CLIMATE CHANGE:

Risk and Resilience Strategies for Water Resources Management in Latin America

In light of increasing climate uncertainty, this report reviews the water resources management risks faced by two Latin American cities: Monterrey, Mexico and Trujillo, Peru. Based on these risks, the report discusses strategies currently employed as well as potential future strategies to mitigate these risks and increase the resilience of households and communities in these cities.

*Keywords:* climate change, water management, variability,
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ACRONYMS

FAO: Food and Agriculture Organization of the United Nations
GIS: Graphic Information Systems
IDB: Inter-American Development Bank
SEDALIB: Servicio de Agua Potable y Alcantarillado de La Libertad (water and sanitation utility company in Trujillo)
UNEP: United Nations Environment Programme
USAID: United States Agency for International Development
Climate Change:

EXECUTIVE SUMMARY

As the severity of risks associated with climate change increases, so does the necessity for resilience strategies to strengthen the capacity of people to decrease the impact of events that negatively affect health, livelihoods and human development. Developing countries are more exposed to these risks as they are not only financially constrained, but often already overwhelmed by other economic, social and political stresses. Adding climate change resilience measures to the other challenges can seem an enormous burden; however, this report highlights the importance and urgency of appropriate strategies to cope with shocks and mitigate their impact.

While climate change poses risks to every sector from energy and transportation to agriculture, this report focuses on the impacts of climate change on water. Water resources management is a growing area of concern, as climate change can create issues of overabundance, scarcity, variability and poor quality, depending on the specific characteristics of each region. The report centers on water resources management in Latin America, a region chosen for its heterogeneity in terms of climate, geography and aggregate resources. While Latin America is recognized as a
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region with large freshwater resources, the unbalanced distribution impacts both water availability and quality very differently in different areas.

This report draws on case studies from two Latin American cities: Monterrey, Mexico, and Trujillo, Peru, to identify the primary risks climate change poses to water resources management. While Monterrey and Trujillo are comparable in population size, demographics and economic indicators, they differ considerably in geography and climate. Where Monterrey, a semi-arid landlocked city is coping with decreasing precipitation, extreme droughts and overcommitted water sources, Trujillo, a temperate coastal city faces increasing precipitation, retreating glaciers and inconsistent river flows. Studying two contrasting cities allows for a more broad assessment of the impacts of climate change on different climatic regions. Based on the reviewed risks, this report discusses both state-led and externally driven strategies currently employed to mitigate shocks and increase resilience.

Looking to successful examples from other cities, the final section of the report identifies new opportunities for Monterrey and Trujillo to further strengthen resilience. These recommended strategies are categorized into a four-part resilience framework encompassing policies, products, behavior and networks. Some key recommendations include: using treated wastewater for public irrigation in Trujillo to reduce the strain on household consumption; offering weather-based index insurance to protect against extreme weather events; developing household-level water rationing plans to cope with scarcity in Monterrey and; incorporating vulnerable stakeholders in the decision-making process to ensure strategies benefit
those with the highest risk. While different strategies require implementation at various levels, all of these recommendations are important in strengthening community and household resilience to the risks of climate change on water resources management.

INTRODUCTION

The challenge of global warming’s impact on water resources management is serious, as it deeply affects the need side – human consumption, crop growth, livestock management, electricity creation, manufacturing, among many others – while at the same time affecting the physical and human security of the local geography.

At its most basic level, the impact on water resources management is the unpredictability of precipitation – how much, what time of year, on what geography? – and the potential for external shocks in the form of natural disasters.

The process that leads to precipitation is the hydrologic cycle. Water in a pot, as it heats on a stove, evaporates. Likewise, as the globe warms, and ocean temperatures rise, or ice peaks and glaciers melt, more water evaporates into the atmosphere, accelerating the “pace of the hydrologic cycle.”

“This accelerated hydrologic cycle is logically projected to result in an overall increased intensity of rainfall events. Consistent with the fact that global warming has already been occurring during the last
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century, streamflow records already document this increase in storm intensity."¹

This challenge is one that affects developed and developing countries alike. In recent years, economic loss to floods and cyclones in the OECD has grown faster than Gross Domestic Product (GDP) per capita. For instance, the Japan earthquake and subsequent tsunami caused an estimated 1 per cent reduction in Japan’s GDP. The 2011 floods in Thailand similarly led to an estimated 2.5 per cent drop in global industrial production and caused damages of USD 40 billion."²

Moreover, developing countries and their poorer citizens are more deeply affected by these external shocks, as they have less ability to prepare for and withstand them. While the unpredictability of global warming's impact will likely grow in the future, disaster vulnerability can be reduced by improvements through international development. And, in doing so, development professionals can maintain international development advances accomplished or underway.

The past, present and future experiences of an arid city such as Monterrey and a coastal city such as Trujillo have and likely will continue to share similarities with other geographically and climatically similar cities worldwide.

Semi-arid and arid regions are likely to experience a decrease of water resources due to prolonged drought, which lessens ground recharge. Coastal areas, by contrast, will continue to experience slowly rising sea levels, leading seawater to further seep into groundwater and freshwater aquifers, an occurrence known as saltwater intrusion. This affects the water's mineral makeup, which in turn affects the treatment of the water for public consumption, and the organisms, including fish, and microorganisms that live in lakes, rivers, and other water sources in the region. A brief comparison of global warming's likely effects in coastal regions and arid regions follows.

### Coastal Regions
- Rising sea levels
- Increased saline intrusion into groundwater aquifers
- Water treatment challenges: increased bromide; need for desalination
- Increased salinity of brackish surface water sources
- Water treatment challenges: increased bromide; need for desalination
- Increased risk of direct storm and flood damage to water utility facilities
- Warmer overall
- Changes in discharge characteristics of major rivers due to upstream changes
- Changes in recharge characteristics of major groundwater aquifers due to upstream changes
- Increased water temperature
- Increased evaporation and eutrophication in surface sources
- Water treatment and distribution challenges (disinfection, byproducts, regrowth)
- Possible increased water demand
- Increased irrigation demand
- Increased urban demand with more

### Arid Regions
- Warmer and probably drier overall with more extreme droughts and heat waves
- Likely reduced quantities of surface water available from local runoff
- Likely reduced quantities of water available to recharge groundwater aquifers
- Very likely increased evaporative losses in inter-basin transfers of surface waters
- Changes in vegetation of watershed and aquifer recharge areas
- Altered recharge of groundwater aquifers
- Changes in quantity and quality (e.g., TOC, alkalinity) of runoff into surface waters
- Increased water temperature
- Increased evaporation and eutrophication in surface sources
- Water treatment and distribution challenges (disinfection, byproducts, regrowth)
- Increased water demand

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With regard to water resources, the cities of Trujillo, Peru, and Monterrey, Mexico, are considered well developed cities, despite their locations in the developing world. Other similarly sized cities with relative wealth often possess adequate water supplies and sources for decades to come. However, the expected influx of citizens to urban areas reduces the “system reliability,” as it contends with the impact of climate change.4

For instance, Trujillo’s future is very likely to mimic that of the Puget Sound, Washington, region:

“\textquote{In reservoir systems that depend on snowpack to enhance reservoir storage, delayed snowmelt results in greater effective} \textquote{storage.} \textquote{\cite{vano2009}}

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storage capacity. In a warming climate, seasonality of streamflow may shift substantially, with more flow occurring on average in the winter due to precipitation falling as rain rather than snow, and a decline and possible disappearance of the spring snowmelt peak.

The primary hydrological manifestation of climate change, which will affect each of the three major Puget Sound water supply systems to varying degrees, will be the decline and eventual disappearance on average of the springtime snowmelt hydrograph peak, and its replacement with an elevated winter runoff peak.

These shifts are projected to become more pronounced throughout the century, although year-to-year variability in weather and inflows should still be expected. There will be years with snowmelt that is similar to current conditions, but years with high springtime snowmelt are projected to progressively become less frequent. The three water supply systems, with current operating policies and in the absence of demand increases, may be generally robust to changes through the 2020s, with reliabilities projected to remain above 98% in all cases. However, other aspects of system performance, such as reduced levels of summer and fall storage, may occur as early as the 2020s.”

TRUJILLO

Background

The city of Trujillo is located off the Pacific coast of Northwestern Peru, in the Moche River Valley and at the foothills of the Andes mountains. It is known as la Ciudad de la Eterna Primavera (the city of eternal Spring), due to its year round mild climate, moderate rainfall and warm temperatures. However, the climate and weather patterns vary in the presence of El Niño, a periodic weather phenomenon that transpires across the tropical Pacific Ocean. Generally occurring during Trujillo's wet season from April to October, El Niño can produce increased rainfall, escalated temperatures and severe flooding.

With over 800,000 inhabitants, Trujillo is the country's second most populated city, as well as the most important economic center of northern Peru. In recent years, Trujillo has experienced significant growth in commercial activity, primarily in agribusiness. This can be partially attributed to the expansion of irrigated agriculture, leading to increased production of water-intensive crops like sugarcane, corn and asparagus. The presence of a large youth population and several major universities suggest this pattern of growth will continue in a sustainable manner.

While still a developing area, according to the Inter-American Development Bank (IDB) [2012], the city of Trujillo exhibits positive economic indicators, a high quality of life and human development, as well as a demonstrated interested in further Sound Region,* Center for Science in the Earth System. 2009. Accessed online in November 2012. Available online at http://cses.washington.edu/db/pdf/wacciach3pswater645.pdf.

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These qualities contributed to the appropriateness of using Trujillo as a model city for the purposes of this research.

**Water Resources Management**

Water resources management in Trujillo is relatively efficient by developing country standards; 89% of the city’s population is connected to potable water by the public utility company, SEDALIB (IDB, 2012). Trujillo has two main water sources: a local groundwater aquifer in the Moche valley, and the perennial Santa River, which provides 70% of the city’s water. Water is conveyed by the Chavimochic Canal, a system in northern Peru that draws water from the river and transports it through tunnels and canals to the coast. The Santa River is the second largest Peruvian river to reach the Pacific Ocean, and is fed by the glaciers of the Cordillera Blanca. The Cordillera Blanca is part of the larger Andes mountain range, and defines Trujillo’s eastern boundary (Jensen et al, 2012).

The Chavimochic Canal, while efficient in transporting water, has actually created an issue of net water importation to the aquifer. Farmers in the Moche valley previously pumped irrigation water from the Moche aquifer, but many now use surface water from the canal system. This change in water source has led to two of the most prominent issues for water management in Trujillo today: waterlogging and drainage congestion (Jensen et al, 2012).

A second water management issue involves the politically sensitive allocation of resources. While the majority of potable water is used for domestic consumption,
another large portion is used for irrigating public land and parks. Disputes over water distribution are growing, especially with projections of increasing variability in the water supply. Water treatment is another major concern for the city. While the infrastructure to supply water to Trujillo’s households is relatively efficient, 66% of wastewater remains untreated, as do flood waters. The current treatment plant does not have the capacity to increase treatment levels (IDB, 2012).

**Climate Change Risks and Vulnerabilities**

Climate change poses a major threat to water resources management in Trujillo, leaving households and communities vulnerable to its impacts. Four major climate change induced risks include: 1) increasing precipitation, 2) increasing temperatures, 3) increasing El Niño frequency, and 4) retreating glaciers.

The intensity and frequency of rainfall is increasing. Annual precipitation averages have increased between 30 and 40% over the last 40 years, with further expected increases of up to 20% above average recorded levels. This intensifies the risk of floods, waterlogging and drainage congestion—disasters that already threaten the city. Additionally, climate models predict temperature increases of up to 1.6 degrees Celsius by 2030. Warmer temperatures not only contribute to changing weather patterns, but can also put a strain on the water supply (USAID, 2011). These issues are often a by-product of El Niño, a major force on Peru’s climate that accounts for many extreme weather events.
The most significant impact that climate change has already had on Trujillo, as well as the largest threat to water management involves the melting Cordillera Blanca glaciers. The glaciers are retreating substantially due to increasing temperatures and, according to UNEP (2001), glacier coverage has decreased by over 15% since the 1970s. The runoff from these glaciers drains into watersheds that flow directly into the Santa River. Glaciers typically buffer stream discharge from seasonal precipitation patterns by providing continuous water to sustain river flows through the dry season. According to Juen, et al. (2007), while retreating glaciers cause an increase in direct runoff, reduced glacial mass leads to a decreased volume of glacier melt. Therefore, while the mean annual total runoff remains relatively the same, seasonal variability is magnified. A 2012 study by Michel Baraer, et al, suggests glacial retreat could lead to a decrease in dry season average discharge of 30%.

“One of the important functions of glaciers is the capacity to regulate water supply through runoffs during dry and warmer periods while storing water in the form of ice during wet and colder periods. As glaciers retreat, this water regulation function will be affected and eventually lost.” (World Bank, 2012)

In sum, melting glaciers bring excess water when water is plenty, and insufficient levels when water needs are greater. This increases the importance of water storage, efficient irrigation and efficient water-use systems. However, high levels of glacial retreat make systems vulnerable by deteriorating river basins and disrupting...
the ecosystem, making water storage and distribution more difficult. Additionally, large influxes of water lead to increasing volumes of glacial lakes and the potential for what is known as glacial lake outburst floods. Since 1940, 30,000 people have died due to flooding lakes fed by the Cordillera Blanca, a devastating statistic for Trujillo and the surrounding communities (USAID, 2011).

**State-Led Resilience Strategies**

In general, there is a lack of adequate adaptation strategies in Latin America; however, there are a few notable advancements in Trujillo: the municipality and public water utility have a history of collaboration during water-related weather disasters, particularly floods, to provide disaster relief and recovery; the city is looking for new technology for wastewater treatment; communities offer volunteers to raise awareness on the risks of climate change; and the municipality is cooperating with the IDB on their recent *Emerging and Sustainable Cities* platform (Lopez, 2011).

At a country-level, Peru has introduced modern satellite observation systems, and is investing in Graphic Information Systems (GIS) (USAID, 2011). These technologies establish the infrastructure for index-based insurance mechanisms, an opportunity that will be further discussed in the resilience strategies section of the report. Additionally, recognizing the need for improvement in water management, Peru passed the Water Resources Law in 2009. Apart from identifying water as a social and economic good, this law focused on integrated management of water resources,
irrigation development and increased water quality. This initiative was particularly important in pushing the water agenda statewide (ICIWaRM, n.d.).

**External Actor Involvement**

In 2012, the IDB conducted a study under its *Emerging and Sustainable Cities* platform to: 1) assess the vulnerability of Trujillo to climate change, 2) provide local information and analysis to assist water resources managers in coping with challenges, and 3) prepare guidelines on how to mainstream adaptation into implementation of IDB funded projects. The Bank developed an outline adaptation plan, from which this report highlights five important resilience strategies:

1. **Develop a public education campaign on climate change and water related risks.** Particularly during the dry season, reducing net demand for water by raising awareness is important to prolong limited water resources.

2. **Strengthen SEDALIB and increase the quality of the water supply.** The IDB is proposing to build an additional water treatment plant to increase the quality of water. An efficient local treatment plant could reduce the high percentage of wastewater and floodwaters that currently remain untreated.

3. **Increase SEDALIB’s pumping capacity of excess water** produced by floods, over-irrigation and drainage congestion.

4. **Abstract water from the river for export out of the basin** to help ease drainage congestion.

5. **Restrict irrigation** in certain areas of the valley if drainage congestion cannot be controlled by other measures (Jensen et al, 2012).
MONTERREY

Background

Located in the state of Nuevo Leon in northern Mexico, Monterrey is one of the most important cities in Mexico. With a population of 1.1 million in the city proper (World Gazateer 2012), it is the third largest city in the country, and it is also the industrial center of northern Mexico (Garcia Monforte, Aguilar Benitez, and Gonzalez Gaudiano 2012). Monterrey is a relatively affluent city, and may be said to be the Mexican city which most resembles an American city.

While in size and importance Monterrey is similar to Trujillo, its climate is quite different, presenting contrasting climate change and water management challenges. The climate in Monterrey is semi-arid and hot with average annual rainfall of around 23.5 inches (Navar 2001). As in many Mexican cities, supplying the city with water has long been a challenge. Thus Trujillo and Monterrey together provide a broad picture of climate change conditions and associated water management possibilities for Latin American cities of this size.

Water Resources Management

Currently, the main concern of water managers in Monterrey is providing sufficient water supply to the city. A growing population and industrial sector make this especially tricky for a city with a dry climate. From the 1940s to the 1970s, a period of great industrial growth in Mexico, Monterrey experienced the highest population growth of any city in Mexico as people migrated to the city to work in search of industry

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jobs (Bennett 1998). This trend continued when NAFTA brought additional industry to northern Mexico. The limited water supply creates tension between industrial and household water use, a challenge compounded by inefficient and politicized governance. There is a need for cooperation among municipal, state, and federal levels of water management (García Monforte, Aguilar Benítez, and González Gaudiano 2012).

The majority of Monterrey’s water, about 60%, comes from the San Juan River via three dams, El Cuchillo, Cerro Prieto, and La Boca. A tributary of the Rio Grande, the San Juan River is also a water source for the downstream state of Tamaulipas. The Cuchillo dam has been a major point of contention due to its impacts on downstream irrigation. Currently, the basin is overcommitted even in years with normal precipitation (Scott, Flores-López, and Gastélum 2007).

Administration is undertaken by the Servicios de Agua y Drenaje de Monterrey (SADM), which focuses on supplying water at the expense of environmental impacts and allocation considerations. Despite this, SADM is considered one of the most efficient entities of its kind in Mexico. Over 99% of households are connected to potable water and sanitation services (García Monforte, Aguilar Benítez, and González Gaudiano 2012). This is due to a substantial expansion of infrastructure and improved water governance which took place after drought led to protests in the 1980s (Bennett 1998).

**Climate Change Risks and Vulnerabilities**

While the impacts of climate change are difficult to predict, projections for the area in which Monterrey is located include increasing temperatures, decreasing precipitation, and an increased frequency of extreme events including droughts and heavy rains.
(Navar 2001). This can be expected to increase the ratio of demand to supply of water for Monterrey and compound the water supply challenges the city already faces from population and industry growth. Competition over limited water resources may also have political consequences in the area.

**State-led Resilience Strategies**

Thus far the city of Monterrey has not focused on addressing climate change risks. However, plans to continue to supply the city given increasing demands are being implemented. These include awareness campaigns to reduce unnecessary water use and infrastructure to supply more water to the city.

Government awareness campaigns have been implemented in many places in Mexico to reduce excessive household water use, since much of Mexico is relatively dry and many cities face water supply challenges. These include television public service announcements, billboards, and the like encouraging Mexicans to turn the water off while brushing their teeth and other strategies for reducing water usage. However, these campaigns have thus far not been effective in Monterrey, with per capita water usage declining by only one percent over the last decade (Garcia Monforte, Agular Benitez, and Gonzalez Gaudiano 2012).

The city’s main efforts to provide sufficient water supply to the city for the future have focused on infrastructure with the Monterrey IV project, which is currently in the planning stages. Six infrastructure projects were proposed to supply water to the city over the next 50 years and the one which has been selected is a 680 kilometer aqueduct from the Panuco basin to the south which will be able to supply six cubic meters of
water per second to the city. This option was selected because the Cerro Prieto basin has the most available water of the six options; however it is also the most expensive option, projected to cost $1 billion in federal and private funding, and will take the city 30 years to pay. For these reasons the project is subject to some controversy. Construction is expected to begin in late 2013 (Woodyard 2012).

**External Actor Involvement**

There has not been a great deal of external involvement in water management or climate change preparation in Monterrey. This constitutes an area for potential increased involvement by development organizations. The Inter-American Development Bank implemented a small project in the San Juan River basin area to assist in water management. The project focused on assessment of water resources and capacity building for decision makers (IADB 2012). Historically, external actors have provided funding for water infrastructure projects in Nuevo Leon but the current Monterrey VI project is not receiving such funding. External involvement could potentially provide crucial assistance in preparing for climate change in Monterrey, including assessment of risks and development of appropriate resilience strategies.

**RISK AND RESILIENCE STRATEGIES**

Increasingly over the past several years, aid groups and others have taken greater notice of climate change problems in the developing world, with hopes of identifying ways to protect the development advances already made.
Many of the available strategies have little long-term negative impact on the environment, and, instead, promote greater sustainability. As such, they have been nicknamed “no regret strategies,” serving as positive investments in the local environment.  

These no-regret strategies can be grouped into four pillars in our applied resilience framework, with much complementarity and interdependence, as well as connections to power and geography: These tools are Policies, Products, Networks and Behavior.

Policies

Policies are the tools used most often by government at the local, provincial, subnational and national levels as well as other representative groups, such as village organizations, to promote resilience through rules and regulations. Globally, policies to address global warming’s impact on water resources have included Integrated Resource Planning (IRP); land use planning; programs to de-habit flood plains; restrictions of commerce, farming and other activities around vulnerable lands; creation of water-buffering lands; evacuation planning; public awareness campaigns to reduce water consumption and to address land use planning programs; and efforts to increase the participation of vulnerable stakeholders in the decisionmaking processes, with hopes of ultimately attaining greater acquiescence.

Use Treated Wastewater for Public Irrigation

Using treated wastewater for public irrigation is a common practice employed both by developed countries like the United States and developing countries like Tunisia and Jordan. There are different methods of treatment, including conventional treatment through treatment plants as well as natural biological treatment. For example, Arizona uses a soil-aquifer treatment system, where wastewater is purified through a series of infiltration basins that feed into an aquifer (FAO, 1992). The new plant expected to undergo construction in Trujillo under the IDB’s plans could allocate a portion of treated wastewater for public irrigation use. This is a “no-regret” strategy, as efforts to recycle processed water and improve utilization not only address climate concerns, but also reduce the strain on household water supply and the tensions surrounding water distribution policies.

**Manage Glacial Lakes**

As mentioned previously, glacial lakes fed by the Cordillera Blanca in Peru pose safety risks to nearby communities due to flooding. It is important to manage flood prone lakes and implement safety measures to reduce this risk. As a simple yet successful example of this, Nepal uses pumps to drain risk prone lakes once they reach a certain volume. The Peruvian government established a unit within the National Water Authority to manage high-risk glacial lakes; however, in practice the unit is limited only to monitoring, as constitutional limitations currently prohibit the implementation of any safety measures (USAID, 2011). This is an issue that should be addressed through policy, as a solution similar to what has been done in Nepal could reduce the number of deaths each year due to glacial lake outburst floods.
Another set of tools that is often underwritten and promoted by governments but serves as its own pillar within the resilience framework is Products, which may include fertilizer or varieties of drought-resistant seeds, to community-sponsored savings plans that encourage stakeholders to contribute funds to lessen the risk of future external shocks. Products that have been used in response to climate change’s impact on water resources, often leading to natural disasters, include insurance, which spread the risk to multiple users, thus lessening the risk to any one user.

The two main forms of insurance are index-based and indemnity-based insurance. Index-based insurance is written against weather-related or economic triggers rather than actual losses incurred by the user. In other words, the insurance is written against events that cause loss, not the actual loss. For example, a longer-than-expected drought or a season’s rain that surpasses a specific number of inches may serve as the trigger to provide funds to users.

By contrast, conventional indemnity-based insurance is written against the actual loss suffered by the user. Thus, while more accurately corresponding to users’ losses, it is exponentially more complicated to operationalize, due to the size of a population and the vast area that may be affected by an external shock such as a natural disaster, the potential for false reporting and difficulty of verifying losses, and the potential cost of providing such a benefit. By contrast, index-based insurance, while more difficult to understand by many users, bears far lower

**Weather-Based Index Insurance in Peru**

Investment in modern satellite observation systems and GIS mapping established the infrastructure in Peru for a weather-based insurance scheme, which is currently benefitting certain areas of Northern Peru. Often referred to as “El Niño Insurance,” this mechanism stems from extensive studies demonstrating a strong correlation between the temperature of the water off the coast of Lima and floods in Peru’s highlands. Therefore, when the seawater reaches a certain temperature, this triggers an automatic disbursement to individuals with this insurance at risk from the impacts of El Niño. This way, households are able to receive payments before floods and other consequences occur, allowing them to take the necessary preparatory or resilience measures to reduce losses and disruption (GlobalAgRisk, 2012).

Households in the coastal city of Trujillo are also adversely affect by floods from El Niño; index-based insurance is a product that, with further research, could serve as an important risk-smoothing and resilience tool for its residents as well. However, it is important to address the limitations of this type of insurance, especially in light of the increasing frequency and variability of El Niño due to climate change. This could
lead to greater risk for the insurance companies, resulting in increased premiums to cover more frequent occurrences and, thus, more payouts. Nevertheless, this option would still be more cost-effective for Trujillo’s households than traditional indemnity insurance, which invokes high premiums due to informational asymmetries such as adverse selection and fraud—risks eliminated by the index-based component.

**Behavior**

While Policies and Products are often supported and introduced at organized community and government levels, household efforts to lessen risk can be identified through Behavior, the third pillar in the resilience strategies framework. Among the behavior modification tools to address the risk to water resources, due to climate change, are emergency planning efforts, water rationing plans, alternative sanitation systems (so households can consume less water for every-day needs), and acceptance of and commitment to land use planning, such as moving residential areas away from vulnerable regions in order to create water-buffering lands for flood-prone areas.

**Alternative Agricultural Practices**

Many indigenous farmers in Peru use raised field agriculture, an early irrigation and drainage system that makes it possible to farm low-lying, flood prone, poorly drained lands. Additionally, some farmers continue to grow or are returning to traditional crop varieties better adapted to varying temperatures and precipitation
levels (i.e., potatoes and quinoa). By utilizing traditional farming practices and
cultivation techniques, small-scale farmers in the Andes are generally more resilient
to climate change risks than their coastal or large-scale agriculture counterparts. As
flood-prone lands become more widespread in Trujillo and increasing temperature
and precipitation levels leave farmers at risk of crop failure, they should look to
these types of indigenous behaviors to increase resilience (USAID, 2011).

**Networks**

A vital connection between Policies, Products and Behavior is the fourth pillar of the
resilience framework strategy, Networks, which connect and represent different
stakeholders within the community and can serve to reach and persuade their
constituents to adopt resilience strategies in order to lessen risk. Among the
examples of strategies undertaken by networks to address climate change’s impact
on water resources management are the inclusion and involvement of vulnerable
stakeholders in decisionmaking processes in order to ensure greater success in
activities such as land use planning, de-habiting flood plains, restricting economic
areas near vulnerable lands, and creating water-buffering lands.

**CONCLUSION**

The potential for devastation to livelihoods and lives due to the warming of the earth
can be reduced, by applying “no regret” resilience strategies, with hopes of lessening
the risk of external shocks and their intensity. With that said, resilience alone will
not tackle the formidable challenges of climate change. Moreover, resilience is not
always ideal, as it can prolong systems and processes that do not serve the best interests of the environment or the people of a region. Finally, while the strategies presented through this resilience framework have been proven in some regions to increase resilience to the impact of climate change on water resources and other environmental necessities, experts argue their successful adoption requires adapting to "local pre-conditions – whether cultural, institutional or climatic," therefore requiring attention be paid toward "barriers to implementation, maintenance and diffusion of adaptation."\(^{8}\) When complementarily instituted within the fabric of communities, these strategies can serve the interests of multiple stakeholders, and, therefore, the interests of practitioners of international development.

REFERENCES


ICIWaRM. (n.d.) “Peru Shared Vision Planning.” Available at: http://www.iciwarm.org/en/about/prjPeru.cfm


World Gazateer. (2012). http://www.world-


