FROM THE AMERICAN PEOPLE

TECHNICAL REPORT

FAST-TRACK IMPLEMENTATION OF CLIMATE ADAPTATION

WORKING PAPER

August 2015

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Engility Corporation Contact:
Michael E. Cote, Senior Climate Adaptation Specialist, Michael.Cote@engilitycorp.com
Engility Corporation
1320 Braddock Place
Alexandria, VA 22314

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Prepared by:

ICF International

Washington, DC

and

Engility Corporation

Alexandria, VA

and

Stratus Consulting

Washington, DC

Editorial assistance: Michelle Colley, Randall Freed, Wendy Jaglom, Thuy Phung, and Peter Schultz

Report Contributors:

Glen Anderson, Engility Corporation, Alexandria, VA, USA

Martin Anderson, ICF International, Washington, DC, USA

Edil Antonio Sepulveda Carlo, Columbia University, New York City, NY, USA

Michael E. Cote, Engility Corporation, Alexandria, VA, USA

Michael Duckworth, Stratus Consulting Inc., Washington, DC, USA

Nora Ferm, USAID, Washington, DC, USA

John Furlow, USAID, Washington, DC, USA

Patricia Garffer, ICF International, Washington, DC, USA

Jim Henderson, Stratus Consulting Inc., Washington, DC, USA

Edward Cody Kent, Columbia University, New York City, NY, USA

Margot Le Guen, Columbia University, New York City, NY, USA

Katy Maher, ICF International, Washington, DC, USA

Nicolai Prytz, Columbia University, New York City, NY, USA

Robert Raucher, Stratus Consulting, Inc., Washington, DC, USA

Ricardo Saavedra, ICF International, Washington, DC, USA

Craig Schultz, ICF International, Washington, DC, USA

John Snyder, ICF International, Washington, DC, USA

Fran Sussman, ICF International, Washington, DC, USA

Megan Sutton, International Research Institute for Climate and Society (IRI), Columbia University, New York City, NY, USA

Contact: Michael E. Cote, Engility Corporation, Michael.Cote@EngilityCorp.com

DISCLAIMER

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ACRONYMS

ACTs	Artemisinin-based combination therapies
CCRD	Climate Change Resilient Development
CLASP	Collaborative Labeling and Appliance Standards Program
CRD	Climate-Resilient Development
CRIS	Climate Resilient Infrastructure Services
DTW	deep tube wells
EDS	Early Detection Systems
EWS	Early Warning Systems
FTI	Fast Track Implementation
GLOF	glacial lake outburst flood
HSH	Hydroponic Shade Houses
HTMA	Heat Tolerant Maize for Asia
IDE	International Development Enterprises
IDRC	International Development Research Centre
IPM	Integrated Pest Management
IRS	Indoor residual insecticide spraying
ITNs	insecticide-treated mosquito nets
LADWP	Los Angeles Water and Power District
MPA	Marine Protected Area
O&M	Operations and Maintenance
ORS	oral rehydration salts
OCV	Oral cholera vaccine
POU	point of use
PPA	power purchase agreement
RDTs	Rapid diagnostic tests
RSA	resource, subpopulation, or asset
S&L	standards and labels
SIDS	small island developing states
SP	sulfadoxine pyrimethamine
SAPWII	South Asia Pure Water Initiative, Inc.
USAID	United States Agency for International Development
VBEEC	Vietnam Building Energy Efficiency Code
WEAP	Water Evaluation and Planning (tool)

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1. CONTEXT AND OBJECTIVES

People, livelihoods, and assets in developing countries are often highly exposed to climate-related stresses such as floods, heat waves, and droughts. Increases in those stresses or exposure to those stresses can exacerbate current climate vulnerabilities, further impeding the achievement of development objectives. In cases where vulnerability is already high, uncertainty about climate change and potential future impacts should not delay action. However, all too often, adaptation programs struggle to transition from acknowledging and assessing vulnerability into actions that reduce vulnerability on the ground. The complex assessment of climate change impacts and disaster-related vulnerabilities—together with decision makers' often low capacity to interpret the findings and their uncertainty, difficulties in obtaining financing, and other factors—frequently delay the implementation of measures to increase climate-related resilience.

The process of assessing vulnerabilities can be so complex and resource-intensive that it frequently hampers decision-makers' ability to move forward and implement measures to address those vulnerabilities.

The initial steps in assessing vulnerability and designing potential adaptation actions can make it difficult for decision-makers to get to actual implementation of adaptation measures. Diagnosing vulnerabilities and designing adaptation actions can require multi-disciplinary expertise, access to climate data, and knowledge of scenarios and projections of future climate. These requirements can reinforce the perception of adaptation as complex, resource-intensive, and uncertain, leading to a pervasive "implementation paralysis" that challenges global adaptation efforts. While resource, governance, and capacity constraints are contributing factors to the slow pace of adaptation, opportunities exist to accelerate the pace of vulnerability assessment and the implementation of low-cost, low-regrets adaptation measures that would provide immediate climate-resilient development benefits. In these situations, a Fast Track Implementation (FTI) approach can be used to streamline the assessment of vulnerability and design of adaptation solutions in order to get to implementation of adaptation options more quickly.

The FTI approach is entirely consistent with CCRD's Climate Resilient Development (CRD) Framework[1], as described in the next section. The CRD Framework supports the development process by helping development practitioners to identify, evaluate, select, implement, and adjust actions to reduce climate vulnerabilities and improve development outcomes. The FTI approach describes conditions under which the early stages of the CRD framework can be accelerated.

The objectives of this report are:

- To explain the general concept of FTI and describe how the FTI approach can be used in practice [in Sections 2 and 3]; and
- To present a large set of adaptation options that could be employed within the FTI approach to advance climate resilient development [Appendix A].

[1] USAID, 2014. See footnote #1.

2. THE FTI APPROACH AND CRITERIA

The FTI approach employs a set of screening criteria to streamline assessment of climate vulnerabilities and design of appropriate adaptation options within the stages of the CRD Framework, shown in Figure 2.

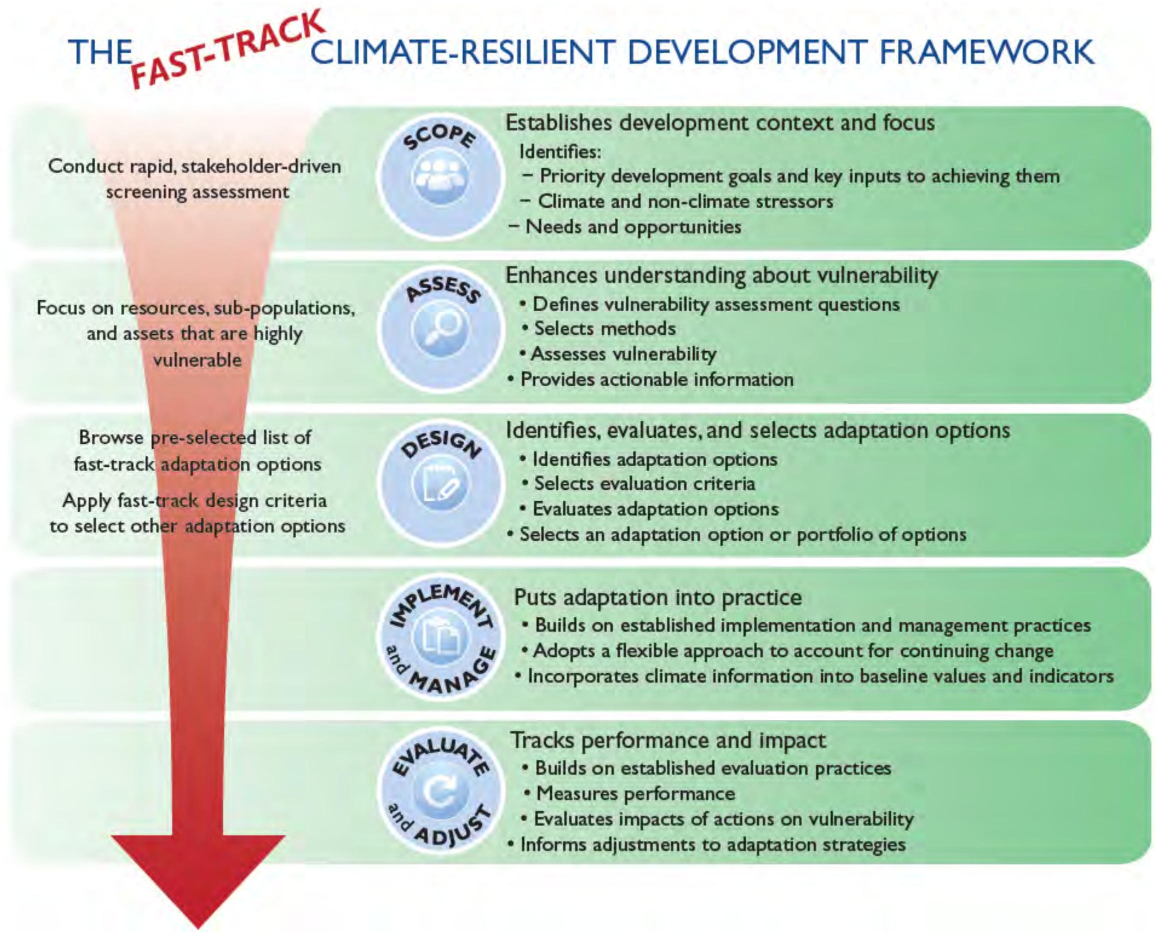

Figure 2. The FTI approach (depicted by the red arrow at left) aims to streamline vulnerability assessment and adaptation design in certain circumstances, to move to implementation more quickly.

The FTI approach is designed to be used by development and adaptation practitioners, resource managers, and other stakeholders likely to be affected by climate change, with responsibility for decision-making that can address vulnerabilities at the local and regional (sub-national) levels. In some cases, the approach may also be used at the national level[2]. The stages of the CRD Framework (shown on the right of Figure 2) facilitate the systematic inclusion of climate considerations in all types of development decision-making; FTI is an opportunistic approach that is applicable in only those situations where:

[2] While the approach can be applied at the national level, the specific FTI adaptation options provided in the Appendix are generally most appropriate for use at the local or regional (sub-national) level.

- Critical development inputs are already highly vulnerable to climate stressors, and this can be rapidly ascertained in a screening exercise at the scoping stage;
- The adaptation options to reduce potential impacts are straightforward and inexpensive; and
- Sufficient human and financial resources are available to launch implementation.

The FTI approach helps to accelerate the "Scope," "Assess," and "Design" stages of the CRD Framework in these situations, and thus it enables quick decision-making that will get to implementation of adaptation quickly. It can be used for stages where a streamlined approach is useful and warranted (perhaps even necessary), while leaving the option of switching to more comprehensive analyses during other stages (for example, in cases where good quality observed and projected climate data are readily accessible). In most cases it is advisable for the FTI approach to serve as a complement to a more comprehensive and deliberate process of scoping, assessing, and designing climate-resilient development approaches in order to address all-important vulnerabilities, not just the ones that are amenable to the FTI approach.

This approach adds value by providing decision-makers with a quick and simple way to diagnose climate vulnerabilities and design adaptation solutions. The approach can help decision-makers crystallize thoughts and focus on addressing the other barriers that hinder implementation of adaptation, moving the conversation from "What to do?" to "How can we get the resources or build capacity to do this?" In the cases to which it applies, it can streamline the process by which decision makers identify discrete development problems with clear climate vulnerabilities and clear solutions, and thereby help them obtain access to climate-related funding.

The initial **scoping stage** is characterized by a rapid screening assessment informed in part by stakeholder consultations to determine whether critical development inputs are already highly vulnerable to climate stressors. This entails identification of the critical development inputs and a preliminary assessment of the climate and non-climate stressors that may put critical inputs at risk, compromising development goals. If critical inputs are already highly vulnerable, and climate change is likely to further strain development goals, adaptation action need not await the completion of a full vulnerability assessment. It should be noted that, in cases where the FTI approach can be deployed, it may still be desirable to conduct a detailed vulnerability assessment to identify less obvious threats, to design potentially expensive and long-lasting adaptations that require a high level of detail about vulnerabilities, or to meet other decision-making needs.

Key Definitions

Vulnerability is "the degree to which something can be harmed by or cope with stressors such as those caused by climate change. It is generally described as a function of exposure, sensitivity, and adaptive capacity."

Exposure is "the extent to which something is subject to a stressor. For example, flooding is a climate stressor that can affect infrastructure. Infrastructure built in a floodplain is exposed to this stressor, but infrastructure built at higher elevations is not exposed to flooding."

Sensitivity is "the extent to which something will change if it is exposed to a stressor. For example, agricultural crops are sensitive to increased night-time temperatures. However, some plants will fail at lower temperatures and are thus more sensitive to this climate stressor than others."

Adaptive capacity is the "combination of the strengths, attributes, and resources available to an individual, community, society, or organization that can be used to prepare for and undertake actions to reduce adverse impacts, moderate harm, or exploit beneficial opportunities. Adaptive capacity is fundamentally about the ability of an affected system to change in response to climate stressors."

Definitions from USAID (2014).

Key FTI criteria at the **assessment stage**:

- High baseline exposure and/or vulnerability
- Anticipated increases in future vulnerability as a result of climate change
- Inputs have a high development value

The **assessment stage** helps to define the specific climate vulnerabilities that will be addressed, by assessing climate stressors alongside non-climate stressors. It provides detail on the conditions that contribute to the vulnerability of critical inputs. Ideally, this detail will be readily available through a combination of first-hand knowledge, brief consultations or workshops, and field visits. If detailed technical analyses or modeling is required in order to assess vulnerability, the FTI approach is not appropriate and the CRD Framework should be applied in full. At this stage, practitioners should screen for inputs that are critical to achieving development goals, that are highly exposed or otherwise vulnerable to current climatic conditions, and that are likely to become more vulnerable as the climate changes.

Key FTI criteria at the **design stage**:

- Low initial and ongoing cost
- Effective in reducing climate vulnerability, not susceptible to damage
- Straightforward to implement
- Co-benefits, and limited disadvantages
- Flexibility and reversibility

At the **design stage**, the FTI approach focuses on identifying implementable, low technology, and low regrets adaptation options. It is beneficial if these options also have significant co-benefits and are flexible and reversible in case new information in the future indicates that a modified or entirely different adaptation approach is preferable. The emphasis on identifying these types of options helps to shift the conversation from "What to do?" towards "How can we get resources or build capacity to do this?" FTI criteria are used to screen potential adaptation options to identify those that increase resilience to climate change, and provide the greatest likelihood of meeting the established development objectives. Practitioners should look for options that are inexpensive in terms of both initial start-up costs related to capital investment, labor and materials, and ongoing costs associated with operations and maintenance. They should look for options that are *technically* straightforward, in that they don't require sophisticated technology or expertise to develop and implement, and that are *institutionally* straightforward, in that they don't require complex or lengthy approval processes, don't require complex approaches to comply with regulations, and are otherwise unlikely to get stuck in administrative procedures. FTI adaptation options are effective if they reduce the impacts of climate change on inputs, and if they themselves are robust and durable in the face of a changing climate. Ideally, FTI adaptation options will provide benefits or promote development goals that are separate from the climate impact that they are primarily intended to address. Similarly, FTI adaptation options should not conflict with development goals or targets in other areas. Finally, FTI adaptation options should be flexible enough to adjust to changing climate conditions over time, and should not be difficult, expensive, or time-consuming to reverse. A more detailed explanation of the FTI design criteria, and examples of adaptation options that meet these criteria, are provided in appendices to this report.

Overall, a fast-track implementation approach is most relevant and useful in situations where critical inputs are already at highly vulnerable and where that vulnerability is likely to increase in the future; where the adaptation options are straightforward, inexpensive, low-regret, and have co-benefits; where resources are accessible, decisions can be made quickly, and institutional capacity exists to manage implementation; and where there are existing monitoring and evaluation capacities and/or indicators.

A fast-track process that is firmly anchored in "development-first" principles helps to ensure that any adaptation solutions will advance development objectives. An open process conducted in consultation with stakeholders contributes to a full assessment of climate vulnerabilities, while also helping to identify some of the co-benefits, synergies, and prerequisites for potential adaptation options.

3. APPLYING AND TESTING THE FTI APPROACH

The CCRD team has developed a set of adaptation options that represent good candidates for fast-track implementation to address specific vulnerabilities in six high-priority sectors: coastal, urban services, agriculture, health, water resources, and energy. These sectors were selected based on alignment with USAID priorities, and for their relevance to CCRD core team strengths and project experience. A suite of adaptation options for each combination of climate vulnerabilities in these six sectors is presented in Appendix A, *Compilation of Fast-Track Implementation Adaptation Options*, along with a discussion of how the options meet the FTI assessment and design criteria. As examples, the adaptation options profiled include:

- Monitoring, protection, and restoration to counter coral reef degradation;
- Improved routine maintenance to reduce disruption in services and damage to transportation infrastructure;
- Crop rotation to decrease the spread of climate-sensitive pests and disease-carrying insects into agricultural zones;
- Early detection and rapid diagnostics for water-borne diseases;
- Rainwater harvesting to counter water scarcity and stress; and
- Modification of zoning regulations for the siting of new energy infrastructure, to reduce vulnerability to extreme weather and precipitation events.

The broad set of FTI adaptation options represents a first cut which can be refined based on lessons learned from deployment of adaptation options in the field. The number of adaptation options can also be increased as the FTI approach is tested and developed for sectors and climate vulnerabilities that are not covered in this initial round.

Thus the FTI approach can be applied in two ways:

- Practitioners whose work is aligned with the sectors and climate vulnerabilities explored in this document can browse the pre-selected list of FTI adaptation options in Appendix A to determine whether any of the adaptation solutions described meet their site-specific needs.
- Outside of the climate vulnerabilities and sectors covered in this document, practitioners can apply the FTI criteria to evaluate potential adaptation options.

As a next step the CCRD team will pilot the FTI approach, along with other CCRD tools, with local stakeholders in Piura and Trujillo (Peru), Nacala-Porto (Mozambique), and Santo Domingo (Dominican Republic), as part of the Climate Resilient Infrastructure Services (CRIS) program. The CCRD team aims to integrate rapid diagnostics and fast-track approaches in CRIS pilots by working with local stakeholders to quickly assess vulnerability by identifying highly vulnerable infrastructure based on historic performance (i.e., resources, subpopulations, or assets (RSAs) with high baseline vulnerability) and prioritizing no or low-regret, cost-effective, and straightforward adaptation actions. As part of this pilot, the CCRD team will apply and refine FTI criteria for implementation, monitoring and evaluation of fast-track adaptation.

Rapid implementation of adaptation actions is not always the best course, as there can be adaptation options that are more difficult to implement in the near term (e.g., due to the need to build institutional capacity, establish political support, or acquire financial resources) but are more cost-effective in the long term.

The fast-track approach is a way to quickly and efficiently assess and manage some of the most significant climate vulnerabilities, particularly in situations where time and resources do not permit one to comprehensively address all climate vulnerabilities. It can be viewed as a way to 'buy time' or relieve the pressure of acute climate vulnerabilities with cost-effective adaptation while more expensive and time-consuming measures are being developed. It can allow a community to demonstrate early successes, thereby helping to create buy-in for more comprehensive and costly analyses and adaptation actions.

Key FTI criteria at the **implementation stage**:

- Transparent, effective governance, capable of rapid decisions
- Management and institutional capacity
- Access to funding and other vital resources
- Development projects in the implementation pipeline
- Identifiable project champion.
- Alignment with interest of local stakeholders and funders

Key FTI criteria at the **monitoring and evaluation stage**:

- Existing national monitoring and evaluation systems and capacities
- Existence of relevant qualitative and quantitative indicators

APPENDIX A: COMPILATION OF FAST-TRACK IMPLEMENTATION ADAPTATION OPTIONS

This appendix summarizes the suite of adaptation options that address specific combinations of vulnerabilities in six sectors (coastal, urban services, agriculture, health, water resources, and energy) and have high potential for fast-track implementation. Each combination of vulnerabilities comprises a changing climate hazard; a resulting impact; and a resource, subpopulation, or asset (RSA) at risk. The combinations presented below represent situations that meet the fast-track assessment criteria, namely high baseline vulnerability, anticipated increases in future vulnerability as a result of climate change, and RSAs at risk that have a high development value (see **Figure 1**).

Each potential adaptation option was then analyzed to determine how well it meets the fast-track design criteria, in terms of straightforwardness, cost-effectiveness, co-benefits, limited disadvantages, and reversibility/flexibility (see **Figure 1**). The analysis also included a literature review from readily available sources to identify examples where each adaptation option has been implemented, in order to provide an evidence base for its effectiveness. The number of examples is shown in parentheses next to each option; note that the literature review was not exhaustive, so the number of examples should not be interpreted to be a comprehensive and thorough inventory of all instances where an option has been applied.

Along these lines, it is important to note that the level of detail and number of options vary by sector, and this variability does not necessarily reflect a complete inventory of FTI adaptation options so much as it reflects differences in the level of effort of the sectoral review teams and availability of information.

It should also be emphasized that the adaptation options identified in the select six sectors presented in this document are by no means a complete list of adaptation options in those sectors. Nor are they the 'best' adaptation options for those sectors. Rather, they provide examples of adaptation measures that can be well-suited for fast-track implementation. In addition, the adaptation options are not entirely generalizable. An adaptation option can be a good candidate for fast-track implementation in one set of geographical, climate, economic, and social circumstances but may not be so in another. Furthermore, while the FTI approach addresses some of the technical capability requirements for managing climate vulnerability (in the assessment and design phases), it does not address other barriers to implementation of adaptation such as human and financial resources, legal and regulatory components, or information transfer and coordinated decision-making. Approaches for addressing these important considerations may be developed based upon the lessons learned from the deployment of the initial fast-track information contained in this document.

In many instances, adaptation options can address climate vulnerabilities in multiple sectors; hyperlinks to other sections of the document are provided where this is the case. For each combination of climate vulnerabilities (e.g., sea level rise; salinization of freshwater resources; coastal populations in small island developing states), a table is presented to allow a comparison of how the adaptation options meet each of the fast-track criteria.

This compilation of options is accompanied by more detailed matrices covering individual sectors. Please refer to these Excel-based spreadsheets for a complete description of how each adaptation option meets the fast-track criteria, and for further details of all examples.

1. COASTAL

1.1. SEA LEVEL RISE/SALINIZATION/COASTAL POPULATIONS

Climate hazard	Sea level rise.
Impact	Salinization of freshwater resources. Saltwater intrusion into coastal aquifers (especially shallow ones) and surface water will be exacerbated by sea level rise, particularly in areas where freshwater resources are already stressed.
RSA at risk	Coastal populations in small island developing states (SIDS).

Potential adaptation options

- Rainwater harvesting (5 examples) (also see Rainwater harvesting under Water Resources)
- Water conservation and efficiency and reducing water demand (5 examples) (also see Water conservation and protection measures under Water Resources)
- Enhance water storage options (3 examples)
- Desalination (1 example)

Integrated water resources management, drought emergency planning, and protection of groundwater resources are longer-term measures that require significant cross-agency cooperation and planning, technical capacities and financial resources, and therefore are not good candidates for fast-track implementation.

Table 1-1. Potential Adaptation Options for Sea-level Rise/Salinization/Coastal Populations

	Rainwater harvesting	Water conservation and efficiency, and reducing water demand	Enhance water storage options	Desalination
Straightforward	Systems can be installed in all types of locations, but work best in areas with consistent/reliable precipitation. Scale of systems can vary widely, from supporting one household to entire communities. Most straightforward among the four options presented in this table.	Types of systems and approaches can vary widely. Conservation measures that are most commonly used on small islands include leakage control; metering and pricing; water reuse; and use of water-saving devices. These measures are technically straightforward but must be supported by the necessary policies and enforceable legislation to be successful.	Depends on type of strategy used. Infiltration galleries are suitable for serving as community water supplies on small coral sand islands. Cost comparisons with other water supply technologies indicate that, for communities which rely on groundwater supplies, the use of infiltration galleries is the least expensive option.	Requires more extensive and costly water management systems to transport seawater, apply treatment, and then transport to communities for use. Private contractors and multiple government agencies likely need to be involved. Least straightforward among the four options presented in this table.

Table 1-1. Potential Adaptation Options for Sea-level Rise/Salinization/Coastal Populations				
Low cost	Depends on scale and type of system used, but installation and operating costs are generally low. Least costly among the four options presented here.	Initial capital costs vary and are dependent on the type of system or approach taken. For recycling, initial costs involve construction of treatment plants, which may be costly. Long term operations and maintenance costs vary depending on system or approach taken. Maintenance costs for recycling water can be costly, while conservation and reducing demand may be less expensive.	Capital and O&M costs vary depending on type of strategy used. For infiltration galleries, costs include labor, materials, fuel and electricity, and the level of maintenance needed. Estimated unit costs (including capital costs and O&M costs) of supplying groundwater from galleries on three islands where the technology has been used range from \$0.24-\$1.22/m^3.	High for initial construction of desalination plants. High O&M costs – available technologies are based mostly on membranes and are more costly than conventional methods for the treatment of freshwater supplies. Energy intensive. Most expensive among the four options presented here.
Effectiveness				
• **Reduction in climate vulnerability**	Does not protect existing resources from salinization, but provides additional freshwater supply.	Does not protect existing resources from salinization, but can allow for more water to be available for usage, particularly during dry periods.	Infiltration galleries protect groundwater supplies from salinization, maintaining a freshwater supply.	Producing freshwater from sea water, allowing for sustained drinking water access.
• **Limitations of protection**	Droughts and dry periods will limit water supply; limited storage capacity means that water supply during dry periods could be very low.	Are focused on conserving what is already available. Water reuse is often providing water that is not necessarily usable for drinking, mostly for sanitation, agriculture, etc.	Water storage options generally do not enhance supply but protect what is available in case of periods of drought or other threats. Infiltration galleries are dependent on groundwater supply.	Any disruption to energy transmission and supply will affect desalinization processes.
• **Susceptibility to Damage of the Protection System**	Systems themselves could damage houses and buildings if not properly installed, especially with heavy rain and high winds during storm events.	Depends on type of strategy used. These options do not necessarily address issues associated with sea level rise or destruction from storms.	Infiltration gallery systems can be adapted to dry/wet conditions, but potentially are at risk from sea level rise and flooding from storm events.	Plants could be damaged by sea level rise, storm surges, and flooding, therefore impacting the water supply.
Provide co-benefits	Reduces runoff; can utilize local labor and materials; water can be of better quality than what is available in rivers, wells, etc., and so can provide health benefits.	Health benefits from protection of water supply; education of community on water and climate issues; local labor for construction.	Health benefits from protection of water supply; protects habitat for species sensitive to salinization.	Local labor opportunities; health benefits of improved water quality.
Limited disadvantages	Depends on frequency and amount of rainfall; limited storage capacity; leakage problems; health issues associated with water quality, safety, and mosquitoes; reduces revenues to public utilities.	Do not address issues of inadequate water supply; require community buy-in and outreach/education.	Does not address water supply issues, and options are dependent on an initial supply of water for storage. Infiltration galleries require significant areas of land to be effective.	High labor and construction costs, potentially vulnerable from storms and increasing sea level rise depending on plant location.
Reversibility and Flexibility	Technology is flexible and reversible and can provide benefits regardless of climate vulnerability.	Options are generally flexible and reversible, and provide benefits regardless of climate vulnerabilities.	Depends on type of system used. Infiltration gallery system is adaptable to changing conditions.	Plants are difficult to move, and systems require significant investment so are less flexible and reversible without financial loss.

Table 1-1. Potential Adaptation Options for Sea-level Rise/Salinization/Coastal Populations				
Guidance on when/where this option is most likely applicable	Best suited to areas that have evenly-distributed rainfall during the year. The effective roof area and the material used in constructing the roof influence the collection efficiency and water quality. Some technical and financial capacity must be available. Contamination of supplies is a concern that must be addressed by control of collection area or treatment.	Measures must be supported by policies and enforceable legislation. The operation of a pricing system requires meter readers, and an appropriate billing and revenue collection system. Also requires high level of community involvement. Only applicable to Small Island Developing States with public water supply systems.	Infiltration galleries are suitable for serving as community water supplies on small coral sand islands.	Most effective if systems are located where impacts from storms and sea level rise would cause minimal damages. Most applicable where energy supply is abundant and financial resources are available.
Examples of implementation	• A World Bank project is installing 170 rainwater catchment and storage systems to supply safe water to approximately 4,000 people in 80 rural communities in Vanuatu. • Rainwater harvesting is practiced throughout Grenada. The level of sophistication varies from simple containers storing roof runoff to relatively sophisticated catchment design, conveyance, filtration, and storage and distribution systems.	• The bauxite/alumina companies in Jamaica recycled industrial effluent to reduce the rate of freshwater withdrawal from aquifers and reduce pollution. • Leakage control is widely used in small island developing states (SIDS), such as Seychelles, Bahamas, and Solomon Islands. • Several SIDS use dual distribution systems to supply potable water and non-potable water (in two separate pipes).	• Infiltration galleries can generally be divided into two categories: open trenches and buried conduits. Open trenches, covered with simple roof structures, are used on Kiritimati (Christmas Island), Kiribati. Buried conduit systems have been installed and are successfully operating on a number of atolls in the Pacific and Indian Oceans. • Boreholes and wells are two other water storage technologies that are widely used in some SIDS.	• Desalination is carried out in the British Virgin Islands on the islands of Tortola and Virgin Gorda. The capital cost of a plant of 90m3/day is approximately $4.5 million. Energy is the primary operating cost, with consumption ranging from 3 to 6 KWh/m3 of potable water produced, depending on the size of the plant and the technology employed.

1.2. WARMER SST AND LOWER PH/REEF DEGRADATION/CORAL REEFS

Climate hazard	Rising sea surface temperature and ocean acidification (CO_2 concentration).
Impact	Coral reef degradation. Reef-building corals can be damaged by climate-related stress (e.g. warmer water) as well as non-climatic pressure (e.g. over-fishing).
RSA at risk	Coral reefs.

Potential adaptation options

- Reef protection (marine protected areas, marine reserves, networks of protected areas, etc.) (4 examples)
- Reef monitoring (2 examples)
- Reef restoration (2 examples)

Reef construction and artificial reefs and reef migration are more technically complicated and expensive, while marine conservation agreements require significant coordination among different stakeholders. As a result, these options are less suited for fast-track implementation.

Table 1-2. Potential Adaptation Options for Warmer SST and Lower PH/Reef Degradation/Coral Reefs

	Reef protection	Reef monitoring	Reef restoration
Straightforward	Applicable in areas where management can be effective at either the local or national level and strategies for reef protection are well understood and extensively applied.	Monitoring can be adapted to local conditions and issues of concern. Support from research organizations, non-profits, and funding agencies can help countries undertake monitoring efforts.	Applicable in most areas. Most effective in addressing climate change when used in conjunction with other management efforts that protect reefs from other stressors (overfishing, pollution, etc.).
Low cost	Costs of reef protection primarily involve enforcement and potential losses to established industries.	Costs can vary widely and include costs for monitoring instruments and equipment, as well as labor and materials for ongoing monitoring.	Costs include diving equipment, materials required for restoration efforts. Ongoing costs include long-term maintenance and monitoring of restoration efforts.
Effectiveness			
• **Reduction in climate vulnerability**	Does not directly reduce climate vulnerabilities but enhances resilience.	Monitoring itself will not directly reduce climate vulnerabilities, but can help contribute to information gathering on climate vulnerabilities which will help countries prepare to adapt to and reduce climate vulnerabilities.	Does not directly reduce climate vulnerabilities but enhances resilience.
• **Limitations of protection**	Will not prevent impacts of climate change, but could enhance resilience and allow for research and monitoring.	Monitoring will not provide protection but could provide information in support of protection.	Restoration may not protect reefs from ocean acidification and strong storms.
• **Susceptibility to Damage of the Protection System**	Reduces stresses of overfishing, pollution, etc., but does not necessarily reduce likelihood of damage from climate impacts.	Monitoring will examine how susceptible the areas are to damage.	Restored reefs could be more resilient to storms but could also sustain damages depending on strength and frequency of storm events.
Provide co-benefits	Reef protection can provide economic benefits to associated industries (e.g., fisheries, tourism).	Provides information that can benefit the conservation of biodiversity, tourism, disaster risk mitigation, and livelihoods.	Reef restoration can provide economic benefits to associated industries (e.g., fisheries, tourism).

Table 1-2. Potential Adaptation Options for Warmer SST and Lower PH/Reef Degradation/Coral Reefs			
Limited disadvantages	Prohibiting fishing activities could have impacts on the local economy.	This component is not expected to have significant disadvantages.	Requires significant effort to undertake restoration, monitor progress and maintain protection.
Reversibility and Flexibility	Protected areas could potentially be expanded or reduced therefore option is reversible and flexible.	Monitoring can be done regardless of threat.	Restoration can be done regardless of climate threats in order to restore reefs.
Guidance on when/where this option is most likely applicable	See 'Straightforward' criterion.		
Examples of implementation	• The Seaflower Marine Protected Area (MPA) around the San Andres islands is Colombia's first MPA, the largest in the Caribbean, and protects the Caribbean's most extensive open ocean coral reefs. It covers 65,000 km^2 in the San Andres Archipelago. The MPA is zoned for management levels ranging from total protection to controlled industrial fishing.	• The World Bank funded a project in the Maldives to pilot capacity building in tourist resorts for coral reef monitoring. This will provide technical support to develop a technology platform (referred to as 'the Coral Reef Monitoring Framework') that will enable easy access to data and decision support tools.	• In Votua Village, Fiji, coral restoration efforts started in 2004 with the assistance of OISCA, Japan. A couple of the villagers involved with the enforcement of the Marine Protected Area (MPA) learned basic skills for propagating coral fragments and established two 4' x 8' propagation racks in the MPA with the materials and training provided by OISCA.

1.3. SLR/SHORELINE RECESSION/COASTAL POPULATIONS

Climate hazard	Sea level rise.
Impact	Shoreline recession. Beach erosion caused by rising relative sea levels, combined with coastal squeeze from land.
RSA at risk	People who live in, or earn their livelihood from, beachfront land.

Potential adaptation options

- Mangrove conservation and regeneration (4 examples)

1.4. SLR AND STORM SURGE/INUNDATION/COASTAL POPULATIONS AND INFRASTRUCTURE

Climate hazard	Sea level rise, storm surge, and rising wave height.
Impact	Coastal inundation and flooding. Changes in high and extreme water levels will result in more frequent and more severe flooding events. An increase in wave height can be a secondary effect of shoreline recession and sandy barrier erosion.
RSA at risk	Populations and assets located in the coastal flood zone.

Potential adaptation options

- Mangrove conservation and regeneration (4 examples)

Table 1-3 and 1-4. Potential Adaptation Options for SLR Shoreline Recession/Coastal Populations and SLR and Storm Surge/Inundation/Coastal Populations and Infrastructure	
Mangrove conservation and regeneration	
Straightforward	Planting techniques are well established; the main issue is in permitting.
Low cost	Low initial cost and negligible ongoing cost.
Effectiveness	
• **Reduction in climate vulnerability**	Various studies indicate that mangroves reduce wave forces by up to 70–90% with their dense and extensive above-ground root systems. Mangrove ecosystems also moderate climatic extremes by providing shade and increasing air humidity, while also reducing wind velocity and soil water evaporation. In short, they are a first line of defense for coasts and coastal communities, since they buffer storm and wave forces while binding coastal land that would otherwise erode away.
• **Limitations of protection**	Will not protect against slow, long-term inundation; limited protection in case of a direct hit from a land-falling tropical cyclone.
• **Susceptibility to Damage of the Protection System**	Trees subject to drowning due to sea level rise, mangroves will decline in size if not allowed to migrate inland due to sea level rise; trees subject to storm damage. Young plants are especially vulnerable to high winds of waves. Non-climate stressors such as pollution and overexploitation of fuel wood can also damage mangroves.
Provide co-benefits	Supports biodiversity and species habitat; increases pollutant filtering; supports local livelihoods (providing fuel wood and other forest products, enhancing fisheries, and creating employment opportunities).
Limited disadvantages	Reduction in beach access.
Reversibility and Flexibility	Trees can be removed, if desired, and replaced with a stronger protection system (e.g., sea wall). However, the co-benefits make mangrove plantation attractive regardless of the extent of future sea level rise.
Guidance on when/where this option is most likely applicable	Coastal areas where mangroves are degraded or removed due to development pressures.
Examples of implementation	• In India, the Tata Chemicals Society for Rural Development in partnership with Mangroves for the Future, International Union for Conservation of Nature and local communities, aimed to restoring original mangrove cover. The project had several goals, including the protection of coastal areas of Okhamandal and Gujarat against the impact of tsunamis and storm surges. • The Mangrove Afforestation Project, led by Bangladesh's Forest Department, was initiated in 1966. These initial plantings proved highly successful in protecting and stabilizing coastal areas and led to a large-scale mangrove afforestation initiative. To date, approximately 120,000 ha of mangroves have been planted.

2. URBAN SERVICES

2.1. EXTREME PRECIPITATION AND STORM EVENTS/WATER QUALITY AND AVAILABILITY/POPULATIONS AND ASSETS

Climate hazard	Increased frequency and intensity of extreme precipitation, with flooding and landslides; Increased intensity and frequency of hurricanes, storms, tropical cyclones; Interactions with the effects of SLR.
Impact	Sanitation concerns and disruption of services and damage to public water supply and sewer systems, including wastewater treatment facilities.
RSA at risk	Affects critical infrastructure services and the vulnerable populations that rely on those services.

Potential adaptation options:

- Regularly clearing drains (9 examples)
- Solid waste removal in unplanned settlements (3 examples)
- Green infrastructure – vegetation (7 examples)
- Bans or fees on plastic bags (6 examples)

Table 2-1. Potential Adaptation Options for Extreme Precipitation and Storm Events/Water Quality and Availability/Populations and assets

	Regularly clearing drains	Solid waste removal in unplanned settlements	Green infrastructure – vegetation	Bans or fees on plastic bags
Straightforward-ness	Technically straightforward. Municipality needs to have a system set up for running the program – through having municipal waste pick-up crews or enlisting volunteers.	Technically straightforward. Municipalities need to have a system set up for collecting waste. Requires ongoing coordination across agencies and local groups. Needs public outreach to encourage the use of waste receptacles.	Planting is straightforward if funding, tools, and labor is present. Needs a certain degree of technical capacity to select appropriate species and management techniques to help the plants survive. Needs public outreach to prevent the harvest of plants for unintended purposes. Larger projects may involve more complicated political process.	Somewhat straightforward, requires regulations and enforcement mechanism. If plastic bags are banned, there needs to be viable alternatives at a reasonable price. An outreach campaign is needed to alert consumers to the rationale behind the ban or fee. A gradual phase-in of the ban can be more successful (e.g., a fee precedes the ban).
Low cost	Low. Can use volunteers and requires little extra resources. However, high initial cost if use more high-tech equipment such as vactor trucks for thorough cleaning.	Low-medium. Cost of setting up routes, workers, waste handling. Can depend on existing capacities.	Low-medium. Cost of trees, planting, zoning, planning, and early maintenance.	Medium. Some costs on business and consumers, but programmatic costs (including administration and enforcement) will occur.
Effectiveness				
• **Reduction in climate vulnerability**	Reduces leaves and garbage that clog drains during heavy precipitation events, reduces the level of pollution in drained water.	Reduces the amount of waste in floodwaters, thereby reducing the prevalence of water-borne illnesses and blockages of drainage canals and other infrastructure.	Vegetation planted along streets and walkways can absorb water during heavy precipitation events, reducing runoff and other associated issues.	Reduce plastic bags that clog drains during heavy precipitation events.
• **Limitations of protection**	Does not 'fix' a drainage system, only lessens the impacts of flooding. Might not protect against more extreme impacts. A more thorough cleaning requires more resources.	Will continue to operate, but limited in ability to deal with increasingly severe climate change events.	More extreme events would likely overcome this measure. May not reduce runoff or heavy precipitation effects on a larger scale, e.g., metropolitan level.	Only as effective as the drainage system it is protecting. For rainfall events with return periods greater than that of the drainage system, overflowing will occur.

Table 2-1. Potential Adaptation Options for Extreme Precipitation and Storm Events/Water Quality and Availability/Populations and assets				
• **Susceptibility to Damage of the Protection System**	Minimal. However, if done through a volunteer program, a reduction in participation would significantly affect the success of the option.	Requires effective enforcement and maintenance of operations. If these requirements are not met for various reasons, the option will be significantly weakened.	Some plants may be weak at early ages of growth. Informal harvesting of trees or other vegetation would clearly also impact the effectiveness of the system.	No degradation is expected over time, as long as the ban/fee is enforced and consumption of plastic bags decreases.
Provide co-benefits	Reduces waste around drains reduces pollution of waterways and urban areas and may also reduce the incidence of diseases. May encourage residents and municipalities to maintain satisfactory sanitary conditions in their neighborhoods.	Reduces littering and potentially improved health effects if improper disposal and storage of solid waste is conducted. Also, this option can create valuable community-government partnerships that could be useful for future initiatives.	Reduces heat island effect, greenhouse gases, and cooling costs. Increases prevalence of green spaces. Provides habitats for local species.	Programs that include fees or taxes can raise revenue for other environmental projects. Can also reduce the disposal of bags in landfills, and animal deaths due to accidental ingestion.
Limited disadvantages	Limited disadvantages, unless there is improper handling of waste cleared from drains (e.g., waste from drain dumped in another vulnerable area or collected and placed on street/near drains causing further drain blockages).	Waste collectors would need to understand proper practices for collecting, handling, and disposing of waste in order to ensure that no other unintended issues (e.g., health and safety) arise.	New and foreign species or soil type can be invasive. Trees can die due to harsh conditions, roots may structurally impact roads or walkways, fallen branches and leaves may cover storm drains. Vegetation may need to be used in urban settings where growing areas are smaller.	Increased possibility of salmonella or viruses growing in unwashed alternative bags. Some degradable bag alternatives (e.g., paper) may have other disadvantages over plastic bags, because of the energy and natural resources that go into their manufacture.
Reversibility and Flexibility	Since it is more of an operations-based practice, this option is likely very flexible and reversible.	Can be adapted to account for issues that arise.	Vegetation can largely be resilient in a changing environment. Planting can also be done in relatively short timeframes (from months to years), so plans can be changed with some flexibility.	The ban can be reversed and the tax or fee removed or changed in magnitude. May be extended to include disposable plastic products, may be expanded from municipal to national level.
Guidance on when/where this option is most likely applicable	Widely applicable, although works best where ease of community/city coordination is high.	Harder to apply in areas with no existing solid waste management systems, but easier to expand if ones already exist.	Widely applicable if native plants are used in project location.	Requires enforcement, viable alternatives, and an effective public relations campaign to maximize effect.
Examples of implementation	• In addition to revamping its stormwater drainage network, the municipal government of Mumbai has started clearing clogged drains every year before monsoons. • City of Berkeley, CA, started an Adopt-a-Drain Program for volunteers to clean storm drains. There are a total of 6,000 drains in the city. Volunteers are asked to clean fallen leaves and other debris from the adopted storm drains and gutters. Public Works then picks up the bagged product after a call from the program member.	• Dar es Salaam, Tanzania developed an innovative solid waste management strategy at the scale of the community, in which residents of unplanned settlements make a nominal payment of 100 shillings (less than US$0.10) per collection. • In Accra, Ghana, establishing access for garbage collection vehicles to serve all settlements, businesses, and households with collection points was identified as a priority to reduce the impact of flooding.	• Durban, South Africa developed a climate change adaptation plan, which includes planting of vegetation to increase water-absorbing capacity of the urban landscape. • Wyong Shire Council of Australia has a section of their website on tree planting in urban areas for residents considering planting trees in their front years along streets. The section includes tables of appropriate trees to grow in certain locations, including approximate size, most conducive soil types, and additional comments resilience and lifetime for each type of tree.	• Ho Chi Minh City, Vietnam proposed a tax on plastic bags in 2012. The city aims to reduce plastic bags by 40% by 2015. • In March 2002, Bangladesh was the first country to impose a nationwide ban of plastic bags, after they were found to have been the main culprit during the 1988 and 1998 floods that submerged two-thirds of the country. However, nine years after that, plastic bags are still everywhere due to lack of enforcement and cost-effective alternatives.

2.2. EXTREME PRECIPITATION AND STORMS/TRANSPORTATION INFRASTRUCTURE/POPULATIONS AND ASSETS

Climate hazard	Increased frequency and intensity of extreme precipitation, with flooding and landslides; Increased intensity and frequency of hurricanes, storms, tropical cyclones; Interactions with the effects of SLR.
Impact	Disruption in services and damage to transportation infrastructure, including: roads, bridges, ports, airports, rail, and other transportation.
RSA at risk	Critical infrastructure and transportation services, as well as the populations that rely on transportation infrastructure for access to services and for evacuation.

Potential adaptation options

- Improved routine maintenance (and possibly making operational changes) for roads (3 examples)

Raising roads, building embankments, and improving drainage systems are not good candidates for fast-track implementation because they are fairly capital or resource intensive. Planning and developing new design standards for transportation and drainage systems are less resource intensive but can be technically demanding and time consuming, and therefore are also not suitable for fast-track implementation.

2.3. EXTREME PRECIPITATION AND STORMS/DAMAGE AND LOSS/ASSETS

Climate hazard	Increased frequency and intensity of extreme precipitation, with flooding and landslides; Increased intensity and frequency of hurricanes, storms, tropical cyclones; Interactions with the effects of SLR.
Impact	Damage and losses to physical structures & assets, including: houses, commercial buildings, public service facilities (schools, administration, hospitals).
RSA at risk	Dwellings, public facilities and utilities within informal settlements on marginal land and near cities, as well as cities.

Potential adaptation options

- Early Warning Systems (8 examples)
- Tire walls used instead of concrete to reduce erosion on hillsides around informal settlements (7 examples)

Figure 3. Tire walls under construction. (Source: Shore, 1999)[3]

[3] Shore, K. 1999. "Stopping Landslides in Rio: Recycling Scrap Tires into Retaining Walls." International Development Research Centre (IDRC). Accessed August 5, 2013. http://idl-bnc.idrc.ca/dspace/bitstream/10625/23631/1/113432.pdf

Table 2-2 and 2-3. Potential Adaptation Options for Extreme Precipitation and Storms/ Transportation Infrastructure/Populations and Assets/Damage and Loss/Assets			
	Improved routine maintenance (and possibly making operational changes) for roads	Early Warning Systems	Tire walls used instead of concrete to reduce erosion on hillsides around informal settlements
Straightforward	Depending on the type of option pursued, Operations & Maintenance (O&M) can be fairly straightforward. For example, repaving roads may be done by low-skilled engineers, while protective barriers (e.g., riprap, or rock pilings, along bridge foundations and piers) may be constructed by volunteers.	Technically straightforward. To properly work, the system needs cooperation among government, relief agencies, and communities. Requires clear communication of flood risks and a dialogue about mitigation options to the public.	Very feasible, but walls must be constructed safely and under supervision of an engineer (some engineering skill is required). One question is whether a citizen's manual has been --or could be--developed so that a supervising engineer is not needed.
Low cost	No required upfront costs. Ongoing costs for O&M depend on the scope and frequency of various measures, include labor and material costs.	Low. Considerable literature/ examples exist on design. Can become more expensive If improved research and forecasting or capacity building to enable citizens to make use of warning system is needed.	Low. Uses locally available materials (scrap tires and local soil for filling tires) for the most part, and local labor. Unclear whether much maintenance is required over time; walls appear to be durable.
Effectiveness			
• **Reduction in climate vulnerability**	More routine maintenance increases a road's ability to meet its design life in a changing climate.	These systems reduce climate vulnerability by allowing residents to prepare in advance of a flood and move property out of range or protect property (buildings, in particular).	Slopes that are predisposed to be unstable may result in a landslide during an extreme event. Tire walls may be effective at stopping landslides during the rainy seasons. Studies indicate that tire walls are sturdy and lasting, but follow-up evidence of their effectiveness after examples has not been found.
• **Limitations of protection**	Protection is only as strong as the original design and material strength of the transport segment. Landslides, floods, and other natural hazards remain as stressors, until the transport assets are removed from the exposed area. As a result, capital-intensive projects may still be required.	More rapid flooding might not allow time for evacuation.	Unclear whether technology has limits in terms of the magnitude of rains.
• **Susceptibility to Damage of the Protection System**	Not applicable.	No information about durability of towers, measurement gages, etc. Media broadcasts are durable.	Technology was new at the time of adoption, and so it is unknown how high the walls may be built, or how solid they will remain on a very swampy or compressible ground over the long term.
Provide co-benefits	May help increase the reliability of the transport network from a traffic and commerce perspective, reducing reduce road closings, traffic delays and associated economic costs.	Damages from flooding affect a number of assets/populations, therefore this approach benefits multiple aspects of damages, not only structures. Warning systems that are coupled with information provision (e.g., hazard maps) and planning can have other benefits – increased access to, and understanding of, information can help provide a defense against other stressors	Some emissions mitigation benefits as tires are not burned. Also benefits in terms of improving community pride and security and resulting in better built houses.
Limited disadvantages	Regarded as temporary measures, should not preclude the implementation of capital-intensive projects. Perpetual O&M activities may eventually exceed the costs of reconstruction or other capital-intensive projects.	Unlikely to cause unintended problems, since does not reduce flooding in one area or increase it in another. Mass evacuations could cause problems for nearby areas.	No apparent disadvantage.

Table 2-2 and 2-3. Potential Adaptation Options for Extreme Precipitation and Storms/ Transportation Infrastructure/Populations and Assets/Damage and Loss/Assets			
Reversibility and Flexibility	Can be stopped at any time.	As more information is developed about climate change--e.g., better forecasts, etc.--may need systems to disseminate more complex information (e.g., a tower with a siren may not provide that information, in contrast to a radio announcement). No major investment and so system is easily reversed.	Medium in terms of reversibility.
Guidance on when/where this option is most likely applicable	Applicable to high traffic corridors and areas vulnerable to climate change, particularly where rainfall is expected to increase. Would be most effective when combined with capital-intensive projects to ensure the integrity and resilience of the road and bridge system.	Applicable where geography permits advance warning in time and citizens can be engaged. Having effective evacuation and other reactive responses to the warning is crucial to its effectiveness. The warning system itself must be designed to incorporate good data, communication of warning, and effective response mechanisms.	Applicable in areas that face hillside erosion around a settlement during rainy seasons. Could be more effective if combined with measures to clean up gullies and drainage systems.
Examples of implementation	• The largest problems facing Mozambique's current road network appear to be overloading and missing maintenance and repair. Mozambique's Road Sector Strategy 2007-2011 indicates that standard maintenance will now be applied to preserve as much of the network in good and fair condition as possible. The basic strategy includes: prioritize maintenance and drainage upgrades in areas most at risk of flooding; increase the frequency of drainage maintenance in face of increased frequency of large storms; and repair and clean channel and drainage structures in high vulnerability areas before the rainy season.	• In Chitwan, Nepal, a siren-based early warning system was set up in 2001. Watchmen stay in towers and observe the level of water in the river during the monsoon period. If water levels approached an alarming height, the watchmen inform the local communities through sirens placed in the towers to warn of impeding floods. If water levels reach a dangerous level, another sound signal is given to alert people to leave their houses and to retreat to a safer place. • In Manila and Pasig City, Philippines, early warning systems alert residents to rising water levels in the river through siren, radio, and TV. Residents are directed to prepare and evacuate.	• In Rio de Janeiro, Brazil, tire walls were developed for a slum to mitigate the impact of landslides. They used a saw to slide off one side wall in each tire, then filled them with soil and tied them together with ropes. Tires were layered up to 6 meters tall. The walls appear to be constructed in 1999. It's unclear how the tire walls will hold up over time. • A research project was conducted in Selangor, Malaysia, to study the strength of tire walls. The trial site was a previously failed slope. Study showed that tire walls demonstrated excellent performance for repairing slope of up to 5 m high. The walls worked well despite having to use unsuitable tropical residual soil fill.

2.4. EXTREME PRECIPITATION/INCREASED EROSION AND FLOODING/POPULATION AND ASSETS

Climate hazard	Increased frequency and intensity of extreme precipitation.
Impact	Increased inland erosion and flooding.
RSA at risk	Population and infrastructure located on unstable land near and within cities.

Potential adaptation options

- Planting vegetation to reduce erosion
- Rock armor/Rip rap (rock or other material to armour shorelines)
- Constructing gabions (rock-filled wire baskets placed along a stream bank) to reduce erosion
- Forbidding development in areas highly prone to erosion

Soil replacement is not a good candidate for fast-track implementation as it is expensive and only provides temporary protection. Public education on soil protection is a longer-term measure that is more time consuming and resource-intensive. Drainage works requires significant expertise (e.g., in hydrology, structural and geotechnical engineering) and upfront capital investments.

Figure 4. Vegetation planted to combat erosion in Nacala, Mozambique. Source: Charlotte Mack, ICF International

Figure 5. Gabion installed to combat erosion in Nacala, Mozambique. Source: Charlotte Mack, ICF International

Table 2-4. Potential Adaptation Options for Extreme Precipitation/Increased Erosion and Flooding/Population and Assets				
	Planting vegetation	Rock armor/ Rip rap	Gabions	Forbidding development in areas highly prone to erosion
Straightforward-ness	The actual activity of planting trees is straightforward if funding, tools, and labor are available. Some degree of technical expertise is required to select the appropriate plant type. If done on a local level, planting and maintenance would require community-level stakeholder buy-in so that trees or other planted vegetation are not harvested or used for unintended purposes. However, larger projects may involve more complicated processes (political support, municipal coordination, etc.). Any project should incorporate and engage the local community and promote development objectives.	Fairly simple to design, construct, and maintain; however, some degree of engineering expertise is required.	Fairly simple to design, construct, and maintain; however, some degree of engineering expertise is required.	Regulation is simple to design but can be difficult to enforce.
Low cost	Cost of labor, tools, and seeds for planting. Will also need to consult with local horticulturalist or arborist to ensure that proper species are used. Additional resources may be required to build political or community support, though resources for actual activity is relatively low and straightforward. There are likely ongoing maintenance costs to facilitate growth of plants during the initial growing stages. Plants may require protection from flowing water during root establishment. After plants have established, maintenance costs are low.	Initial materials, equipment, and construction costs. Relatively higher upfront costs than vegetation planting. Low ongoing costs if left intact. Higher ongoing costs if people remove the rocks for other purposes.	Initial materials, equipment, and construction costs. Typically more expensive than rip rap. Low ongoing costs if left intact. Higher ongoing costs if people remove the rocks for other purposes.	Cost is high because this is a long-term measure that requires strengthening of institutional capacity and public awareness raising.
Effectiveness				
• **Reduction in climate vulnerability**	Vegetative cover holds the soil in place and reduces erosion. Dense and short vegetative covers like grass are often more effective for control of water erosion as they cover the soil surface and reduce the impact of rain. On the other hand, tall and sparse vegetation are more effective for control of wind erosion as they reduce the wind velocity.	Rock armour and rip rap are large stones placed along the slope of a streambank to absorb erosion forces.	Protects the slopes from stream erosion. Can reduce or eliminate the need for bank sloping (compared to riprap) by creating a vertical wall.	Reduces the chance of damage as fewer people and infrastructure is located in erosion-prone areas. Reduces development pressure and its impact on erosion.
• **Limitations of protection**	May not protect against extreme erosion or extreme flooding that causes severe erosion.	May not be sufficient to protect against extreme precipitation events and associated flooding.	Reduced protection if the rocks from the gabions are removed.	Needs to be combined with other measures (vegetation planting, hard armor) to be effective.
• **Susceptibility to Damage of the Protection System**	Some plants may be weak and can be damaged at early ages of growth. Informal harvesting of plants (e.g., for firewood) can impact the effectiveness of the system. However, if the roots are left intact after harvesting, the plants can still provide protection against erosion.	Minimal.	Minimal.	Minimal.
Provide co-benefits	Increases flood storage and infiltration capacity, decreases storm water runoff and heavy precipitation impacts, improves water quality. Reduces heat island effect, greenhouse gases, and cooling costs. Increases prevalence of green spaces.	No apparent co-benefit.	Provides a high degree of protection against storms.	Flood protection and environmental protection benefits.
Limited disadvantages	New and foreign species of plants may be introduced, which could negatively impact native species and ecosystems.	Cannot be used on streambanks with very steep slopes. Typically involves grading the streambank to a gentler slope.	Filling and construction of gabions can be labor intensive. Gabions require ongoing inspection and maintenance (more than riprap). Not aesthetically pleasing.	Can face opposition from local community and developers.

Table 2-4. Potential Adaptation Options for Extreme Precipitation/Increased Erosion and Flooding/Population and Assets				
Reversibility and Flexibility	Vegetation can largely be resilient in a changing environment. Planting can also be done in relatively short timeframes (from months to years), so plans can be changed with some flexibility. Vegetation can be removed if desired.	Can be reversed but not easily once rocks have been placed on streambanks.	Can be reversed but not easily once gabions have been placed on streambanks.	Can be amended or reversed.
Guidance on when/where this option is most likely applicable	A strong community and governmental buy-in is important in making sure that the activity is successful. There also needs to be a very good understanding of local habitats and what types of species can survive in relevant conditions.	Where streambanks are not very steep in slope, where rocks are not removed for unintended purposes.	Where streambanks are steep in slope, where rocks are not removed for unintended purposes.	Where the government has the capacity to enforce zoning regulations and where there are alternatives to developing in the erosion-prone areas.

3. AGRICULTURE

3.1. DROUGHT AND SEASONAL PRECIPITATION CHANGE/REDUCED YIELDS/FARMERS AND CONSUMERS

Climate hazard	Increased frequency and intensity of drought, and changing patterns of seasonal precipitation.
Impact	Failed crops and reduced yields from rain-fed agriculture. Crops are damaged directly due to water scarcity, and drought-induced soil degradation reduces land fertility.
RSA at risk	Subsistence and smallholder farmers that depend on seasonal rainfall to earn their livelihood. Food consumers that depend on rain-fed produce.

Potential adaptation options

- Provision of drought resistant crop varieties and diversified crop seeds through local seed markets via seed fairs and vouchers (4 examples) (also see Introduce symbiotic endophytes to increase drought tolerance under Water Resources)
- Small-scale well irrigation using treadle pumps (3 examples)
- Micro-catchment rainwater storage (3 examples) (also see Rainwater harvesting – dug out pond under Water Resources)
- No till / low till farming (3 examples) (also see Conservation Agriculture under Water Resources)
- Permanent organic cover (mulching, cover cropping) (3 examples)
- Distribution of seasonal climate forecasts directly to farmers and community training in the farm-level interpretation and use of such forecasts (3 examples)
- Drought index insurance (3 examples)
- SMS based climate and weather services (3 examples)
- Radio based agriculture and climate information (3 examples)

Table 3-1. Potential Adaptation Options for Drought and Seasonal Precipitation Change/Reduced Yields/Farmers and Consumers

	Provision of drought resistant crop variety	Small-scale well irrigation using treadle pumps	Micro-catchment rainwater storage (zai pit)	No till/low till farming	Permanent organic cover	Distribution of seasonal climate forecasts	Drought index insurance	SMS based climate and weather services	Radio based agriculture and climate information
Straightforward-ness	Simple to set up a distribution program.	Moderate technical knowledge required.	Technical knowledge required of field staff: Moderate; of farmers: Low.	Requires training and specialized equipment.	Farmers can easily be trained to implement this measure.	Training can use low-tech educational methods.	Requires a working insurance market.	Many farmers have mobile phones. Requires some capacity from the met services.	Many farmers have access to radio. Does not discriminate against illiterate farmers.

Table 3-1. Potential Adaptation Options for Drought and Seasonal Precipitation Change/Reduced Yields/Farmers and Consumers									
Low cost	High initial cost to set up a local seed production system, but distribution cost is low. Once seeds are produced and sold locally, the program can be self-sustaining.	Initial and maintenance costs of treadle pumps are low. Drip irrigation systems cost about $20; inexpensive ones can require replacement every two years.	Cost is mostly labor: need 100 person days per ha initially to dig pits, 20 person days per ha per year to maintain pits.	Basic equipment needed is inexpensive and simple enough to manufacture locally. Labor requirements are lower than conventional farming.	Primary cost is personnel to train farmers in the field, which is low. Manure or cover-crop seeds may need to be purchased but they are inexpensive.	Low initial training costs. Ongoing costs depend on existing agriculture extension services' capacity, will decrease as farmers get more familiar with the forecasts.	Relatively high initial cost; Pilot projects in Ethiopia and Kenya/Rwanda have start-up budgets of $1-1.5M for the first four to five years. It takes time for the program to become self-sustaining.	Initial set up costs depend on the scale of the service. O&M costs are relatively static and low.	Radio production is cheap compared to other mass media. O&M costs are relatively static and low.
Effectiveness									
Reduction in climate vulnerability	Mitigates the impacts of droughts, increases yield.	Mitigates the impacts of droughts, increases yield.	Mitigates the impacts of droughts, increases yield.	Mitigates the impacts of droughts, can double yield under normal conditions.	Reduces evaporation and runoff, increases yield and yield stability.	Enhances farmers' ability to make decisions to prepare for the weather.	Reduces the economic vulnerability of farmers due to drought.	Enhances farmers' ability to make decisions to prepare for the weather.	Enhances farmers' ability to make decisions to prepare for the weather.
Limitations of protection	Drought tolerant crops are still susceptible to droughts that are severe or prolonged.	Small scale systems can only tap into shallow ground water (7.5 meters or less), may not work during severe droughts when ground water drops below this.	Pits are far less effective without organic matter (crop residue, compost or manure) to absorb and hold moisture. Organic matter and manure may be scarce.	Works best in combination with other conservation agriculture practices such as mulching, cover cropping and crop rotation.	Yields will still drop during droughts. Small farm size may prevent effective rotation with cover crops.	Limitations stem from the level of information uptake and the salience of the forecast itself.	Little limitation. As long as there is a chance of returning droughts, index insurance schemes can reduce the economic vulnerability of farmers due to droughts.	Limitations stem from the level of information uptake among targeted farmers and the salience of the forecast itself.	Limitations stem from the extent to which farmers actually listen to the radio programs and to which the information is understood and integrated in their farming practices.
Susceptibility to Damage of the Protection System	Because this is primarily a distribution system, its susceptibility is minimal.	Minimal for treadle pumps. Drip irrigation systems are susceptible to theft and damage by rodents.	Small pits are easily filled with soil and sediment during torrential rains. High rainfall can cause flooding of holes and growth of weeds.	Effort needs to be made to make programs self-sufficient so they do not collapse if government or external support is withdrawn.	Grazing livestock often eat crop residue and cover crops. Farmers may also be used to burning crop residues instead of mulching them. Pests can live in the mulch and destroy crops.	Effectiveness depends on robust mechanisms for forecast dissemination (bulletins, mass media etc.) and follow-up (climate informed extension advisory).	Insurance companies can go bankrupt which leave farmers with unpaid claims and distrust in the system. The model may need to adjust to reflect long-term changes in climate.	Individual phones can break but they are easily replaceable. Sustained power failure can affect mobile phone charging. Phone service may be disrupted.	Radio sets are usually sturdy, and easily replaceable. Since radio sets usually run on batteries, the option is not constrained by unstable power grids or rural access to electricity.

Table 3-1. Potential Adaptation Options for Drought and Seasonal Precipitation Change/Reduced Yields/Farmers and Consumers									
Provide co-benefits	Can help develop the local seed market. Can benefit women's rights by increasing their income since women traditionally sell seeds.	Locally made and distributed pumps contribute to the economy.	Increased yields, soil rehabilitation, reduced need for chemical fertilizer, decreased downstream flooding and siltation, increased groundwater recharge.	Reduces the required labor and mineral fertilizer input. Rehabilitates degraded soil and reduces erosion. New equipment manufacture & maintenances benefits local artisans.	Improves soil nutrition and moisture, reduces the need for mineral fertilizer. Helps reduce weed intensity and therefore the labor required to weed or herbicide use.	Prepares farmers for the full distribution of climate variability, not just drought.	Can give farmers basic financial literacy training; Can allow farmers to apply for and receive bank loans and other types of credit that was previously unavailable to them.	SMS met services are often combined with market information, agro-advisory and other knowledge inputs that are valuable for making strategic farm-level decisions.	Encourages inter-communal discussion and knowledge-sharing, promoting regional cooperation. Many shows give farmers a voice, bolstering their confidence.
Limited disadvantages	National seed interventions, which distribute free seed directly to farmers, can undermine local seed producers and sellers.	Widespread and poorly managed irrigation can deplete groundwater.	Water logging of pits during high rainfall. Labor-intensive intervention but labor is required during dry season when farmers have spare time. Can increase land use conflict between farmers and pastoralists	Tilling destroys weeds; reduced tillage can result in more initial weeds and therefore require additional labor for weeding or herbicide use.	Conflict with grazing animals, which typically eat crop residues. Potential for increased pest damage	Information on the total seasonal rainfall amount is only of limited value to the farmers; may require additional investment to forecast the likelihood of water deficits and the onset of the rainy/dry season.	Index insurance schemes will almost always have some level of basis risk (the disconnect between payouts and losses) for hazards that are not insured and for losses that impact only a few people.	May further marginalize illiterate farmers and the very poorest who cannot afford a mobile phone. May need additional investment in outreach to encourage information uptake.	Access to batteries may be an issue; the cheap ones are of poor quality and last only a short time.
Reversibility and Flexibility	Depends on the level of intervention. National level interventions can reduce local resilience and the variety of crops available.	During wet conditions irrigation is redundant and farmers can simply not use the pumps.	Can be reversed. Pits quickly erode and fill in if unmaintained.	Switching to no-tillage is beneficial under many conditions. Farmers can easily drop the practice.	Improves soil moisture and nutrition under drought and normal conditions. Farmers can easily drop the practice.	Information dissemination models do not constrain the use of updated and improved forecast technology; easily reversed.	If farmers can pay for insurance contracts on a per-season basis, they can easily upgrade or discontinue.	Technological development continuously improves mobile applications and services; easily reversible.	Very flexible as local broadcasters control the information; easily reversible.

Table 3-1. Potential Adaptation Options for Drought and Seasonal Precipitation Change/Reduced Yields/Farmers and Consumers									
Guidance on when/where this option is most likely applicable	Areas experiencing prolonged drought where the opportunity cost of not using higher yield crops is low. Seed vouchers and fairs work where seeds may be available but not accessible to farmers due to costs. Local interventions minimize market distortion. Insurance is a good co-intervention.	Most appropriate for farmers with a small plot of land (1/3 ha) in locations with intermittent drought where irrigation can supplement rainfall, and where shallow renewable ground water is available. Areas where groundwater supply is already under pressure would not be suitable.	Areas that are experiencing chronic drought or salvaging or rehabilitating wasteland. Also effective in high rainfall, high slope areas where soil infiltration is reduced by slope. Training is easiest in areas with established farmer field schools or strong agriculture extension services.	Requires long periods of instruction and should be implemented where strong agriculture extension services are available. Most effective when combined with a permanent organic cover.	Requires long periods of instruction and should be implemented where strong agriculture extension services are available. Most effective when combined with no-till/low-till farming or micro-catchments.	Lead-times for forecast delivery must be in synch with local farmers' needs. The climate forecast models that are used must be validated and show regional robustness and accuracy, as well as on a down-scaled level indicating local variations.	Successful when part of a holistic solution to mitigate weather-related vulnerabilities. Need partnerships between government, farmers, and insurance companies. Need reliable long-term climate data (10-20 years of historical rainfall or yield data) as the basis for insurance indices.	Success is more likely if combined with good extension follow-up (helping farmers translate SMS information into decisions) and arrangements that enable the appropriate response (e.g., access to drought resistant seeds). Areas need access to electricity and mobile networks.	When tailored well to local farmers' information demand, radio can address the production nuances within a region or community (e.g., the 10% of farmers in a community that produces crop Y when the rest produce crop X). Farmers' actively participating in the shows makes local tailoring easier.
Examples of implementation	In Ethiopia, local committees were formed to procure and distribute emergency seed aid to farmers in need.	IDE introduced treadle pumps to farmers in Kenya, Ethiopia, Niger, encouraged retailers to work directly with farmers.	In Burkina Faso, the World Bank provided guidance to farmers to take up the zai pit techniques.	In Uganda, conservation agriculture practices are promoted and taught through the Farmer Field Schools.	In Tanzania, vegetable growers as well as coffee and banana growers commonly mulch their fields.	In Senegal, a project was implemented to communicate downscaled seasonal forecast to farmers.	In Ethiopia, a village-level drought index insurance product was designed and packaged with other activities like microloans)	In India, Agro-met SMS is a district-level agro-met service, provides 5-day weather forecast to farmers.	Farm Radio Malawi encourages farmers to make informed decisions on specific agriculture practices or technologies.

Figure 6. Zai pits on a farm, Burkina Faso (Source: Water Spouts Blog).

Figure 7. A SMS based weather service customer in Andhra Pradesh, India (Source: Krishnendu Halder/Reuters).

Figure 8. Half Moons for Water Harvesting in Illela, Niger (Source: FAO).

Figure 9. Community SMS Knowledge Worker in Uganda (Source: Grameen Foundation).

3.2. WARMER TEMPERATURES AND CHANGING PRECIPITATION/PEST OUTBREAKS/FARMERS AND CONSUMERS

Climate hazard	Higher temperatures and changing patterns of seasonal precipitation.
Impact	Increase and spread of climate-sensitive pests and disease-carrying insects into agricultural zones. More frequent and severe outbreaks damage crops and may kill or lower the value of livestock. Food security may be severely threatened in affected regions.
RSA at risk	Subsistence and smallholder farmers (especially those without access to pesticides). Markets and food consumers in affected countries.

Potential adaptation options

- Farmer monitoring and reporting (3 examples)
- Rat traps to replace, supplement or pre-empt pesticide use (2 examples)
- Crop rotation (3 examples)
- Mobile phone alerts and advisory (3 examples)

Table 3-2. Potential Adaptation Options for Warmer Temperatures and Changing Precipitation/Pest Outbreaks/Farmers and Consumers

	Farmer monitoring and reporting	Rat traps to replace, supplement or pre-empt pesticide use	Crop rotation	Mobile phone alerts and advisory
Straightforward	Technically and institutionally straightforward. Farmers monitor their fields for pest damage or the presence of pests in traps. They report to agricultural extension workers who then report to the national agricultural research institutions.	Rat trapping is a simple and low-tech measure. Farmers are already familiar with the principles of trapping.	Crop rotation simply involves changing the type of plant grown in a plot from season to season. Some design or experimentation is required to ensure crops planted do not support the same species of pests and do not otherwise negatively impact each other.	Many farmers have mobile phones. Many pests have a predictable life cycle based on the temperature and humidity of their environment. Information dissemination requires cooperation with telecom operators and coordination among information providers.
Low cost	Cost of a training program is low if agriculture extension services and research institutions already exist. Long term costs are primarily agriculture extension worker salaries paid for by national or municipal governments.	Traps are low-cost. They may be less expensive than pesticides and are reusable. Local manufacture and sale of traps would lower costs.	Training on proper crop rotation takes time and may require an effective agricultural extension or farmer field school. If farmers are already practicing crop rotation, training cost is low. If new crops are introduced, there will be additional costs for seed distribution.	Relatively high initial set up costs to establish the necessary infrastructure and communication channel, which vary with the scale of the service. Costs per farmer reached are higher for call centers/help lines than SMS services. May also require investments in pest monitoring. Ongoing costs involve maintenance and content generation.
Effectiveness				
Reduction in climate vulnerability	When monitoring and reporting is combined with advice, farmers' ability to identify and control pests increases, resulting in increase in yield and income.	Reduce food loss, reduce diseases spread by rats.	Reduce pests by interrupting their life cycle. Damage from one pest type attracts other pests, and preventing damage from the initial pest reduces this attraction.	By receiving locally tailored information about pest outbreaks and management tips, farmers are enabled to apply vulnerability mitigation techniques and use pesticides more effectively.

Table 3-2. Potential Adaptation Options for Warmer Temperatures and Changing Precipitation/Pest Outbreaks/Farmers and Consumers				
Limitations of protection	Pest monitoring of farmers' fields only identifies new pest threats after they are present in a country or region.	Trapping will not eliminate rat populations. Additional actions such as securely storing food and reducing rubbish available to rats will further reduce rat populations.	Crop rotation requires a long interval between crops to effectively reduce pest populations. Some pests are not specific to crop species.	Information take-up (to what extent the individual farmer incorporates the advice in his/ her farming practice) might be a limiting factor.
Susceptibility to Damage of the Protection System	No apparent susceptibility.	Traps have a limited life, and rats can become sensitive (resistant) to traps.	No apparent susceptibility.	Phones can break but are easily replaceable. Sustained power failure will affect phone charging. Phone service may be disrupted.
Provide co-benefits	Can decrease unnecessary pesticide use, reducing environmental impacts. Monitoring requires farmers to visit their fields and observe them more carefully; this scrutiny can aid farmers in making better decisions in other areas (e.g., water management).	Decreased health vulnerabilities posed by rats. Traps reduce the use of expensive and dangerous pesticides. Rats provide a source of protein in some areas.	Legumes and deep rooted crops can improve nutrition of the soil. Crop rotation helps control weeds. Crops grown in the off-season can be used as animal fodder.	Can be combined with dissemination of weather, agricultural, and market information that are valuable for making farm-level decisions to manage climate variability. Reduce use of pesticides.
Limited disadvantages	Farmers will need to be continuously encouraged to monitor for pests or they may lose interest.	Traps are labor intensive since they need to be reset daily. Traps can be expensive for very poor farmers to buy.	Farmers rotate their crops based on their agricultural needs and to control pests and improve soil. These goals can conflict with each other and reduce the effectiveness of rotation on pest control.	A phone-based system may further marginalize illiterate farmers and the very poorest who cannot afford a mobile phone.
Reversibility and Flexibility	Monitoring decreases the uncertainty of emerging or changing pests; easily reversible	Traps are completely reversible, and are important even if rat populations do not increase.	Reduces the pest burden under any climatic conditions, although the order and type of crops may need to be changed and these changes tested to match local conditions; easily reversible	Many mobile phone based agro-services projects require high up-front investments to build the necessary infrastructure and environment; can be reversed but less likely due to upfront costs.
Guidance on when/where this option is most likely applicable	Where relatively strong agriculture extension services are already available.	Appropriate where farmers are storing food on or near farms, where food storage is inadequate but difficult to improve, and where pesticide use is a significant hazard.	For farmers to include pest management as a goal for crop rotation will probably require support from agriculture extension workers. Many competing demands determine which crops farmers plant, such as markets, soil nutrition, and personal preference.	Success depends on the local weather and pest monitoring capacity and the quality of forecasts and analyses delivered by national met services. Value increases when delivered with other agricultural information and advisory (e.g., seasonal climate forecasts, market information, crop management and efficiency tips).

Table 3-2. Potential Adaptation Options for Warmer Temperatures and Changing Precipitation/Pest Outbreaks/Farmers and Consumers				
Examples of implementation	• In Thailand, the project 'Strengthening Farmers' Integrated Pest Management (IPM) in Pesticide Intensive Areas' trained farmers to do an agro-ecosystem analysis by drawing on a large piece of paper all of their observations and manually collecting insects in plastic bags. By monitoring, farmers are better able to identify and control pests in their fields and reduce pesticide use.	• In Mozambique, villagers were provided with traps and encouraged to trap rats intensively as part of an assessment of the impact rats were having on villagers. Farmers who had been using a simple locally made trap were given more sensitive factory-made traps. • In South Africa, FAO distributed commercially made break-back traps to four villages.	• In the project 'Strengthening Farmers' IPM in Pesticide Intensive Areas' in Thailand, farmers were taught crop rotation by local agricultural extension workers. • DFID and the Natural Resources Institute from the UK implemented a project to identify and test technologies for the control of insect pests that attack sorghum using IPM in Kenya. Crop rotation was identified as an appropriate pest control technology.	• In Kenya, M-Kilimo Farmers' Helpline is a call center operating 6am - 11pm on a daily basis since 2009. In-house agricultural experts address topics such as land preparation, planting, pest management, harvesting, post-harvest, and marketing of agriculture produce. In the event that an agricultural expert is unable to respond at once, the helpline agent contacts the second-line consultants and responds to the farmer within 24 hours.

3.3. HIGHER TEMPERATURES/CROP AND LIVESTOCK DAMAGE/FARMERS

Climate hazard	Higher global average temperatures will result in greater frequency and magnitude of heat waves.
Impact	Persistent high temperatures or short periods of very high temperatures directly damage crops reducing yields or causing crop failures, and injuring or killing livestock.
RSA at risk	Subsistence and smallholder farmers.

Potential adaptation options

- Low cost drip irrigation (3 examples)
- Crop shading (4 examples)
- Identifying, promoting, and providing heat resistant crop varieties and seeds genetically improved to withstand heat stress (3 examples)

Table 3-3. Potential Adaptation Options for Higher Temperatures/Crop and Livestock Damage/Farmers

	Low cost drip irrigation	Crop shading	Identifying, promoting and providing heat resistant crop varieties and seeds genetically improved to withstand heat stress
Straightforward-ness	Simplified drip irrigation systems consist of a reservoir, mesh filter, valve, and plastic tubing; reservoirs can be durable plastic bags, buckets, or drums. Simplified systems are best for vegetable garden plots due to their small size. Some training on proper set up and maintenance is required.	Shade net shelters can be built simply from wooden supports. The netting is available in a wide variety of intensities worldwide. Requires some technical knowledge to determine the optimal intensity of netting for the local climate and crop.	Not technically straightforward, requires an active national or international agriculture research. However, once the crop varieties are developed, distribution to farmers can be simple and low-cost.
Low cost	Low cost systems sold by International Development Enterprises range from $20 for a 20 square meter plot to $42 for a 100 square meter plot. Systems have a lifetime from five to ten years.	Shade structures and netting are inexpensive. A 200 meter square shelter was built from galvanized pipe in India for less than $1000. The cloth used to cover roofs will need to be replaced after several years.	Research is expensive but distribution is relatively low-cost.
Effectiveness			
Reduction in climate vulnerability	With sufficient water, vegetable plants can dissipate heat in temperatures up to the mid-90's degrees Fahrenheit. Drip irrigation minimizes surface runoff and deep percolation losses.	Shade cloth of moderate intensity (15-30% depending on the climate) increases yield compared to plants grown in full sun by up to 25%.	Increases the heat tolerance of crops; essential to counteracting a future where climate change may lead to as much as a 40% reduction in crop yield in tropical and subtropical areas by the end of the century.
Limitations of protection	In air temperatures in the high 90's and 100's, or hot windy weather, water loss is too rapid, and plants cannot absorb water through their roots fast enough to cool.	Only applicable to some crops (e.g., vegetables).	Heat-tolerant crops (depending on the variety) will all have a temperature threshold for when adverse impacts on the plant become unavoidable. Current research typically focuses on developing resilience in the temperature span from 35 to 45°C.
Susceptibility to Damage of the Protection System	Can be damaged by storms. Plastic bag reservoir is less durable than a hard sided reservoir. Drop kits and spare parts to repair are not always available in the local market.	Can be damaged by storms. Low net structures can be trampled by livestock, while structures supported by pipes are higher and when supported by wires can protect against hail damage.	No apparent susceptibility.

Table 3-3. Potential Adaptation Options for Higher Temperatures/Crop and Livestock Damage/Farmers			
Provide co-benefits	Increased yields compared to purely rainfed agriculture. Enables vegetable gardening which improves nutrition and can provide additional income (cash-crops). Reduced labor requirements compared to hand- watering. Reduced water use over conventional irrigation systems.	Net structures can be built to provide protection from birds, insects and hail. Even when not designed for this, structures provide some protection. Higher value vegetable crops can be grown under shade net which can increase nutrition and income.	Under a business-as-usual scenario (using conventional crops), farmers would over-exploit water and use excessive fertilization to maintain or increase productivity. This option will mitigate such impacts. Research initiatives also further consolidate and extend the networks for genetic crop variety breeding and add to the knowledge on genetics and physiology of abiotic plant stress, which is important to building climate resilience in agricultural production.
Limited disadvantages	No apparent disadvantage.	Cloth needs to be of the correct intensity to increase yields. Nettings are often combined with more complicated techniques such as hydroponics or used to start hybrid seedlings. Establishment of a shade net nursery by every farmer on a small piece of land is not practical or economically viable. Building them cooperatively could be good for local cohesions, but could also be politically more difficult.	Research of this type is a long-term, future-oriented adaptation effort with limited immediate impact on poor smallholder farmers.
Reversibility and Flexibility	Irrigation improves crop yields and enables vegetable gardening when temperatures are moderate. Irrigation also allows farmers to grow crops during the dry season, increasing the number of harvests each year. Easily reversible.	Shade shelters create a controlled environment which can be used to grow vegetables under a variety of conditions. A simple shade shelter can be set up and taken down as necessary.	Does not involve any infrastructure or institutional construction that might be difficult to reverse. Continued research will strive to deliver new and improved climate-resilient crop varieties, ensuring flexibility in the face of climate uncertainty.
Guidance on when/where this option is most likely applicable	Most useful in arid climates where dry soil limits the ability for plants to cool via transpiration. Also suitable for enabling farmers to grow higher value garden vegetables. Training and maintenance support needs to be available as well as a potential market for produce.	Shade cloth is inexpensive and available worldwide. Simple shelters can be built quickly almost anywhere. More sophisticated structures require additional training and should be implemented in areas with sufficient agriculture extension support.	Areas which already have high temperatures and are projected to experience temperature increases. Option typically requires active national or international agriculture research centers and agriculture extension services to produce seeds and distribute them to farmers.
Examples of implementation	• The Burkina Faso government distributed 6 million Euro ($7.6 million) in aid to farmers to fund irrigation projects focusing on smallholder farmers. Irrigation systems supplied varied in size and complexity, and were used to grow garden vegetables (e.g., tomatoes and onions) and fruit trees (e.g., bananas and mangos). • International Development Enterprises introduced low cost drip irrigation systems in Nepal. Within four years, 2250 farmers adopted the system. Conventional drip irrigation systems are designed for larger plots of land (greater than 4 ha) and cost from $1500-2500 per ha. The simple drip irrigation systems are designed for a fraction of the area of conventional systems, 0.01 ha or less, and have significantly lower costs ($20 for 20 square meters).	• In Guyana, The National Agriculture Research Institute offered assistance to farmers to support demonstration Hydroponic Shade Houses (HSH). The HSH are greenhouse-like structures covered with shade netting to reduce temperature and solar radiation received by plants instead of increasing it as with a greenhouse. The farmers also use inexpensive hydroponics to water and fertilize the plants. HSHs are used to grow cash crop vegetables. • An experiment in South Africa shows that tomato plants grown in shaded conditions produced more fruit than those grown in full sun.	• The 'Building Resilient Food Security Systems to Benefit the Southern Egypt Region' project includes introduction of heat tolerant varieties of common crops such as sorghum, wheat and tomato. This project component was budgeted at US$ 1,744,835 over 4 years. • Funded by USAID under the 'Feed the Future' initiative, the Heat Tolerant Maize for Asia (HTMA) aims to develop and deploy heat stress resilient, high yielding maize hybrids with potential impact on the maize-dependent and climate change vulnerable regions in South Asia. • The International Rice Research Institute's breeding program for heat-tolerant rice is developing varieties that will still flower normally and retain the ability to set seed even at higher temperatures, as well as varieties that flower earlier in the day so that the heat-sensitive reproductive processes occur before the critical temperature thresholds are breached.

Figure 10. A shade net structure to shelter vegetable seedlings in India. (Source: Sundaram, n.d.)[4]

Figure 11. A drip irrigation system designed by International Development Enterprises. (IDE) (Source: IDE, 2013)[5]

[4] Sundaram, V. (n.d.). Establishment of Shade Net Nursery for Production of Hybrid Vegetable Seedlings. Karaikal, India. Retrieved from http://dste.puducherry.gov.in/sundarraman.pdf
[5] Product List iDEal Global Supply. (2013). Denver, CO: iDE. Retrieved from http://www.ideorg.org/OurTechnologies/GlobalSupply.aspx

4. HEALTH

4.1. HIGHER TEMPERATURES AND SEASONAL PRECIPITATION CHANGES/VECTOR-BORNE DISEASES/EXPOSED POPULATIONS

Climate hazard	Higher temperatures and changing patterns of seasonal precipitation.
Impact	Shifts in the spatial distribution, seasonal activity, and intensity of transmission of vector-borne diseases, specifically malaria.
RSA at risk	Populations living in areas where climate conditions are suitable for malaria transmission. Particularly at risk are the populations living on the margins of current areas with high incidence of malaria epidemics.

Potential adaptation options

- Long-lasting insecticide-treated mosquito nets (5 examples)
- Indoor residual insecticide spraying (4 examples)
- Intermittent preventive treatment for pregnant women with sulfadoxine pyrimethamine (4 examples)
- Improved diagnosis using rapid diagnostic tests (7 examples)
- Effective treatment of cases with artemisinin-based combination therapies (3 examples)
- Behavior change communication campaigns (6 examples)
- Surveillance systems - Malaria Early Warning Systems (3) and Malaria Early Detection Systems (2 examples)

Table 4-1. Potential Adaptation Options for Higher Temperatures and Seasonal Precipitation Changes/Vector-Borne Diseases/Exposed Populations

	Long-lasting insecticide-treated mosquito nets	Indoor residual insecticide spraying (IRS)	Intermittent preventive treatment for pregnant women with sulfadoxine pyrimethamine (SP)	Rapid diagnostic tests (RDTs)	Artemisinin-based combination therapies (ACTs)	Behavior change communication campaigns	Surveillance systems Early Warning Systems (EWS) and Early Detection Systems (EDS)
Straightforward-ness	Low-tech, of simple design, and already manufactured in vast quantities.	A proven, low-tech, and easy method to control vector population, but must be delivered at high coverage (80% or more).	The process is straightforward; suitable for rapid scale up through antenatal care clinics once public health officials are trained.	Low-tech, easy and quick to implement. The option only diagnoses malaria so needs to be complemented with treatment.	A proven technique that is relatively easy and quick to scale up, recommended as first-line treatment of malaria.	Less straightforward to implement and scale up compared to other options presented here. Far-reaching campaigns can take 2-5 years.	EWS using seasonal climate forecasts is less straightforward due to the technical and financial resources required. EDS is more straightforward.

Table 4-1. Potential Adaptation Options for Higher Temperatures and Seasonal Precipitation Changes/Vector-Borne Diseases/Exposed Populations							
Low cost	Low cost, $5/net. Designed to be effective without re-treatment for the life of the net (about 3 years). Also training and educational costs.	Low cost but variable, depending on insecticide used. Estimated cost to spray a structure is $10-$40. Often need to spray twice a year.	Very low cost since SP is a cheap drug. Highly cost-effective to prevent maternal malaria.	Low cost. The price of RDTs range from $0.30-0.66 per test; the most expensive ones cost up to $2.00. Also training and educational costs.	Low to medium cost. One of the most expensive among the options here, but highly cost-effective. Mean cost/ patient for the most effective ACT is $4.46.	Variable depending on the scope and duration of the campaign. A far-reaching one lasting for 5 years would cost about $30 million to implement.	There is a lack of information on costs. Likely expensive due to the need to set up and operate the system. However, costs associated with data transmission from mobile phones are low.
Effectiveness							
Reduction in climate vulnerability	According to the Presidential Malaria Initiative, this has been shown to reduce malarial illnesses among children under five and pregnant women by up to 50%.	Reduced probability of malaria transmission where IRS coverage is high (at least 80% or more of the houses in the targeted area are sprayed).	All the examples found show considerable reductions in the prevalence of maternal malaria after implementation of this measure.	Improved the accuracy of diagnosing malaria.	Considerably effective in preventing malaria complications.	Increases knowledge and awareness about malaria prevention and treatment.	Seasonal climate forecasts have been successful in predicting malaria risk in epidemic regions with up to five months of lead time. EDS also helps identify outbreak earlier.
Limitations of protection	Provides protection regardless of changing climate vulnerabilities.	Not specified.	Not specified.	The RDTs can suffer damage to its components when exposed to high temperatures.	Not specified.	Few limitations since communication and awareness campaigns do not depend on changing climate vulnerabilities.	A surveillance system is a protection against unexpected climate impacts, thus provides benefits across all climate impact ranges.
Susceptibility to Damage of the Protection System	Can maintain their full protective effect through at least 20 washes (three years). However, nets can have holes,which reduce their effectiveness.	In regions with long or multiple malaria seasons, multiple spray rounds may be needed. Additionally, mosquitoes can become resistant to the insecticide.	There has been evidence of increasing resistance of the parasite to SP in several African regions.	Need a cooler box to reduce exposure to high temperatures and humidity.	Some patients develop further complications, in which case ACT treatment is not enough. Malaria parasites can develop resistance to artemisinin drugs if these are used as mono-therapy.	This measure without integration of malaria prevention and control interventions will not be robust and durable in reducing malaria.	Should be robust and durable since it relies on SMS from mobiles phones, which is increasingly available throughout Africa. Susceptibility resides in the cooperation and diligence of volunteer practitioners providing the daily relevant data.
Provide co-benefits	Helps reduce anemia among children, an important complication of malarial infection.	Many IRS campaigns also involve the establishment of entomology labs and insectories, which builds local capacity.	Reduces the probability of neonatal mortality and the odds of low birth weight; is also closely related to a decrease in anemia, parasitemia, the number of abortions,	Serves as a screening tool to reduce the number of incorrect malaria diagnoses, which decreases unnecessary ACT treatment and reduces parasite resistance to drugs.	Generally complemented with public education and training of health workers, which increases public awareness and builds capacity of the health workforce.	Can lead to greater levels of awareness and education regarding public health issues other than malaria.	May enhance collaboration among health ministry services and healthcare practitioners. Seasonal climate forecasts can be useful to other

Table 4-1. Potential Adaptation Options for Higher Temperatures and Seasonal Precipitation Changes/Vector-Borne Diseases/Exposed Populations							
			and stillbirths.				resource managers in health, hydrology, and agriculture sectors.
Limited disadvantages	None identified.	DDT is a persistent organic pollutant; stringent measures need to be taken to avoid its misuse and leakage outside public health.	Increasing resistance of malaria parasite to SP. There's a need to improve the quality of antenatal clinic services.	Necessity of training health workers into use of RDTs.	An RDT intervention should be done before implementing any ACT intervention.	Generally implemented to help other malaria control and prevention interventions to be successful.	Can potentially take away time from the health worker's schedule to report the data via SMS.
Reversibility and Flexibility	Easily reversible and flexible.	Can be easily discontinued.	Can be easily discontinued.	Can be easily discontinued.	Flexible since there are at least 5 different ACT treatments today.	Reversible and flexible, but implementing new campaigns will result in additional costs.	Highly flexible and reversible since it relies on SMS of mobile phones.
Guidance on when/where this option is most likely applicable	Should be complemented with aggressive mass media campaigns regarding proper and consistent use of the nets.	Not suitable in areas with limited structures, such as forested areas of southeast Asia and the Amazon region. Intervention should take place before the onset of the transmission season.	Not recommended for use outside of Africa. Needs to be complemented with distribution of insecticide-treated nets. Monitoring and evaluation is needed for new drugs used for the treatment.	Cost-effective where high quality microscopy is not readily available and in areas that lack health facilities. Needs to be complemented with ACTs.	Should follow RDT interventions. Should include training, education, and monitoring and evaluation of drug efficacy.	Usually needed before, during and after any malaria control, prevention, and case management intervention.	EWS should be used at the beginning of the rainy season, at least 5 months before the peak malaria season. Needs to be combined with control and prevention interventions.
Examples of implementation	• The Global Fund To Fight AIDS, Tuberculosis, and Malaria is the major international funder providing insecticide-treated mosquito nets (ITNs) to malaria endemic countries	• The Presidential Malaria Initiative in Uganda has an ongoing project consisting of IRS campaigns of two cycles a year in the northern districts of Uganda.	• In a project in Mozambique, pregnant women visiting the antenatal clinic services of a district hospital were given SP, alongside a long-lasting insecticide-treated mosquito net.	• In a project in the forest and hilly areas of Cambodia, RDTs were distributed to a target population of 1.6 million through the public health sector, private sector, and volunteer malaria workers.	• A project involves improving ACT treatment, through ensuring prompt and effective treatment of uncomplicated and severe malaria, in 51 districts of Zimbabwe.	• A project focusing on behavior change communication in Cameroon includes mass media broadcasts and training of mass media practitioners and civil society organizations.	• Seasonal climate forecasts were used to predict probabilities of anomalously high and low malaria incidence in Botswana. An Early Detection System via SMS was successfully implemented in Madagascar.

4.2. HEAT WAVES AND AIR QUALITY/MORBIDITY AND MORTALITY/VULNERABLE POPULATIONS

Climate hazard	Increased positive temperature anomalies, increase of frequency and intensity of heat waves. Enhanced ground-level ozone and changing patterns of atmospheric circulation.
Impact	Increased short-term mortality and indirect morbidity from heat-related causes and their negative consequences on air quality, particularly from heat strokes, bacterial respiratory issues and cardiovascular diseases.
RSA at risk	Susceptible and vulnerable populations in high-density urban areas, such as urban poor, elderly, and children, and people with underlying respiratory and cardiovascular health issues.

Potential adaptation options

- Extensive green roofs (6 examples)
- Painted white roofs (3 examples)
- Urban green spaces (4 examples)
- Cool pavements (2 examples)
- Phased alert systems and weather information dissemination (3 examples)
- Cool shelters (2 examples)
- Education, awareness, and communication (4 examples)

Table 4-2. Potential Adaptation Options for Heat Waves and Air Quality/Morbidity and Mortality/Vulnerable Populations

	Extensive green roofs	Painted white roofs	Urban green spaces	Cool pavements	Phased alert systems and weather information dissemination	Cool shelters	Education, awareness, and communication
Straightforward-ness	Relatively low-tech compared to Intensive Green Roofs, which can support a variety of plants but are thicker and require more maintenance.	Simple and has been used as insulation technique historically (e.g., Greece, India). Only requires about 3 days for painting and drying.	Can be low-tech and informal, but larger projects may be less straightforward and hampered by spatial and regulatory constraints.	Technologies exist and are relatively straightforward, but some technical capacity is required to install the cool pavements.	Straightforward given that regional and local meteorological stations are widely available and reliable to some extent.	Simple to set up. Need community outreach to make people aware of the shelters and overcome any perception bias (e.g., only poor people go to shelters).	Relatively straightforward such as through distribution of pamphlets and training.
Low cost	Labor and material costs are $9-$15/ square foot, which is still more expensive than traditional roof materials. Maintenance costs are $0.20-.30/square foot/year.	About $0.50/square foot to paint roofs white with elastomeric acrylic paint. White roofs need to be cleaned and repainted more frequently than other membranes.	Costs vary greatly depending on the type of vegetation, location, area covered, and other factors. Maintenance is required (e.g., watering, weed control, pest management).	Installing costs vary greatly from $0.10-$4.50/ square foot. There are additional maintenance costs. Cool pavements may need to be replaced more frequently than traditional pavements.	Relatively expensive to set up (e.g., $210,000 in Philadelphia), but benefits outweigh the costs. Institutional capacity is needed to monitor and adjust the system over time.	Using existing buildings and recreational centers will require low costs. Costs of installation of electrical devices can be low as well. There are additional maintenance costs.	Costs include training of local staff, printing of brochures and pamphlets, and broadcast of radio and TV commercials. There are additional operating, monitoring, and evaluation costs.

Table 4-2. Potential Adaptation Options for Heat Waves and Air Quality/Morbidity and Mortality/Vulnerable Populations							
Effectiveness							
Reduction in climate vulnerability	Reduces the urban heat island effect as plants provide shade, removes heat from air through evapotranspiration, and absorbs heat in plant thermal mass.	Reduces the urban heat island effect by reflecting solar and having high infrared emissivity.	Reduces the urban heat island effect as plants provide shade, removes heat from air through evapotranspiration, and absorbs heat in plant thermal mass.	Reduces air temperature by reducing the amount of heat absorbed into the pavement.	Gives lead time to institutions and communities to prepare for heat waves, thus reducing heat mortality and morbidity.	Decreases exposure to heat, thus reducing mortality from heat waves.	Raises public awareness on heat-related health problems and creates behavioral change, reducing heat-related health impacts.
Limitations of protection	May not significantly reduce mortality during extreme heat waves.	May not significantly reduce mortality during extreme heat waves.	May not significantly reduce mortality during extreme heat waves.	Reflectivity decreases over time as traffic makes the pavement darker and the surface wear away.	Usually use historical climate datasets to define thresholds, which may not be flexible enough to address future variability.	Electric fans may not prevent heat-related illness when temperature is above 35°C.	The populations (especially the elderly) can underestimate the vulnerabilities as they were able to cope with past heat episodes.
Susceptibility to Damage of the Protection System	Resilience of plants to climate variability depends on plant species and module technology.	Although retrofitting is affordable, roofs can be degraded and have declining albedos due to weathering, air pollution, microbial growth and possibly other causes as soon as within one to two years.	Green spaces can be damaged by extreme weather events and climate variability, urban sprawl, and daily usage by people or vehicles.	Roads, hence both traditional and cool pavements, are susceptible to climate (rain, heat, floods, etc.).	Extreme weather events (e.g., storm) can damage weather stations and telecommunication networks if they are not protected and/or not well-maintained.	Cool shelters can be damaged by extreme events other than heat waves (e.g., heavy precipitation).	None identified.
Provide co-benefits	Improves air quality, reduces runoff, extends the life of roof membrane, reduces energy consumption, reduces CO_2 emissions, provides aesthetic and recreational values.	Improves indoor comfort and indoor air quality, extends the life of roof membrane, reduces energy consumption, reduces CO_2 emissions.	Provides habitat, improves air quality, reduces energy consumption, and provides aesthetic, recreational, and public health benefits (e.g., reducing stress).	Reduces energy use, permeable pavements can decrease stormwater runoff, reduces CO_2 emissions, increasing visibility for drivers at night, slows atmospheric chemical reactions that create smog.	Little co-benefit as the option only addresses preparedness to heat waves.	Little co-benefit as the option only addresses exposure to heat stress.	Education and communication efforts can address other environmental and public health issues, encouraging environmentally and socially friendly behaviors.

Table 4-2. Potential Adaptation Options for Heat Waves and Air Quality/Morbidity and Mortality/Vulnerable Populations

Limited disadvantages	Weight can be a challenge on some roofs.	No major disadvantage.	Falling vegetation can cause power outages; tree roots can clog, break, or damage sewer, drainage pipes and building foundations.	Construction of new roads will lead to increased car circulation and thus increased GHG emissions.	No major disadvantage.	There should be coordination in communication messages (e.g., during smog days vulnerable groups are often advised to stay at home); Air conditioning can increase urban heat island effect and energy use.	No major disadvantage.
Reversibility and Flexibility	Easily reversible. Flexible in the sense that the planted vegetation can be changed.	Flexible and easily reversible.	Larger-scale projects may not be easily reversible. Flexible as the vegetation can be changed.	Not easily reversible and flexible compared to other options presented here.	Reversible and flexible – can be monitored and adjusted over time.	Flexible as cool shelters can be used for other purposes when there is no heat wave threat.	Highly flexible and reversible.
Guidance on when/where this option is most likely applicable	Especially suitable to temperate and hot/humid climate. Most efficient if installed at the neighborhood or city scale. May be hard to implement in informal settlements or highly sloped roofs.	Especially suitable to hot/dry climate. Most efficient if installed at the neighborhood or city scale. At least one fully dry day is necessary to allow paint to dry.	Small-scale projects should be adopted in highly dense cities with little idle land area; need to consider distance or walking time from home, and users' values and pattern of life when planning.	Especially suitable in cities with low-rise buildings; urban geometry (i.e., how buildings and cities are planned) can influence the impact of cool pavements on the air temperature.	Most applicable to places with a reliable meteorological forecast, a good understanding of the relationship between heat load and health, and capacity to accompany phased alert systems with effective action plans.	Best to combine this measure with a heat alert system. Needs to have back-up power for this measure to be effective in case of electric blackouts.	Effectiveness depends on the uptake within target groups. Campaigns need to be tailored to local needs and culture. Risk awareness activities in schools have been found to be effective.
Examples of implementation	• In Durban, South Africa, a green roof pilot project was started in 2008 as part of the Municipal Climate Protection Program. The roof covers 5,920 square feet on a government building's roof with 1% slope.	• A group of students in Cebu, Philippines, won a competition and received support to paint the roofs of 50 houses white. 20 roofs with a combined area of 700 square meters were completed in one day.	• In Sao Paulo, Brazil, an education program was conducted to teach local communities how to grow vegetable using idle land in the favelas (slums).	• A study on pavements for Delhi, India, highlighted the benefits of light-colored pavers, aggregates, and top-coats, preferably with heat reflectivity of 0.29 or higher.	• After one of the most extreme heat waves in the country in the summer of 2007, the government of Macedonia implemented a phased alert system and a plan to increase heat wave preparedness.	• The City of Ahmedabad, India has a Heat Action Plan, which includes provision of cool centers such as temples, public buildings, malls, and temporary night shelters for those without access to water and/ or electricity.	• After several natural disasters including a deadly heat wave in 1998, the Odisha State Disaster Management Authority, India started a Disaster Risk Management program, in which awareness raising had a major role.

4.3. EXTREME STORMS/WATER-BORNE DISEASES/VULNERABLE POPULATIONS

Climate hazard	Higher frequency and intensity of extreme precipitation events and storms, with increased probability of flooding.
Impact	Increased incidence and burden of water-borne diseases (e.g., diarrhea, cholera).
RSA at risk	Urban low-income populations already experiencing a large burden of the disease, particularly in areas with poor sanitation infrastructure. Children are the most vulnerable population.

Potential adaptation options

- Improved sanitation and waste management (3 examples)
- Safe water treatment (4 examples) (also see options to address water quality issues under Water Resources)
- Cholera treatment centers (3 examples)
- Treatment (oral rehydration salts (ORS) with Zinc supplementation) (3 examples)
- Cholera early detection systems (6 examples)
- Cholera early warning systems (4 examples)
- Oral cholera vaccine (5 examples)
- Cholera rapid diagnostic tests (3 examples)

Table 4-3. Potential Adaptation Options for Extreme Storms/Water-Borne Diseases/Vulnerable Populations

	Improved sanitation and waste management	Safe water treatment	Cholera treatment centers (in the event of an outbreak)	Treatment (oral rehydration salts (ORS) with Zinc supplementation)	Surveillance systems – Cholera early detection systems	Surveillance systems – Cholera early warning systems	Oral cholera vaccine (OCV)	Cholera rapid diagnostic tests
Straightforward-ness	The construction of latrines or systems to avoid water contamination can be low-tech. Personal hygiene behavior can be hard to change and may take longer time.	Several water treatment options (e.g., chlorination, flocculent/disinfectant powder and solar disinfection) are widely implemented. Implementation is quick and easy to scale up.	Straightforward to put in place, but will be most effective if there are prior efforts to map health facilities and partners with capacity to run cholera treatment centers.	ORS has been implemented since the 1970's as the most efficient and straightforward cholera treatment option to prevent dehydration. Zinc supply with ORS is recommended.	Straightforward but requires some kind of existing institutional capacity, in the form of healthcare facilities and cholera/ epidemiological experts.	Requires research to identify the climate and environmental variables that strongly correlate with cholera outbreaks, thus requiring expertise in remote sensing, climate science, and epidemiology.	Requires expertise in epidemiology and public health and public outreach for mass vaccination campaigns. Requires good logistic infrastructure (storage and transportation).	Easy to use, rapid, and low-tech, since no special instrument or equipment is needed. The tests results are ready generally in 10-15 minutes, making this option very quick and straightforward.

Table 4-3. Potential Adaptation Options for Extreme Storms/Water-Borne Diseases/Vulnerable Populations								
Low cost	Public toilets can costs from 3 to 15 cents per use. Basic latrines can cost $500-1000. Maintenance requires a vacuum truck to empty the waste every few months, which costs a few hundred dollars per tank.	Disinfectant powder, chlorination, solar disinfectant, ceramic and slow sand filtration are all low cost technologies. In addition there are monitoring and training costs.	Precise cost information was not found. Costs will include items such as large quantities of safe water, adequate waste disposal systems, medical supplies, and training of doctors and nurses.	Low cost, $0.08-0.11 per sachet. Use of zinc with ORS reduces the total cost of treatment over time. Ongoing costs are limited.	Relatively low cost to set up and maintain. Set-up costs include coordination among different stakeholders, training of health workers, and technology for communicating the data.	Precise cost information was not found. Significant funding must be allocated to training of local authorities, coordination efforts, and technology and infrastructure needs.	In two vaccination campaigns in Indonesia and Micronesia, cost per person vaccinated was around $9.	$4 to $14 per device. There are costs associated with storage in refrigerators, but some test instruments can be stored at ambient temperatures for long periods of time.
Effectiveness								
Reduction in climate vulnerability	Significantly reduces the incidence of all diarrhea-type cases including cholera.	Reduces occurrence of cholera; also prevents risks of dehydration during the disease and is thus a necessary treatment option.	When cholera strikes, it can take only few hours to kill, hence the great benefits of having treatment centers close to at-risk populations.	Most effective technique to reduce mortality from dehydration in cholera cases.	Has been proven to be effective in detecting and tracking cholera cases throughout the areas where the system is in place.	Can predict the likelihood of outbreaks months in advance, in which case health authorities can quickly mobilized resources for epidemic control.	Reported estimated vaccine efficacy is around 80%. Also offers indirect protection to those not vaccinated but living in areas with increasing vaccine coverage.	Most tests have been found effective in correctly diagnosing the cholera bacteria Vibrio cholera.
Limitations of protection	None found. In all cases of cholera outbreaks, safe sanitation is the key to containing the disease.	Protection of chlorination is limited in turbid waters.	During very severe outbreaks, treatment centers may get overcrowded. If hygiene standards are not high enough, disease could spread further.	Inadequate for treating dehydration caused by acute diarrhea, where the stool loss and probability of shock are high: IV fluids and antibiotics will be needed.	No limitation. For example, the surveillance system in Haiti was effective even during civil unrest and during the pass of a hurricane.	To account for a changing climate, further research incorporating more robust epidemiological and remote-sensing data is needed.	Not specified. However, vaccines are constantly tested to be effective in different settings. OCV is typically not recommended for pregnant women and children under two.	Not specified, but tests are developed to detect the cholera-causing bacteria Vibrio cholera under any type of circumstances and in any type of setting.

Table 4-3. Potential Adaptation Options for Extreme Storms/Water-Borne Diseases/Vulnerable Populations								
Susceptibility to Damage of the Protection System	Poorly engineered communal latrines or community storage systems can be damaged and compromised by strong floods, landslides, and earthquakes.	None found.	In the event of a flood or landslide, treatment centers may be complex to install or visit due to close roads or no available land.	Supply of those treatments can be disturbed by extreme weather events, although that probability is relatively low.	Needs laboratory confirmation in order to quickly identifying the onset of an epidemic and not misclassify other diarrhea-type diseases with cholera.	Once the system is implemented, periodic research should be conducted to assess any changes in the relationship between climate/ environmental variables and cholera outbreak.	Vaccination campaign can be affected by weather conditions, security concerns, availability of cold storage facilities and cold boxes for transportation, and population movements.	Some tests require refrigeration for long-term storage and need to be stored in humidity proof plastic bags for transportation to the field.
Provide co-benefits	Provides general health benefits; waste collected can be used as fertilizer and to generate electricity; maintenance and waste collection services can create jobs.	Disinfectant powder also removes heavy metals and chemical contaminants from water; Reduces vulnerability to other water-borne diseases; May boost economic development if the products are locally produced.	Can raise awareness on disease prevention (e.g., how to wash one's hands, avoid food poisoning, limit the spread of the disease within households, etc.).	ORS and zinc can also help decrease under-nutrition among children who have been affected by diarrhea. In addition to being an efficient treatment, zinc is a good prevention option to build resistance to the cholera virus.	Can provide a framework for setting up surveillance systems for other infectious diseases. Some aspects of the system, such as the SMS component, can be used for environmental and disaster management.	Can provide a framework for the development of Early Warning System for different infectious diseases and other sectors such as agriculture, water management, and flood control.	Can serve as a framework for mass vaccination campaigns of different diseases. Builds capacity of local health workers and health authorities.	In the cases where field technicians with no prior lab experience receive the proper training by experts, local public health systems would have additional personnel who are capable of conducting lab work.
Limited disadvantages	Can fail to reach the poorest and most at-risk.	Chlorination may leave taste and odor objections.	No major disadvantage.	No major disadvantage.	Needs existing health facilities, requires training of health workers.	Needs resources for climate studies and training, technology, and infrastructure.	Can be hampered by lack of logistic infrastructure and waste management through a high-temperature incinerator.	Sometimes need to confirm the diagnosis with a laboratory analysis.
Reversibility and Flexibility	Provides protection regardless of changing climate stresses. Reversible, though de-installation of sanitation infrastructure can be costly.	Decreased water quality due to climate change can require more robust water treatment. Easily reversible.	Changing climate patterns may require relocation of treatment centers. The option is easily reversible.	Provides protection regardless of changing climate stresses. Easily reversible.	Flexible enough to even track other types of diseases; can be used for applications other than disease surveillance and control.	Highly flexible and reversible because it incorporates new data as they become available.	Highly flexible and reversible as vaccines are tested periodically for effectiveness and can be redeveloped accordingly.	There are different kinds of tests and new ones can be developed. Therefore, it is a highly flexible and reversible option.

Table 4-3. Potential Adaptation Options for Extreme Storms/Water-Borne Diseases/Vulnerable Populations

Guidance on when/where this option is most likely applicable	Needs robust educational campaigns to promote adoption of safe hygienic practices.	Needs to be accompanied with training; Needs safe water storage.	At-risk populations due to medical complications and/or lack of access due to money, cultural reasons, or distance should be identified prior to installation of treatment centers.	Should be prepared with the safe drinking water. Public communication campaigns and leveraging private supply are central to achieving significant reductions in mortality.	Should be implemented in conjunction with Climate Early Warning System and establishment of cholera treatment centers when outbreak occurs.	Developing effective climate-based forecasting models is a required prerequisite; should be implemented in conjunction with a Cholera Early Detection System.	Requires expertise, public outreach, and good logistic infrastructure. A cholera surveillance system would aid in identifying the population most at risk.	Suitable in places with minimal laboratory infrastructure, such as refugee camps or remote rural areas. Can contribute to the effectiveness of early detection systems. Must be combined with treatment.
Examples of implementation	• In Kumasi, Ghana, a project aims to address the barriers that prevent people in urban areas from accessing adequate sanitary facilities. It installs a household toilet and set up a network of local operators that provide household waste collection service.	• In Kambaya, Guinea, UNICEF partnered with a local NGO to produce chlorine bottles to prevent cholera. The bottles are sold at moderate prices. However, during a cholera outbreak, the product can be distributed for free.	• The 2010 earthquake in Haiti triggered a cholera epidemic. Doctors Without Borders and other NGOs supported the Haitian Ministry of Health in addressing this issue by installing several cholera treatment centers.	• "Scaling Up Zinc Treatment of Childhood Diarrhea" (2003-2010) is a project in Bangladesh that aims to achieve universal coverage of childhood diarrhea with zinc treatment, which will reinforce the effects of ORS on mortality reduction.	• In Haiti, the Ministry of Public Health and Population set up a National Cholera Surveillance System following the confirmation of the first cases of cholera in the country in a century after the massive earthquake in January 2010.	• A study analyzed the relationship between climate variables, hydrology, and cholera outbreaks during the 1978-1999 time period in the Lake Victoria region of Eastern Africa. It found that cholera epidemics are closely associated with warm and wet El Niño years.	• A mass vaccination campaign was undertaken in Aceh Province, Indonesia, as a preventive measure following the December 2004 earthquake.	• Studies evaluating the effectiveness and usability of different rapid diagnostic tests were conducted in Bangladesh, India, and Guinea-Bissau.

5. WATER RESOURCES

5.1. SLR/POTABLE WATER AVAILABILITY/COASTAL AND SMALL ISLAND STATE COMMUNITIES

Climate hazard	Interactions with the effects of SLR.
Impact	Reduced volume of potable water. When combined with higher sea levels, lower seasonal rainfall amounts can decrease the size of the narrow freshwater lens, putting pressure on supply of drinking water (both inland and at the coast).
RSA at risk	Coastal communities and communities in small island states.

Potential adaptation options

- Dug wells (1 example)
- Boreholes (1 example)
- Hand pumps (3 examples)
- Solar-powered pumps (3 examples)
- Hydraulic ram pumps (1 example)
- Rain water harvesting (2 examples) (also see Rain water harvesting under Water Resources)
- Slow sand filtration (1 example) (also see Biosand filter under Water Resources)
- Outreach on water management and climate (1 example)
- Groundwater protection (2 examples)
- Water conservation and protection measures (1 example)

Table 5-1.1. Potential Adaptation Options for SLR/Potable Water Availability/Coastal and Small Island State Communities

	Dug wells	Boreholes	Hand pumps	Solar-powered pumps	Hydraulic ram pumps
Straightforward-ness	Very simple – created by digging hole in ground. Depth depends on type of ground and changes in groundwater table so that low tide does not produce dry well and high tide does not inundate well with saltwater. Requires inner lining, which can be brick, stone, concrete, etc.	More complicated than dug wells – requires drilling and stronger pumps.	One of the simplest methods for extracting groundwater. Decisions on which type of hand pump to use depend on cost, location of well, cultural considerations, amount of use, and water quality.	Varies – the simplest model involves solar array wired directly to a pump. Can also include batteries, which allow for 24-hour pumping.	More complicated system that uses weight of falling water to provide lift.

Table 5-1.1. Potential Adaptation Options for SLR/Potable Water Availability/Coastal and Small Island State Communities					
Low cost	Costs vary and include costs for labor, construction materials, and hand pump. Hand pump usually costs $80-2,000. Maintenance training is also necessary immediately following installation. Pumps need periodic inspection and repair, replacement of gaskets and moving parts. Wells should be inspected daily (if open, periodically if closed) and cleaned of debris.	More expensive than dug wells. Requires prior hydrogeological assessment. Drilling and installation requires experts. Requires high-skilled workers, thus higher initial costs. Pumps need periodic inspection and repair, replacement of gaskets and moving parts. Wells should be inspected daily (if open, periodically if closed) and cleaned of debris.	Costs range significantly. Simple hand pumps cost $55-$465. Hand-operated diaphragm pumps and piston hand pumps cost $1,800 but have longer lifespan. Limited maintenance is required. Replacement costs are only significant if spare parts are not readily available.	Relatively higher cost. Averages from $2,100 (0.13 l/s from well depths of 75 m) to $13,000 (0.35 l/s from well depth of 40m). Little operation, training (even for installation) or maintenance cost especially for direct array systems. Some inspection to ensure battery status and direct sunlight.	Pump is only a fraction of total system cost. Pump drive and delivery piping are typically most expensive components. Pump from North America or Europe might be $1,500 to $4,000, but locally produced version might be 20% of that. Little to no operational costs. More training is required for installation, maintenance, and operation.
Effectiveness					
Reduction in climate vulnerability	Generally effective at providing water during extended dry periods. This option alone is not sufficient to augment water supplies but is often supplemented with rainwater harvesting.	Very efficient at producing water even during extended dry periods. Deep wells provide more protection against contamination than dug wells.	Enables use of additional water supplies. Hand pumping reduces the chance of over-extraction. Hand-pumped wells are less susceptible to surface pollution than bucket-drawing methods.	Provides 24-hour access to water.	Increases water supply.
Limitations of protection	Surface and sub-surface water pollution can decrease water quality of dug well water.	Though less vulnerable to contamination, water quality reduction is still possible.	Does not reduce the chance of contamination due to proximity of wells to houses, latrines, and animals.	Requires battery upkeep. Does not reduce the chance of contamination due to location of wells.	Require large source flows since only a small fraction of flow can be delivered to users.
Susceptibility to Damage of the Protection System	Construction and location are both very important. Sea level rise, as well as runoff, can create water quality or salinization issues.	Less susceptible than dug wells due to depth, however this is still contingent upon correct siting.	Seasonal precipitation changes and sea level rise don't impact pumps specifically.	Minimal; change in climate may affect the amount of sunlight.	Change in climate may reduce source flows.
Provide co-benefits	None found.	None found.	None found.	No recurring fuel costs. Run silently and is pollution-free.	Make use of renewable energy source, few environmental impacts.
Limited disadvantages	Over-pumping can lead to salinization (hand pumps, which are more labor-intensive, can mitigate this problem). Study in Kiribati showed that wells often in proximity to pit latrines or livestock, which increase possibility of contamination.	Requires highly-skilled workers. Maintenance is more difficult due to depth. Spare parts may be less accessible since this method requires more specialized technology. May involve land ownership issues.	Not as easy to access/use as solar, hydraulic ram, or windmill pumps, which operate independently of individual labor.	Non-battery version requires back-up battery system for pumping in poor weather. Residents can abuse the system by leaving taps on, which reduces water pressure further down the system.	Can require more specialized personnel for installation.
Reversibility and Flexibility	Depends on initial cost of pump and construction materials. While wells are not flexible, the ability to dig low-cost wells makes this somewhat flexible.	Higher initial cost makes this option less flexible and reversible. However, wells can be capped easily.	Low initial and O&M costs suggest that this is a flexible technology. Portable and can stop the use of pumps at any time.	High capital costs mean lower reversibility. Arrays also need to be aligned optimally, so somewhat limited flexibility in terms of location. Systems that store energy efficiently are more flexible given changes in weather.	High capital costs mean that this is less reversible and flexible.

Table 5-1.1. Potential Adaptation Options for SLR/Potable Water Availability/Coastal and Small Island State Communities					
Guidance on when/where this option is most likely applicable	Not useful in sand aquifers; it is impossible to have lining that prevents fine sand from infiltrating. Often used to supplement rainwater harvesting, especially in low-lying, very small islands. Requires spare parts to be readily available; and capacity for community water committees that oversee well cleanliness and maintenance.	Useful when distance from land surface to water table is too great for technologies such as dug wells (e.g., small, high islands). Therefore not very useful for many small, low islands where groundwater is shallow. Requires that island has adequate supply of groundwater.	Hand pumps are optimal on low-lying islands with shallow groundwater. Hand-operated diaphragm pumps are optimal when the village/end-user is within 750 m of well. Piston hand pumps are only effective if well is within 30 m of house.	Optimal on islands that receive long periods of consistent sunlight. Requires space with access to direct sunlight and alternative energy source for continuous pumping (if not part of system). Community engagement is key to success of the option.	May be feasible on small, high islands in lieu of motor-driven pumps, which incur high usage costs.
Examples of implementation	• Dug wells are used widely on Small Island Developing States.	• Boreholes are used widely on Small Island Developing States.	• Locally-produced, shallow well hand pumps can be found in Papua New Guinea, Solomon Islands and Kiribati. • Hand-operated diaphragm pump and pistol hand pumps are used in Kiribati.	• Five 40-watt solar modules were mounted directly above the well to power the pump in a village in the Federated States of Micronesia. Water from the wells was pumped to two 19 m^3 ferrocement storage tanks.	• Hydraulic ram pumps are found in the Solomon Islands and Vanuatu.

Table 5-1.2. Potential Adaptation Options for SLR/Potable Water Availability/Coastal and Small Island State Communities					
	Rain water harvesting – rooftop rainwater harvesting system	Slow sand filtration	Outreach on water management and climate	Groundwater protection	Water conservation and protection
Straightforward-ness	Minimal labor and engineering skill.	Simple construction but can be labor-intensive. Can be constructed from local materials.	Relatively easy to implement. Training materials are available and can be tailored to the local situation.	Typically takes the form of a containment structure, constructed from concrete or masonry, which direct spring flows to an outlet pipe. Spring capping is found in many forms, ranging from relatively simple, uncovered systems to more sophisticated, covered systems.	Leak detection can include regular soundings, district metering, and waste metering. Conservation devices can include dual flush toilet cisterns, flow restrictors on showers and taps, and replacing taps with hand pumps.
Low cost	Relatively low cost. Cost varies considerably depending on location, type of materials used, and level of implementation. Low O&M costs. During operation, the major concern is to prevent the entry of contaminants into the tank while it is being replenished during a rainstorm.	Low cost if local materials are used. For large-scale plants, land acquisition can add significant costs (requires larger area than rapid sand filtration, but may not be an issue for small, rural communities). Very low O&M cost since no chemicals or energy inputs are required.	Depending on the size of the program. An outreach and education program in Majuro, Republic of Marshall Islands (see examples of implementation below) cost $100,000. Since programs are usually short in duration, little to no O&M costs are involved.	Low cost – locals can be trained to develop and cap springs. Minimal intervention required for O & M – only periodic inspection and cleaning of chamber. Local people can be trained to manage.	Leakage control involves cost of equipment, training, and conducting study. Metering costs include purchase and installation, plus reading and periodic billing and revenue accounting. Meters average US$140-200 per domestic installation. Meters need to be tested regularly and, if necessary, repaired.
Effectiveness					
Reduction in climate vulnerability	High reduction in climate vulnerability. Can serve as an important (and in some cases only) additional source of freshwater.	Removes nearly all turbidity and pathogens without use of chemicals. Removes suspended materials as well as bacteria.	Increases knowledge on water conservation and rainwater harvesting, etc. Programs designed for schools would provide education for students, who would educate their parents.	Effective at protecting springs and supplying water - more complicated versions are designed to exclude leaves, soil and other contaminants such as animal and bird excreta.	Leakage control can reduce lost water by up to 50%. Metering and water pricing reduces water consumption by 25-30%.
Limitations of protection	In most cases, a rain water catchment system cannot meet demand during extended dry periods.	Process is slow and requires large amount of land. Toxic chemical contaminate on of raw water may impact surface layer.	Programs do not directly reduce climate change impacts, but rather enable communities to better adapt to them.	Simpler versions likely do not prevent as many contaminants.	None found.
Susceptibility to Damage of the Protection System	Similar to susceptibility of the home as it is part of the house structure (e.g., damaged if the roof is damaged by a storm).	Clogging may occur if water is very turbid.	None found.	None found.	None found.
Provide co-benefits	Can serve as an emergency source of supply. Can also address water quality issues since the rainwater collected locally can be either quality controlled or treated for potable use on-site.	Compared to rapid sand filtration, there is a net savings of water as large quantities of backwash water are not required.	Can increase general environmental and climate change awareness.	None found.	Leakage control systems generally improve knowledge and administration of the water supply system, and provide for improved security. Metering assists in the development of a pricing structure that is appropriate to the individual water supply system.

Table 5-1.2. Potential Adaptation Options for SLR/Potable Water Availability/Coastal and Small Island State Communities					
Limited disadvantages	Completely dependent on the frequency and amount of rainfall. Water may be contaminated if the storage tanks are not adequately covered. Uncovered or poorly covered storage tanks can be unsafe for small children. Contamination can also occur from dirty catchment areas.	Limited disadvantages beyond larger land requirement compared to rapid sand filtration.	None found.	Poor construction can limit flow.	Leakage control and meter maintenance require trained technicians; repair requires trained plumbers, though this can be done by the community. Some conservation devices are not accepted by local communities.
Reversibility and Flexibility	Does not have a lot of flexibility in the face of uncertainty. However, additional systems can often be built in communities that do not have adequate storage.	Option is potentially reversible due to relatively low cost.	Reversibility does not apply here. Flexibility is a necessary component of success – educational programs must be tailored to local communities and existing water supply schemes.	Removal of containment structure is possible, but might be expensive. Many versions exist for different sizes and types of springs.	Water conservation and reductions in demand are desirable regardless of climate change impacts.
Guidance on when/where this option is most likely applicable	Best suited to areas that have evenly-distributed rainfall throughout the year. The effective roof area and the material used in constructing the roof influence the collection efficiency and water quality. Some technical and financial capacity must be available. Contamination of supplies is a concern that must be addressed by control of collection area or treatment.	Requires a more specific sand size to be effective. Viable for communities aiming to treat surface water. Most suitable for communities with gravity-operated surface water supply systems, or systems with large storage capacity.	Needs capacity for training teachers, and organizational capacity for delivering the program.	Requires that locals are open to using spring water.	Measures must be supported by policies and enforceable legislation. The operation of a pricing system requires meter readers, and an appropriate billing and revenue collection system. Also requires high level of community involvement. Only applicable to Small Island Developing States with public water supply systems.
Examples of implementation	• Given the amount of rainfall in the Metro Iloilo area in the Philippines, rooftop rainwater harvesting is an appropriate option for augmenting water supplies. By appropriately designing roofs; installing gutters, tanks, and cisterns; and training people on the necessary maintenance of these systems, the large surface area dedicated to buildings can be harnessed at almost any scale to provide a source of water.	• On La Digue, Seychelles, the installation of slow sand filters has proven to be the most cost-effective method for the treatment of raw water. • Water supplied to Apia and part of the west coast of Upolu, Western Samoa, is treated using slow sand filters which work well under normal flow conditions.	• A program in Majuro, Republic of Marshall Islands included outreach/education on rainwater harvesting and water conservation, curricula development in schools on climate change and water, and implementation of a "School Met" system (climate monitoring program where students use meteorological kits to track precipitation).	• This measure is used widely in Small Island Developing States.	• Widespread use on Small Island Developing States such as Seychelles, Bahamas, Malta, Solomon Islands, Federated States of Micronesia, Samoa, French Polynesia.

5.2. SEASONALITY OF SNOWMELT AND MORE INTENSE PRECIPITATION/FLOOD DAMAGE/COMMUNITIES IN FLOODPLAINS

Climate hazard	Earlier and more rapid snow melt and more frequent and intense extreme precipitation events.
Impact	Flood damage. In addition to flooding, surface inundation can cause erosion and landslides.
RSA at risk	Communities and property located in river floodplains, particularly in mountain catchments.

Potential adaptation options

- Cluster villages at elevations above flood zone (i.e., on raised land) and with flood- and erosion-resistant construction materials (1 example)
- Flood-resistant housing – Jute panels and Plinths (2 examples)
- Floating gardens (1 example)

Table 5-2. Potential Adaptation Options for Seasonality of Snowmelt and More Intense Precipitation/Flood Damage/Communities in Floodplains

	Cluster villages at elevations above flood zone (i.e., on raised land) and with flood- and erosion-resistant construction materials	Flood-resistant housing – Jute panels and Plinths	Floating gardens
Straightforward-ness	Requires some technical capacity and institutional coordination.	Jute panels are treated bamboo poles on concrete bases that are strengthened with metal tie rods to make resilient walls. A plinth is a combination of soil, cement, stone, and brick that raises the house and is strong enough to withstand flooding.	Simple to implement. Floating gardening has been practiced in Bangladesh for years. It takes about a day of labor to construct a single floating platform. Additional time is required for planting seedlings and cultivation.
Low cost	In the example found (see examples of implementation below), high standards were used in the Gaibandha river erosion project – the houses were built with concrete floors, brick and mortar walls, steel roof trusses, and door and window frames. This cost 1,000 British pounds/ house, though costs will be lower if houses are built outside of flood zone. In this case less permanent materials can be used, as long as they can withstand strong winds, and costs can be reduced in half.	Jute panels cost about 62 British pounds for all walls in 10 houses; panels are easy and inexpensive to replace. Casting and finishing a plinth for two floors and cement cost about 31 British pounds. There is little ongoing cost.	Very low cost. All construction and agricultural materials can be found locally.

Table 5-2. Potential Adaptation Options for Seasonality of Snowmelt and More Intense Precipitation/Flood Damage/Communities in Floodplains			
Effectiveness			
• **Reduction in climate vulnerability**	Clustering villages at elevations above flood zone reduce or eliminate the chance of flooding of houses, including destruction of houses and human health vulnerabilities associated with inundated living quarters.	Jute panels increase resilience of walls by providing extra structural support; bracings and fastenings that bind the walls firmly to the house 'skeleton' increases resilience to winds; concrete bases provide additional flood prevention. Panels can be moved easily during major flooding events for reconstruction later. Plinths reduce structural flooding during major events and eliminate flooding during smaller events. Chance of floor washing away is more or less eliminated as opposed to earthen floors. Jute panels and plinths can be combined to increase resilience of houses to flooding and wind.	Useful for providing agricultural livelihood opportunities during water-logging periods.
• **Limitations of protection**	Severe storms that bring floods are likely to bring high winds as well. Using better/more expensive materials during the construction process will help prevent wind damage.	Jute panels only protect against flooding directly caused by precipitation through damaged walls. Major flooding events can still inundate houses, though plinths will reduce the extent of flooding. Plinths do not protect against high winds.	Not suitable in all open waters and cannot withstand devastating floods or strong waves. However, floating gardens can provide re-building benefits in extreme flooding events even if they don't provide prevention benefits.
• **Susceptibility to Damage of the Protection System**	Relocation area must be free of erosion vulnerabilities, which could reduce the flood prevention benefit. Relocation area could be more exposed to wind, which could damage weaker houses.	Jute panels are not strong enough to withstand severe flooding events. Plinths can withstand repeated flooding, unlike conventional earthen floors.	Floating gardens cannot withstand extreme flooding events or extreme waves.
Provide co-benefits	Typically allows for flood-free livelihoods (i.e., animals and crops are out of flood-zone, as well).	No apparent co-benefit.	In addition to providing benefits during flooding, floating gardens have increased crop yield in winter months. Provides nutritional security regardless of climate change, increases household-level income and increases land-use efficiency.
Limited disadvantages	May require some land acquisition, and requires acquired land to be in erosion-free area.	No apparent disadvantage.	No apparent disadvantage.
Reversibility and Flexibility	Houses are not mobile and must be in an erosion-free are, so this option is not particularly flexible. Likelihood of raised land becoming more flood-prone than lower elevations is very unlikely, though, so reversibility does not apply in this case.	Jute panels can be dismantled if a severe flood is forecast (for reconstruction later). Since materials and labor are low in cost for plinths, they are a relatively flexible option that can be used for houses in flood-prone areas.	Provides flood-protection, nutritional security, crop yield benefits, and land-use efficiency regardless of climate change impacts. Option is flexible so long as households have enough space for floating platform. If climate change increase frequency of extreme floods, floating gardens are still useful for rebuilding agricultural plots in post-event flooded areas.
Guidance on when/where this option is most likely applicable	Applicable where there is available land located above flood zone to build a clustered village. It is imperative the clustered village be built in erosion-free area, and that the amount of area per household is enough to continue livelihood practices. Requires collaboration between local government, communities and international and local NGOs.	Applicable to houses located in areas prone to heavy precipitation, flooding, and high winds.	Most useful in wetlands during normal floods or for rebuilding after large flooding events. Large-scale application will require involvement of government's agricultural extension program, while local applications require involvement of both local community and government. Needs access to market to sell agricultural goods.

Table 5-2. Potential Adaptation Options for Seasonality of Snowmelt and More Intense Precipitation/Flood Damage/Communities in Floodplains			
Examples of implementation	• Practical action has helped to develop four cluster villages on raised land that have resettled 342 displaced and vulnerable dam dwellers in Bogra, Gaibandha, and Sirajganj, Bangladesh.	• Practical Action has worked with local communities in Bangladesh for a few years to develop low-cost, flood-resistant housing. The house is built on a raised plinth made from sand, clay, and cement, and jute panels were installed to make resilient walls.	• In 2007, a study in Kishoreganj, Bangladesh found 23 villages suitable for floating gardens.

Figure 12. The whole community worked together to make a large raised platform for the cluster village in Bangladesh (Source: Practical Action, 2010).[6]

Figure 13. A house built on a plinth and with jute panels in Bangladesh (Source: Practical Action, 2010).

Figure 14. Floating platforms for seedling raising and vegetable cultivation in Bangladesh (Source: Irfanullah et al., 2011).[7]

Figure 15. Vegetables grown on a floating garden in Bangladesh (Source: Irfanullah et al., 2011).

[6] Practical Action. 2010. Flood Resistant Housing: Low-cost Disaster-resistant Housing in Bangladesh. http://practicalaction.org/flood-resistant_housing

[7] Irfanullah, H., A. K. Azad, Kamruzzaman, & A. Wahed. (2011). Floating Gardening in Bangladesh: a means to rebuild lives after devastating floods. Indian Journal of Traditional Knowledge. Vol 10(1), January 2011. pp. 31-38.

5.3. DECREASED SEASONAL PRECIPITATION/WATER SCARCITY AND DROUGHT/VULNERABLE POPULATIONS

Climate hazard	Decrease in seasonal precipitation.
Impact	Increase in water scarcity and stress. Increased competition for access to water can heighten the probability of drought and degradation of groundwater during dry seasons. Prolonged drought can lead to desertification.
RSA at risk	Rural populations in drought-prone areas, particularly if reliant on shallow wells for drinking water, and dependent on rain-fed agriculture.

Potential adaptation options

- Rainwater harvesting (2 examples) (also see Micro-catchment rainwater storage under Agriculture)
- Deep tube wells (DTW), water-efficient irrigation practices, water pricing, creation/renovation of tanks and canals, cross-dams (1 example)
- Sand dams for water supply augmentation (1 example)
- Conservation agriculture (1 example) (also see No till/ low till farming under Agriculture)
- Introduce symbiotic endophytes to increase drought tolerance (1 example) (also see Provision of drought resistant crop variety under Agriculture)

Table 5-3. Potential Adaptation Options for Decreased Seasonal Precipitation/Water Scarcity and Drought/Vulnerable Populations

	Rainwater harvesting – dug out pond	Rainwater harvesting – rooftop rainwater harvesting system	Deep tube wells (DTW), water-efficient irrigation practices, water pricing, creation/renovation of tanks and canals, cross-dams	Sand dams for water supply augmentation	Conservation agriculture	Introduce symbiotic endophytes to increase drought tolerance
Straightforward-ness	Dug out ponds for rain water harvesting in lowlands of catchment area. Construction is simple, using household labor and owned by individual farmer or community.	The system consists of a sheet roof, gutters, collection pipe, and plastic or reinforced cement concrete storage tank. Minimal labor and engineering skill.	Uses simple technologies, management practices, and pricing scheme to achieve greater efficiency and sustainable groundwater irrigation.	Very straightforward construction. Cement retention walls are built across small, ephemeral streams. Upstream portion is filled with sand, creating an artificial aquifer. Construction usually takes less than three months.	Requires some training and specialized equipment. These practices are a variation of minimum tillage practices that have been previously implemented in Africa.	Confer drought tolerance from plants that thrive in high-stress environments to other crop species by introducing the tolerant species' fungal symbiotic endophytes. This option is currently under research.

Table 5-3. Potential Adaptation Options for Decreased Seasonal Precipitation/Water Scarcity and Drought/Vulnerable Populations						
Low cost	Moderate initial costs. Construction of optimal size dug out pond, effective silt trap and minimization of evaporation losses are essential for water availability from dug out ponds. Use of water for irrigation would require more labor. Low O&M costs. Needs to desilt the pond before each wet season.	Relatively low cost. Cost varies considerably depending on location, type of materials used, and level of implementation. Low O&M costs. During operation, the major concern is to prevent the entry of contaminants into the tank while it is being replenished during a rainstorm.	Requires initial capital costs to set up the irrigation system. O&M costs can be recovered 100% through a pre-paid water charge system.	Requires investment for sand (cheap & local) as well as cement (potentially cost more). Construction material costs are approximately $5,000/dam. Sand dams have a very long life (30-50 years) and have little to no O&M costs. Maintenance/inspection is usually provided locally, often by farmers who built the dams.	Conservation farming involves additional costs for labor during the weeding process, since only 15% of the soil surface is tilled during field preparation. However, conservation farming outperforms conventional tillage methods, generating higher returns to land and peak season labor.	Research costs are high, but when established the technique has the potential to create an 'inexpensive and viable strategy' for increasing crops' resilience to climate change.
Effectiveness						
Reduction in climate vulnerability	Provides an additional source of freshwater.	Provide an additional source of freshwater.	Expands cropped area and rural piped water supply.	Provides water supply drinking, irrigation, and making mud bricks for house construction. Artificial aquifers created by dams are less prone to evaporation than open water storage, since water is stored in sand/gravel.	Improved water conservation.	Increasing drought tolerance in crops could reduce crop losses or even help extend crops into currently uncultivable areas.
Limitations of protection	It was observed that 46% of ponds dry up within 1.5 months from wet season, 22% within 2 months, and 32% remain useful until the onset of the next rainy season. Principal reasons are rainfall variability, higher evaporation losses, and storage capacity reducing over the wet season due to moderate sediment deposition from overland flow.	In most cases, a rain water catchment system cannot meet demand during extended dry periods. Greater storage capacities to account for rainfall variability can be too expensive. Hence, it is often be necessary to have an alternative source to supplement the rainwater supply.	Water quality in groundwater can limit efficacy of protection. For example, arsenic in groundwater in Bangladesh limits this option's effectiveness.	Since a prerequisite of sand dams is to allow river to flow, does not provide any flash flood protection.	One of the conservation agriculture techniques, ox-drawn ripper, has mixed success due to difficulty of use.	This ability of fungal endophytes to confer drought tolerance has been studied in very few plant species. However, the host range of fungal endophytes is greater than previously thought and it is possible for endophytes to colonize distantly related plant species.

Table 5-3. Potential Adaptation Options for Decreased Seasonal Precipitation/Water Scarcity and Drought/Vulnerable Populations						
Susceptibility to Damage of the Protection System	Moderate. Sediment deposition can reduce capacity.	Similar to susceptibility of the home as it is part of the house structure (e.g., damaged if the roof is damaged by a storm).	Some hand wells dry up due to the deep tube wells operating at full capacity. This issue is being addressed by integrating drinking and irrigation water supply.	If there is decreased precipitation during the rainy season, small streams may not be sufficient to recharge artificial aquifer.	None found.	Not specified in the research.
Provide co-benefits	Use of ponds can augment year round water supply for livestock, which can substantially contribute to household income and food security.	Increased irrigation water for vegetable gardens, increased household income.	Reduces the hardship of rural women and children who are in charge of collecting water for household use. Improves health and sanitation.	Help to restore degraded drylands by raising the water table – increases capacity of soils to absorb water and enables tree and plant growth.	Improved soil conservation, increased yield and income. More efficient distribution of labor as preparing the land is shifted from peak planting season to the dry season.	This same method can also be used to confer crop tolerance to other stressors such as heat, disease, salt, and metals.
Limited disadvantages	Lower than normal rainfall can result in reduced water supply. This can affect feasibility of pond and livelihoods of the household. The storage capacity required for meeting household needs in dry years requires more labor input for construction and desilting.	Completely dependent on the frequency and amount of rainfall. Water may be contaminated if the storage tanks are not adequately covered. Uncovered or poorly covered storage tanks can be unsafe for small children. Contamination can also occur from dirty catchment areas.	Necessary to specify minimum well spacing based on the hydrogeological conditions of the area to ensure that the annual withdrawal remains less than the annual potential recharge.	Sand dams only work as transportation infrastructure for seasonal, low-flow rivers.	Dry-season land preparation can be very arduous.	No disadvantages mentioned in the research.
Reversibility and Flexibility	Does not have a lot of flexibility in the face of uncertainty. However, additional systems can often be built in communities that do not have adequate storage.	Does not have a lot of flexibility in the face of uncertainty. However, additional systems can often be built in communities that do not have adequate storage.	Most of investment could be removed or re-arranged if climate threat changes.	Helps cope with existing fluctuations in precipitation and water supply, in addition to vulnerabilities enhanced by climate change.	Can be adjusted or removed if desired.	Not specified in the research.

Table 5-3. Potential Adaptation Options for Decreased Seasonal Precipitation/Water Scarcity and Drought/Vulnerable Populations						
Guidance on when/where this option is most likely applicable	Suitable in areas where the subsurface layer lying at 1 to 3 m depth is clayey, favorably minimizing seepage losses.	Arid and semi-arid regions. Some technical skill and financial resources are required to set up the system.	Tube wells will not work well in areas with groundwater quality concerns (e.g., contaminated with arsenic).	Appropriate for any dryland region with seasonal rivers that have sandy sediment. Requires protection of land on either side of the dam (terraces and trenches to prevent erosion). Most successful as a method of community development or as a road crossing over a seasonal river in a wildlife reserve, or as part of a public works program. Ideal in mid to high catchment areas, where seasonal flow is less. Bedrock must be accessible in riverbed.	Zambia, and Africa in general, have seen successful spreading of conservation farming. Hand-hoe methods especially do not require increased investment.	Needs more research.
Examples of implementation	• Dug out ponds were used to increase water supply for livestock and domestic needs in the Makanya catchment in rural Tanzania.	• Rooftop rainwater harvesting systems were constructed to increase domestic water supply in the Makanya catchment in rural Tanzania.	• The Barind Multi-purpose Development Project in northwestern Bangladesh uses groundwater irrigation from deep tube wells for 0.4 million acres of semiarid land.	• SASOL, a local NGO in Kitui, Kenya has worked for more than ten years on the construction of sand dams, and over 400 have been constructed so far.	• A survey of 125 farms in Central and Southern Provinces of Zambia shows that a variety of conservation farming techniques were used (e.g., ox-drawn rip lines, hand-hoe basins for dry-season land preparation, retention of crop residue from prior harvest, and nitrogen-fixing crop rotations).	• In a laboratory research, wheat crops treated with symbiotic endophytes have survived up to 18 dry days while untreated wheat succumbed within 10 days.

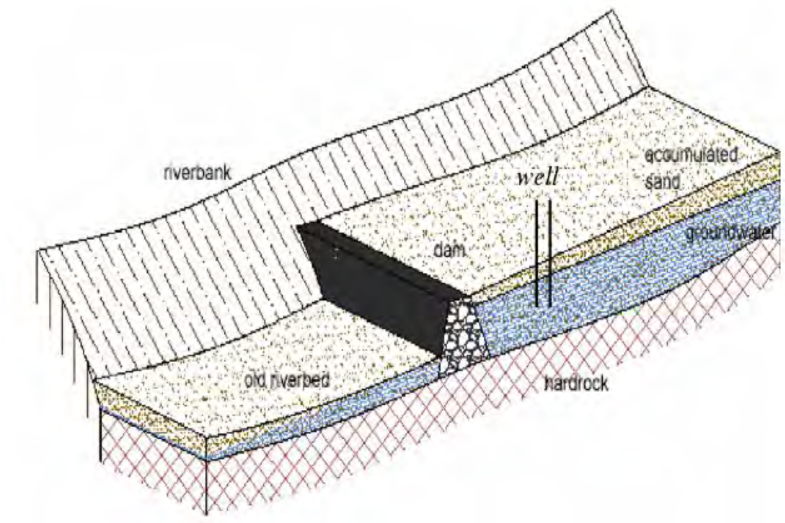

Figure 16. Diagram of a sand dam (Source: Lasage et al., 2008).

Figure 17. A finished sand dam (Source: Excellent Development, 2013).[8]

[8] Excellent Development. 2013. Pioneering sand dams. http://www.excellentdevelopment.com/what-we-do/pioneering-sand-dams

5.4. WARMER TEMPERATURES AND CHANGING PRECIPITATION/REDUCED SURFACE WATER QUALITY/FRESHWATER STREAMS, LAKES, WETLANDS

Climate hazard	Higher temperatures and changes in precipitation patterns, particularly more frequent and intense extreme precipitation events.
Impact	Lower surface water quality. Decreased summer flow and higher temperatures (which leads to increased evaporation) provides less dilution of nutrient and pathogen inputs. High intensity precipitation events increase surface runoff and erosion, increasing the nutrient load to surface water.
RSA at risk	Freshwater streams, lakes and wetlands.

Potential adaptation options

- Green Infrastructure: construction of wetlands for wastewater and stormwater management (2 examples)
- Point-of-use (POU) treatment: Faucet filtration systems (1 example)
- POU treatment: Chlorine disinfectant w/ safe water storage (1 example)
- POU treatment: Chlorine-flocculant sachets (1 example)
- POU treatment: Biosand filters (1 example)
- POU treatment: Ceramic filters (candle filters or ceramic water purifiers) (1 example)
- POU treatment: Solar water disinfection (1 example)
- POU treatment: Boiling (1 example)

Other adaptation options that were considered in the water sector but are not good candidates for fast-track implementation include flood early warning systems, disaster insurance, small multi-purpose reservoirs, and lowering lake levels to mitigate glacial lake outburst flood (GLOF) events. In fact, none of the options reviewed for GLOF events meet the fast-track implementation criteria.

Table 5-4. Potential Adaptation Options for Warmer Temperatures and Changing Precipitation/Reduced Surface Water Quality/Freshwater Streams, Lakes, Wetlands

	Green Infrastructure: construction of wetlands	POU Treatment: Faucet filtration systems	POU Treatment: Chlorine disinfectant w/ safe water storage	POU Treatment: Chlorine-flocculant sachets	POU Treatment: Biosand filters	POU Treatment: Ceramic filters (candle filters or ceramic water purifiers)	POU Treatment: Solar water disinfection	POU Treatment: Boiling
Straight-forwardness	Easy to construct, requiring no complex technologies.	Simple units to be attached to faucets, though some technologies are too advanced for less developed regions.	Simple 3-step process. Liquid alternatives are widely available in developing countries. Easy to transport and store.	Simple 5-step process. Powders are pre-measured in sachets – the only measurement is for quantity of water.	More complex than other POU options, but can use local materials and are still easy to use. Simple construction but can be labor-intensive.	Has been used since 19th century. Quality control is essential during production, but easy to use. Already high level of acceptance so education may not be necessary.	Can use household items (plastic bottles which are widely available in the developing world). The only non-commercial POU option.	Easy to do and most homes already have the hardware.

Table 5-4. Potential Adaptation Options for Warmer Temperatures and Changing Precipitation/Reduced Surface Water Quality/Freshwater Streams, Lakes, Wetlands								
Low cost	Low initial and maintenance cost.	Single-faucet units range from US$100 to 500. Requires regular maintenance and replacement, the rate depends on source water quality.	Chlorine concentrate costs US$1 per 1,000 liters of water. NaDCC tablets cost ~US$10 per 1,000 liters water. Low to medium O&M costs.	One sachet treats 10 liters of water. Cost is about US$ 0.01 per liter. Relatively more expensive than other chlorine POU treatment. Low to medium O&M costs.	Between $25-$100/household. Highest up-front cost for POU. Training and education on use is necessary for success. Little maintenance cost, very long lifespan.	Filter and pot cost roughly US$8-$10. Replacing filter costs $4-$5 USD. Requires regular cleaning, but this appears to incur little to no cost. Filters last two to three years.	$0.63 USD to treat water for one individual for one year, including training costs. Parts are very easy and cheap to replace	Cost is low and depends on fuel cost.
Effectiveness								
Reduction in climate vulnerability	The wetland compensates for climate change impacts on water quality by providing natural filtration of wastewater and prevents inundation to creek during large storm events.	In areas with connections and water quality issues, this will allow for consumption of otherwise non-potable water.	Effective against many pathogens.	Effective against many pathogens. Unlike other chlorine treatments, it is effective even in turbid water – the change in color makes effect obvious. Very effective against arsenic.	Produces greater volume of water than other POU, reduces turbidity. Effective against E. Coli and other pathogens. Highest documented post-intervention usage.	Effective against many pathogens.	Effective against many pathogens.	Effectively kills most pathogens if water reaches 212°F (100°C). Kills many pathogens even if water is heated to below-boiling temperature.
Limitations of protection	The capacity of the natural system has a certain limit.	Does not address overall water quality issues (pathogen/nutrient sources), or watershed-level management issues.	Turbidity can impact effectiveness (more turbidity means more chlorine must be used, but turbidity is difficult to measure by sight). Organic matter can absorb chlorine before it disinfects microbes.	In one study, 54% of treated samples did not contain high enough levels of residual chlorine to adequately disinfect water. It is possible that pre-measured amounts are not sufficient.	None found.	Produces lower volume of treated water, and this decreases over time even with proper maintenance. Effectiveness is reduced if production methods are not adhered to.	May require initial filtration method, especially to reduce turbidity. Limited to number of bottles a family has, and takes a long time to treat	Does not remove chemicals or turbidity.
Susceptibility to Damage of the Protection System	Low susceptibility. However, blockage must be prevented and the proper vegetation must be maintained.	Reductions in source water quality will require either more frequent replacement or a more complex filtration system	If climate change impacts decrease water quality further (including turbidity), higher dosages are required, and chlorine may not be effective beyond a certain point.	Pre-measured amounts could be insufficient given a further decrease in water quality due to climate change. Chlorine may not be effective beyond a certain point.	Greater concentrations of pathogens might require faster replacement.	Low to none.	Low to none for bottles. Reduced solar capacity due to climate change would limit the feasibility of this option.	None.

Table 5-4. Potential Adaptation Options for Warmer Temperatures and Changing Precipitation/Reduced Surface Water Quality/Freshwater Streams, Lakes, Wetlands								
Provide co-benefits	Recreational, aesthetic, and habitat benefits. Employs local labor.	None identified.	25%-48% diarrheal disease reduction (estimate).	18%-42% diarrheal disease reduction (estimate). Filtration through cheesecloth (part of the overall process) reduces both turbidity and chlorine taste.	21%-64% diarrheal disease reduction (estimate).	Candle: 51% - 72% diarrheal disease reduction (estimate). Ceramic water purifier: 29% - 59% diarrheal disease reduction (estimate).	26%-37% diarrheal disease reduction (estimate).	None.
Limited disadvantages	No significant social/environment al costs.	No significant social/environment al costs.	End-users have shown resistance due to the residual taste and smell of chlorine-treated water. As a result, users will treat water, but wait 2-3 days before consuming, which presents additional health hazards associated with open, stagnant water storage.	Even though it solves the sight and taste issues, resistance to this option still occurs because it doesn't entirely solve either problem.	Less effective in cleaning water in beginning stages.	Fragile, replacement parts not readily available.	Does not improve look, taste, or smell.	Can be labor and time intensive. Does not improve taste. Wood fuel can lead to deforestation. May increase health hazards such as burns or indoor air pollution.
Reversibility and Flexibility	High. The wetland does not require investment in large-scale infrastructure and will continue to provide water quality and recreation benefits.	High – better source water quality will only further improve water quality post-treatment.	Inexpensive and effective against many pathogens, so high reversibility and flexibility.	Relatively inexpensive compared to non-POU water treatment options and effective against many pathogens, so high reversibility and flexibility.	Higher up-front costs make it less reversible, but can still be reversed. The option deals with water quality issues regardless of climate change impacts.	Inexpensive and effective against many pathogens, so high reversibility and flexibility.	Low cost of supplies suggests reversibility, but multiple factors involved in disinfection process limit flexibility.	Flexibility depends on how climate change affects concentrations of pathogens, chemicals, turbidity, and fuel costs.
Guidance on when/where this option is most likely applicable	Needs adequate space but would be applicable in most developing countries with adequate rainfall due to low technical and cost requirements. Can be used either alone or integrated with other water treatment systems.	Requires either market for off-the-counter technologies or capacity for an organization to distribute. Requires education on maintenance and policy continuity. Good option for areas with low/no connectivity to water district.	Chlorine treatment must be purchased on a regular basis. Depending on uptake, may require ongoing education on both use and importance of subsequent storage. Requires safe water storage containers.	Must be purchased on a regular basis. Depending on uptake, may require ongoing education on both use (ensuring pre-measured amounts are sufficient for disinfection) and importance of safe subsequent storage.	Requires safe water storage containers, and highly dependent on a production facility being nearby (or subsidy of transporting filters to intervention locations).	Production methods must be strictly adhered to. Requires regular cleaning.	Requires households with enough space to store bottles for disinfection process.	Most applicable where fuel cost is low. Requires safe water storage containers.

Table 5-4. Potential Adaptation Options for Warmer Temperatures and Changing Precipitation/Reduced Surface Water Quality/Freshwater Streams, Lakes, Wetlands								
Examples of implementation	• The municipality of Udonthani, Thailand turned existing waterways from municipal sewers into natural treatment systems to supplement the existing municipal wastewater treatment.	• A paper analyzes the feasibility of implementing faucet filtration systems in the Metro Iloilo area of the Philippines. However, the measure has not been implemented.	• The above information is taken from a survey of chlorine disinfectant with safe water storage in Rural South India.	• The Children's Safe Drinking Water Program, a partnership between P&G, the CDC, and other organizations, distributed approximately 85 million chlorine-flocculant sachets free of charge from 2004-2011.	• As of November 2010, the South Asia Pure Water Initiative, Inc. (SAPWII), a non-profit organization based in Connecticut, has introduced biosand filters to 14 villages in and around the Kolar District.	• Commercial ceramic candle filters have been sold in India for decades. Potters for Peace, IDE, and the Practical Foundation have sold filters or consulted with smaller filter producers in South India.	• A solar water disinfection project was created in the southern state of Tamil Nadu in 2002. An estimated 275,000 families use this method in all of India, with ~100,000 of those in Tamil Nadu.	• According to a 2005-2006 Indian Demographic and Health Survey, approximately 10.6% of the Indian population said they boiled their water on a regular basis.

Figure 18. A finished ceramic filter and container with a cross-section of the mechanics of a ceramic filter (Source: Jeffreys, 2012).

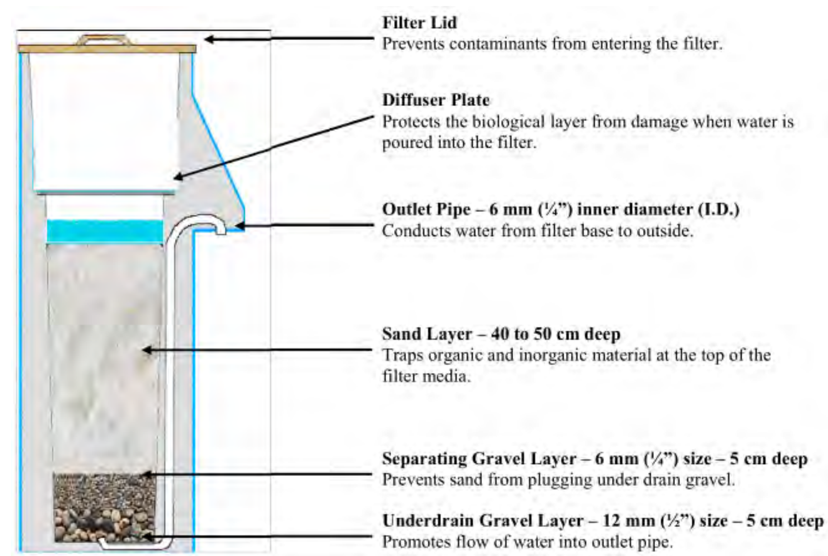

Figure 19. Cross-section of a Biosand Filtration System (Source: Jeffreys, 2012).

6. ENERGY

6.1. SLR AND STORM SURGE/DAMAGE AND LOSS/GENERATION, TRANSMISSION, AND DISTRIBUTION ASSETS

Climate hazard	Sea level rise and storm surges.
Impact	Increased vulnerability of traditional (i.e., conventional fossil fuel and nuclear) and renewable energy infrastructure and resources to weather variability (damage from storms, floods, and permanent water intrusion).
RSA at risk	Renewable and conventional energy generation, transmission/transportation, and distribution assets and resources located near coasts and offshore. For example, on or near coasts, there can be substantial wind farms and related infrastructure (e.g., substations), electricity and natural gas lines, conventional generation facilities, power for telecom towers and other important distributed uses, and biomass resources. Offshore renewable assets (wind and tidal) and resources could also be affected. Coastal subpopulations would be heavily affected by decreased availability, and increased pricing, of energy.

Potential adaptation options

- Revise building codes and infrastructure siting policies (3 examples)
- De-energize electrical infrastructure (3 examples)
- Substation and equipment protection (6 examples)

There is no inexpensive short-term solution for substation and equipment raising and re-location, while long-term solutions for this option are expensive. As a result the option is not a good candidate for fast-track implementation.

Table 6-1. Potential Adaptation Options for SLR and Storm Surge/Damage and Loss/Generation, Transmission and Distribution Assets

	Revise building codes and infrastructure siting policies	De-energize electrical infrastructure	Substation and equipment protection
Straightforward-ness	Technically straightforward but can be institutionally and legally challenging, especially in places with weak enforcement of building regulations; can face resistance from building owners and developers.	Simple and quick to develop plan to de-energize electrical equipment prior to storm. Less straightforward to provide power to critical loads during grid de-energized period. Less likely to face institutional and legal barriers.	Technically straightforward to provide physical protection to low-lying substation and other critical infrastructure. Less likely to face institutional and legal barriers.
Low cost	Low initial cost to revise building codes or conduct study to identify less at-risk areas for infrastructure siting; little ongoing cost if this is part of normal monitoring and enforcement of building codes/ infrastructure siting policies.	Inexpensive to develop de-energizing plan; more expensive to identify critical loads and provide back-up alternatives.	Building concrete walls is more expensive than installing sandbags but provides longer term protection. The up-front cost of physical protection is higher than revising building codes and infrastructure siting policies and de-energizing electrical infrastructure.
Effectiveness			
Reduction in climate vulnerability	Locating equipment on first floor instead of basements or at ground level and locating infrastructure in less at-risk areas reduces damage.	Reduces damage to equipment, allows quicker restoration.	Reduces damage from sea level rise and storm surges.

Table 6-1. Potential Adaptation Options for SLR and Storm Surge/Damage and Loss/Generation, Transmission and Distribution Assets			
Limitations of protection	Does not address possible loss of utility interconnection. Only applies to new infrastructure and does not address impact to existing infrastructure. Revised building codes may not address the impacts of sea level rise (if the building itself is not elevated or protected from sea level rise by physical infrastructure).	De-energize sections of the grid, isolates equipment to minimize damage to the whole system. Addresses impact to existing infrastructure. Does not protect against physical damage from sea level rise and storm surges.	Addresses impact to existing infrastructure. Protects against physical damage from sea level rise and storm surges. However, height of protective wall may be insufficient for large storm surges.
Susceptibility to Damage of the Protection System	Potential for increased vulnerability to other storm damage (wind) if equipment is located on higher floors of buildings.	None.	Temporary sandbags and concrete walls are of low susceptibility to damage from sea level rise and storm surges.
Provide co-benefits	Revised building codes can reduce the chance of fuel leakage and associated pollution during storms.	Reduced safety risk to emergency responders and others from fallen energized power lines. Reduced chance of fire damage to infrastructure.	Added theft and vandalism security.
Limited disadvantages	Revised building codes may reduce available rental space, increase noise, and increase fire risks. Infrastructure siting may require infrastructure to be in areas attractive to other development.	Populations who are disconnected by de-energized infrastructure can be impacted during a storm or flooding incident.	May reduce some access for maintenance.
Reversibility and Flexibility	Building codes/infrastructure siting policies are easily reversible but changing location of equipment/infrastructure once installed is difficult.	De-energized plans are easily reversible.	Walls can be demolished, but potential impacts to coastal ecosystems can be irreversible or it can take a long time for ecosystems to recover. Walls can be designed so that they can be heightened to cope with future sea level rise or storm patterns.
Guidance on when/where this option is most likely applicable	Any location susceptible to flooding or in low lying areas; more applicable to places with existing effective enforcement of building and siting regulations.	Any utility service area, but more applicable to areas with higher coordinating capacity as this action requires significant coordination with the utility and service delivery partners.	Where substation and other critical energy infrastructure are located in low-lying areas and are expensive and difficult to relocate.
Examples of implementation	• New York City is developing new building codes after Hurricane Sandy to require energy equipment to be located above potential flood levels. • The UK Government commissioned a study (The Pitt Review) to provide recommendations for changes in siting policies for new critical water, electrical, and other infrastructure (as well as improvements to existing infrastructure).	• Northern Power Grid in UK established a code of practice to de-energize substations prior to flooding. • Atlantic City Electric, which serves the barrier islands on New Jersey's eastern seaboard, developed plans to shut down and de-energize sections of the grid during hurricanes. • Con Edison in New York is redesigning its electrical networks to preemptively de-energize customers in flood-prone areas to restore power faster once floodwaters recede and keep customers in surrounding areas with power.	• Waltham substation in the north of Gloucester, UK built 1,000 meters of sandbag defenses to prevent flooding of the substation in summer of 2007. Once the flooding receded, a permanent concrete wall was built around the substation. • After major damage from a hurricane, the Armed Forces Retirement Home in Gulfport, Mississippi was rebuilt with new back-up and emergency systems and all utility infrastructures installed on the first floor. Fuel storage tanks and emergency generators were located on a raised platform on the land side of the main building to protect against wind and storm surge. • Con Edison is investing $1 billion on storm protection measures over the next four years in New York City and Westchester County, such as building concrete flood barriers around substations and critical equipment and installing floodgates in tunnels.

Table 6-1. Potential Adaptation Options for SLR and Storm Surge/Damage and Loss/Generation, Transmission and Distribution Assets			
Conclusion	This option is particularly good for reducing the vulnerability of new infrastructure and equipment to sea level rise, storm surges, and flooding. However, it relies on a government's ability to enforce building codes and infrastructure siting policies. Revised building codes may reduce available rental space, increase noise, and increase fire risks. Infrastructure siting may require infrastructure to be in areas attractive to other development.	This option is particularly good for reducing damage to the electrical system from a storm event, limiting the extent of power outages and enabling faster power restoration after the storm. However, critical loads need to be identified and have back-up systems installed. There needs to be plans for protecting or evacuating de-energized customers who will be isolated.	This option is particularly good for situations where critical electrical infrastructure are located in high-vulnerability areas from sea level rise and storm surges, and are difficult and expensive to be relocated (even after long-term costs and benefits are taken into account). However, protective measures may not be enough for very large storm events. Sea walls need to be built so that additional height can be added if necessary to account for future sea level rise and storm surge height.

6.2. WARMER TEMPERATURES AND HEAT WAVES/INCREASED ENERGY DEMAND, STRESSED SYSTEMS, HIGHER POLLUTANT EMISSIONS/TRANSMISSION ASSETS, EXPOSED POPULATIONS

Climate hazard	Higher temperatures, and increases in the frequency, intensity and duration of heat wave events
Impact	Increased energy demand, especially for cooling. Increased stress on power grids will result in more system failures and will require the construction of additional grid transmission and distribution infrastructure. Lower efficiencies of generation equipment will result in increased fuel use, more expensive generation alternatives being brought on-line, and higher emissions.
RSA at risk	Transmission/distribution grid systems; communities served by overloaded/unreliable power grids; electricity consumers impacted by higher costs (decreasing funds for other activities); communities impacted by higher air emissions, especially urban populations in warm climates with poor air quality; increased fossil-fuel resource depletion to meet higher energy demand. (Could have the opposite effects in the minority of areas with extreme heating, not cooling, demands).

Potential adaptation options

- Improve industrial energy efficiency (4 examples)
- Reduce energy consumption in residential and commercial buildings (6 examples)
- Implement TOD (Time of Day) metering and differential pricing (5 examples)
- Toughen energy efficiency standards that specify the minimum allowable energy performance for appliances, lighting and equipment (4 examples)

Table 6-2. Potential Adaptation Options for Warmer Temperatures and Heat Waves/Increased Energy Demand, Stressed Systems, Higher Pollutant Emissions/Transmission Assets, Exposed Populations

	Improve industrial energy efficiency	Reduce energy consumption in residential and commercial buildings	Implement TOD (Time of Day) metering and differential pricing	Toughen energy efficiency standards of appliances, lighting, and equipment
Straightforward-ness	Well-established techniques exist. Actions can be simple such as energy audits and benchmarking.	Well-established techniques with low technology and equipment requirements exist.	Not as well-established as industrial, residential, and commercial energy efficiency, but option is still relatively simple. Public engagement is necessary to encourage changes in energy usage patterns.	Governments need to be able to enforce energy efficiency standards. Can face resistance from manufacturers of less energy efficient equipment.
Low cost	Energy efficiency measures can pay for themselves and result in cost savings over time.	Energy efficiency measures can pay for themselves and result in cost savings over time.	Initial costs of local demand analysis that already exists in many places, and of purchasing and installing TOD meters that can be paid back over time through energy savings. Ongoing costs are part of regular monitoring and maintenance of metering system.	Initial costs of establishing standards and ongoing costs of enforcing them. The standards will result in energy savings over time.
Effectiveness				
Reduction in climate vulnerability	Since the industrial sector uses large amounts of energy, reductions in this sector will decrease stress on the energy system and lower the chance of failures.	Decreases stress on the energy system and lower the chance of failures. Measures such as weatherization also reduce temperatures in buildings.	Reduces peak load energy demand, decreases stress on the energy system and lower the chance of failures. Decreases the need to build additional capacity, at least in the short term.	Reduces energy consumption of households and businesses. In particular, more efficient air conditioning will reduce peak load energy demand during heat waves.

Table 6-2. Potential Adaptation Options for Warmer Temperatures and Heat Waves/Increased Energy Demand, Stressed Systems, Higher Pollutant Emissions/Transmission Assets, Exposed Populations				
Limitations of protection	Reduces the chance of outages but does not provide protection from higher temperatures if outages do occur. If increases in energy demand continue as temperatures rise, adding capacity will be necessary.			
Susceptibility to Damage of the Protection System	None.			
Provide co-benefits	Lower GHG emissions. Lower energy costs for businesses.	Lower GHG emissions. Lower energy costs for residential and commercial building tenants.	Lower GHG emissions. Lower energy costs for consumers who change their usage to off-peak hours.	Lower GHG emissions. Lower energy costs for households and businesses.
Limited disadvantages	Simple, low-cost energy efficiency measures may mask the need to replace inefficient equipment.	No disadvantages.	Consumers who do not have flexibility in their time of usage will pay higher energy costs.	Products with higher energy efficiency may be more expensive.
Reversibility and Flexibility	Easily reversible.	Easily reversible.	While pricing can be modified, it may be politically difficult to undo TOD pricing.	Energy efficiency standards are adjustable; however, the ease with which standards are changed will depend on the regulatory agency.
Guidance on when/where this option is most likely applicable	Places with inefficient industries and 'low-hanging fruit' opportunities to improve energy efficiency.	Places with high concentration of residential and commercial buildings (e.g., metropolitan areas)	TOD pricing will be most effective where power cuts are used to meet peak demand, and rate payers are aware of the nature of the problem.	Places with good institutional capacity to enforce energy standards. The regulatory authority must be sympathetic to the need for climate risk management and flexible enough to make the necessary change.
Examples of implementation	• Bangladesh has undertaken a pilot to benchmark plant-level energy use with other plants in the industry to identify opportunities for energy efficiency improvement. • The Alliance to Save Energy implemented a project to increase energy efficiency of 5 rice mills and measure the results to share with over 80 other rice mills in Tamil Nadu, India.	• The US-China Sustainable Building Partnership is working on reducing energy use in existing buildings, promoting green design and certification for new buildings, and promoting US-China cooperation in building energy efficiency. • The government of Vietnam developed a national code in 2005 to require energy efficiency measures in the construction and renovation of buildings (the Vietnam Building Energy Efficiency Code, or VBEEC).	• Ghana's standards and labels (S&L) initiative started with a room air conditioner minimum energy performance standard, which achieved great success and set a precedent for future standards. • The Collaborative Labeling and Appliance Standards Program (CLASP) has assisted India and China with developing appliance standards and labeling. • South Africa is moving from a voluntary labeling program to a mandatory standard and labeling program for 12 common appliances.	• Kerala State Electricity Board in India has made TOD metering applicable to domestic customers drawing more than 500 units a month. The rate increases for peak hours from 6 to 10 pm, and decreases for off-peak hours from 10 pm to 6 am. • TOD tariff system has also been implemented in Delhi, Karnataka, and Punjab of India. • Tanzania is conducting a study to identify measures to improve demand-side management capability, including developing and improving TOD tariffs.
Conclusion	This option presents a synergy between climate change adaptation and mitigation. It is particularly applicable to places where many low-hanging fruit opportunities for reducing industrial energy efficiency exist. It also presents an opportunity for technology transfer and capacity building in developing countries.	This option presents a synergy between climate change adaptation and mitigation. It is particularly applicable to metropolitan areas where there is a high concentration of residential and commercial buildings and where residents feel the most impacts of high temperatures through the urban heat island effects. It also presents an opportunity for technology transfer and capacity building in developing countries.	This option presents a synergy between climate change adaptation and mitigation. It is most applicable to areas where power outages frequently occur during peak hours. It relies on public awareness and education to gain communities' support.	This option presents a synergy between climate change adaptation and mitigation. It also presents an opportunity for technology transfer and capacity building in developing countries. It is most applicable to areas where the government has the capability to enforce energy efficient standards.

6.3. PRECIPITATION AND HYDROLOGIC CHANGES/DECREASED WATER AVAILABILITY/GENERATION ASSETS

Climate hazard	Changes in precipitation patterns, earlier and more rapid snowmelt, and changes in hydrology.
Impact	Decreased availability and increased competition for water for operation of energy infrastructure. Water resources for hydro generation may decline. Competition for energy infrastructure cooling water will increase. Reduced flow in rivers may result in higher temperature rise from cooling water discharge from thermal power plants, impacting downstream uses, flora, and fauna.
RSA at risk	Thermal, nuclear and hydro power plants; freshwater ecosystems; water consumers (e.g., agriculture, domestic and industrial water users); populations relying on biomass for cooking and heating fuel, especially those rural, off-grid subpopulations with little or no access to other alternative energy resources and assets.

Potential adaptation options

- Promote low/no water use power generation alternatives and develop standards/regulations for power plant water use (e.g., gallons/MWh) (3 examples)
- Utilize "grey" water for thermal power plant cooling (5 examples)
- Research/plant/manage biomass species requiring less water (2 examples)
- Increase planting/use of biomass/energy crops in marginal lands (4 examples)
- Improve/increase biomass storage to reduce harvesting during rainy/mud season

Table 6-3. Potential Adaptation Options for Precipitation and Hydrologic Changes/Decreased Water Availability/Generation Assets

	Promote low/no water use power generation alternatives and develop standards/regulations for power plant water use	Utilize 'grey' water for thermal power plant cooling	Research/plant/manage biomass species requiring less water	Increase planting/use of biomass/energy crops in marginal lands
Straightforwardness	Simple to promote low/no water use power generation alternatives (e.g., wind, solar, fuel cells) but hard to implement them widely. Simple to design standards, guidance, and regulations for power plant water use; however this option can face institutional and political barriers as implementation can increase energy costs.	Straightforward method of replacing freshwater with 'grey' water from wastewater treatment plants and other sources to cool thermal power plant. However, a certain degree of technical capacity is required. Institutional and political straightforward, less likely to face opposition.	Straightforward method of researching into biomass species to identify low water use varieties. However, a certain degree of scientific expertise is required. Less likely to face opposition if the new species are grown on existing land used for energy crops.	Straightforward method of researching to identify marginal lands and plant energy crops on those lands. Can face institutional and political barriers if the marginal lands have competing uses.
Low cost	Developing standards, guidance, and regulations is low cost, but implementing low/no water use cooling for new power plants and low/no water use power generation alternatives is expensive. However, low cost incentives such as tax credits related to consumptive water use equipment will promote implementation.	Relatively high initial capital cost to install the connection between wastewater treatment plant and power plant, as well as the chemical treatment equipment at power plant to treat grey water before use, plus ongoing O&M cost.	Relatively low initial costs to research and promote biomass species requiring less water. Low additional costs for on-going research, management, and replanting of biomass.	Initial relatively low cost to identify marginal lands and promote planting of energy crops on them. Low long-term costs for management and replanting of biomass except some species that are sterile hybrids (e.g., Miscanthus) where replanting requires additional expense.

Table 6-3. Potential Adaptation Options for Precipitation and Hydrologic Changes/Decreased Water Availability/Generation Assets				
Effectiveness				
Reduction in climate vulnerability	Reduces impacts of drought and low precipitation on power generation. Increases availability of water resources that can be used for other purposes such as drinking, sanitation, or agriculture.	Reduces impacts of drought and low precipitation on power generation. Increases availability of water resources that can be used for other purposes such as drinking, sanitation, or agriculture.	Provides the ability to continue sourcing biomass for cooking, domestic heating, and power generation in arid and drought prone areas or where precipitation patterns have changed.	Provides the ability to continue sourcing biomass for cooking, domestic heating, and power generation. Reduces the conflict with food and feed production.
Limitations of protection	Low/no water use cooling methods decrease power generation efficiency and require higher capital and operating costs. Reduced dependence on water availability will depend on the alternative generation technology selected (e.g., solar thermal plants still require water for cooling). Subject to compliance with regulations. Only effective for new installations unless retrofitting is required.	Only effective if there is a ready source of "grey" water near a power plant operation.	Severe droughts may prevent even drought tolerate biomass species from being established and growing.	Marginal lands may have competing uses and become unavailable for energy crops growing.
Susceptibility to Damage of the Protection System	Siting and design of no/low water use power generation alternatives should take into account the impacts of climate change on the facility's lifetime to minimize future vulnerabilities.	None other than potential corrosion of power plant cooling systems with grey water than must be treated before use.	Biomass crops may be damaged by fires, storms, excessive rainfall, and other extreme weather events.	Biomass crops may be damaged by fires, storms, excessive rainfall, and other extreme weather events.
Provide co-benefits	Promotes use of renewable technologies (such as wind and solar energy) that reduce GHG and criteria air pollutant emissions. Reduces impacts on ecosystems from discharge of cooling water.	Reduces discharge of "grey" water into rivers and streams with possible pollution consequences. May lower costs of power generation because of lower costs of water.	Promotes the management and utilization of existing biomass resources, helping to prevent soil erosion and de-forestation.	May reduce removal of existing biomass that currently provides shelter and shade, retains moisture, and reduces water run-off and soil erosion. May increase CO_2 captured and contribute to enhanced wildlife habitats if the marginal land was empty.
Limited disadvantages	Some generation technologies may be more capital intensive and have higher operating costs than traditional coal-fired plants. Low/no water-cooling methods may add to costs of generation due to possible lower cooling efficiency.	Needs proximity to suitable, treated wastewater source. May increase the cost of treatment of water in a power plant resulting in higher operating costs and higher energy costs. Some issues with chemical treatment of grey water before using it for cooling must be addressed.	Potential for increased fire risks.	Care must be taken to not introduce invasive species (e.g., reed canary grass) that may disrupt existing indigenous species.
Reversibility and Flexibility	Limited reversibility once the alternative generation technologies/ cooling systems are installed. Can reduce support for alternative generation if threat diminishes. Regulations can be amended or reversed.	Can be reversed if there is another, more suitable source of cooling water in future.	Easy to stop promoting biomass resources that require less water and stop managing those that have been planted.	Easy to stop managing and re-planting but not so easy to remove all planted biomass crops from the marginal lands.

Table 6-3. Potential Adaptation Options for Precipitation and Hydrologic Changes/Decreased Water Availability/Generation Assets				
Guidance on when/where this option is most likely applicable	Any new power generation facility where there is reduced availability of and competing uses for water.	Any location where a power plant is located within reasonable pipeline pumping distance from a wastewater treatment facility.	Any areas where biomass is grown for domestic cooking/heating and commercial uses.	Any areas where biomass is used for domestic cooking/heating and commercial uses and marginal land is available.
Examples of implementation	• Eskom, a South African electricity public utility, establishes each year for each power plant water use targets (liters of water per unit of electricity produced). It has introduced technologies to save water such as dry cooling and desalination of polluted mine water for use at power stations.	• Los Angeles Water and Power District (LADWP) is supplying Valley Generating Station recycled "grey" water to use in its cooling process. • Emirates Central Cooling Corporation in Dubai has switched from using desalinated water to using treated sewage water for its cooling towers in Dubai Healthcare City.	• A study suggests that agave, which is currently known for its use in the production of alcoholic beverages and fibers and can withstand low and intermittent rainfall, can be a good bio-energy crop. Abandoned agave plantations in Mexico and Africa that previously supported the natural fiber market could be reclaimed as bioenergy cropland.	• A study suggests that there are about 116 million acres of marginal land around Mississippi and Missouri Rivers that is unsuitable for traditional crops because of flooding, erosion, and poor soil. This marginal land can be used to grow energy crops that require little or no fertilizer and will help stabilize the soil.
Conclusion	This option addresses water shortage and competing uses for water. It also reduces the impacts of discharged cooling water on fauna and flora. However, dry cooling is expensive to install and maintain; it also reduces power generating efficiency and increases energy costs. Installing no/low water alternative generation technologies is expensive. A less expensive option is to provide financial incentives to encourage the use of no/low water technologies.	This option is most applicable in locations where a power plant is located within reasonable pipeline pumping distance from a wastewater treatment facility. It does not reduce power generating efficiency as dry cooling and may reduce energy production costs due to lower price of water, but may increase costs due to the need of water treatment in power plants before use for cooling.	This option is most applicable in locations where biomass is grown for domestic cooking/heating and commercial uses and water availability is an issue. A certain degree of technical expertise is required to identify low water use biomass varieties. It will be less likely to face opposition if the new species are grown on existing land used for energy crops.	This option is most applicable to areas where biomass is used for domestic cooking/heating and commercial uses and marginal land is available (there is no competing use of the marginal land).

6.4. INCREASED WEATHER VARIABILITY/DECREASED RELIABILITY AND INCREASED VULNERABILITY/RENEWABLE AND CONVENTIONAL ENERGY ASSETS

Climate hazard	Increased weather variability (e.g., changes in wind speed and direction) with higher frequency and intensity of extreme precipitation, storms, and floods.
Impact	Decreased reliability and predictability of renewable energy sources. Increased vulnerability of energy infrastructure and fuel supply systems in all locations to weather events. Changes in weather patterns, including wind speed and direction, will cause disruptions in the ability of existing renewable generation facilities to provide reliable capacity and to be financed. Extreme precipitation can damage electricity and fuel distribution infrastructure.
RSA at risk	Impediment to renewable energy asset development (e.g., wind); damage to conventional power plant, electricity transmission and distribution assets, and fuel distribution networks; decreased energy availability for subpopulations affected by extreme weather events.

Potential adaptation options

- Modify zoning regulations for the siting of new energy infrastructure to reduce vulnerability to extreme weather and precipitation events (3 examples)
- Weather-index-based insurance/weather derivatives (6 examples)
- Establish power purchase agreements (PPAs) with neighboring countries and/or large energy users to help respond to the impacts of extreme weather events on energy systems (four examples)
- Require the incorporation of climate vulnerabilities into renewable resource assessments in the planning phase of investments (6 examples)

Table 6-4. Potential Adaptation Options for Increased Weather Variability/Decreased Reliability and Increased Vulnerability/Renewable and Conventional Energy Assets

	Modify zoning regulations for the siting of new energy infrastructure	Weather-index-based insurance/weather derivatives	Establish power purchase agreements (PPAs) with neighboring countries and/or large energy users	Require the incorporation of climate risks into renewable resource assessments
Straightforward-ness	Technically straightforward, available knowledge on climate change impacts will inform zoning regulations. Local government needs to be able to enforce zoning.	Technically straightforward, but implementation can be difficult in immature insurance/financial markets.	Technically straightforward, less politically and institutionally simple because agreements may be complex to negotiate.	Technically straightforward, renewable projects already have the required expertise (e.g., hydrological/wind/solar modeling) to incorporate climate into the assessments.
Low cost	Low initial cost to modify zoning regulations; little ongoing cost as this is part of normal enforcement of zoning regulations.	There will be cost to purchase the weather insurance/ derivatives, but the impacts of weather events will be reduced when they occur.	Legal costs are high but lower than developing alternative energy sources.	Low because incorporating climate risks adds little cost to the existing analysis.
Effectiveness				
Reduction in climate vulnerability	Prevents construction at high vulnerability locations.	Reduces the financial vulnerability of energy projects to extreme weather events.	Diversifies energy sources and reduces exposure to power outages from extreme events.	Avoids developing projects in sites most vulnerable to resource disruption. Projects can plan for climate risks.
Limitations of protection	Protects new infrastructure but not existing ones. Climate change impacts are difficult to predict, and zoning changes may be inadequate.	These instruments are relatively new and unknown, may hinder their adoption in the near future.	Does not reduce impacts during widespread extreme events that affect large areas.	Climate change impacts are difficult to predict. Damage can still occur if the event is of greater magnitude that what the project planned for.

Table 6-4. Potential Adaptation Options for Increased Weather Variability/Decreased Reliability and Increased Vulnerability/Renewable and Conventional Energy Assets				
Susceptibility to Damage of the Protection System	Depending on the severity of the weather event, structures built to meet new zoning requirements may still suffer damage.	Widespread extreme events can hurt the weather insurance/derivative provider and increase costs of buying insurance/ derivatives.	Damage to transmission lines during extreme weather or precipitation events may curtail cross-border energy trading.	None.
Provide co-benefits	Construction that complies with climate-sensitive zoning may be eligible for lower flood insurance premiums.	Can give a boost to renewable energy development and make development feasible at more sites.	Increases energy security, increases regional trade, cooperation, and economic growth.	More robust planning and modeling will facilitate and increase renewable project financing.
Limited disadvantages	Climate change impacts are difficult to predict, and zoning changes may be inadequate.	Insuring away some vulnerability could lead to development of sites with mediocre renewable resources.	Can delay the construction of energy infrastructure necessary to meet local or national demand.	Increased data and analysis requirements will lead to longer project development times.
Reversibility and Flexibility	Changes to zoning laws are reversible.	A company can choose to stop purchasing weather insurance/ derivatives.	PPAs can be written with termination clauses that address climate change uncertainty.	Policies and requirements of incorporating climate risk s can be changed.
Guidance on when/where this option is most likely applicable	The regulatory authority responsible for land-use zoning must be sympathetic to the need for climate risk management and flexible enough to make the necessary changes.	Insurance can mitigate vulnerabilities for any renewable project, however, it is most useful for projects that seek debt financing at sites with wide variability in the availability of the renewable resource.	The regulatory authority responsible for energy planning must be sympathetic to the need for climate risk management. Neighboring countries or large energy users with excess capacity must be available.	Financing entities are in the best position to require this type of analysis since climate risk affects a project's profitability.
Examples of implementation	• New York City announced that it will revise its zoning codes to help property owners update buildings to meet new flood standards in the wake of Hurricane Sandy. • Under the Boston Zoning Code, Boston Redevelopment Authority has begun asking developers of projects that may be subject to more frequent coastal flooding due to sea-level rise to analyze the effects of climate change.	• Munich Re, a German reinsurance company, offers covers against turnover losses resulting from a lack of wind to ensure that on- and offshore wind power projects do not slide into financial distress in such low-wind years.	• Bhutan provides electricity to India and the sale of this electricity contributes to 40% of Bhutan's national revenue. • The SIEPAC Project is a major undertaking to connect the power grids of six countries: Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica and Panama. This network will serve more than 30 million people throughout Central America.	• FutureWater performed a rapid assessment on the impact of climate change on hydropower generation in the Tana Basin in Kenya using the WEAP (Water Evaluation and Planning tool) approach. • A study was conducted to evaluate climate change impacts on renewable energy resources in Croatia, including photovoltaic, wind, and hydro energy.
Conclusion	This option is most applicable to places where the authority is able to enforce zoning laws. However, since the precise nature of changing climate stresses is difficult to predict, structures built in compliance with the zoning law can still be damaged by extreme weather events.	This option is most useful for projects that seek debt financing at sites with wide variability in the availability of the renewable resource. It is however a relatively new instrument and is difficult to implement in an immature insurance/ financial market.	This option is most useful for countries with neighboring nations or large energy users with excess capacity. However, it can be complex to negotiate an agreement and it does not reduce the impact during a widespread weather event.	This option is most applicable to financing entities who would like to know the climate risks a project faces to inform their decisions. As climate change is difficult to predict, damage can still occur if the event is of greater magnitude that what the project planned for.

APPENDIX B: FTI DESIGN CRITERIA

FTI Design Criteria	Components
Straightforward (Straightforward)	Can the option be designed and implemented relatively quickly and easily (note that speed is not always needed, depending on the rate of climate change and impacts)? **Technically straightforward.** Does the option require sophisticated technology or expertise to develop and implement? **Institutionally and legally straightforward.** Are existing institutions supportive or are new ones needed? For example, the option does not require a complex or lengthy approvals process. **Political and cultural considerations.** The option does not involve any complications due to political or cultural objections or considerations.
Cost (low)	**Initial/up front costs.** Startup cost related to engineering or other design, programmatic cost, capital investment (equipment, infrastructure, or land), labor or materials, permits, trials, or pilots. **Ongoing costs**. Costs associated with operations, maintenance, or otherwise implementing the option once it is in place.
Effectiveness (effective)	**Reduction in climate vulnerability.** How well does the option reduce the consequences/impacts of climate change in the near term (addresses immediate problems) and over time (e.g., as climate change worsens or as other stressors, such as population growth, occur). Note that options can be effective in reducing climate vulnerability by decreasing exposure or decreasing climate sensitivity, or improving adaptive capacity. *For example, relocating buildings further inland or building a sea wall reduces exposure; changing building materials reduces sensitivity to the influences of climate if the new building materials are less easily damaged (e.g., concrete vs. wood). As another example, if the introduction of grey water recycling results in reduced frequency (or reduced severity) of urban water shortage problems, this demonstrates a reduction in climate vulnerability, by reducing sensitivity to drought. Adaptive capacity may have elements of these--but also includes the ability to respond to consequences, and so includes a host of other actions: e.g., funding and educating a more robust public health system, or designing and building better evacuation routes, or providing a flood warning system--all enhance adaptive capacity.*
	Limits of protection (Robustness in the face of uncertainty). Will the adaptation option provide benefits for a range of expected (and unexpected) climate events or differences in the magnitude and/or directions of climate change? What is the extent of climate vulnerability that each adaptation option is able to counter before it is rendered less effective? *For example, does it provide protection against most floods, or also against the rare, high consequence flood event? What about low probability high consequence events, such as the "perfect storm"? Some options, like surrounding dykes for flood protection, are very effective at preventing moderate impacts. However, in the case of extreme high water floods they can actually become a liability because they prevent the floodwater from draining.*
	Susceptibility to damage of the protection system. How fragile is the adaptation option itself — does it degrade or become damaged over time? Ideally, options should be robust and durable. *For example, for culverts to be effective, they require systematic maintenance and cleaning. As another example, established mangrove forests can withstand severe storms, but young plants are vulnerable to high winds and waves.*

FTI Design Criteria	Components
Co-benefits (provides co-benefits)	Provides benefits in areas (e.g., other climate adaptation or promotes development or other goals) that are separate from the climate impact it is responding to. *For example, re-establishing wetlands improves water quality for downstream cities, but also provides more resilient habitats for endangered species. As another example, planting trees provides flood control but also may reduce urban heat island effects.*
Disadvantages (few or limited disadvantages)	These would include adaptation options that are not detrimental in other, non-climate areas (despite being useful for increasing resilience to climate change). These options will be more acceptable to stakeholders, since they do not conflict with other goals and targets. *For example, providing A/C for urban residents will reduce health effects associated with heat stress, but put more stress on energy networks. Adaptation options that meet this criterion will create minimal conflict with needs in other areas.*
Reversibility and Flexibility of the option in face of uncertainty (reversible and flexible as needed)	**Reversibility —** does the option involve construction, land use changes, tree planting, or other changes that are difficult, expensive, or time consuming to reverse? **Flexibility —** can the option adjust or be adjusted to evolving information on conditions? For example, can a sea wall be built higher over time, or can a tax or charge be changed?
Guidance on when/where this option is most likely to be applicable	**Pre-requisites for implementation —** What conditions (e.g., institutional capacity, forecast skill, agricultural extension services, resource availability, climate conditions) are required to make this FTI feasible and/or effective? **Bundling —** Does this FTI adaptation option require the application of one or more additional FTI options to be successful? **Cross-cutting/Synergies —** Would this FTI adaptation option reduce other climate vulnerabilities within or across sectors?