to climate change cannot be expected to suffice to foster adaptive behavior (Ray et al., 2017; Zografos et al., 2016). Under this scenario, our study has shown the existence of several strategies used by residents to deal with climate change, some of which are adaptive and others not. Thus, it would be very valuable to analyze the socio-economic and governance determinants of adaptive capacity of residents across Lima neighborhoods.

3.7 Conclusion

This research has integrated new institutionalism and environmental behavior to study urban dwellers' agency in adapting to climate change within the normative structures of their socio-urban milieu. This approach was used to examine the responses Lima residents to the extreme events brought by the 2017 El Niño Costero, which was used as a temporal analogue. We identified the socio-psychological processes leading to the adoption of five strategies (i.e, coping, sustainability, morality, technology, and laissez-faire) for dealing with climate change. These strategies were found to be the result of the interaction of residents' cognitive processes (i.e., cognitive dissonance, optimism bias, technological paradigms, locus of control, authoritative bias) with evolving social norms (i.e., gender roles, social ties, religious norms, urban lifestyles and a related disconnection from nature, paternalism, absent government practices). The findings contribute to understanding why, even in situations with widespread climate change awareness and previous experience with extreme events, individuals do not adopt adaptive practices, a key concern of the climate change community. This paper lays the groundwork for future studies exploring and comparing culturally based socio-psychological adaptation. Examining individual-level factors is further needed to inform the development of adaptation policies such that these consider the diversity of urbanites' conditions and effectively incentivize personal and societal resilience.

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Preface to Chapter 4

In Chapter 3, I identified the socio-psychological processes leading to coping, sustainability, morality, technology, and laissez-faire strategies for dealing with climate change. The focus was on understanding how the behavioral and normative dimensions interplay to shape dwellers' diverse responses to climate change. In Chapter 4, I shift the analysis from specific adaptive strategies to adaptive behavior, which is greater in time and space. Specifically, I identify the significant socioeconomic, socio-institutional, and psychological determinants of individuals' adaptive behavior, intentional and non-intentional. I also compare the specific determinants associated with five types of adaptive behavior through thematic indices (structural, knowledge, consumption, planning, and environmental). This is the first study that uses survey data to investigate the adaptive behavior of urban dwellers' in the Global South. The development of the survey builds on the results of Chapter 3 to further investigate perceptions of water management, beliefs about nature, trust in authorities and responses to climate risks, and the emergent social norms about water practices.

This Chapter's findings further underscore the importance of the behavioral and normative dimensions, in addition to the socio-economic one, in explaining the variance of urbanites' adaptation. Findings also show the key role of urban-specific processes related to the object of risk (i.e., water) to explain adaptive behavior. Thus, I discuss the need to conceptualize adaptive behavior as inherently situated and contextual and use context-appropriate measurements.

This chapter is ready to be submitted to a journal. The format has been modified to be consistent within the thesis. All references cited in Chapter 4 appear at the end of the chapter.

CHAPTER 4: What Motivates Urban Dwellers to Adapt to Water Insecurity?

An Empirical Study in Lima, Peru

Abstract

This paper examines the determinants of adaptive behavior in face of climate-driven water insecurity, using a survey of 400 urban dwellers in Lima, Peru. This urban milieu is characterized by continuous water stress and is at risk of permanent water scarcity due to climate change. Lima dwellers show wide understanding that the climate is changing and have recent experience with climate extremes. In this context, the study uses regression analyses to identify the significant socioeconomic, socio-institutional, and psychological determinants of individuals' adaptive behavior. The study further examines the differences between intentional and non-intentional adaptive behavior, using separate indices to identify and compare the significant determinants to both behaviors. In addition, the study compares the specific determinants associated with types of adaptive behavior through five thematic indices (structural, knowledge, consumption, planning, and environmental). Findings show that education, continuous water availability, climate change concern, and cultural environmental values are significant determinants of intentional and nonintentional adaptive behavior. Yet, each thematic index has distinct significant determinants, which allows a more in-depth understanding of adaptive behavior. In the discussion, we reflect on the importance of water-related determinants, the intentionality of adaption behavior, and on the need to contextualize social and psychological determinants to the realities of urban dwellers in the Global South.

4.1 Introduction

Climate change is a pressing challenge for urban dwellers in the Global South. City residents already face multiple risks in the urban milieu (Arku et al., 2017; Jabeen et al., 2010; Pelling & Wisner, 2012), and climate change is an additional problem encountered in people's private and public spheres (Global Center on Adaptation, 2019; Klein et al., 2018). Specifically, city residents need to increase their resilience to the changing climatic conditions and the impacts that these bring. Thus, climate change requires shifts in people's lives from changing everyday habits to altering private spaces (Duchi et al., 2020; Swim et al., 2009). While there is evidence of adaptation starting to take place in cities in the Global south (Araos et al., 2016; Dulal, 2019; Kareem et al., 2020), our understanding of what motivates urban dwellers to adapt is limited (Flórez Bossio et al., 2019). Most work has focused herein on documenting adaptation needs, examining adaptation planning, or devising adaptation options (Chapagain et al., 2020; Chen et al., 2016; Kabisch et al., 2017; Le, 2020; Rosenzweig et al., 2018a), but what are the determinants of individuals' adaptive behavior?

The issue of individuals' adaptation lies at the intersection of two sets of scholarship. Climate change scholars have identified an extensive array of socioeconomic and institutional factors, and to a lesser extent, urban characteristics, that may increase the capacity to adapt to climate change (Florez Bossio et al., 2019; Morteaux & Barnnet, 2017). The climate change adaptation literature largely focuses on the resources and context-specific processes that structure social and institutional capacities, stressing the roles of governments, communities, and households, and to a lesser degree, the role of individual citizens (Carman & Zint, 2020; Deng et al., 2017; Helm et al., 2018). Studies that do approach individual-level adaptation have mainly focused on classifying adaptive strategies (i.e., as autonomous or planned), as coping, adapting or transforming, as generic or specific (Berrang-Ford et al., 2011; Eakin et al., 2014; Ford et al., 2015), or assessing individuals' support for adaptation policies (García de Jalón et al., 2013; Hagen et al., 2016; Lam, 2015; Leiserowitz, 2006). As yet, little attention has been paid to understanding the determinants of adaptive behavior (Barnes et al., 2020; Carman & Zint, 2020; van Valkengoed & Steg, 2019), and within the small number of studies that do, studying urban dwellers' behavior has remained at the margins (with notable exceptions Daoudi et al., 2019; Wamsler & Brink, 2014a; Zander et al., 2019).

Environmental behavior scholars, however, have examined the cognitive, affective, and experiential factors that explain pro-environmental behavior, such as risk perception, perceived self-efficacy, perceived controllability, experience with hazards, climate change awareness, and more recently, the psychological distance to climate change (Gifford et al., 2011; Lange & Dewitte, 2019; Steg et al., 2016). Pro-environmental behavior usually covers desired sustainable practices that enhance low-carbon lifestyles (de Leeuw et al., 2015; Lin, 2013; Poortinga et al., 2004; Steg & Vlek, 2009), which is closely aligned to climate change mitigation responses (Gifford et al., 2011). Though these practices support the long-term response to climate change, they do not address the individual needs to prepare and respond to the impacts of climate change. Nonetheless, some scholars have started to shed light on the psychological antecedents of individuals' adaptive behavior (Bradley et al., 2020; Clayton et al., 2015; Cologna & Siegrist, 2020; Domingos et al., 2018; Reser et al., 2012), although mostly in the Global North²⁵ (Amoah & Addoah, 2020; Carman & Zint, 2020; González-Hernández et al., 2019; Zander et al., 2019). Their findings outline the importance of people's psychological mechanisms in the process of adaptation, recognizing that these remain bounded by institutionalized social norms (Grothmann & Patt, 2005; Lo, 2013; Reser & Swim, 2011; van der Linden, 2015; van Valkengoed & Steg, 2019; Weber, 2010).

Although the importance of psychological mechanisms in adaptation is widely accepted, current research has produced separate theoretical frameworks of the determinants of adaptive responses to climate change (Barnes et al., 2020). The separation happened even when early climate change studies had pointed out the neglect of cognitive and affective variables in research (Grothmann & Patt, 2005), and environmental behavior scholars had acknowledged the influence of social norms (Swim et al., 2009). There is a need to synthesize and integrate the knowledge produced in both lines of research to provide a comprehensive understanding of urban dwellers' adaptive behavior. In responding to this gap, this study examines the determinants of individuals' adaptive behavior facing threats to water security in a developing country context. The aim of this study is twofold: 1) to provide a comprehensive model that explains the variance in adaptive behavior of urban dwellers, examining the importance of each theoretical perspective; and 2) to identify and compare significant determinants of intentional and non-intentional adaptive behavior. To the best of our

²⁵ Taking a closer look at Carman & Zint's (2020) systematic review of adaptive behavior database, we identify only 40 empirical studies at the individual level (not including studies only assessing households) that study personal adaptive behavior (i.e., we discard those which only assess policy support). From those empirical studies, 8 of the are in developing countries, yet none of these are in Latin America.

knowledge, our study is the first to use survey data on the determinants of adaptive behavior of urban dwellers in the Global South, and among the first globally to consider these determinants in the context of increased water insecurity due to climate change. We begin the paper by reviewing the relevant literature to adaptive behavior before outlining the methodological approach for our case study in Lima, Peru. Then, we present the results of the regression analyses performed for seven adaptive behavior indices, which is followed by a discussion of our findings.

4.2 Determinants of Urban Dwellers' Adaptive Behavior

Adaptive behavior to climate change refers to personal actions and practices that reduce the possible harm of climate change, which may bring additional benefits to individuals' household, community, or the environment (Carman & Zint, 2020). Many possible adaptation responses have been suggested in the literature (IPCC, 2014). However, a simple adaptation response (e.g., moving furniture upstairs or saving money) does not mean an individual is acting in a comprehensive manner to deal with climate change threats in their locality. Urban dwellers often find themselves dealing with multiple stressors that may have triggered such responses (e.g., earthquakes, gentrification, pandemics) (Arku et al., 2017; O'Brien et al., 2004). Therefore, it is important that the analysis of adaptive behavior includes a set of actions and practices that together enhance resilience, considering local risks and climatic threats over the mid- and long-term perspectives. Then, adaptive behavior can be conceived as an approach to living in the context of a changing climate, meaning that the extent of such behavior is greater in time and space than specific responses. Such behavior requires that individuals overcome barriers, such as financial costs, mental effort, lack of comfort, social pressures, or low self-efficacy, to address their current and future wellbeing (Grothmann & Patt, 2005; Price et al., 2014; Steg & Vlek, 2009). In such a challenging setting, what influences some people to behave more adaptively than others?

Past research has characterized the capacity to adapt; that is, factors which theoretically are associated with adaptive behavior. Scholars widely underscore financial and technological assets, education, and access to essential services as key determinants (Berrang-Ford et al., 2011; Flórez Bossio et al., 2019; Mortreux & Barnett, 2017). Taken together, these factors proxy the socioeconomic status of an individual. Yet, empirical studies of adaptive responses have shown mixed findings of the explanatory power of socioeconomic variables. For example, homeownership was revealed to predict responses to cope with floods in Cologne, Germany,

though income was insignificant for most behavioral intentions (Grothmann & Patt, 2005). In contrast, income was found to have a significant effect on adaptation measures in Mannheim, Germany, along with education, age, and gender (Osberghaus et al., 2010). Similarly, Botzen et al. (2009) found education to be a significant predictor for household protection against floods in the Netherlands, but not income. Much less attention has been given to urban-specific factors (Flórez Bossio et al., 2019) which also reflect on the socioeconomic status of urban dwellers. Research that addresses socio-urban dynamics has shown that factors such as place identity, socio-spatial inequalities, land use regulations, and social fragmentation shape how actors respond to hazards (Flórez Bossio et al., 2019; Handayani et al., 2017; Krellenberg et al., 2014; Romero-Lankao et al., 2014). These place-based processes require in-depth knowledge of the study locations in order to collect the appropriate data that can serve as predictors of adaptive behavior. In the context of climate threats to water security, urban factors that compound the socioeconomic status of dwellers may include the differentiated provision of water services in the city, including the source, payment, or timing to access drinking water (Thaker et al., 2016).

Adaptation studies have moved from only considering *fixed* socioeconomic characteristics to also include the *changeable* social factors that influence the adaptive capacity (Grothmann et al., 2013). The assessment of socio-institutional factors mediating adaptation has meant an increased involvement of social scientists in the study of climate change since the early 2000s (Smit & Wandel, 2006; Wang et al., 2018). Since that time many studies have provided evidence of the importance of social capital and social norms for adaptation (Larson et al., 2013; Liang et al., 2017; Lo, 2013; Pelling & High, 2005; Wolf et al., 2010; Yu et al., 2019). Regarding social capital, the built trust and social networks have been considered central to successful adaptation. It is argued that individuals ought to trust and engage with others in their societies to raise the resiliency of their communities, especially when dealing with uncertain scenarios (Earle et al., 2010; Kuhlicke et al., 2011). Hence, trust has been measured in relation to others in a general way, or specifically with regard to authorities, industry, scientists, and institutional responses to climate change (Cologna & Siegrist, 2020). Social networks have been equally important in the literature examining adaptation. Evidence shows that social networks strengthen the cohesion of individuals and communities in dealing with climatic uncertainty and risks, which may enable or prescribe adaptation (Adger, 2003; Jones & Boyd, 2011; Pelling & High, 2005).

While social capital factors have been consistently assessed in the climate change literature, the inclusion of institutions (i.e., rules, formal and informal norms) has been more limited (Grothmann et al., 2013; van Valkengoed & Steg, 2019). The examination of formal and informal norms is important because these guide individuals' behavior; they delineate the extent to which actions and practices are deemed acceptable within a society (Ostrom, 1990, 2014). Social norms can facilitate or constrain a person's willingness to take actions to lower the risks (Bisaro et al., 2018; Flórez Bossio et al., In review; Matthews & Sydneysmith, 2010; Oberlack, 2017). In a meta-analysis of adaptive behavior, van Valkengoed and Steg (2019) find that perceived descriptive norms are positively associated with adaptive behaviour, though this was based on a small number of studies. In comparison to informal norms, adaptation research has given more consideration to formal norms at the community and governmental level, especially in managing natural resources (e.g., water governance) (Bakker, 2012; Bettini et al., 2015; Brown et al., 2009; de Loë et al., 2007; Kashyap, 2004; van de Meene et al., 2011). At the individual level, the perception of these institutional arrangements may also influence adaptive behavior. In broader social science research, study findings show that people behave differently based on how they experience fairness in everyday issues (Lupfer et al., 2000), such as the distribution of water, from the decision-making process to the outcomes of such allocation (Gross, 2008; Nancarrow et al., 2010). Research is still needed to examine whether individuals' perception of the fairness of water institutional arrangements influence their adaptive behavior.

Behavioral scientists explain that social norms further influence individuals' cognitive processes, thus one's appraisal of risks (Clayton et al., 2015; Swim et al., 2009). The inclusion of risk perceptions in adaptation research has been prominent, likely influenced by Grothmann and Patt's (2005) sociocognitive model of private proactive adaptation (MPPACC), which extended Rogers' (1975) protection-motivation theory to climate change adaptation. However, the MPPAC and related studies link risk perception and perceived adaptive capacity only to adaptation intentions (i.e., willingness to act), which do not directly lead to adaptation actions (Ford & King, 2015; Lo, 2013). The few studies that do examine these constructs in relation to adaptive behavior provide mixed results (Akompab et al., 2013; Koerth et al., 2013; Liu et al., 2013; Reser et al., 2012). Thus, researchers continue to examine the determinants and mediators of risk perception. These factors include experience with previous hazards, holistic affect, climate change awareness, knowledge, and concern, as well as values and worldviews (Deng et al., 2017; Dessai et al., 2004;

Lee et al., 2015; Steg & Sievers, 2000; Weber, 2010; Whitmarsh, 2008) and only recently, social norms (van der Linden, 2015). Research findings depict an increase in climate change awareness in recent years, but also that people generally see climate change risk as low and not personally relevant, which leads people to justify inaction (Lorenzoni et al., 2006; Lorenzoni et al., 2007; Luís et al., 2018; Price et al., 2014; Weber, 2006). In fact, Taylor et al. (2014) find that when individuals are more familiar with projected climate change impacts, their beliefs about climate change have a low positive impact on the willingness to adopt protection measures. Instead, knowledge about climate change impacts is a significant predictor of the intention to take protective actions. This underscores the importance of examining general perceptions of climate change along with risk perceptions of specific climate threats.

Addressing the lack of personal relevance of climate change is of great importance to understanding adaptive behavior. Personal relevance can be approached through the Construal Level Theory (CLT) (Liberman & Trope, 1998; Trope & Liberman, 2010), which proposes that psychological distance to a construct (e.g., climate change) is defined as high (far) or low (close). Such distance is usually measured in temporal, spatial, and social terms. Researchers have started to use this theory to understand the psychological distance to climate change (Deng et al., 2017; Spence et al., 2012). Spence et al. (2012) conclude in a study from the UK that perceived impacts in developing countries (i.e., far social distance), perceived impacts on people similar to the respondents (i.e., close social distance), perceived impacts on people's local area (i.e., close geographic distance), and perceived impacts to occur at close time scales, were important predictors of preparedness to act (i.e., mitigation actions). This theoretical approach remains to be applied to adaptive behavior, and in the context of the global South. The way that geographic or social distances are defined (and measured) changes in developing countries, where large parts of the population are very likely to feel the impacts of climate change. In such a milieu, as it is in Lima, it would be more appropriate to address social distance in terms of those who are highly vulnerable.

Environmental behavior research, building on cultural theory (Douglas, 1978; Douglas & Wildavsky, 1982; Wildavsky & Dake, 1990), has provided evidence that individual values and beliefs about the environment influence pro-environmental behavior (De Groot & Steg, 2008; Poortinga et al., 2002; Schultz et al., 2005; Stern, 2000). A prominent strand of this scholarship

proposes the existence of four cultural worldviews based on group-grid scale. The 'group' assesses how much of people's lives is controlled by the group they live in, and 'grid' the amount of control and structure that people accept. The resulting competing worldviews include hierarchical, egalitarian, individualistic, and fatalistic (Dake, 1992; Douglas & Wildavsky, 1982). Scholars have expanded cultural theory to include environmental values (Kahan et al., 2011; Lima & Castro, 2005; Price et al., 2014; Steg & Sievers, 2000; Thompson, 2003) where egalitarian perspectives frame the environment as 'fragile', underscoring the need to enhance individuals' behavior towards being pro-social or pro-environmental. Hierarchical views frame the environment as 'tolerant' up to a certain point where damage is irreparable, thus supporting policy restrictions on individual behavior. Individualistic perspectives frame the environment as 'benign,' able to recover from damages, thus it privileges the economy above the environment and relies on technology and science to manage any problem. Fatalistic perspectives frame the environment as 'capricious,' unpredictable and uncontrollable, thus justifying inaction (Lima & Castro, 2005; Poortinga et al., 2002; Steg & Sievers, 2000). Concerning climate change, Kahan et al. (2011), argue that people with hierarchical and individualistic perspectives in the US are more likely to deny climate change science (e.g., global temperatures are increasing, climate change is human-induced) compared to those with egalitarian and communitarian perspectives. Price et al. (2014) further demonstrate with a study in Australia that individualistic and fatalistic perspectives frame the environment as 'elastic' to justify damaging behaviors or inaction, while hierarchical and egalitarian perspectives frame the environment as 'ductile' to justify environmental policies. The authors conclude that cultural environmental values²⁶ biases directly influence pro-environmental behavior in the household, which included water consumption in their study. Their conclusion suggests that there may be a relationship between environmental cultural values and adaptive behavior, which has yet to be examined empirically.

4.3 Methodology

Based on previous fieldwork in Lima and the review of climate change adaptation and environmental behavior literatures, we developed a survey instrument, collecting data on the socioeconomic, socio-institutional, and psychological determinants of adaptive behavior. We

 $^{^{26}}$ In their study, cultural environmental values are renamed as cultural environmental biases. For clarity and consistency, we keep naming them values here.

measure adaptive behavior with an index of adaptive actions and practices²⁷ aimed at reducing the harm of climate change impacts and taking advantage of potential benefits. We developed two main indices: the Intentional Adaptive Behavior Index (IAB Index) that assesses intentional actions and practices in response to climate change; and the General Adaptive Behavior Index (GAB Index), which measures general actions and practices that enhance individuals' resilience to climate threats to water security, though these have not necessarily been taken solely in response to climate change. The GAB index includes structural, knowledge, consumption, planning, and environmental-friendly actions and practices. Additionally, we analyze the five GAB index themes as separate thematic indices.

4.3.1 Study Area

The study context, in Lima, Peru, is characteristic of large cities in developing countries that face numerous social stressors as they continue to expand rapidly while increasingly facing the climatic threats. Climate change threatens to decrease the annual water availability in Lima's catchment area, increasing the occurrence of droughts, and extreme weather events and intense periods of rainfall (Calvo, 2012; Miranda Sara et al., 2017). From February to April 2017, urban residents experienced an extreme climatic event, known as El Niño Costero, which severely affected the country's north and central coast, including Lima. In the city, residents endured drastic rainfall increases that led to flooding, mudslides, and water pollution, which together affected water supply citywide, from 3 days to 3 months depending on the city area (Flórez Bossio et al., In review). We use this period as a "temporal analogue," a methodological approach that considers recent experiences with climatic phenomena as a means to gain understanding of future vulnerability and adaptive responses (Ford et al., 2010).

Building on a citywide qualitative study in 2018, this study was conducted in 2019 in four Lima districts (see Figure 9): Los Olivos (north), Villa Maria del Triunfo (south), Miraflores (center), and Lurigancho-Chosica (east). These districts were selected based on their distinct urban development paths and socioeconomic conditions (see Table 6), which account for varying sensitivities to water insecurity in Lima. Lurigancho-Chosica and Miraflores were established in the nineteenth century. Lurigancho-Chosica is a district with very low density, as it includes vast

²⁷ We distinguish between actions and practices, whereby actions are taken once, with a clear start and end; practices are regularly performed.

agricultural and industrial areas, in contrast Miraflores has a high population density as it is largely residential, but also hosts a great array of businesses. Los Olivos and Villa Maria del Triunfo developed later in the mid-twentieth century, both with a mix of residential and industrial areas.

Figure 9 - Location of Lima districts

Lima Districts



Table 6 - Lima Districts' Characteristics

	Location			Socioeconomic Characteristics		Urban characteristics			
	District	Year of establishment	Area	Population (2017 census)	Human Development Index (2012, UNDP- Peru)	Informal Human Settlements (Fernández de Córdova et al. 2015)	Density – Pop./km2 (2017 census)	Water Supply (% of households with connection to public water service - Census 2017)	
1	Lurigancho- Chosica	1894	East	240,814	0.60	High	1018	53.95%	
2	Villa Maria del Triunfo	1961	South	398,433	0.58	High	5,645	78.6%	
3	Miraflores	1857	Center	99,337	0.79	Low	10,326	100%	
4	Los Olivos	1989	North	328,884	0.65	High	17,856	99.75%	

The historical development of the districts does not match the current status of water provision. Miraflores and Los Olivos have water supply coverage above 99%, both also have the highest human development index (HDI) scores. Conversely, the water supply coverage in Lurigancho-Chosica and Villa Maria del Triunfo lags behind with 53.9% and 78.6% respectively, these districts also have the lower HDI scores. Even though there are considerable differences across districts,

the city's many socio-economic profiles and population groupings are not consolidated in distinct large homogenous areas, instead the social composition of districts is heterogeneous, with scattered degrees of diversity in terms of migrant origin, socio-occupational categories, and per capita income (Fernández de Córdova et al., 2016).

4.3.2 Participants

Multistage sampling was used for each district, first randomly selecting three zones of 1km² in each district (i.e., random area sampling); and subsequently randomly selecting three public spaces in each zone from a list of public spaces identified in Googlemaps (e.g., parks, plazas, bus stops, markets). Participants were randomly selected in these public spaces, with the condition that they lived in the selected district and had been living in Lima for at least the last 24 months. This time condition was introduced to ensure that all participants had been settled in the city when an unusual ENSO phenomenon happened in early 2017 (see more in Florez Bossio et al. in review), thus guaranteeing that all participants had already experience with extreme climatic events²⁸. Additionally, the sampling was stratified for gender to have an equal number of men and women. In total, 400 participants were surveyed, 100 per district. The survey response rate was 62%.

4.3.3 Materials and Procedure

The design of the survey instrument was informed by previous qualitative research on the adaptive capacity of residents of Lima using in-depth semi-structured interviews with residents and policymakers (see Florez Bossio et al. in review). The questionnaire was context-relevant according to the climate threats to the city's water security, and culturally appropriate. The survey was developed using the KoboToolbox software that enables surveyors to collect data using mobile phones, avoiding input errors during data collection. The instrument was pre-tested with Lima residents (n=10) to ensure that the questions and response categories were clear, and that all possible responses were included in the survey. Results of the testing phase were used to refine the questionnaire. From March to June 2019, the survey was administered in-person by the lead author and three research assistants. Our research study was approved by McGill University's Research Ethics Board. Respondents were informed of the survey's aim, reassured that their

²⁸ Research has mixed evidence on the influence of direct experience on individuals' risk perceptions and adaptation (Adger et al. 2012, van der Linden 2015). In our study all respondents were in Lima during El Niño Costero phenomenon, though affected differently, we do not assess previous experience, nor engage in discussing its influence.

responses remain anonymous, and told they could stop the interview at any time. The survey took on average 20-30 minutes to complete.

4.3.4 Survey Measures

4.3.4.1 Adaptive Behavior

The dependent variables are seven indices of adaptive behavior. Broadly, adaptive behavior was the sum of self-reported actions and practices that increase resilience in the face of climatic threats to water security (i.e., shortages and droughts). Each index was analyzed on its own in relation to the set of independent variables. We acknowledge the drawbacks of self-reported measures (Manfredo & Shelby, 1988) and have followed Kormos and Gifford (2014) recommendations to ensure the quality of behavioral measurements. The Intentional Adaptive Behavior (IAB) Index assesses the number of actions taken in response to one self's concern about climate change, including both mitigation and adaptation measures. Respondents were asked if they had ever taken, or regularly take, an action based on their concern about climate change. The type and number of actions given by respondents were collected. The General Adaptive Behavior (GAB) Index was built based on 18 possible actions that individuals could take to adapt to climate change threats to water security in Lima (see Table 7). The index was designed to include consumption, knowledge, structural, planning, and environment-friendly actions that had been preidentified during our previous fieldwork in Lima and in the adaptation literature. Respondents were asked if they had taken each of the 18 actions in the last year. If a response was affirmative, respondents were asked the main reason for taking this action. Stemming from the GAB index, five thematic indices were created to group actions that shared a common goal. The Consumption index consists of actions taken that reduce water use in daily activities. The Knowledge index contains the actions taken that increase knowledge about climatic threats. The *Planning Index* counts actions taken that logistically and economically prepare individuals for uncertain future climatic events. The Structural index includes actions taken that increase water efficiency by changing or installing physical features in individuals' households. The Environmental index consists of actions taken that support environmental sustainability. The five thematic indices values were dichotomized for analysis (1 = above mean and 0 = below the mean).

Table 7 - GAB Index & Thematic Indices

General Adaptive Behavior Index							
Structural Index	Consumption Index	Knowledge Index	Planning Index	Environmental Index			
 Installed water efficient faucets Installed water efficient toilets 	 Reduced the amount of water I use for cleaning my home Reduced the amount of water I use for my personal hygiene Reduced the amount of water while showering Reused water for cleaning purposes 	 7. Sought information about dealing with droughts 8. Sought information about dealing with floods 9. Sought information about environmental pollution 10. Sought information about Lima's water constraints 11. Dedicated time to learn about climate change 	 12. Established a neighborhood committee for emergencies 13. Organized a family savings method for emergencies 14. Discussed with household members about emergency plans 15. Stored water at home for emergencies 	16. Recycled waste 17. Consumed organic products 18. Biked to work or school			

4.3.4.2 Socioeconomic Determinants

Socioeconomic information was collected from respondents, including age, gender, education, income, and homeownership. Also, two water-related socioeconomic variables were included: water frequency (number of water service hours per week, calculated based on number of days with service, and number of hours per day); and source of water provision. For ease of interpretation, education, income, and water provision were recoded into binary responses (1 = higher education and 0 = lower education), (1 = higher income and 0 = lower income), and (1 = water provision by truck and 0 = home connection to water service). In the case of age, two dummy variables were created to pay special attention to young adults (age: 18-34) and seniors (age: 55+).

4.3.4.3 Socio-institutional Determinants

Socio-institutional determinants of adaptive practices encompass social networks, social trust, and social norms. Regarding *social networks*, respondents were asked about how many neighborhood organizations they participated in. Based on the World Values Survey, *social trust* was first measured in relation to others in the respondents' district (1 = most people can be trusted, and 0 = need to be careful). Second, on a 5-point Likert-scale, respondents answered three questions about their *trust in institutional responses* to ensure water availability during droughts at the district, city, and national levels. A reliable scale was obtained (a = 0.75).

Two 5-point Likert questions were used to assess perceived social norms about water (based on similar questions about perceived social norms used by Reser et al., 2012 & Van der Linden 2015). The *prescriptive water use norm* question enquires about the extent to which respondents feel pressure to reduce their water consumption. Similarly, the *descriptive water use norm* question asks whether important referent others are taking personal action to reduce water misspend. Lastly, respondents were asked about their *perception of fairness regarding Lima's water institutional arrangements*. Respondents answered three similar 5-point Likert questions on whether they considered water access, water price, and water distribution to be fair in the city.

4.3.4.4 Psychological Determinants

To address environmental values, we draw on Price et al. (2014), who developed two dimensions of cultural environmental biases. The first one, environment as elastic, measures individualized cultural environmental biases with individualistic and fatalistic items that negate collective action to conserve the environment. The second one, environment as ductile, measures collectivized cultural environmental biases with hierarchical and egalitarian items that support such collective action. Respondents were asked to rate their agreement with 5-point Likert items, six items per dimension. Reliable indices were not obtained for either dimension, or for each of the four subgroups (i.e., individualistic, fatalistic, hierarchical, and egalitarian)²⁹. Thus, all items were evaluated on their own.

Two questions were used to assess residents' perceived water risks. First, respondents were asked to rate *the likelihood of water shortages* in Lima in the next three years. Likewise, respondents were asked to assess the level of *personal harm* stemming from water shortages, if they occurred. Moving from specific water risks to climate change, we adapted Spence's (2011) measurement of *climate change concern*. On a 5-point Likert-sale, respondents answered three similar questions about their general concern about climate change, their concern about climate change impacts in Lima, and their concern of personal impacts of climate change. A reliable index was obtained (a = 0.94).

²⁹ Cultural theory has been subject to intense academic debates. Some scholars oppose it due to the operationalization of the worldviews; and to the weak validity of the constructs (Boholm, 1996; Rippl, 2002; Sjoberg, 1998b as cited in van der Linden 2015). Our methodological issues with it support the latter claims. However, when disaggregating the construct items and further analyzing its association with adaptive behavior, we found that two items, pertaining to the individualism and fatalism worldviews, were strongly significant in the IAB and GAB indices.

Further, we adapted previous psychological distance to climate change constructs considering geographic, social, and temporal distance (Reser et al., 2012; Spence et al., 2012). Perceived *geographic distance* was evaluated using two questions, one that assessed perceptions that climate change would impact distant locations and one that assessed perceptions that climate change would affect the individual's district. Perceived *social distance* was assessed using two questions, one assessed respondents' perception that climate change was likely to have an impact on people similar to themselves; and one that climate change was likely to have an impact on vulnerable people. Unlike the approaches of Reser et al. (2012) & Spence et al. (2012), we assess the social distance questions separately because "people similar to themselves" and "vulnerable people" are not mutually exclusive if one perceives one's self as being vulnerable. To measure *temporal distance*, respondents were asked when they felt the effects of climate change would be felt in Lima. All psychological distance questions were recorded in five-point Likert scales.

Lastly, following Ajzen's (1991) understanding that individuals' perceived controllability refers to the extent to possibly control a situation at all regardless of one's skills and abilities (in contrast to specific-behavior self-efficacy construct), respondents were asked to indicate how much freedom of choice and control they felt over their lives on a scale from 1 to 10 (using the question as phrased in Inglehart et al., 2014).

4.3.5 Management of No response

All questions offered "Don't know" and "No response" response options as appropriate. Participants only gave "no response" answers to the income question. Respondents answered "don't know" to two sets of questions 1) climate change concern 2) psychological distance to climate change. Due to the low numbers of these responses, these were deleted listwise for regression analyses. Thus, the results are valid for understanding resident's adaptive behavior of those who know what climate change is.

4.3.6 Analysis

Statistical analysis was done using SPSS Version 20. All seven indexes were initially tested for linearity between the dependent variable and the set if independent variables; homoscedasticity; and the normality of residuals. Only the GAB Index complied with all the required assumptions. Based on these results for the GAB Index, a hierarchical multiple regression was performed, where

each theoretical dimension was included sequentially in three steps, leading to an integrated model (see section 4.4.2). In the case of the IAB index, a Poisson regression model was deemed appropriate given that the index is a count variable, and the data had a Poisson distribution (see section 4.4.3). Given the distribution of the five thematic indices, these were transformed from count to binary variables, and a logistic regression model was used for their analysis (see section 4.4.4).

4.4. Results

Analyses were conducted in four stages. First, the social and psychological constructs with multi-item scales were assessed (which are reported above). Second, descriptive statistics and correlations were computed. Third, all seven indices were initially tested for consistency with the assumptions of hierarchical multiple regression. . Fourth, the IAB index and the five thematic indices were further assessed with suitable regression models (Poisson and logistic, respectively).

4.4.1 Respondent Characteristics

Table 8 details the socio-demographic characteristics of the survey respondents. Respondents were most likely to be aged 35–54, with other age groups fairly represented. Over 50% of respondents only having primary or secondary education, while almost 28% had university studies (both percentages are similar to the population's educational distribution reported for Lima in Latinobarometro 2017). Table 9 presents the number of observations, range, means, and standard deviations of all independent and dependent variables.

Variable	Percentage of Respondents (N=400)
Gender	
Male	50 %
Female	50 %
Age	
18 - 24	19.5%
25 - 34	20.5%
35 - 54	39.5%
55 - 69	16%
70+	4.5%
Education (highest level of attainment)	
Primary	11.5%
Secondary	40.3%
Technical	21%
Bachelor	22.8%
Graduate	4.5%
Income (Monthly in PEN)	
No income	19.5%
Below 700	15.8%
Between 700 and 999	15.8%
Between 1,000 and 1,999	25%
Between 2,000 and 5,999	15.8%
6,000 and above	4.3%
No response	4%

Table 8 – Socio-demographic characteristics of survey respondents

Variables	Mean	Std. Deviation	Range	N
Independent				
Gender	.50	.501	1	400
Young Adults	.40	.491	1	400
Seniors	.21	.404	1	400
Education	.27	.446	1	400
Income	.47	.500	1	384
Home ownership	1.19	.395	1	400
Water Source	.05	.218	1	400
Water Frequency	15.97	10.377	24	400
Social Organizations	.28	.450	1	400
Social Trust	1.90	.304	1	400
Water Use Norm Prescriptive	3.72	.700	4	400
Water Use Norm Descriptive	3.28	.917	4	400
Water Price Fairness	2.24	.736	3	400
Water Distribution Fairness	2.35	.762	3	400
Water Access Fairness	2.51	.876	3	400
Trust Institutional Response	2.63	.744	3	400
Human Nature Interactions Fatalistic	2.84	.998	4	400
Human Nature Interactions Individualistic	3.00	1.014	4	400
Water Risk Likelihood	2.41	.726	2	400
Water Risk Personal Harm	3.70	.913	4	400
Climate Change Concern	3.03	.805	4	400
Temporal Distance	1.28	.597	3	383
Social Distance Close	3.69	.782	4	388
Social Distance Far	3.82	.771	4	380
Geographical Distance Close	3.95	.708	3	390
Geographical Distance Far	3.42	.988	4	386
Controllability	7.45	1.792	9	400
Dependent			1	1
IAB Index	.64	.841	4	400
GAB Index	.3713	.16267	.89	400
Consumption Index	.59	.492	1	400
Knowledge Index	.31	.464	1	400
Planning Index	.46	.499	1	400
Environment Index	.63	.483	1	400
Structural Index	.42	.494	1	400

Table 9 - Independent & Dependent Variables

4.4.2 General Adaptive Behavior (GAB) Index

The total number of implemented actions and practices per respondent ranged from 0 to 16; on average respondents took 6.7 actions (SD = 2.9). Based on the synthetic theory-based approach, hierarchical multiple regression analysis was used to examine to what extent socioeconomic, social, and psychological determinants explain adaptive behavior (Table 10). In the hierarchical multiple regression, each dimension is included sequentially in three steps, starting from a baseline model (i.e., Model 1) to an integrated model (i.e., Model 3). All three models were statistically significant.

The first model shows the influence of socioeconomic characteristics. Results show that gender, education, water frequency, and water source are all significant predictors of adaptive behavior, explaining a total of 11.1% of the variance in the GAB index (F(8, 339) = 5.289, p < 0.001, R^2 = .111). Therefore, being female, higher educated, and having a home water connection and extensive water service is associated with increased adoption of adaptive practices. In other words, the socioeconomic status of an individual starts to explain adaptive behavior, along with gender.

Dimension	Variables	Model 1 (Socioeconomic)	Model 2 (Socioeconomic + Social)	Model 3 (Socioeconomic + Social + Psychological)
Socioeconomic	Gender	.105*	D.S.	<mark>ე.</mark> ვ.
	Education	.192**	.167**	.151**
	Water Frequency	.141**	.165**	.168**
	Water Source	095*	105*	D.S.
Social	Social Organizations		.100*	.115**
	Water Price Fairness		145**	159**
	Water Distribution Fairness		132**	0.s·
Psychological	Human-Nature Interactions - Individualist			115**
	Human-Nature Interactions - Fatalistic			187**
	Climate change concern			.012**
Statistics		·	·	
F-Value		5.289	4.254	4.139
R ²		.111	.171	.259
R ² change		n/a	.060	.088

Т	able	10 -	GAB	Index
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N = 348. Variables reported are only those which are significant. Variable entries are standardized beta coefficients; *p < .05. **p < .01. ***p < .001.

The second model assessed whether individuals' perceived social institutions explain any additional variance in the GAB index while controlling for socioeconomic determinants. Results show that socio-institutional determinants explain an additional 6% of the variance in the GAB

index (F(16, 331) = 4.254, p < 0.001, R^2 = .171, R^2_{change} = .060). An individual's participation in neighborhood organizations is associated with the increased practice of adaptive actions. At the same time, perceptions of water price and distribution inequalities are associated with increased performance in the GAB index.

The last model, including the three dimensions, tested the explanatory power of psychological determinants in addition to socioeconomic and social determinants. Climate change concern, and fatalistic and individualistic cultural environmental values are significant predictors of the GAB index explaining an additional 8.8% of the variance (F(27,320) = 4.139, p < 0.001, R² = .259, R² change = .088). Individuals with stronger concern for climate change perform better in the GAB index. In contrast, individuals with stronger individualistic and fatalistic cultural environmental biases are associated with a lower GAB index. In total, the integrative model explains 25.9% of the GAB index variance.

For the regression analysis, the data met the assumption of independent errors (Durbin-Watson value = 1.950), that multicollinearity was not a concern (tolerance and VIF), and the histogram of standardized residuals indicated that the data contained approximately normally distributed errors, as did the normal P-P plot of standardized residuals. The scatterplot of standardized residuals showed that the data met the assumptions of homogeneity of variance and linearity.

4.4.3 Intentional Adaptive Behavior (IAB) Index

The goal of developing the IAB index was to examine the significant socioeconomic, social, and psychological factors that explain intentional adaptive practices, and to compare these to the statistically significant determinants of the GAB index. Given that the IAB index provided count data on actions that residents take to respond to climate change intentionally, Poisson regression model was used. Two measures were used to assess that the data had a Poisson distribution, one whereby the index mean (.689) was similar to the variance (.729). The Kolmogorov-Smirnov test that proved not significant (p = .962). Further, we conclude that the model fits reasonably well because the deviance of goodness-of-fit test is close to 1 (p = .916) (see Table 11).

The Omnibus test indicated that the Poisson model is statistically significant (p = .000). We find that education, water frequency, perceived fairness of water access, fatalistic and individualistic cultural environmental biases, perceived water risk harm and likelihood, climate

change concern, and social distance (far) are significant predictors. Thus, residents who have attended university, have extended water access at home, and observe inequality in the accessibility of water in Lima, take more intentional actions in response to climate change (49%, 1.6%, and 0.8%, respectively). Likewise, those who perceive a higher level of water risk likelihood, who are highly concerned about climate change, and who think climate change will impact the most vulnerable people, score higher in the IAB index (51.7%, 25.2%, and 46.5%, respectively). In contrast, individuals who score higher (1-point) in the individualist or fatalistic cultural environmental values, score lower in the IAB index (17% and 14% respectively). Surprisingly, individuals who rate higher the possible personal harm due to water shortages score lower in the index (16.3% lower than those who think they will be less harmed). In comparison to the GAB Index (Model 3), four new predictors were significant to understand the intentional actions to respond to climate change: perceived fairness of water access, social distance to climate change, and perceived water risk likelihood and harm.

Dimension	Variables	IAP Index	GAB Index
		(Exp(B))	(also significant in Model 3)
Socioeconomic	Education	1.490**	x
	Water Frequency	1.016*	x
Social	Water Access Fairness	.808*	
Psychological	Human-Nature Interactions - Fatalist	.830*	x
	Human-Nature Interactions -	.860*	x
	Individualist		
	Water risk likelihood	1.250**	
	Water risk harm	.837**	
	Climate change concern	1.465***	x
	Social Distance - Far	1.192*	
Statistics			
Goodness of Fit	Pearson Chi-Square	.917	n/a
Omnibus Test	Likelihood Ratio Chi-Square	108.244***	n/a

Table 11 – IAB Index

N = 348. Variables reported are only those which are significant. Variable Entries are exponentiated beta coefficients; *p < .05. **p < .01. ***p < .001.

4.4.4 Thematic Indices

The five thematic indices that together comprise the GAB index were further analyzed to identify significant predictors for each. Due to the distribution of the five thematic indices, it was necessary to transform the dependent variable from count to binary, using each index mean to define and divide high (= 1) and low (= 0) scores. A logistic regression model was then used to analyze the thematic indices. The five indices were tested with the -2 log-likelihood statistic and

the Hosmer and Lemeshow, all indices displaying good model quality (see Table 12). Further, the Omnibus test indicated that that four of the proposed models (i.e., consumption, knowledge, structural and environmental indices) were statistically significant.

The significant predictors vary markedly for each thematic index. Being female and perceiving low water price fairness are associated with increased actions to reduce water use in daily activities (Consumption Index). In contrast, individuals, with the fatalistic cultural environmental bias, obtained a lower score in this index. Being young, with higher education, concern about climate change, and perceiving climate change as geographically close, is associated with actions taken to increase own's knowledge about climatic threats. Education and the number of hours of water service are associated with increased actions taken to increase water efficiency in an individual's home (Structural Index). Water frequency and climate change concern are positively associated with the Environmental index, which measures actions taken that support environmental sustainability. Lastly, the individualistic cultural environmental bias is negatively associated with the Environmental-friendly and Planning indices.

Dimension	Significant Predictors		Thematic Indices					
	_	Consumption	Knowledge	Planning	Structural	Environmental		
Socioeconomic	Gender	2.595***						
	Young Adults		2.304*					
	Education		4.876***		2.582**			
	Water Frequency				1.058***	1.044**		
	Water Price Fairness	.688*						
Psychological	HIN - Individualistic			.711**		.707*		
	HIN - Fatalistic	.740*						
	CC concern		1.693*			1.588*		
	Geographical Distance - close		1.564*					
Statistics								
Model Quality	-2 Log Likelihood	415.749	359.851	450.763	394.165	394.610		
Omnibus Test	Chi-Square	50.825**	80.339***	30.736	83.185***	60.991***		
Hosmer and	Chi-Square	6.066	9.825	13.583	10.472	6.974		
Lemeshow Test								

Table 12 – Significant Predictors for the Thematic Indices

N = 348. Variables reported are only those which are significant. Variable entries are exponentiated beta coefficients; *p < .05. **p < .01. ***p < .001.

4.5. Discussion & Conclusions

This study examines the socioeconomic, socio-institutional, and psychological determinants of adaptive behavior related to climate change induced water insecurity. We measured adaptive behavior as a set of actions and practices that together enhance resilience in consideration of the climatic threats to a given locality in mid- and long-term perspectives. We built two indices, one based on respondents' intentional practices and actions to deal with climate change (where it was

deemed acceptable to count adaptation and mitigation actions), and one theoretically-laden index to measure adaptive behavior, which included structural, knowledge, consumption, planning, and environmental-friendly actions and practices. We further analyzed the themes of the theoreticallyladen index separately to comprehend the determinants of adaption behavior better. Overall, our findings highlight the importance of each theoretical dimension in explaining the variance of adaptive behavior, and the need for comprehensive analysis that integrates social and psychological variables when studying individual-level adaptation.

4.5.1 Intentionality of Adapting

Our study shows that the factors that determine intentional and non-intentional adaptive behaviors differ at the individual level, which is imperative to consider in the design of adaptation policies. When we examine adaptive behavior as intentional actions and practices, we observe that individuals' who score higher in the IAB index are generally more aware of threats to Lima's water security, who are concerned of its impacts in an already water-stressed context characterized by socio-spatial inequalities, and who believe that others, who are more vulnerable, will be mostly affected. These individuals choose to take actions that will reduce the impacts of climate change, taking into consideration the wellbeing of others (e.g., other who are more vulnerable), which speaks of their preference of self-transcendence values over self-enhancement ones (Schwartz, 2012). Our results advance previous findings that showed that Lima residents who have low selftranscendence values are indifferent with environmental issues, and perform less proenvironmental actions (Camarena Urbano, 2013). However, the fact that individuals prioritize self-enhancement or self-transcendence was not significant for interpreting the results of the GAB index, which measured adaptive behavior building on the theoretical understandings of what increases resilience. Therefore, if studies only examine the factors that determine intentional adaptive behavior, and design policy measures according to these results, the measures would overlook factors that could enhance the resilience of a part of the population, such as the participation in neighborhood organizations and the perception of water price fairness, that are only relevant for the GAB Index, or consider targeted policies for gender or age groups as these were relevant for the Consumption Index and the Knowledge Index, respectively.

4.5.2 Water-specific Urban Processes

Building on previous qualitative research findings of the adaptive capacity of Lima residents (Flórez Bossio et al., In review), we designed a survey instrument that incorporates the sociospatial inequalities regarding water across the three theoretical dimensions. The analysis of our survey data found the water-related determinants to be statistically significant in all dimensions, including the differentiated provision of water (socio-economic dimension), perceptions of fairness of Lima's water governance (socio-institutional dimension), and perceptions of water risks (psychological dimension). Hence, urban-specific processes related to the object of risk at study (here, water) are critical to understand adaptive behavior. Notably, in examining the adaptive behavior to climate-driven water insecurity, the results underscore the importance of individuals' perceptions of fairness regarding Lima's water governance, in terms of price, accessibility, and distribution. Individual's perception of current institutional arrangements concerning the object at risk is a predictor of adaptive behavior, rather than the trust in future responses during crises. Thus, we learn that the institutional arrangements, which condition the lived experiences with water, inform individual's behavior in dealing with a changing climate over the evaluation of future institutional responses to the expected risks. The significance of the perceptions of water governance inequality informs on current vulnerability of urban dwellers in Lima, and the sociospatial inequalities that reign in the city. This situation demands the attention of local authorities to improve the management of the water system, work towards water security for all Lima districts, and improve the transparency of their decision-making processes.

4.5.3 The Limits of Social Trust in Lima

In contrast to previous adaptation studies (Cologna & Siegrist, 2020), we found that social trust was not associated with adaptive behavior. In Lima, we found a strong level of distrust in others³⁰. It may be that for a socially contested urban milieu where distrust reigns, social trust is not relevant as it is in other contexts. However, our findings do support the argument that when individuals have more social connections (i.e., participate in neighborhood organizations), this enables adaptation (Jones & Boyd, 2011; Pelling & High, 2005), as seen with the GAB Index. This determinant was not associated with any of the thematic indices, suggesting that increased social

³⁰ Our survey measured trust at the city level but had so few cases of (positive) trust that we could not include this variable in the regression (which is consistent with the low interpersonal trust reported for Peru by Latinobarometro 2018). We did included in the regression analysis the measurement of social trust at the district level, which was not significantly related to adaptive behavior.

connections may explain a general tendency to adapting to new circumstances, regardless of the specific topic at hand. The significance of social networks also suggests that a certain level of social trust is required, but rather in those who are proximate individually, rather than an individual's larger social environment. The lack of social trust may further elucidate the lack of significance of the perceived social norms for water use (both descriptive and prescriptive norms). If citizens do not trust each other, and instead expect others to take advantage of any given situation³¹, their perception that others are putting their effort to reduce water consumption or that others expect the same from them, then becomes less relevant in explaining adaptive behavior. In such contested social environments, the role of personal norms (i.e., the normative standards which individuals use to assess their own actions) may acquire more relevance, this remains to be studied. Additionally, further research is needed to understand the informal social norms that enhance or hinder adaptation actions that are not water-specific, such as the social expectations to contribute to the environmental wellbeing or the social norms that regulate what is considered as fair, in terms of public services provision.

4.5.4 Contextualizing Psychological Constructs

Our findings further show that psychological determinants are critical to understand adaptive behavior, even when we controlled for the socioeconomic and socio-institutional determinants. However, the psychological constructs need to be understood within the context of Lima, and the worldviews of its residents. The most prominent determinants were climate change concern and environmental values, followed by psychological distances to climate change. Climate change concern was significant for both the IAB and GAB indices. Yet, when looking more closely at the thematical indices, we find that climate change concern is only associated with knowledge and environmental practices, and not with consumption, planning, or structural responses. This tells us that climate change problem, executing actions and practices that support the general wellbeing of the environment, instead of responses that deal with the local risks. Integrating these results with the qualitative findings of the larger research project on which this study builds (see Florez Bossio et al., in review 2020), we can conclude that the climate change discourse (in policies and the media)

³¹ Peruvian scholars and media often refer to the attitude of taking advantage of others or situations as an aspect of the so-called "cultura combi" that reigns in Lima.

in Lima incentivizes the adoption of environmental-friendly actions but reckoning on local risks and suitable responses is missing.

We expected that similar to those with higher climate change concern, individuals' environmental values would be associated to their adaptive behavior. As noted in the methodology section, reliable indices were not obtained for Price et al.'s (2014) constructs of environment 'as ductile' and 'as elastic', and so we tested the distinct socio-environmental perspectives that formed the two constructs (i.e., hierarchical, egalitarian, individualistic, and fatalistic). The regression analyses evidenced that dwellers with specific fatalistic and individualistic values (based on singleitems) take fewer adaptive actions. Our findings expand on previous studies that conclude that fatalistic and individualistic values lead individuals to justify inaction (Lima & Castro, 2005; Poortinga et al., 2002; Price et al., 2014; Steg & Sievers, 2000). We acknowledge the limitations of using these constructs, which had been previously tested in a Western cultural setting. Thus, we underscore the need to build reliable constructs that portray current environmental values, and related worldviews, in the different cultural regions of the Global South. Similarly, our findings support the use of Construal Theory in climate change adaptation studies, but also call for contextualizing its use. The psychological distance to climate change in terms of social and geographical distances were significant for the IAB and Knowledge indices, respectively. However, our results put into question the assumption that an individual who perceives far social distance of climate change impacts, would take less adaptive actions. Instead, we observe in Lima that dwellers who see far social distance respond to climate change intentionally taking personal actions. This finding calls for further analysis to understand and compare the effects of social distance to climate change in other urban milieus.

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5.1 Summary of chapters

In the previous chapters of this thesis, I examined the process of adapting to climate change in urban areas within the Global South context. The thesis responds to the knowledge gap in understanding how urbanites respond to climate change threats. I examined the normative and behavioral aspects of adapting to climate change, advancing a theoretical framework that integrates the agency of urbanites with their socio-normative context. To do so, I used a temporal analogue by assessing how Lima dwellers respond to climatic threats to water security. Specifically, I addressed three research questions:

1. How is the capacity to adapt to the effects of climate change in urban areas of developing countries being assessed?

2. What characterizes the capacity to adapt of Lima residents to climate-related risks to water security?

3. To what extent, and how, do socio-economic, socio-institutional, and psychological determinants explain adaptive behavior of Lima residents?

I examined urban adaptation using a mixed-method research design with qualitative and quantitative data collection methods. In Chapter 2, I addressed the first research question above by using a systematic literature review to evaluate the assessment of adaptive capacity in urban areas of developing countries. Chapter 3 and 4 were empirical studies. In Chapter 3, I addressed the second research question by characterizing the capacity to adapt of urban dwellers' in Lima, Peru, following an extreme climatic event in 2017, which was used a temporal analogue. In Chapter 4, I addressed the third research question with regression analyses to examine the determinants of adaptive behavior of Lima residents. Each chapter has contributed to the scholarship by providing frameworks that integrate disciplinary approaches to better understand urban adaptation.

In Chapter 2, I critically examined the scientific assessment of adaptive capacity between 2000 and 2017, advancing a conceptual framework. The framework focused on key components of urban adaptive capacity in three dimensions: the characterization of adaptive capacity, the external factors mediating adaptive capacity, and the dynamics of adaptive capacity. This conceptual framework was used to analyze 38 original research studies of urban adaptive capacity. The study

found four emergent research patterns: 1) adaptive capacity varies across and within scales, 2) the relevancy of objective and subjective approaches to assessing adaptive capacity, 3) the importance of both governance and social institutions for adaptive capacity; and 4) the limited attention paid to urban determinants in explanations of adaptive capacity. Further, the study underscores the need to move beyond treatments of adaptive capacity as static in time and space and to address the relationships between coping, adaptation, and transformation.

In Chapter 3, I advanced a conceptual approach to understanding adaptive capacity as a process shaped by both behavioral and the institutional factors. The approach was used to investigate the capacity of Lima dwellers to adapt to climate threats to water security (i.e., water shortages and floods) drawing upon in-depth fieldwork. The case study builds on the case of residents' responses to the extreme events brought by the 2017 El Niño Costero, which was used as a temporal analogue, whereby past experiences are used to understand current and future responses. Data was collected during four months of fieldwork in Lima in 2018. I conducted 130 in-depth interviews with residents, policymakers, and stakeholders. The interviews delved into dwellers' experiences with water in the city, during the 2017 climate extremes, and on their perceptions of climate change. I also performed qualitative document analysis of policy documents at the national and city level in order to identify and characterize the formal institutional arrangements that frame the process of adaptation in Lima. My analysis identified the socio-psychological processes leading to coping, sustainability, morality, technology, and laissez-faire strategies for dealing with climate change. These five strategies were found to be the result of the interrelation of residents' cognitive processes (i.e., cognitive dissonance, optimism bias, technological paradigms, locus of control, authoritative bias) with evolving social norms (i.e., gender roles, social ties, religious norms, urban lifestyles and a related disconnection from nature, paternalism, absent government practices). The findings contribute to understanding why even in situations with widespread climate change awareness and previous experience with extreme events, individuals do not undertake adaptive practices, a key concern of the climate change community. The study highlights the challenges for behavioral change, the cognitive bias in addressing climate change, and the weak formal rules to incentivize adaptation. Thus, Chapter 3 argues that adaptation governance needs to consider the heterogeneity of residents' interests, experiences, and beliefs.

In Chapter 4, I examined adaptive behavior in Lima. Building on the qualitative results of Chapter 3, I developed a survey instrument to collect data on dwellers' adaptive behavior to water insecurity (i.e., water shortages and droughts). The fieldwork in 2019 lasted over three months, with 400 participants surveyed in four city districts, 100 per district. Regression analyses were used to identify the significant socioeconomic, socio-institutional, and psychological determinants of individuals' intentional and non-intentional adaptive behavior. The study also compared the specific determinants associated with themed adaptive behaviors through five thematic indices (structural, knowledge, consumption, planning, and environmental). To the best of my knowledge, this study is the first to use survey data on the determinants of adaptive behavior of urban dwellers in the Global South. The results confirm the significance of the socioeconomic, socio-institutional, and psychological dimensions in explaining the variance of adaptive behavior. Key findings for the adaptation literature include the observation that urban-specific processes (e.g., provision of city services) related to the object of risk (e.g., water) are associated with adaptive behavior across the theoretical dimensions, and that the factors that determine intentional and non-intentional adaptive behaviors differ at the individual level, where those individuals who intentionally adapt have a preference for self-transcendence values. I also observed that climate change concern is associated with behaviors aiming to tackle climate change globally, rather than in response to local threats. Further, the findings challenge the assumption that social trust is a condition for adaptation, leading me to conclude that in socially contested milieus social trust is less relevant.

5.2 Theoretical and Methodological contributions

The literature on climate change adaptation has grown significantly during the last decade, and increasingly has addressed urban adaptation. The exposure of urban areas to climatic events is now generally well understood, along with the inherent vulnerabilities of these areas in developing country contexts. Urban adaptation governance and planning has risen in the international research agenda, though the adaptation of urban dwellers has remained at the margins of the climate vulnerability and adaptation literature, neglecting the agency of dwellers in the adaptation process. Further, the individual-level assessments of adaptation beyond urban areas (i.e., rural, national studies) has built on deterministic approaches to explain the capacity to adapt and provided a weak link to explain how the theoretical determinants of adaptive capacity shape adaptive behavior on the ground. These shortcomings are surprising given that vulnerability and adaptation research has had a strong focus on communities. In this thesis, I tackled these challenges by taking an inter-

disciplinary approach and integrating vulnerability and adaptation research, institutionalism, and environmental behavior to study human adaptation to climate change in urban settings. Each chapter has contributed to the theoretical examination of urban adaptation.

In Chapter 2, I developed a conceptual framework to examine how urban adaptive capacity is assessed. The framework takes into consideration the socio-cultural and urban processes that shape adaptive capacity, and the internal dynamics of adaptive capacity in urban settings. The framework examines adaptive capacity under three broad dimensions: adaptive capacity characterization, external factors, and adaptive capacity dynamics. In Chapter 3, I also advanced a process-oriented approach to analyzing adaptive capacity of urban dwellers, framing adaptive capacity as a process and not a sum of determinants. The theoretical approach integrates elements from both environmental behavior and new institutionalism literatures, focusing on areas wherein individuallevel socio-psychological dynamics intersect with broader socio-normative dynamics in the process of adaptation. The approach is based on the premise that, in a specific socio-urban culture, while institutions structure the range of possible adaptive practices of dwellers, it is individual cognitive and affective processes that can explain the distinct ways in which they adapt. In Chapter 4, I moved forward from assessing adaptive capacity to adaptive behavior, with the aim of providing a comprehensive model that explained the variance in adaptive behavior of urban dwellers dealing with climate-driven water insecurity. Building on climate change adaptation and environmental behavior literatures, the study laid out a theoretical framework which included socioeconomic, socio-institutional, and psychological determinants of individuals' adaptive behavior. I show that each theoretical dimension is necessary to understand the full variance of adaptive behavior of dwellers in the same urban milieu.

The theoretical framework of this thesis—as advanced in Chapters 3 and 4—can be further used by climate change researchers to study adaptation of individuals in other urban settings, especially in developing countries. As I have concluded in this thesis, research focused on urban adaptation is less prominent in the Global South, and even less so on individual-level adaptation. Current theories for understanding urban adaptation need to better account for adaptive behavior as inherently situated and contextual. Broader social, political, and economic processes happening at the urban scale of the Global South need to inform adaptation research as these processes shape the local institutional contexts wherein individuals will adapt. This thesis has started to contribute to this endeavor. Thus, the thesis will help advance the urban adaptation literature beyond a deterministic conceptualization and measurement of adaptive capacity towards research that fully engages with urban processes and individual-level factors, in both qualitative and quantitative studies. This transition responds to recent calls to move adaptation research from a normative stance to an empirical one focused on action (Klein et al. 2017), and thus inform the development of adaptation policies that address the diverse spectrum of residents in a locality, and thus effectively enables citizens to continuously adopt practices that enhance personal and societal resilience.

This thesis further contributes to the scholarship by proposing a methodological approach to measure adaptation as a set of action and practices that individuals already take and that together enhance resilience, considering local risks and climatic threats over the mid- and long-term perspectives. With this approach, I addressed two methodological issues facing the adaptation literature. First, the approach assesses actual adaptive behavior instead of the willingness to adapt or the support for adaptation policies. The studies that use the latter measures do not have enough evidence to assert that they lead to adaptation. Second, the approach moves from measuring one-time responses to measure adaptive behavior as a set of actions based on the understanding that adaptive behavior is a way of living in the context of a changing climate, and thus the extent of the behavior is greater in time and space than specific responses.

Measuring adaptative behavior (Chapter 4) was enhanced by the development of the survey instrument that took into consideration the findings of the case study in Lima (Chapter 3). Hence, the survey was not developed to fit the available data, which constricts what is conceptualized as adaptation and its determinants. Limited data availability in data-poor contexts is often used as an argument to measure adaptation's determinants as a sum of resources, which I have contested in this thesis. Instead, the thesis survey integrated the lessons from the qualitative study, specifically on the distinct ways that residents were dealing with climatic risks to their water security, using a temporal analogue approach. Although the temporal analogue approach has been used before in climate change research (Ford, 2009; Ford et al., 2010; Glantz, 1991; McLeman & Hunter, 2010; Statham et al., 2015), I show that this approach is absent in the empirical urban adaptation literature (insights in Chapter 2). My thesis contributes to the scholarship by presenting the way that survey

development can be informed by past and current experiences of climatic threats to understand current and future adaptive behavior, the temporal analogue approach.

The thesis examined the adaptive capacity of urbanites in a large metropolitan area. The urban adaptation literature struggles to balance city-wide studies that pay attention to structural conditions in the governance of urban areas with dwellers' agency in the process of adaptation. Studies either provide an overview of adaptation at the city level, focused on the governance, or inversely present case studies at lower urban levels that focus on the vulnerabilities of communities but have a weak connection to city-wide dynamics. These studies provide significant insights on urban adaptation governance and the vulnerabilities of urban groups, but approaches that deal with urban dwellers' agency within the normative structures of the socio-urban milieus are missing. The methodological approach of this research has proven that it is feasible and advantageous to address the adaptation of dwellers in a large metropolitan area, as it is Lima with almost 10 million inhabitants, and examine individuals' agency within the larger socio-urban context. For example, I found that Lima's water management institutions structured residents' perceptions of water related risks, such that different population groups had different views based on their perception of access and distribution of water in the city. However, the influence of water management institutions does not explain the extent and diversity of dwellers' coping and adapting responses. It is individual-level factors (e.g., construal of self as independent or interdependent, perceived vulnerability, beliefs about science) that further shed light on residents' strategies for dealing with climate change.

Furthermore, I have shown that urban social dynamics are important to understand urbanite adaptation. Research findings from vulnerability and adaptation studies in rural areas cannot directly be transferred to explain adaptation processes in urban areas. Researchers ought to consider the particularities of urban areas under study. In my dissertation, I have contribute to this endeavour. First, in Lima, residents prioritize social ties with their families and their colleagues over their ties with neighbors. Day to day, urbanites are less likely to be socializing or collaborating with their neighbors, either in managing the resources of their localities or in associations that sustain their livelihoods. Therefore, in managing the water crises, residents turned to those with whom they had a regular interaction, but who nonetheless could be living across the city. Second, Lima residents relied in services provided by their employers when these had further access to information and resources that could help them cope with the water and electrical shortages.

role played by employers in coping and adapting to climate risks is an issue that has been weakly considered in adaptation studies. Third, in some cases, Lima residents reported knowing more about the coping and adapting mechanisms of the districts in which they work than where they live, as they spent more time in the former. Thus, research should consider the place of labor in addition to the place of residence to investigate urban adaptation.

5.3 Comparison of Empirical Findings

In Chapters 3 and 4, I examined the process of adaptation of urban dwellers in Lima. Both chapters demonstrate that individual-level adaptation is shaped by social and psychological factors. In Chapter 3, I focused on adaptive capacity, and in Chapter 4, I examined adaptive behavior. How did the Chapters' results complement and differ from each other?

Both Chapters were built on the premise that Lima residents already had a recent experience with an extreme climatic event, El Niño Costero. Adaptation literature has paid a considerable amount of attention to understand how recent experiences with climatic events can shape people's perception about climate change, and thus the capacity to adapt (Clayton et al., 2015; Grothmann et al., 2013). In Chapter 3, I underscore that it is not only past extreme events that should be considered as previous experience but also brief and lengthy experiences with water limitations. I showed that Lima residents' experience with recurrent water limitations enhanced their know-how in reconfiguring their water-use practices when hit by El Niño Costero. In Chapter 4, I further build on this understanding of previous experience and adapting to climate change. I set a condition to participate in the survey to only those who had experienced El Niño Costero in Lima in 2017. Hence, I put into question the argument that experience with extreme events solely leads to increased adaptation. All dwellers surveyed had experienced El Niño Costero, but they had varying uptake of adaptive actions and practices in the GAB index.

In Chapter 3, I explained how current socio-environmental inequalities of water shape dwellers' experiences with climatic hazards and their coping responses, which are moderated by the location of individuals' households and their residential water infrastructure. In Chapter 4, I confirmed these findings by demonstrating that the differentiated provision of water is statistically significant with adaptive behavior. In Chapter 3, I had highlighted that the socio-environmental inequalities of water were mediated by the city's water management. Building on those results, in Chapter 4, I demonstrated that dwellers' perception of fairness regarding Lima's water governance informs

individual's behavior in dealing with a changing climate, instead of peoples' evaluation of future institutional responses to the expected water risks. In Chapter 3, I had also detailed that water governance institutions structured residents' perceptions of water risks, such that different population groups had different views about their own vulnerability to climate risks. In Chapter 4, I further showed that the perceptions of water risks were statistically significant with adaptive behavior. Both Chapters' findings underscore the importance of examining water-specific urban processes (e.g., water distribution rules, water access inequality) when studying individual-level adaptation to climate-driven water insecurity.

Regarding social norms about water in Lima, in Chapter 3, I found that following El Niño Costero, residents had a new or greater appreciation of water resources for their daily life and for Lima as a whole, and that social norms on preserving water were emerging. This study identified that residents were becoming comfortable in condemning the misuse of water of acquaintances and strangers. Building on these results, descriptive and prescriptive norms about water use were included in the survey instrument of Chapter 4. However, the results did not show a statistical significance of these water norms with adaptive behavior. Given the high level of mistrust found in Lima in both Chapters, I hypothesize that in a socially contested urban milieu where distrust reigns, social trust is less relevant to explain adaptive behavior. In such contexts, individuals' personal norms, those used to assess one's own actions, may acquire more relevance. In Chapter 3, I revealed that certain districts, which are still being developed, had stronger social ties, which proved to be conducive to self-organize during the extreme events of 2017. In these communities, prescriptive and descriptive norms may explain adaptive behavior as theorized in the adaptation literature.

Further, both Chapters show that women have a higher tendency to reduce their water consumption, as coping and adapting to climatic threats. In Chapter 3, I provided an in-depth understanding of the role of women in preserving water, as they organize alternative water practices in their households, with families relying heavily on women as household protectors. The study evidenced that women reported coping actions focused on changing their behavior to reduce water consumption in contrast to men who focused on increasing water provision for their households. Then, Chapter 4 further substantiated this result, with a significant association between gender and the Consumption Index. In Chapter 3, I also found that the gendered

differences in coping actions between men and women were less pronounced among the youth (aged between 18–25), signaling that the youth is more adaptable to changing their behaviors. This differs slightly with the regression results in Chapter 4, which show that being a young adult was significantly associated with actions taken to increase one's own knowledge about climatic threats (Knowledge Index), but not with taking actions to decrease water consumption (Consumption Index).

Beyond demographic characteristics, in Chapter 3, I concluded that residents' beliefs about governmental responsibility for adaptation, in conjunction with the perceived impacts, mediate adaptive strategies. While residents have different positions regarding who bears greater responsibility (i.e., authorities or individuals), most residents were expecting authorities to provide them with the relevant information before making adaptive decisions. In Chapter 4, I then investigated the relationship between trust in institutional responses at district, city and national levels with adaptive behavior. Though the regression analyses did not find significant associations, the data does show that residents have a strong level of distrust in authorities responding to climate change, with fewer than 20% trusting the national government, fewer than 30% trusts the Lima government, and fewer than 35% trusts the districts governments. Integrating both Chapters' findings, I can conclude that while dwellers generally distrust government responses to climatic threats, they do trust that authorities have the knowledge to cope and adapt to climate change, and they expect authorities to share this knowledge with them. This conclusion stresses the role of authorities in shaping the adaptation scope of individuals.

In Chapter 3, I identified five types of strategies that Lima dwellers were using to deal (or not) with climate change, which I labeled coping, sustainability, morality, technology, and laissez-faire approaches, shaped by socio-psychological processes. In Chapter 4, I further developed these findings by measuring intentional and non-intentional adaptive behavior. The latter study shows that these behaviors differ at the individual level, thus strengthening the approach of examining individual perceptions and cognitions, together with the social institutions found in an urban milieu. I also expanded Chapter 3 findings in Chapter 4 by analyzing five thematic indices (Consumption, Knowledge, Planning, Structural, Environmental) to identify significant predictors for each index. Results show that significant predictors vary markedly for each thematic index. Moreover, the data display that residents take on average more environmental-friendly actions and

practices, and less knowledge and structural actions. Integrating the results of both Chapters, it is clear that Lima's climate change discourse focuses on fostering the adoption of environmentalfriendly actions, but public discussion on local risks and suitable individual responses is lacking.

In Chapter 3, I found that a set of residents did not feel vulnerable regarding the prospect of water shortages occurring in the near future. These dwellers had reported having enough water in their household water tanks during El Niño Costero. A subset also considered having enough means to cope with climatic events, and thus lacked incentives for adapting. In Chapter 4, I built on these results and found that those who had a far psychological social distance to climate change (i.e., seeing others as more vulnerable to water risks) reported more intentional actions to deal with climate change, mostly focused on environmental-friendly actions. Consolidating the results of both Chapters, I conclude that there is more than one behavioral path when individuals feel low vulnerability to climatic threats, one of inaction and one of actively taking environmental actions. I further put in evidence that the psychological distance construct plays out differently in the Global South context than in the Global North, specially in terms of how individuals conceive their social and geographical distances to climate change (Chapter 4). For example, Lima dwellers who perceived a far social distance of climate change impacts, respond intentionally taking adaptive actions. This finding is opposed to what has been theorized and observed in Global North contexts, where those who perceive a far social distance tend to take less adaptive actions. I hypothesize that the difference between the Global South and North in this matter is related to the fact that individuals in the Global South conceive that vulnerable people (i.e., far social distance) are prominent within one's own city or district, and thus Global South urbanites may have a higher level of perceived relatedness to vulnerable people. Research should further explore this initial finding and hypothesis.

5.4 Future Research

In this thesis, I examined urban dwellers' adaptation process in a developing country context with a case study in Lima, Peru. The findings raise new questions to be addressed by future research. First, my thesis finds that research on urban adaptation in the Global South is focused on a rather limited number of countries and their urban areas. While there are some studies on urban adaptive capacity in the Global South, studies of adaptive behavior are lacking. The uneven geographic distribution means many developing countries are "off the map" in existing urban adaptation research, even though they are expected to be significantly impacted by climate change.

Thus, future research should extend its geographical scope to include urban areas in all developing regions. Extending the research's geographical scope should advance current understandings of urban adaptation and improve the development of socio-psychological constructs and theories for adaptation.

Second, my thesis concludes that empirical research on adaptation has had a narrow understanding of adaptive capacity as static in time and space, and non-reciprocal between social entities. While theoretical adaptation papers address the adaptability and transformability of urban areas, empirical papers are far from examining these processes on the ground. Future empirical research on urban adaptive capacity should design longitudinal studies that facilitate the analysis of the coping, adapting, and transforming levels of adaptive capacity, which will also allow addressing the potential for maladaptation. Likewise, future research should further address the differentiated adaptive capacities of social groups, accounting for multiple adaptive paths within urban milieus in changing socio-natural contexts. Understanding the dynamics of adaptive capacity is critical to inform adaptation planning to design policies that accurately respond to the diversity of dwellers' experiences and beliefs that shape how each individual responds to climate change, and thus appropriately incentivize adaptive behavior.

Third, my research has identified significant socio-economic, socio-institutional, and psychological determinants of adaptive behavior to climate-driven water insecurity. Identifying these determinants opens the possibility for researchers to test whether social cues (i.e., signals that provide information about social facts) can incentivize individuals' adaptive behavior. Research has shown that communicating social cues can induce behavioral change as individuals seek to comply with what is socially expected (Cialdini et al., 1991). Thus, the significant social and psychological determinants can be used to inform relevant cues for Lima. To this date, this approach has predominantly been applied to reduce greenhouse gas emissions in the energy domain and increasingly to change consumption behaviors (Leoniak & Cwalina, 2019; White & Simpson, 2013). The use of social cues to foster individual-level adaption to climate change has yet to be examined.

Fourth, my research findings put in evidence the knowledge gap on the social determinants of people's perceptions of science in non-western settings, and the relation of such perceptions to climate change adaptation. For a long time, the crisis of science (i.e., loss of public trust in science)

has nurtured the political debates about climate change, putting into question the climatic process' very existence and its anthropogenic causes (Dahlstrom & Rosenthal, 2018; Nicholson, 2010). Hence, climate change scholars have largely paid attention to how science is communicated and its effect in lay people's understanding of climate change. While these studies provide insightful findings of effective communication strategies, my thesis finds that little is known about the role of cognate-cultural norms in influencing people's science perceptions in relation to human-nature interactions, and thus their adaptive responses to climate change. In Lima, epistemological beliefs mediated the way that dwellers conceived the adaptation scope for the city, and hence affected their strategies to deal with climate change (e.g., individuals that believe science is limited in understanding nature, rely on praying to increase their resilience). These findings should be considered in future adaptation research that seeks to understand the problematized inaction of individuals in the face of the changing climate. It should also be addressed at the policy level, as cognate-cultural norms may obstruct the implementation of adaptation measures.

Fifth, there is a need to expand the study of adaptive governance in urban areas to include the relationship between authorities and residents. The literature has largely focused on the multilevel legislation and policies that regulate adaptation in cities, and it is expected that local governments within follow the same set of policy guidelines for adaptation. In Chapter 3, I shed light on the fact that district policymaking shapes urban dwellers' adaptation scope. Local governments' different approaches to adaptation create different incentives for urban dwellers to engage or not in adaptation. Thus, understanding the relationship between urban dwellers and authorities is critical for adaptation. In Chapter 4, I further demonstrated that the perceptions of fairness of water governance are significantly associated with adaptive behavior. Thus, urban adaptation studies should further investigate and compare national and local governments' policy styles and their choice of adaptation policy instruments, as well as the norms that regulate urban planners' professional practices. This work should not only categorize policy approaches or evaluate the quality of adaptation planning, but critically examine how policy and planning approaches affect residents' adaptive strategies and the overall city resilience.

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APPENDIX A: Supplementary Materials for Chapter 2

Online Resource 1: Systematic Literature Review Steps

- 1. Development of an urban AC conceptual framework.
- 2. Identification of keywords (and their combination) to use in the search.
- 3. A systematic review of ISI Web of Science using the selected keywords.
- 4. A review for inclusion of the articles using review parameters.
- 5. A formal revision of the selected articles using a questionnaire for data extraction and synthesis of the results.
- 6. Analysis of the results using the three dimensions of the conceptual framework of urban AC.

Online Resource 2: List of 38 articles reviewed

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Online Resource 3: Articles by exclusion criteria



Online Resource 4: The conceptual framework for Examining how research assesses urban adaptive capacity to climate change.

Features	Questions	Response options			
1. Basic Case Study Information					
Year of the article	When was the article published?	2000 to 2017			
Region	In which geographic region is the research?	Africa; Asia; Latin America			
Country Income level ¹	Which is the country income level of the urban location?	High income country; upper-middle income country; lower-middle income country; low-income country			
Study Scale	Which is the scale of the research?	City, district, community, household or individual			
Urban Population Size	What is the urban population size?	< 500,000; <1 million; >1 million			
Stressors	Does the research focus on one or more than one stressor?	1; > 1			
Scholarship	Under which scientific scholarship is AC framed?	Natural hazards; vulnerability science; resilience science			
Research Design	What is the type of research design?	Quantitative; qualitative; spatial analysis; mixed method (qualitative & quantitative); mixed method (all)			
2. Adaptive Capacity Characteristics					
AC attributes	What attributes constitute urban AC?	Open-ended answer			
AC agency	Who has the capacity to reduce vulnerability and/or increase resilience?	Individuals; communities; governments			
AC type	Does the research consider objective and/or subjective AC?	Objective; subjective; both			
AC range	Does the research focus on coping, adaptive or transforming capacities?	Coping; adapting; transforming; all			
3. Multilevel factors shaping Adaptive Capacity					

¹ Country income levels from the United Nations World Economic Situation and Prospects 2017 based on the per capita Gross National Income (GNI) in September 2016. Countries with less than \$1,025 GNI per capita are classified as low-income countries, those between \$1,026 and \$4,035 as lower-middle income countries, those with between \$4,036 and \$12,475 as upper-middle income countries, and those with income of more than \$12,475 as high-income countries.

Online Resource 5: Articles by Publication Year



Source: Own elaboration.

Online Resource 6: Cases included in the systematic literature review

A. Urban Area Cases included in the Review

	Urban Area	Country
1	Dhaka	Bangladesh
2	Rio de Janeiro	Brazil
3	Santos	Brazil
4	San Salvador**	El Salvador
5	Concepcion	Chile
6	Santiago de Chile****	Chile
7	Bogota	Colombia
8	Nadi	Fiji Islands
9	Accra***	Ghana
10	Georgetown	Guyana
11	Ahmedabad	India
12	Bangalore	India
13	Delhi**	India
14	Semarang	Indonesia
15	Tegal	Indonesia
16	Lasem	Indonesia
17	Busan	Korea
18	Daegu Metropolitan City	Korea
19	Mexico City**	Mexico
20	Lagos	Nigeria
21	Ibadan	Nigeria
22	Cavite City	Philippines
23	Malolos	Philippines
24	Metro Manila	Philippines
25	Dakar	Senegal
26	Bergriver	South Africa
2/	Cape Town	South Africa
28	Ekurhuleni	South Africa
29	Paramaribo	Suriname
30	De Neng	i aiwan
31		Vietnam
32		vietnam

** This urban area is part of two studies. *** This urban area is part of the three studies. **** This urban area is part of the four studies.

B. Urban Areas within Territorial Studies Included in the Review

	Urban Area	Country
1	65 cities in Anhui, Henan, Jiangsu and Shandong provinces	China
2	20 cities in Pearl River Delta area in Southern China	China

APPENDIX B: Supplementary Materials for Chapter 3

- 1. Semi-structured interviews Stakeholders' Questionnaire
 - 1. Has your organization been working on climate change adaptation? What is the role of the organization in Peru? And Lima?
 - 2. From your perspective, what are the major climate threats to Lima? How is this been dealt with?
 - 3. How was the experience in Lima with the last climatic events (2016/2017)? Was the city prepared? Were there differences among the districts? Why?
 - 4. In your opinion, was the city under water insecurity during this period? If yes, where in the city?
 - 5. What were the main coping strategies to deal with the impacts? Are there adaptation strategies to deal with the impacts in the future?
 - 6. Do the strategies consider how urban residents can adapt to climate extreme events? How?
 - 7. If not, do you think it would be necessary? What could be done? How could your organization support it?

- 2. Semi-structured interviews Residents' Questionnaire
 - 1. How long have you lived in Lima? Were you in Lima during the last 12 months?
 - 2. Do you have access to water in your household? What is your experience with the water service?
 - 3. Do you remember any issue with your water during the last 12 months? What happened?
 - 4. Were you or your family affected by El Nino 2017? What was your experience? Had this happened here before? Do you think it will happen again?
 - 5. How did you overcome the challenges/impacts of El Nino 2017? What specific measures did you take?
 - 6. Did you receive assistance? From whom?
 - 7. How do you prepare for periods of droughts and/or floods?
 - 8. What you think are your possibilities to deal with the next climatic events?
 - 9. Do you think climate change may affect El Nino? And the droughts?