P L A N N I N G F O R C L I M A T E C H A N G E

ADAPTATION



a primer

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I N T R O D U C T I O N

Despite efforts of government and society to mitigate greenhouse gas emissions, consequences due to climate change are inevitable. These consequences include extreme weather such as excessive heat and heavy precipitation, sea level change through the melting of polar ice caps, and heat waves. Society must adapt to these effects through efficient and proactive land use planning, employing both long-term and short-term approaches. The International Panel on Climate Change defines adaptation as "adjustments in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts" (IPCC, 2001).

While mitigation strategies can decrease the rate and the effects of climate change, it will not prevent them from occurring- because greenhouse gases remain in the atmosphere for decades, the earth will continue to warm even if humans reduced emissions to zero. Because even small increases in global temperature can have major implications, humans must couple mitigation measures with the appropriate actions to adapt to climate changes.

Adaptation will require creativity, compromise, and collaboration across agencies, sectors and traditional geographic boundaries. {Pew Center}

Due to the multifaceted nature of global warming, adaptive strategies will require changes in land use planning, government regulation, and individual behavior. For the purposes of this primer, both short-term and long-term adaptive strategies are detailed for each section of the report.

Short-Term Adaptation

Most short-term adaptation strategies focus on regional or community domains within a period of one to two years. In the short-term, most adaptive land-use methods will be autonomous, meaning that individual citizens will make changes in order to adapt to climate change. An example is a farmer who decides to plant crops which prefer drier, warmer climates, such as grapes for wine.

Long-Term Adaptation

Long-term adaptation strategies apply over a time span of thirty or more years. Planned anticipatory adaptation has the potential to reduce vulnerability and realize opportunities associated with climate change, regardless of autonomous adaptation. Implementation of adaptation policies, programs, and measures usually will have immediate benefits, as well as future benefits. Adaptation measures are likely to be implemented only if they are consistent with or integrated with decisions or programs that address non-climatic stresses. The costs of adaptation often are marginal to other management or development costs.[1]

The drawbacks to long-term adaptation measures are the lack of concrete information and costliness. For example, the UK Environment Agency has estimated that, to increase reservoir capacity by 10-15%, it will cost $5.5 billion ($3 billion pounds). Additionally, because of uncertain information and the inability to predict the level of climate change in a certain period of time, much of the long-term measures (improved infrastructure) could become obsolete before their planned design-life (Stern, 2006).

[1] IPCC. 2001b. Climate Change 2001: Impacts, Adaptation and Vulnerability. *Chapter 18: Adaptation to Climate Change in the Context of Sustainability and Equity.*. Report of Working Group (WG) II to the AR4.

Government has a role in providing a clear policy framework to guide effective adaptation by individuals and firms in the medium and longer term. There are four key areas:

- High-quality climate information
- Land-use planning and performance standards
- Long-term policies for climate-sensitive public goods
- A financial safety net to help the poorest of society

It is important to note that the poorest of society may not have the resources to adapt to climate change. It is the responsibility of government to provide a financial safety net for these individuals.

Creating an Adaptation Plan

Effective adaptation is a process, involving specific steps that must be followed sequentially. The International Council on Local Environmental Initiatives (ICLEI) outlines the five milestones that must be reached in order for a community to effectively adapt to the various implications resulting from global warming. These milestones are:

1) *Initiating the climate resiliency effort*
2) *Conduct a climate resiliency study*
3) *Set preparedness goals and develop a preparedness plan*
4) *Implement the preparedness plan*
5) *Measure the progress made on the plan and update the plan when necessary*.

Each milestone requires a specific set of activities to be accomplished before the proceeding milestone can be addressed by the municipality. Each of these activities is described in great detail within the *ICLEI* report. A recent study evaluated the following six urban areas that have been early actors in implementing adaptation plans: London, New York, Seattle, Boston, Halifax, Vancouver and Seattle. The most successful plans incorporated four major elements:

- *Building public awareness about the issue and engaging stakeholders to identify the problems and to help formulate solutions*
- *a systematic study of the impact to be expected from global warming and where they are likely to occur*
- *identify the various options available for to municipality to reduce the vulnerability of the effected area*
- *develop the adaptation strategy and put this plan into action*

The study also revealed common barriers to implementing adaptation plans, including a poor understanding by the public of the true impacts of climate change; scientific uncertainty about the timing and extent of impacts; the practice of making major infrastructure decisions based on past weather conditions and seasonal trends; a short-term focus on the costs of adaptation rather than on the impacts of failing to adapt; difficulties getting the needed attention and commitment from the necessary political leaders; difficulties coordinating action across the government departments and the various levels of government; and, general lack of financial resources available for the cities to implement these plan (Cites Preparing for Climate Change pg.11).

The presence of these barriers can make the completion of the first milestone, as described by ICLEI, one of the most daunting tasks of implementing an adaptation plan. However by addressing the task systematically and by incorporating stakeholders throughout the process, real progress can be made.

Figure 1: Examples of Early Preparedness Efforts by Urban Areas

C A S E S T U D I E S	
Boston Metropolitan Region (USA)	Miami-Dade County, Florida (USA)
In 2004 Boston developed a major academic report, *Climate's Long-Term Effects on Boston* (CLIMB). The five-year project will provide quantitative data on the impact of climate change on infrastructure.	Miami-Dade County, already a leader on reducing greenhouse gas emissions for over ten years, formed a Climate Change Advisory Task Force (CCATF) to make recommendations on necessary actions to make the community as climate resilient as possible. The County is also a member of ICLEI's Local Governments for Sustainability program.
London (UK)	New York City, New York (USA)
In 2001, the Greater London Authority established the London Climate Change Partnership (LCCP) with representatives from a wide range of government agencies. The LCCP has prepared guides and strategies for areas expected to be impacted by climate change, including transportation, buildings, and financial sector. Mayor Ken Livingstone also revised the London Plan to incorporate both mitigation and adaptation policies and appointed a senior policy officer to develop a preparedness strategy using a process of extensive stakeholder involvement.	The New York City Department of Environmental Protection established a Climate Change Task Force in 2003 to evaluate climate change forecasts, impacts, indicators, and adaptation and mitigation strategies for water, sewage, and stormwater management in the region. Task force responsibilities include: developing climate change scenarios, coordinating research, and outreach.

Source: Center for in the Earth's System (The Climate Impacts Group), et al. (2007). *Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments.*

Why Plan For Climate Change?

The effects of climate change are inevitable and could have negative effects on each sector of land use. Below is a table which outlines some possible impacts of climate change on various sectors of government and of land use:

Table 1: Impacts of Climate Change on Various Land Use Sectors

SECTOR	Impacts in Some Regions Could Include:
Hydrology and Water Resources	• Shift in the timing of spring snowmelt • Increased risk of drought and of flooding • Increased competition for water • Warmer water temperature in lakes and rivers • Changes in water quality
Agriculture	• Changes in crop yield (potential ability to "double crop") • Increased risk of heat stress • Increased demand for irrigation • Increased risk of pest outbreaks and weeds
Biodiversity	• Shift in the distribution and range of species • Loss of species not able to adapt to climate change • Loss of habitat
Forests	• Increased risk of insect outbreaks • Increased risk of forest fire • Increased competition from invasive species
Recreation	• Increased opportunities for warm season activities • Reduced opportunities for cold season recreation (due to lack of snow or ice) • Increased reliance on snow-making at ski areas • Shifts in tourism dollars within or among communities
Energy	• Reduced heating demand during winter months • Increased cooling demand during summer months • Increased or decreased hydroelectric generating capacity due to potential for higher or lower stream-flows
Transportation	• Lower maintenance and infrastructure costs associated with snow and ice • More travel disruptions due to landslides and flooding

	• Increased maintenance requirements for roadside and median strip vegetation
Infrastructure	• Need for new or upgraded flood control and erosion control structures • More frequent landslides, road washouts and flooding • Reduced effectiveness of sea walls
Coastal ecosystems	• Increased erosion or damage to coastal infrastructure, dunes, beaches and other natural features • Saltwater intrusion into coastal aquifers due to sea level rise • Increased risk of pollution from coastal hazardous waste sites due to sea level rise
Aquatic ecosystems	• Shifts in species range and distribution • Increased competition from invasive species • Loss of near-shore habitat and coastal wetlands due to sea level rise
Business	• Price volatility in energy and raw product markets • Increased insurance premiums due to more extreme weather events • Impacts on business infrastructure located in floodplains or coastal areas
Public Health	• More heat related stress, especially among the elderly and the poor • Increase in vector-born illnesses (i.e., West Nile) • Reduced summer air quality due to increased production of ground-level ozone
Emergency Response	• Increased demands on emergency response services related to extreme weather events

Source: Center for in the Earth's System (The Climate Impacts Group), et al. (2007). *Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments.*

N A T U R A L H A Z A R D S

Natural hazards are environmental events which have the potential to adversely affect humans, their built environment, and their activities. They can be weather-related (flooding, excessive heat), geologic (landslides, volcanoes) or ecological (wildfires). Environmental risks to humans are increased by poor location or design of land developments. Although scientific computer models have advanced to the point of making reasonable predictions about future weather events, no one has the ability to know for certain where and when a natural hazard will occur. Although land use planning cannot prevent natural hazards from occurring, adaptation strategies can mitigate their associated risks.

Table 2: Adaptation Methods in Response to Natural Hazards & Land Use Issues

N A T U R A L H A Z A R D S A N D L A N D U S E			
Climate Change Event	**Preparedness Goal**	**Adaptation Method**	**Best Practices**
All Natural Hazards	Protect life and property	Floodplain zoning	Numerous localities, including Blacksburg, VA
		Climate change buffer	State of Maryland
		Building code and design standards	RECO (Berkeley, CA); LEED requirements (Seattle, WA); use of high-albedo paving and roofing materials
		Public health plan stressing public warning and increased medical services	Philadelphia Heat Health Warning System
		Avoidance of construction in high-risk area	Incentives offered for relocation
Flood and stormwater runoff	Reduce impervious surface	Increase density of development	Smart Growth; Urban Growth Boundaries; Transfer of Development Rights (TDR)
		Low-impact development	State of Maryland
		Provide accessible public transit (reduces demand for highway construction)	Bogota, Columbia Bus Rapid Transit (BRT)

Extreme Heat

From 1979-2003, excessive heat exposure caused 8,015 deaths in the United States. During this period, more people in the United States died from extreme heat than from hurricanes, lightning, tornadoes, floods, and earthquakes combined (Center for Disease Control and Prevention, 2006). With increases in the annual average temperature in the southeastern United States ranging from 4-10°F, climate change will increase the number of extreme heat days, the regional heat index, and inevitably increase the number of deaths caused by heat (Snover. et al., 2007).

Long term extreme heat adaptation methods should be based on improved land use planning and construction techniques to mitigate the urban heat island (UHI) effect, a phenomenon during which buildings and pavement within a city absorb heat from the sun and release it at night, effectively raising urban air temperature by 6-8°F during warm summer months (Akbari, Berdahl & Pomerantz, 2000). The UHI effect is of particular concern due to the increasing rates of mortality in urban areas during extreme heat events, a trend which will be compounded by the expected doubling of the global urban population by 2030 (Stone & Norman, 2006). Negative health effects on urban residents that result from the UHI effect include heat-related illnesses such as heat stroke. Respiratory conditions such as asthma also result, due to the linear relationship between high temperatures and the level of ozone ("smog") production. This relationship can be clearly seen in Los Angles, where the incidents of smog increase by 3% for every degree that the temperature rises above 70°F (Akbari, Berdahl & Pomerantz, 2000).

Short-Term Adaptation Strategies

Short term adaptation methods include an increased emphasis on emergency response preparation, such as illustrated in current FEMA guidelines, and the implementation of more adequate education programs to inform citizens on the dangers of extreme heat and on various extreme heat avoidance methods.

Long-Term Adaptation Strategies

Long term adaptation methods to extreme heat include emergency response preparation and the implementation of public education programs, as well as increasing the use of efficient building practices. The incorporation of "high albedo" (i.e. highly reflective) materials on buildings and on roadways can greatly reduce the amount of thermal energy that these structures absorb, therefore contributing to the reduction of the UHI effect. Green roofs and tree canopies can also combat this effect. A recent study showed that increasing canopy tree cover from 45-60% and reducing residential lawn space and impervious areas by 25% in a residential area would combine to contribute to an approximate 40% reduction in parcel net black flux (an derivative used to indicate warming per residential parcel) (Stone & Norman, 2006).

Green roofs establish both soil and vegetation on rooftops, improving insulation and lowering the amount of Infrared (IR) radiation absorbed. This regulates building temperature through the seasons and improves building efficiency (Takebayashi & Moriyama, 2007).

Best Practices

In 2005 the city of Chicago implemented a "Green Roof Grant Program," which grants $5000 to residential and commercial building owners who install green roofs on their property. This program has been very successful, with over 20 projects being commissioned in its inaugural year, including one on Chicago City Hall. According to officials from the city's Department of Environment, the instillation of a green roof can ultimately improve the energy efficiency of a building up to 30 percent, which has translated into $40,000-$50,000 a year in electricity for the City Hall alone (Pilloton, 2006).

Drought

Drought is the most costly natural hazard facing the United States. The worst drought within the last 40 years occurred in 1988 and caused the equivalent of over $56 Billion in economic losses (in 2000 dollars) and over 5,000 deaths (NOAA, 2006). Long term adaptation measures for drought are complicated by the unpredictable nature of where and when droughts will occur. As temperatures increase, certain areas experience a gradual increase in the frequency of dry years, intermingled with wet cycles, and finally coupled with gradual shifts in the recharge and discharge interactions of groundwater and surface water systems such as changes in the timing of snow melt runoff (Miller, Rhodes & Macdonnell, 1997).

Short Term Adaptation Measures

The short term adaptation measures to cope with the affects of a drought include increased emergency response preparation and detailed water conservation strategies at both state and local levels of government, such as restrictions on the use of water for residential lawns. Farmers may choose to plant crops which require warmer, more arid climates, such as grapes for wine.

Long Term Adaptation Measures and Best Practices

Long term responses to adapt to drought can involve relocation of agriculture to more suitable (less arid) lands. Due to the unpredictable nature of drought, it is important that a water management system at any level of government have substantial long term flexibility. One innovative example of such a system occurs in California. California's water management system utilizes CALVIN (California Value Integrated Network); a large-scale economic-engineering optimization model of California's water supply (Tanaka et al., 2006). The use of this model allows state officials to examine the ability of California's complex and diverse water management system to adapt to significant changes in climate and population, and then to use these findings to develop future California Water Policy (Tanaka et al., 2006).

Wildfire

In dry conditions, of which the United States will see increasingly more, wildfire becomes a real threat to both property and human lives. In 1991 a wildfire in Oakland, California destroyed more then $3 billion dollars of property and killed 25 people (NOAA, 2006).

Adaptation Measures

Long term adaptive measures include smart land use planning and relocation practices which restrict development in high-risk areas. Other responses are prescribed burnings by the Forest Service and an increase in public education in order to inform citizens of behavioral and building practices which might lower the risk of damage to life or property.

Best Practices

The Yellowstone Fuels Project uses the latest in aerial remote sensing technology to supply horizontal and vertical distribution images which can create enhanced maps of forest fuel distribution and structure within the Yellowstone National Park (Despain, Crabtree, Halligan, Saatchi & Aspinall, 2004). These enhanced maps allow planners to avoid developing areas that are especially prone to wildfires due to either high fuel loads or wildfire enhancing topography. These maps could also be used by the US Forest Service to address high-risk areas through various prescribed burning and clear-cut techniques (Despain et al., 2004).

Major Storm Events

Because the amount of water vapor that can be stored in the atmosphere increases rapidly with increases in temperature (Climate.org, 2006) it is easy conclude that as global temperatures rise, the air will become more saturated with water vapor, increasing the kinetic energy available for major storms such as hurricanes and increasing the intensity and the frequency of major storm events. It is documented that over the course of the 20th century in the United States there was an increase in extreme precipitation events, largely contributing to the 5-10% increase in the average annual precipitation levels (Snover. et al., 2007).

Short Term Adaptation Measures

The development of emergency response programs is crucial in flood-prone areas of the country.

Long Term Adaptation Measures

With the increase in precipitation released by storms, flooding poses a serious threat to human lives and property. In order to adapt to this threat advanced planning techniques must be implemented to preserve human structures. Investing in technology such as stronger and taller levees could prevent damage to life and property. Land use planning must anticipate the eventual relocation of urban population if an area proves too susceptible to flooding and major storm events.
Additionally, restoration efforts should be implemented for riparian habitats, which retain surface water flow during major storm events.

Best Practices

Recently the European Space Agency (ESA) has utilized satellites to develop software-based flood simulation models to assess the vulnerability of specific areas to flooding and to study how floods behave (Hogan, 2003). In the future, computer models such as this can be utilized to assist planners in developing long-term floodplain management techniques, such as advanced floodplain zoning requirements.
The Washington State Department of Fish and Wildlife is a leader in riparian habitat restoration, even developing an in-depth riparian habitat restoration guideline for larger stream restoration efforts (WDFW, 2007).

Sea Level Rise

As temperatures increase, glaciers and artic ice caps will begin to melt into the ocean, raising sea levels and adversely affecting natural habitats. Wetlands may disappear as a result of being inundated. Brook trout, which had been common throughout the Washington area, have been decimated by urban pollution. They are now threatened in the few remaining habitable waters due to increased water temperatures. Pelicans, normally found along the southeastern states' Gulf coasts, are now laying eggs along Maryland's coasts. An increasingly warm climate may deem Maryland inhospitable to the Baltimore Oriole- in the near future it may only be found as far south as Philadelphia.[2]

Glaciers in Greenland and Antarctica are melting faster than previously predicted. In the past, wetlands and beaches could retreat naturally inland, but construction such as roads and coastal structures have restricted this option. The result is that the total area of beaches and wetlands may diminish greatly in the US over this century."[3] This bodes ill for the coasts of New York, Louisiana, Alabama, Florida, Georgia, and the Carolinas. Sea level rise will likely increase the risk of severe storms, intensified by climate change, in coastal areas. Scientists are unsure of how large amounts of Greenland glacial melt will affect the fresh-water-saltwater mixing balance in the North Atlantic Deep Water Formation, which redistributes thermal energy globally via ocean currents.[4]

From 1961 to 2003 the average sea level rise per year was 1.8mm. In the last ten years, ending in 2003, the average annual rise was 3.1mm. Aggregate sea-level rise in the 20th century is estimated to be 0.17m. Sea levels have risen about 20 cm over the past century.

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[2] **Warming Imperils Md. Species**
Scientists Fear Loss Of Baltimore Oriole, Native Brook Trout
By David A. Fahrenthold
Washington Post Staff Writer Monday, March 19, 2007; Page B01

[3] http://www.climate.org/topics/sealevel/index.shtml

[4] http://www.climate.org/topics/sealevel/polar_ice_melt.shtml

John Whitehead of Appalachian State University estimates that economic losses due to sea level rise and subsequent disappearance of North Carolina recreational beaches will total $3.9 billion by 2080.[5] Paul bin of ECU estimates that property values of four NC coastal counties will decline by $6.9 billion over the same time period.[6]

Short-Term Adaptation Measures

Residents can adapt to rising sea levels by constructing stilted houses, growing flood- and salt-tolerant crops, and engaging in fish farming as the main source of agriculture. Creating dunes and planting vegetation are also prudent approaches to this challenge.

Long-Term Adaptation Measures

North American coastal cities can respond to rising sea levels by engineering seawalls, bulkheads, dikes, and pumping systems. Governmental action can facilitate adaptation to rising sea levels through flood preparation and insurance programs. Protection can occur on a more intensive scale through existing water resource and coastal protection programs.

Additionally, land use planners should anticipate a mass migration of residents from flooded coastal areas. Assuming that there is enough land open for future settlement, "retreat can be implemented through anticipatory land use regulations, building codes, or economic incentives (Titus, 1991).

Best Practices

New Orleans employs dikes and pumping systems to protect urban areas which are below sea level. Galveston, Texas, which has been rapidly subsiding, has used fill to raise land elevations. There is speculation that Miami will need to do the same, because the permeable soils of Miami will not accommodate pumping strategies. San Francisco now regulates that shoreline projects be protected by dikes or elevated sufficiently against projected sea level rise.

A drawback of some structural measures is the unintended consequence of preventing wetland and shallow-water habitats from naturally moving inland with the concomitant loss of beach or shoreline. From 1978-93 Maryland's use of bulkheads and revetments has caused the effective loss of 300 miles of shoreline.[7]

Salinity Contamination

As the effects of global warming continue, increased salinity will be found in both surface and groundwater sources.

Short-Term Adaptation Measures

A joint report by the Environmental Protection Agency and the Delaware River Basin Commission found that reservoirs can be a leading method of offsetting salinity increases in freshwater systems due to rising sea levels (Hull & Titus, 1986). Adaptations to increased salinity in surface water include requiring a city to source water further upstream (away from the estuary). Industries that are located along estuaries may need to switch to a municipal freshwater source during periods of high salinity.

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[5] http://www.sciencedaily.com/releases/2007/06/070622184644.htm

[6] ibid.

[7] The Regional Impacts of Climate Change: An Assessment of Vulnerability.1997 A Special Report of IPCC Working group II R.T.Watson, M.C.Zinyowera, R.H.Moss (Eds) Cambridge University Press, UK. Section 8.37.2.1, 8.3.7.2.2

Other approaches include physical barriers, extraction barriers, freshwater injection barriers, increased recharge, and modified pumping patterns. Physical barriers of salinity in groundwater include sheet pile cutoff walls, clay slurry trenches and impermeable clay walls. Materials can also be injected into the soil to form a "zone of low permeability" (Hull & Titus, 1986). Extraction barriers are made to withdraw fresh water before it is contaminated with saltwater, but is only a practical approach in locations where water supply is not scarce. Alternatively, freshwater injection barrier methods pump freshwater into the aquifer through a line of wells, causing the higher groundwater level to prevent saltwater contamination. Increased recharge can occur when rainfall is redirected to groundwater reservoirs to raise and replenish the aquifer and slow saline contamination. The pumping pattern of wells may need to be modified. During significant rises in sea level, wells may be shut down and new wells and other surface water distribution means must be permitted. A contaminated aquifer will eventually become fresh again and the well may be reopened, but this does not naturally occur for several decades or even centuries.

Wildlife Adaptation

More than one million of the Earth's land-dwelling plants and animals could be extinct by 2050 due to global warming, according to a 2004 study published in *Nature* (Roach, 2004). As warming occurs, species will migrate to locations they are not native to, such as southern species appearing in the north, and vice versa. In addition, increased sea levels will force lower altitude species into higher altitudes (Lovegren, 2004).

Short-Term Adaptation

Policy can facilitate adaptation of wildlife to climate change. The Global Warming Wildlife Survival Act, passed in August 2007, addresses the impacts of global warming on wildlife on a national scale. The Wildlife Survival Act directs the federal government, in consultation with states and other organizations, to anticipate and prepare for the drastic effects that global warming is likely to have on animals, plants and their habitats. More importantly, it commands the government to take action to protect wildlife from global warming impacts.[8] In order to protect the habitats of aquatic species, it is important to avoid adverse impacts by building artificial reefs and avoid building hard structures (sea walls, dikes) which block migration (Titus, 1991).

W A T E R   S U P P L Y

Water Quantity

As a result of climate change, water availability will become a concern for agriculture, forestry, and municipal sectors as well as for individual citizens. There will be less snow pack, less summer stream flows, more evaporation, and more saltwater intrusion, decreasing the supply of freshwater and increasing competition for water resources (IPCC, USGCRP). Additionally, more intense and longer droughts have been observed and predicted.

Short Term Adaptation

A prudent and feasible short term adaptation strategy is the provision of information to citizens about the importance of water conservation. Individual behavioral changes are crucial to the effort of reducing water consumption, especially in areas where water is already becoming scarce. In addition to information provision, governments could pass legislation requiring specific water conservation

[8] www.defenders.org

methods. Local governments in especially arid areas can reduce low-value water uses such as washing sidewalks and irrigation pastures (Frederick and Gleick).

Additionally, a regulation that requires a climate risk assessment to a development project's Environmental Impact Assessment could ensure that water is being used efficiently. The World Bank is currently working on a screening tool for this purpose (Burton, Diringer, Smith 2006)

Long-Term Adaptation

As the availability of fresh water decreases, governments could negotiate to import water from countries in moist tropics and higher latitudes which may benefit from increased water supplies from storms (IPCC). Within the United States, tradable water programs, which attempt to include environmental and transport costs into the price of water, could be established.

The creation and implementation of municipal wastewater (grey water) reuse programs could be a wise long term adaptation strategy, especially in agricultural and landscaping sectors. Promoting the collection and use of rainwater would be beneficial as well.

Finally, as the risk of flood increases, governments must restrict construction flood plains. Government funding will need to go to researching and creating better systems to predict when flooding and other extreme weather events will occur. In flood vulnerable areas it will be imperative for communities to build structures, such as levees and wetlands, to protect them from the effects of flooding.

Water Quality

Increased temperatures mean precipitation will become heavier and more frequent, increasing the incidence of flooding and other weather-related hazards. This will have adverse effects on water quality, causing sedimentation and increased water pollution from runoff. (IPCC, USGCRP) Algal blooms will also become a problem as the global temperature increases. Algal blooms will reduce the amount of dissolved oxygen in water bodies, causing many detrimental effects on aquatic ecosystems.

Short-Term Adaptation

Local, state and federal governments could pass legislation to decrease the amount of ground pollution and litter, and to reduce the type or amount of agricultural pesticides, both of which pollute groundwater through stormwater runoff. They could also implement bioretention areas in areas which experience heavy runoff.

Long-Term Adaptation

New infrastructure designs are vital and should consider the increased incidence of extreme weather events. Government funding should be provided for the restoration and maintenance of watersheds that have been compromised by urbanization, forestry, or grazing. This will reduce flooding, lower water temperatures (decreasing algal blooms), and reduce heavy sedimentation and nutrient overloads from runoff. Some ways of accomplishing this would be restoring native vegetation, curbing development, and reducing the amount of impervious surfaces that cause heavy runoff.

Table 3: Adaptation Methods in Response to Potential Water Challenges

WATER QUALITY AND QUANTITY			
Climate Change Event	**Preparedness Goal**	**Adaptation Method**	**Best Practices**
Decreased water supply	Expand and diversify water supply	Grey water re-use in irrigation systems	Chapman Companies (New Mexico)
		Rainwater retention and reuse	Water Heroes program (Sierra Vista, AZ)
		Control and reduce evaporation	Limit irritation to before sunrise/after sunset (University of Virginia)
	Reduce demand/improve efficiency	Decrease impervious surfaces	More narrow roadways; porous paving; site "fingerprinting"
		Incentive programs for water efficiency	Home Rewards Rebate Program (Burbank, CA)
		Water-saving irrigation techniques	Drip irrigation (Great Plains)
		Landscaping techniques which do not require irrigation	Xeriscape (Colorado)
		Regulation on water use	Regulations on new homes and renovations (Defra, UK)
	Increase ability to transfer water between users	Tradable water rights	Abstraction Licenses (United Kingdom)
	Increase public awareness about climate change impacts on water supplies	Public education programs	"Think 2" water conservation program (FL)
Decreased water quality	Reduce pollution and sediment in stormwater runoff	Bioretention areas to capture heavy runoff	Georgia Stormwater Management Manual; Low-Impact Development (LID) Measures

L A N D U S E

Land Use Planning

Human settlements are considered to be among the living sectors that could most easily adapt to climate change, provided that appropriate planning, foresight and technical, institutional, and political capacity is available. The most effective sustainable solutions are often developed locally, with technical assistance and institutional support from higher level bodies.[9]

Short Term Adaptation Measures

In the short term, communities can incorporate climate change into land use regulations and standards. For example, communities can provide incentives (tax exemptions, a swifter approval process) for developers who practice infill development or build on brownfields, while providing disincentives (bureaucratic processes, taxes) for developers who attempt to build inefficiently or on greenfields. Additionally, government can provide financial incentives for relocation of residents or businesses from flood- or drought-prone lands, and incentives for citizens to purchase insurance.

Other short-term adaptation methods to climate change involve responses to direct effects of climate change. For example, in response to land erosion due to arid weather and strong precipitation, citizens can plant vegetative buffers to stabilize soil. Municipalities can also pass planning regulations which control setback requirements for new construction, as Maui County, Hawaii did in 2003.[10] Another solution is to mandate a Climate Change Buffer, an increment of land outside normal floodplains, coastal plans, and wildlife areas that extends development restrictions in anticipation of climate change impacts.

Reducing Impervious Surfaces

One result of climate change is an increase in severe precipitation and flooding, a problem which is exacerbated by impervious surfaces like roads and rooftops. The addition of impermeable surfaces in individual construction projects must be strictly regulated in order to increase the greater good.

Transportation is another factor which affects the amount of impervious surface in an area. In order to reduce the need for more roads and highways, cities should consider improvements in existing public transit systems, or the construction of new transit systems or pedestrian access ways. The BRT (Bus Rapid Transit) system developed in Bogota, Columbia in 2000 reduced gas emissions in the city by 40% and eliminated 2,109 vehicles from highways.[11] In addition to reducing air pollution and traffic woes for citizens, the impervious surface construction that was avoided by the BRT helps to reduce flooding impacts and urban heat island effects.

Best Practices

Municipalities can discourage the creation of impervious surfaces by implementing a Low-Impact Development (LID) Program, as Prince George's County, Maryland has done. LID measures include maximizing vegetation and natural cover to maintain predevelopment hydrology, and minimizing the

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[9] IPCC. 2001. Climate Change 2001: Impacts, Adaptation and Vulnerability. *Chapter 7: Human Settlements, Energy, and Industry*. Report of Working Group (WG) II to the AR4.

[10] Norcross-Nu'u and Abbott. Adoption of Erosion-Rate Based Setbacks in Maui, Hawaii: Observations and Lessons Learned. http://www.coastalzone.com/pubabs/CZ05_AEHR.doc

[11] (2007). *BRT System: Botoga, Columbia*.. Retrieved September 19, 2007 from New York Climate Summit Website: http://www.c40cities.org/bestpractices/transport/bogata_bus.jsp.

amount of impervious cover to reduce environmental impacts. LID programs can offer density bonuses, streamlined approval, or other financial benefits if developers incorporate LID measures.[12]

Avoiding Flood Vulnerability

As the risk of flash flood increases due to climate change (and is exacerbated by growing areas of impervious surfaces), floodplain management becomes crucial. Encroachment of new development onto the floodplain not only can expose new occupants to flood damage but also can cause a surcharge in flood level due to cutting and filling.[13]

Adaptation Strategies and Best Practices

The most straightforward solution is to restrict land use in the floodplain to uses that are compatible with periodic flooding, such as recreation and agriculture. Some communities, including Blacksburg, VA, prohibit development in the entire 100-year floodplain- this protects any riparian vegetation on the floodway fringe which provides wildlife habitat and aesthetic benefit. Floodplain zoning has become an often-used method for municipalities to control the amount of development in and around a floodplain. For example, every city and county in Wisconsin is required by law to zone all flood-prone areas.[14]

Promoting Density

Storms and drier weather resulting from climate change will erode coastal areas, and localities will be required to accommodate populations who migrate inward from the coast. Providing capacity for a larger population within an existing municipality will require dense development, including infill development and smaller residential lots.

Local government can alter its zoning regulations to provide incentives for developers to build on smaller lots.

Dense development is also an adaptation method for water resources because it uses less impervious surface, therefore allowing for a higher level of groundwater discharge. A study by the U.S. Environmental Protection Agency (EPA) recently found that high-density developments generate less storm water runoff per house and that high-density development produces less impervious cover in the watershed.[15]

In order to encourage developers to increase density, municipalities are offering incentives such as density bonuses to qualifying projects. In 2006, the Department of Planning and Development in Seattle, Washington introduced the Density Bonus Incentive, which offers greater height and/or floor area to downtown developments with applicable green building techniques.

Another method to encourage density is to offer a Transfer of Development Rights (TDR) program, which allows landowners to transfer the right to develop on one parcel (designated for preservation) to another

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[12] Randolph, John. (2004). *Environmental Land Use Planning and Management*. Washington: Island Press.
[13] Randolph, John. (2004). *Environmental Land Use Planning and Management*. Washington: Island Press.
[14] (2007). *Wisconsin's Floodplain Management.* Retrieved September 19, 2007 from Wisconsin Departmetn of Natural Resources Website: http://dnr.wi.gov/org/water/wm/dsfm/flood/.
[15] U.S. Environmental Protection Agency. (2006). *Protecting Resources with Higher-Density Development.* Retrieved September 5, 2007 from U.S. Environmental Protection Agency website: http://www.epa.gov/cgi-bin/epaprintonly.cgi.

(designated for development).[16] This method helps municipalities control the areas on which development will occur.

A G R I C U L T U R E

The potential impacts of human activities on the global climate system could be devastating to all civilization. Without adaptation, the unprecedented effects on the planet could cripple several institutions that are critical to the survival of humans. To maintain a successful agricultural industry, alterations to agricultural practices will be necessary. Changes in temperature and precipitation patterns will occur, requiring intelligent solutions to the problems that will arise. Heat waves, drought, and severe storms may occur in some areas, while others are subject to increased precipitation and moderate temperatures. For example, the Appalachian area is expected to witness a 3.5 degree Celsius increase in average temperatures and the frequency and intensity of droughts may also increase. Soil moisture will likely be negatively affected by such conditions, because rates of evaporation will also increase.
Global warming will impact agriculture in a variety of ways, including the following:

- A movement of agricultural zones toward the poles
- Variable precipitation patterns
- Changes in agricultural patterns
- An increase in agricultural productivity due to increased carbon dioxide levels

In addition, agricultural soil is at risk due to global warming. The combination of dry weather, higher temperatures and powerful storm events will cause more erosion and nutrient loss from runoff.

All plant life will be affected by climate change- including weeds. As weather patterns shift, weeds will gain habitat and resilience, while domesticated plants suffer from the success of wild plants. Some dangerously aggressive weeds are now restricted to southern latitudes because of their need for high temperatures. As average temperatures rise, these weeds (such as kudzu) will enter prime farming areas like the Corn Belt in the United States.

The increased intensity of storm events may provide enough moisture for pests and diseases, such as fungi, bacteria, insects, and parasitic plants, to thrive in new areas. These affects may have devastating impacts on the agricultural system.

Cattle and livestock will be affected by heat stress, inhibiting health and performance. Cows that are exposed to high temperatures and drought tend to experience lower feed consumption rates, decreased milk production, and lower reproductive capacity. Respiration and energy expenditures increase, stressing the animal. Cattle owners will be challenged to meet increased water consumption rates.

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[16] Randolph, John. (2004). *Environmental Land Use Planning and Management.* Washington: Island Press.

Table 4: Adaptation Methods in Response to Agricultural Challenges

AGRICULTURE			
Climate Change Event	**Preparedness Goal**	**Adaptation Method**	**Best Practices**
Warmer and more arid conditions	Adjust production to reflect changing conditions	Alter planting dates depending on weather	Recommended under "Adaptation" on Environmental Protection Agency (EPA) website: www.epa.gov/climatechange
		Relocate agriculture to areas less affected by climate change	
	Improve information used in managing agriculture	Work with county extension agents to distribute information to farmers on projected climate change impacts to agriculture	IPM cooperative project in Wisconsin
Drought	Improve agricultural water supply and use	Promote irrigation technologies which improve water-use efficiency	Sheepdrove Organic Farm reuse of wastewater (Berkshire, UK); technology such as energy-efficient electric motors and micro-irrigation systems

Short Term Adaptation

Farmers can act proactively to the threat of global warming by shifting planting dates one month earlier or one month later in reaction to increased temperatures. They can also increase the amount of water used to irrigate crops, or altogether modify the variety of crops to a more adaptive variety. An example is a farmer who chooses to grow grapes for wine- this crop prefers a warmer, more arid climate.

Other short-term adaptive strategies include identifying and controlling invasive pest and weed threats before a harvest is ruined; providing information and educational tools about global warming to farmers and producers; and, improving water storage and conservation methods in case of drought.

It is important to note that, in some areas, agricultural production will be increased due to higher levels of carbon dioxide in the atmosphere. In fact, the International Panel on Climate Change (IPCC 2007) believes the negative effects of climate change on agriculture have been overestimated in some studies because they do not account for farm and agricultural market-level adjustments.

Long Term Adaptation

The simplest method of adaptation for those in the agricultural sector is to modify the type of crop grown to a more adaptive variety. In some cases, this is not a plausible option. If farmers cannot change their crop, they will likely need to change irrigation methods to bring more water to each plant. This is also an unattractive option in some cases due to the inevitable increased frequency of drought in some areas due to climate change. In the long term, farmers should take advantage of technology in order to operate irrigation systems at maximum efficiency.

To combat soil nutrient loss and erosion, long-term adoption of a zero-tillage policy is a prudent option. Agroforesty is another possible solution- planting trees and shrubs among crops generally allows soil to hold more water and enhances the nutrient cycle. This method also causes the soil to hold more organic matter, which is beneficial to crop productivity (Kandji, et al 2006).

The best long-term adaptation method for dealing with problematic organisms is Integrated Pest Management. Integrated Nutrient Management is a method to increase yields while preserving the soil quality for the future (Gruhn 2000). Over time, farmers should pay close attention to the duration and severity of pest problems in order to tailor effective management strategies. It remains unclear how successful biological controls and chemical agents will be in the future (Petzoldt, et. al 2006).

To adapt cattle to heat stress conditions, changes to their diet and environment must be made. Adding more complex carbohydrates and proteins to the typical feed mix will promote health during heat stress (Chase 2004). Several nutrients, such as potassium and magnesium, may also encourage resilience. Cows with lighter fur will be favorable to darker breeds because of sunlight absorbance comparisons. Also, the use of breeds that are resistant to drought and heat stress will increase (Chase 2004).

As previously mentioned, access to fresh and sterile water will become increasingly important as temperatures rise. If possible, cattle owners should increase capacity of water distribution devices. Large cattle operations should also provide shade for each animal, ideally coupled with vents, cooling fans, and overhead misters or sprayers.

Public policy will play an important role in agricultural adaptation to climate change, especially regarding effective crop insurance and genetically-engineered crops, which may increase a plant's resiliency.

Table 5: Adaptation Methods in Response to Sea Level Rise

SEA LEVEL RISE			
Climate Change Event	**Preparedness Goal**	**Adaptation Method**	**Best Practices**
Sea Level Rise	Reduce effects of increased water salinity	Corrosion resistant pipes; physical barriers above- and below- ground; retrieve water supply up-river (away from estuary)	EPA and Delaware River Basin Commission Report
	Reduce shoreline erosion	Barriers	Eastern Scheldt Barrier (The Netherlands)
		Sea walls	Yucatan Peninsula
		Dunes, maritime forests	Pine Knoll Shores (Bogue Banks, NC)
	Reduce property damage from erosion, flood events, sea level rise	Setbacks	Galveston, TX
		Elevating land surfaces and beaches	San Mateo County, CA
		Coordinated planning	San Francisco, CA

Figure 2: Summary of Adaptation Best Management Practices

B E S T M A N A G E M E N T P R A C T I C E S			
Climate Change Event	**Preparedness Goal**	**Adaptation Method**	**Example of Application**
Natural Hazards and Land Use			
Flood and stormwater runoff	Reduce impervious surface	Increase density of development	Smart Growth; Urban Growth Boundaries; Transfer of Development Rights (TDR)
Potential Water Challenges			
Decreased water quality	Reduce pollution and sediment in stormwater runoff	Bioretention areas to capture heavy runoff	Low-Impact Development (LID) Measures
Agricultural Challenges			
Drought	Improve agricultural water supply and use	Promote irrigation technologies which improve water-use efficiency	Technology such as energy-efficient electric motors and micro-irrigation systems
Sea-Level Rise			
Sea Level Rise	Reduce effects of increased water salinity	Corrosion resistant pipes; physical barriers above- and below- ground; retrieve water supply up-river (away from estuary)	EPA and Delaware River Basin Commission Report

C O N C L U S I O N

Excessive heat, drought, heavy precipitation, and floods put the lives and livelihoods of individuals at risk. A proactive approach by each community to prepare for the imminent effects of climate change will lessen vulnerability to these events, and will help to protect the health, safety, and prosperity of its citizens. The adaptation methods described in this paper can serve as a foundation for such a practical and aggressive community plan.

The most critical forms of adaptation to climate change will be future land use planning and government regulations. Government officials must prepare for gradual changes in the climate and the resulting natural hazards, and structure a viable action plan for each of these events. With this proactive approach, governments will be able to protect their community from the impacts of climate change.

Actions such as floodplain zoning and low-impact development with proper stormwater management will decrease the risk of flood. Regulating fires and conserving water during drought will become more necessary for a community with a risk of droughts. Adaptation practices such as these will be increasingly essential as the impacts of climate change become more drastic.

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