3. Vulnerability and Adaptation Assessments Under USCSP

3.1 Introduction

This chapter presents the results of the vulnerability and adaptation assessments conducted under the USCSP. These assessments were conducted under two USCSP initiatives: the Vulnerability and Adaptation Program and the SNAP Program. Most of the 49 countries participating in the Vulnerability and Adaptation Program focused on assessing the vulnerability of their climate-sensitive resources (i.e., the potential physical and economic impacts of climate change). However, a number also addressed adaptation (i.e., what steps countries could take to respond to the physical impacts of climate change). Seven participants in the SNAP Program examined how policy responses relating to adaptation could be incorporated into national climate change action plans. Figure 20 lists the countries that conducted vulnerability and adaptation assessments under USCSP.

3.1.1 Objectives and Scope of Vulnerability and Adaptation Assessments

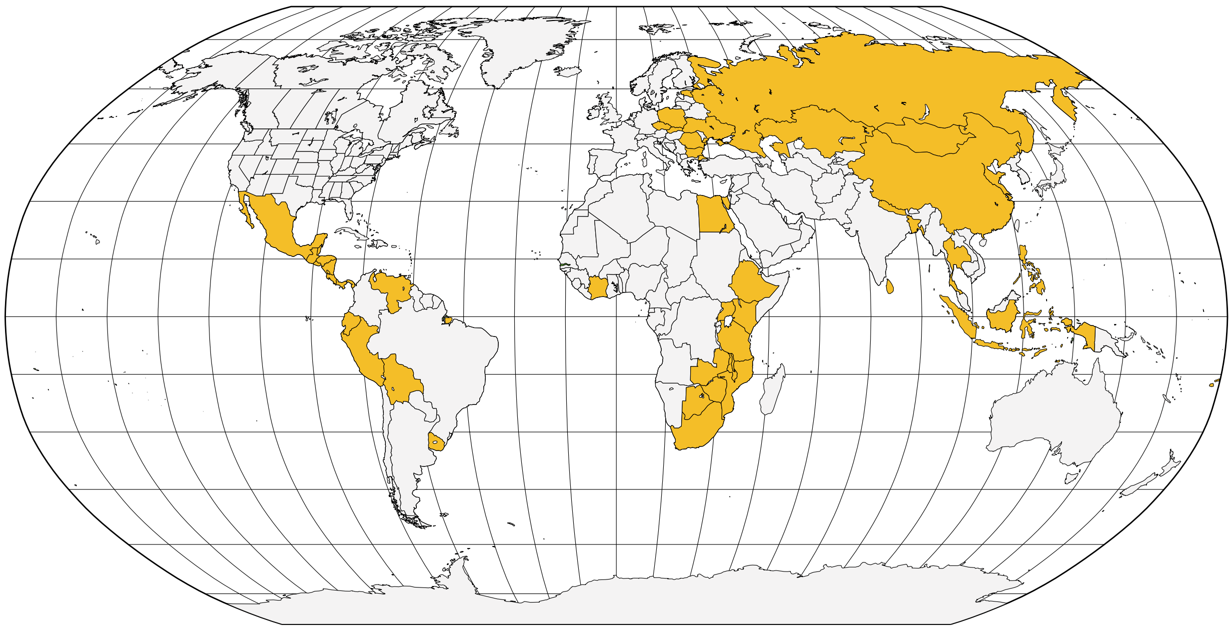
The vulnerability and adaptation assessments were primarily intended to help developing and transition countries understand their potential vulnerabilities to climate change. All of the countries participating in the USCSP are signatories of the UNFCCC, but when they signed, there was little country-specific information on how they could be affected by climate change. The USCSP was one of the first programs to work directly with developing and transition countries to conduct the vulnerability and adaptation assessments. The main purpose of the USCSP was to build capacity, that is, to give countries the training, software, and data they would need to assess potential impacts of climate change. This capacity helps create a foundation upon which future assessments of climate change can be carried out. Thus, the emphasis of the program was on training in-country scientists, who were supported by their governments, and having them conduct their own research.

The vulnerability and adaptation assessments cover eight important sectors that are sensitive to climate change:

- coastal resources
- agriculture
- grasslands/livestock
- water resources
- forests
- fisheries
- wildlife
- human health.

Table 12 displays the sectors assessed by each country that conducted vulnerability and adaptation assessments; about 150 country sector assessments were conducted under the Program.

Figure 20 Countries That Have Conducted Vulnerability and Adaptation Assessments Under the U.S. Country Studies Program



Africa & the Middle East	Asia & the Pacific	Transition Countries	Latin America
Botswana*	Bangladesh	Bulgaria*	Belize**
Côte d'Ivoire	China*	Czech Republic	Bolivia*
Egypt*	Fiji	Estonia*	Costa Rica**
Ethiopia	Indonesia	Kazakhstan*	Ecuador
The Gambia*	Kiribati	Poland*	El Salvador**
Kenya	Marshall Islands	Romania*	Guatemala**
Malawi	Micronesia	Russian Federation*	Honduras**
Mauritius	Mongolia	Slovak Republic	Mexico
Mozambique	Nepal	Ukraine*	Nicaragua**
South Africa	Philippines*		Panama**
Tanzania	Samoa		Peru
Uganda	Sri Lanka		Uruguay*
Zambia	Thailand*		Venezuela*
Zimbabwe			

■ Vulnerability only
* Vulnerability and adaptation
** Countries cooperating in a Central American regional study.

Table 12 Vulnerability and Adaptation Assessments by USCSP Countries by Sector

Country	Coastal Resources	Agriculture	Grasslands/ Livestock	Water Resources	Forest	Fisheries	Wildlife	Human Health
Africa & the Middle East								
Botswana			•	• †	•	•		
Côte d'Ivoire	•	•		•	•			
Egypt	• †	• †		•				•
Ethiopia		•	•	•	•			
The Gambia	• †	•	•	•	•	•		
Kenya		•		•	•	•		
Malawi				•	•		•	
Mauritius	•	•		•		•		
Mozambique	•	•	•	•	•			•
South Africa		fl	fl	fl	fl	fl	fl	fl
Tanzania	•	•	•	•	•			•
Uganda		•	•	•	•			
Zambia		•	•	•	•		•	•
Zimbabwe		•			•			
Asia & the Pacific								
Bangladesh	•	•		•	•	•		
China	• †	•	•	•	•			
Fiji	•							
Indonesia	•	•			•			
Kiribati	•							
Marshall Islands	•							
Micronesia	•	•		•	•		•	
Mongolia		•	•	•	•			
Nepal		•		•				
Philippines	• †	• †		• †				
Sri Lanka	•	•			•			•
Thailand	•	•		•	•			‡
Transition Countries								
Bulgaria		•			• ‡			
Czech Republic		•		•	•			
Estonia	• †	•		•	•			
Kazakhstan		• †	•	• †	•			
Poland	• †	•		•				
Romania		•		• †	•			
Russian Federation		• †		• †	• †			
Slovak Republic		•		•	•			
Ukraine[a]	•	•		• †	•			
Latin America								
Argentina[b]		•						
Bolivia		• †	• †	• †	• †			
Central America	•	•		•				
Ecuador		•			•			
Mexico	•	•		•	•			
Peru	•							
Uruguay	• †	• †	•					
Venezuela	• †				•			

Countries in italics are SNAP participants.

- • Completed vulnerability assessment
- fl Conducting vulnerability assessment [South Africa]
- † Completed adaptation assessment
- ‡ Conducting adaptation assessment
- [a] Ukraine was a SNAP participant, but assessed adaptation as part of its vulnerability and adaptation assessment.
- [b] Argentina did not receive funding from the USCSP on vulnerability and adaptation, but participated in USCSP-sponsored workshops.

3.1.2 Methods for Conducting Vulnerability and Adaptation Assessments

The USCSP provided participating countries with technical assistance and training in assessing their vulnerability and adaptation strategies to climate change (Benioff et al., 1996). Technical advisors were selected to assist with the climate and baseline scenarios, climate model data, and vulnerability and adaptation methods and models. All eight sectors selected for assessment have been subject to past studies on climate change (e.g., Watson et al., 1996). In many cases, the countries adapted the models and methodologies to their unique national circumstances.

The technical advisors provided training, software, and data on specific methods for assessing vulnerability and adaptation through workshops and site visits. Training was provided at two workshops: one in Washington, DC, in January 1994, and the second in Honolulu, Hawaii, in January 1995. The technical advisors also provided written reviews of the accuracy, consistency, and completeness of progress reports, papers, and draft reports submitted by vulnerability and adaptation researchers.

The general approach recommended by the USCSP for conducting a vulnerability and adaptation assessment is presented in Figure 21. The assessment begins with the selection of climate change scenarios and baseline socioeconomic (population, economic conditions) scenarios extending through 2075. The climate change scenarios provide inputs for the biophysical and socioeconomic models or methods that are used to assess potential impacts of climate change. Most of these methods allow the assessment of vulnerability under alternative policy scenarios for adapting to climate change. The vulnerability of each sector is initially analyzed in isolation, and results may then be integrated across sectors to account for interactions among related sectors. For example, an agriculture assessment could incorporate changes in water supply from the water resources assessment. The adaptation assessment is then used to evaluate which, if any, policy options may be implemented in anticipation of climate change to mitigate potential adverse climate change impacts.

Appendices A, B, and C of this report contain more detailed technical information on the methods used by countries participating in the USCSP to prepare their vulnerability and adaptation assessments. Appendix A provides a summary of the key methods used to conduct vulnerability and adaptation assessments. Appendix B contains summaries of the results of vulnerability assessments by 37 countries. Appendix C provides detailed case studies that highlight both representative and unique examples of methods used by a select number of countries to assess adaptation options.

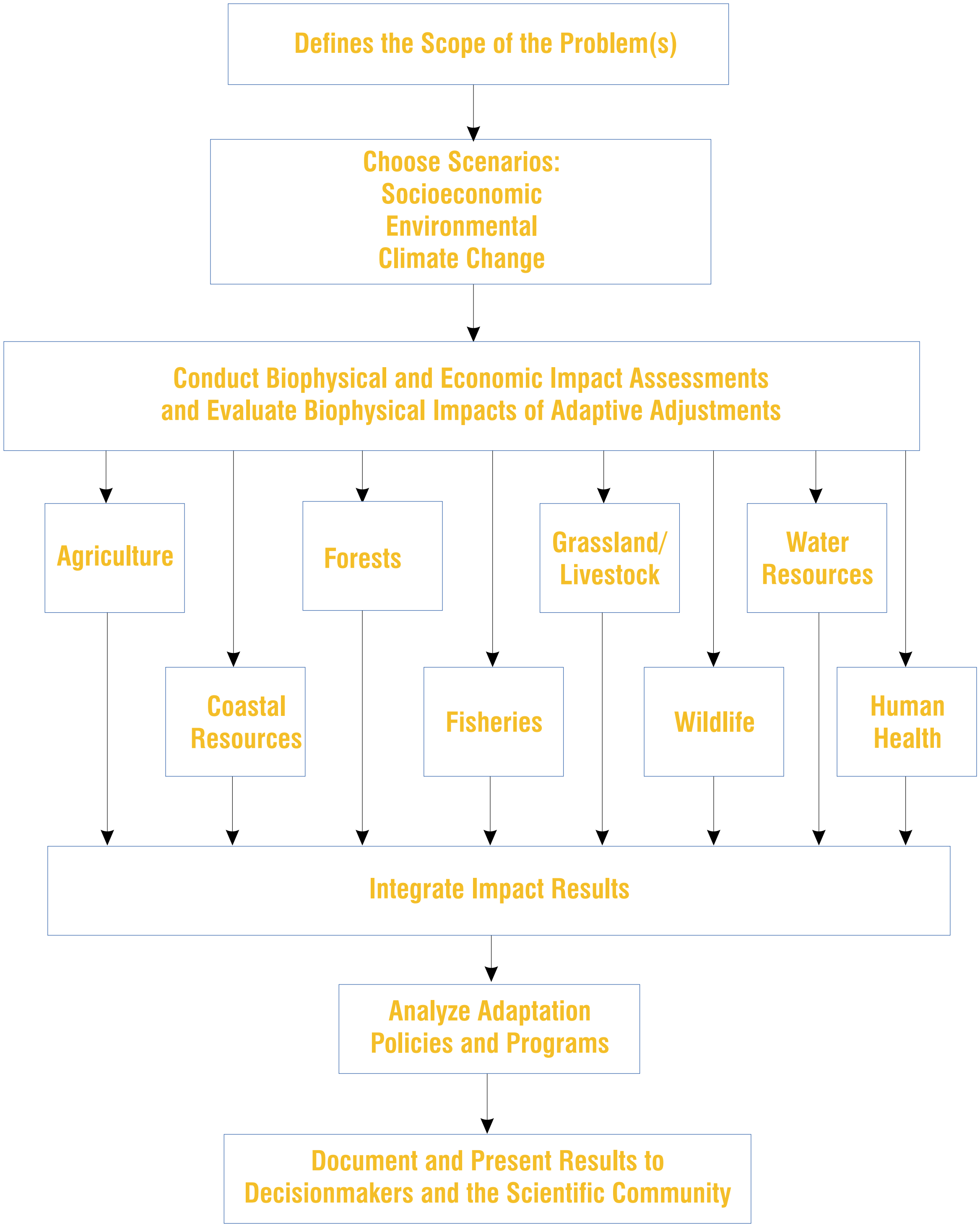
3.1.3 Organization of this Section

This section presents an overview and analysis of the results of the vulnerability and adaptation assessments conducted by countries participating in the USCSP. First the results are summarized by sector: coastal resources, agriculture, grasslands/livestock, water resources, forests, fisheries, wildlife, and human health. Then conclusions are presented on the vulnerability and adaptation assessment process and findings, including a discussion of the challenges inherent in conducting these types of assessments. Finally, the section concludes with suggestions for future work to further refine the methods used for conducting vulnerability and adaptation assessments.

3.2 Results of USCSP Vulnerability and Adaptation Assessments

In this summary of vulnerability and adaptation results by sector, vulnerability results are presented first, followed by results of adaptation assessments. In several sectors, only vulnerability assessments are summarized because no results were available for adaptation assessments. The countries participating in the USCSP tended to focus their evaluations of adaptation options on the relatively heavily managed agriculture, coastal resources, and water resources sectors, and less on the unmanaged systems, particularly forests, grasslands, fisheries, and wildlife.

Figure 21 Vulnerability and Adaptation Assessment Process



Source: Benioff et al., 1996.

3.2.1 Coastal Resources

Vulnerability

Twenty-four countries assessed the vulnerability of their coastal resources to climate change. In general, coastal vulnerability is analyzed by examining the potential impacts from specified levels of sea level rise, most often 0.5 or 1.0 meters (Box 22). Since coastal assessments consider only one variable—sea level—and because the change in sea level is assumed to occur in only one direction (i.e., increase), we can be more certain about potential impacts in this sector than in other sectors such as agriculture and water resources, where the directional impacts of climate change are more uncertain.

Box 22 The Vulnerability of Coastal Resources to Climate Change

The IPCC projects that climate change could result in sea level rise of 15 to 95 cm over the next century, with a best estimate of about 50 cm (Houghton et al., 1996). This threatens to inundate unprotected low-lying lands and wetlands. At particular risk are small islands such as the Marshall Islands and the Maldives and countries with large river deltas, such as Bangladesh, China, Egypt, and Nigeria. Without additional protection, the number of people at risk of flooding by 2100 assuming a 1 m sea level rise could double or triple over the number currently at risk, and most of the people at risk are in developing countries (Watson et al., 1996a; this estimate is based on current population and coastal development). In addition, the intensity of tropical storms could increase as a result of climate change, thereby compounding the risks faced by coastal populations (Henderson-Sellers et al., 1998).

Table 13 presents estimated land loss from inundation and erosion due to sea level rise in 15 countries. This is presented primarily for sea level rise of 0.5 and 1.0 meters, but other estimates are presented as noted. As shown below, in addition to inundation and erosion, some countries considered potential impacts from saltwater intrusion and different conditions for storm surges under increased sea level. Amplified storm surges may create greater vulnerability than sea level rise alone.

An analysis of the results from these countries suggests that with 0.5 m sea level rise, about one half of the land loss is due to erosion and one half is due to inundation. At 1.0 m sea level rise, the portion of land loss attributable to inundation increases faster than the portion attributable to erosion. The total impact (erosion plus inundation) increases almost threefold when predicted sea level rise doubles from 0.5 to 1.0 meters.

The total impact of sea level rise is underestimated by the results presented here, because countries tended to look at only sections of coast and not their entire coast (except for smaller countries and islands such as Kiribati). In doing so, countries generally selected case studies of particularly important or vulnerable coastlines.

A common concern for countries with significant coastal resources is the impact on human populations and on other sectors. For instance, in its study of Chittagong, Bangladesh calculated that 96 percent of the 11.2 km^2 of land lost to erosion under 1.0 m sea level rise would be agricultural land (Huq, 1997). Egypt and Côte d'Ivoire also identified sea level rise impacts on coastal cites as having particular economic importance.

Adaptation

To determine appropriate adaptation responses to sea level rise, a number of countries compared the cost of protecting coastlines from sea level rise with the benefits in terms of the value of land and structures that would be inundated or lost to erosion. For instance, using the replacement cost method, Tanzania estimated the value of structures lost because of 0.5 and 1.0 m sea level rise as US$70 million and US$121 million, respectively. It is estimated that with 1.0 m sea level rise, protection of the vulnerable portion of the coastline of Dar es Salaam would cost US$380 million and protection of the populated coastline of Tanzania would cost US$14.6 billion.[8] Table 14 illustrates other results from comparing benefits and costs of coastal resources adaptation. The benefits exceed the costs in most cases, but the existence of some low ratios points out the importance of carefully evaluating benefits and costs of adaptation. As reported in Appendix B, China, Egypt, Estonia, and Uruguay also estimated costs for protection against sea level rise as part of the USCSP.

Table 15 summarizes the types of coastal resource adaptation options that seven countries selected for in-

[8] Estimates were converted from Tanzanian shillings to U.S. dollars: 1 Tanzanian shilling (Tsh.) = 0.001624 U.S. dollars {9/13/99; *http://www.oanda.com/converter/classic*}

Table 13 Examples of Land Loss from Inundation and Erosion Due to 0.5 and 1.0 m Sea Level Rise

	0.5 meter		1.0 meter	
Country	**Inundation (km^2)**	**Erosion (km^2)**	**Inundation (km^2)**	**Erosion (km^2)**
Bangladesh [a]	NA	5.80 [b,c]	NA	11.20 [b,d]
China [e, f]	1153 [b]	NA	6520	NA
Côte d'Ivoire	8.9	27.6	17.8	55.1
Egypt [e, f, g]	15,473	NA	NA	NA
Estonia	NA	NA	593.0	NA
The Gambia	5.0	NA	92.3	NA
Indonesia	NA	NA	230.04 [h]	NA
Peru	NA	NA	78.32 [i]	NA
Philippines [j]	20.99 [b]	NA	55.6	NA
Poland	845.1 [b]	NA	1727.7	NA
Sri Lanka	41.0 [b]	6.0 [a]	91.2	11.5
Tanzania	NA	2,090	NA	2,117
Ukraine	12.8 [k]	52.25 [k]	190.0 [l]	102.4 [l]
Uruguay	19.8 [e, m]	0.068 [n]	39.6 [e, m]	0.291 [n]
Venezuela	52.6	26.4	77.7	40.5

Note: Many results are only from case studies and are not for the entire country.
NA means not available.

[a] Sandy shores of eastern Bangladesh, i.e. Chittagong, which is a hilly area. A 1.0 m sea level rise is estimated to inundate 17%, or more than 22,000 km^2, of the entire country, and most of this area is in western Bangladesh.

[b] 0.3 m sea level rise.

[c] Agricultural land only.

[d] 0.75 m sea level rise.

[e] Lower bound estimates shown.

[f] Does not distinguish between inundation and erosion.

[g] Alexandria and Rosetta areas only.

[h] Lowland part of Semarang City.

[i] Sum of 10 study areas.

[j] Manila Bay Coastal Area – a 2.0 m sea level rise will result in 89.05 km^2 loss of land by inundation. The greatest potential impact from sea level rise is not the loss of land, but the increased water salinity due to salt water intrusion and more intense storm surges during tropical cyclone occurrences.

[k] 0.46 m sea level rise.

[l] 1.15 m sea level rise.

[m] Coast between Colonia and A Chuy.

[n] Coast of Montevideo.

Table 14 Benefit-Cost Ratios[a] from Coastal Resources Adaptation Assessments in Selected Countries

Location	Level of Protection	Sea Level Rise Scenario 0.3 m	0.5 m	1.0 m
China (Zhujiang Delta)	Full protection	7.7	14.3[b]	12.8
Estonia (Tallinn/Pärnu)	Full protection	—	—	0.9/2.3[c]
Poland (entire coastline)	Full protection	2.6	—	4.6
	Partial protection	3.3	—	—
Venezuela (all study sites)	Full protection	—	0.02	—
Uruguay (entire coastline)	Full protection (sea walls)	7.6 - 21.6	7.0 - 30.8	10.3 - 42.9
	Full protection (beach nourishment)	3.2 - 9.0	3.2 - 13.9	4.9 - 20.4

[a] Benefit-cost ratios calculated from the benefit-cost analyses in the national reports.
[b] Ratio based on a benefit-cost analysis for a 0.65 m scenario.
[c] These ratios are for a 1.0 m sea level rise and a 1.5 m storm surge.

Table 15 Summary of Coastal Resource Adaptation Options

Adaptation Option	Uruguay	Egypt	China	Estonia	The Gambia	Poland	Philippines	Venezuela
Protection	✓	✓	✓	✓	✓	✓		✓
Development planning/ building requirements	✓	✓	✓		✓			✓
Research/ monitoring	✓		✓				✓	
Integrated coastal zone management	✓	✓					✓	

depth evaluation. The countries listed evaluated one or more protection strategies, particularly for economically important areas in the coastal zone, such as large cities or resorts. Technology-based protection options such as building sea walls were the most widely selected responses to sea level rise. However, many countries also considered policy changes such as development planning (e.g., setbacks), although relatively few included an integrated coastal zone management (ICZM) framework among the evaluated options. To be sure, virtually all the assessments of vulnerability as well as adaptation are consistent with ICZM (for more information on ICZM, please consult IPCC, 1990, and Huang, 1997). Two of the countries conducted surveys to obtain stakeholder opinions about what policy adaptation measures should be undertaken.

3.2.2 Agriculture

Vulnerability

In part because of the importance of agriculture in developing and transition country economies, more countries (36) undertook vulnerability assessments of this sector than any other sector (Box 23). These assessments were generally more detailed and extensive than other analyses, and examined the vulnerability of numerous specific crops and cultivars under a variety of climate change scenarios.

Many countries included CO_2 fertilization effects on crop yields in their analysis. In some cases, CO_2 fertilization was found to have a larger impact on crop yields than temperature or precipitation changes, although drier conditions could offset the positive effects of CO_2 fertilization.

Box 23 The Vulnerability of Agriculture to Climate Change

The IPCC concluded that global agricultural production is at little risk from climate change. However, regional crop yields might change considerably. The change in crop yields may alter competitive advantage among nations, resulting in shifts in where crops are grown. A number of studies have found that production of grain crops may increase in high-latitude countries but decrease in low-latitude countries (Rosenzweig and Parry, 1994; Darwin et al., 1995). In addition, changes such as reductions in water supplies and increases in pests, plant disease, and extreme climate events could affect agricultural production. The IPCC identified sub-Saharan Africa, South and Southeast Asia, some Pacific islands, and tropical Latin America as being at greatest risk (Watson et al., 1996a).

Table 16 indicates the general direction of changes in crop yields summarized across different models for most of the countries assessing agriculture, based on scenarios generated from climate change models.[9] This table does not reflect how yields would change after farmers make adaptations such as changing practices or crops. Although the table emphasizes many of the most important crops worldwide, several countries also considered the vulnerability of additional crops of national importance, such as barley, cotton, and groundnuts. There appears to be a mix of estimated increases and decreases in crops, although of the crops studied, more are estimated to decrease than increase. There also appear to be some differences in the regional sensitivity of crop yields to the climate change scenarios. Africa (mainly Egypt and Côte d'Ivoire) and Asia (particularly Bangladesh and the Philippines) show a tendency toward decreases in crop yields, whereas Europe and Latin America (mainly Bolivia) show a tendency toward increases in crop yields. Because results are limited and scattered, these conclusions should be treated as preliminary.

Some individual countries did estimate increases across all crops (e.g., Romania), whereas others found decreases across most or all crops (e.g., Cote d'Ivoire, Egypt, Bangladesh, and Bulgaria). Overall, the results suggest that while agricultural impacts may not be catastrophic, especially when potential adaptation measures are considered, individual countries and regions within countries could experience significant negative or positive impacts. Thus, some countries could be harmed while others could benefit.

Table 16 also suggests the importance of different types of crops and their response to an increase in atmospheric concentrations of CO_2. Crops can be classified into two groups, C_3 and C_4, according to how efficiently they use CO_2 during photosynthesis. The C_3 crops such as rice, wheat, soybeans, potatoes, and vegetables, which make less efficient use of CO_2 during photosynthesis, may be less vulnerable to climate change because increased CO_2 may enhance their growth. The C_4 crops, on the other hand, such as grasses, maize, sugar cane, millet, and sorghum, may be more vulnerable to climate change. For instance, maize yields decrease in 7 of the 13 countries. This is quite consistent with other studies of climate change impacts (see Reilly, 1996).

Some countries noted that current interannual climate variability may be of more immediate concern than long-term climate change. For example, Indonesia found that the vulnerability of its agriculture sector to variable El Niño/Southern Oscillation effects under current climate conditions is greater than the vulnerability to climate change over the next 20 years, but in 60 years the effects of climate change could be as great as the El Niño effects.[10] Other issues that may be important in understanding vulnerability of agriculture to climate change include the following:

- Warmer temperatures may lead to increases in pests and diseases harmful to crops.
- Changes in frost-free dates may affect soil nutrient changes.
- Changes in precipitation may induce flooding or drought, causing direct physical impacts on agricultural lands.

Adaptation

The assessments also examined management adaptations that could lessen climate change impacts in the agriculture sector, including:

- shifts to alternative planting dates
- changes in fertilizer (nitrogen) applications

[9] Countries calculated crop yields under a series of climate change scenarios developed using General Circulation Models. For additional explanation ofthese models and the methods used to estimate changes in crop yields as a result of climate change, please see to Appendix A.

[10] Some recent research has found that climate change could result in more frequent El Niños (e.g., Timmerman et al., 1999).

Table 16 Direction of Crop Yield Changes across General Circulation Model Scenarios

Country	Crop					
	Wheat	**Maize**	**Soybean**	**Rice**	**Other**	**Other**
Africa & the Middle East						
Côte d'Ivoire		↓		↓ [b]		
Egypt	↓	↓	↓	↓	↑ Cotton	↓ Barley
Ethiopia	↑↓					
The Gambia		↓			↓ Millet	↑ Groundnuts
Kenya		↑↓				
Zambia	↑↓	↑	↑↓	↑	↑ Oils[a]	↑ Cassava
Zimbabwe		↑↓				
Asia & the Pacific	Wheat	Maize	Soybean	Rice	Other	Other
Bangladesh	↓			↓		
China[a]	↑↓	↑↓		↓		
Indonesia				↑↓		
Mongolia[a]	↑↓					
Philippines		↓		↑↓		
Sri Lanka					↑↓Tea	
Transition Countries	Wheat	Maize	Soybean	Rice	Other	Other
Bulgaria	↑↓	↓				
Czech Republic	↓	↑			↓ Potato	↑ Early Vines
Estonia					↓ Barley	
Kazakhstan[a]	↑↓					
Romania	↑	↑				
Russian Federation	↑↓					
Slovak Republic	↑					
Ukraine	↑					
Latin America	Wheat	Maize	Soybean	Rice	Other	Other
Argentina	↑↓	↓	↑			
Bolivia		↑[c]	↑↓		↑ Potato	
Mexico [a]		↓ [d]				

Note: Summary based only on GCM scenarios, and includes CO_2 fertilization unless otherwise noted. Countries that conducted only sensitivity analyses (Nepal, Poland, Uruguay) are not included because the range of sensitivity analyses is so broad that crop yields would generally have mixed results. Results for these countries are summarized in Appendix A.

[a] Does not include CO_2 fertilization.

[b] Results are mixed when adaptation is assumed.

[c] Irrigated maize is estimated to have decreased yields. Irrigated land in Bolivia is a small fraction of total arable land (CIA, 1999).

[d] Indicated as an increase in land area unsuitable for crop.

⌡Yield decreases for all GCM scenarios.

″ Yield increases for all GCM scenarios.

″⌡Yield increases and decreases for all GCM scenarios.

- use of alternative crops and cultivars
- increased irrigation and water management
- changes in diets away from vulnerable crops.

For example, because the Gambian diet includes meals prepared from maize and millet, both of which may experience significant declines in yields, adaptation may best involve switching to other, less vulnerable crops.

Many of these scenarios did not include the costs of these alternative actions. The studies did not assess whether financial or other resources would be available to adopt these adaptations. As noted by several countries, the ability to cope with vulnerability of agriculture to climate change is dependent on other changes such as changes in population and other impacts such as sea level rise or erosion. For instance, Egypt's ability to adapt will depend on the rate of population growth; a slow growth rate may enable agricultural productivity to keep pace with demand.

Table 17 summarizes the adaptation options that were selected for further evaluation by four countries participating in the SNAP Program. Three of the four countries, Uruguay, Egypt, and Kazakhstan, addressed the potential for reduced crop yields. Their adaptations were designed to offset negative impacts. In contrast, the Russian Federation sees climate change as potentially increasing yields and production. Their adaptation options are designed to take advantage of this opportunity by expanding agriculture to new areas that could become suitable for cultivation and assisting current productive areas in transitioning to cropping systems more appropriate for new climate conditions.

Most of the adaptation options focus on educational and outreach activities that provide farmers with additional information about growing conditions and encourage farmers to change their management practices or crop mix to maintain viability in the market. The table also shows that the options covered a wide range of policy, technology, research, education, and outreach activities. It is interesting that the removal of crop subsidies, which could have benefits under the current climate and make the agricultural system more resilient to climate change, was not evaluated in depth as an adaptation option, although some countries did identify this as an option. This may be due to strong opposition to removing such programs. Finally, all of the options pertain to activities that countries can implement domestically, although regional coordination such as efficient irrigation use of international rivers might be taken into consideration in future studies.

Many of the options considered by all of the countries were no-regrets options—soil conservation, the development of regional centers to provide technical assistance on farming, establishment of seed banks, or planting of more productive crops. Those are the only options identified by more than one country. The first two of these options would most likely require government involvement. Soil conservation needs to be applied on a broad scale to be effective and would probably require government programs. The establishment and operation of regional technical assistance centers would require government funding.

Table 17 Summary of Agricultural Adaptation Options Analyzed by SNAP Countries

Option	Option Type	Kazakhstan	Uruguay	Egypt	Russian Federation
Regional assistance centers/seed banks	Outreach	✓	✓		
Pest/disease forecasts	Research/outreach	✓			
Free market transition	Policy	✓			
Soil conservation	Education/outreach	✓	✓		✓
Development or introduction of new cultivars	Research		✓	✓	✓
Irrigation efficiency	Education/outreach		✓		
Irrigation capacity expansion	Technology		✓		
New crops (switching to different cultivars or developing different crops than currently used)	Education/outreach			✓	
Management practices suitable for new climates	Education/outreach			✓	✓

Although there is some similarity in the options across countries, Kazakhstan's circumstance as a transition economy also led to a unique policy option, supporting the transition to a free market. This transition is already under way because it is expected to have benefits greater than costs under the current climate. However, a free market is also expected to help in adapting to climate change because farmers will see changes in production and demand through changes in prices and will be able to switch crops as long as they have the necessary technical capability and financing. Interestingly, the Russian Federation, which is also in a transition to a market economy, did not identify this option, but focused on outreach, management, and technology options.

3.2.3 Grasslands and Livestock

Vulnerability

Twelve countries conducted, or are conducting, vulnerability analyses for the grasslands and livestock sector (Box 24). These countries generally studied specific regions within the country or types of grasslands, because there is considerable variability within countries. For instance, Mongolia found that while the impact of climate change on pasture production in the Gobi Desert areas may be negative, in colder regions of the country climate change could have favorable effects on plant production. Even with these regional variations, Mongolia still found that at all sites, plant quality and livestock production decline under climate change scenarios.

Although not directly comparable across countries, average biomass generally is estimated to increase for warm-season grasses and decrease for cool-season forbs and legumes as optimal grassland conditions shift toward the poles. There appear to be smaller impacts on livestock yields than on grassland biomass, because livestock can adjust consumption (e.g., they can graze over a larger area should grassland productivity decline). To some extent, this implies that there is currently excess capacity of grasslands in the livestock sector or that analysts are assuming that the area of production can increase.

Box 24 Vulnerability of Livestock to Climate Change

Livestock could be directly and indirectly affected by climate change. Change in climate can directly affect milk production, growth, and reproduction. Livestock can be indirectly affected by changes in grassland biomass and quality, changes in distribution of disease, and changes in the marketplace, i.e., changes in feed availability and price (Watson et al., 1996a).

Although countries found no significant overall change in grasslands and livestock, several countries did note that changes in interannual climate variability would have important impacts. For instance, Uruguay found that because seasonal variability is already a major concern for farmers, increased variability would be detrimental to the production of livestock. Similar results regarding the impact of climate variability on grasslands are discussed in Allen-Diaz (1996). Some countries did find positive net impacts of climate change, such as Tanzania, where scenarios with increased precipitation and temperature led to increased rangeland carrying capacity.

3.2.4 Water Resources

Vulnerability

While most of the vulnerability analyses of water resources focused on runoff, that is, the portion of precipitation on land that ultimately reaches rivers or lakes, some countries also considered factors such as water supply and demand, flooding and drought, river salinity, water quality, irrigation, and hydroelectric generation (Box 25).

Box 25 Vulnerability of Water Resources to Climate Change

Higher temperatures are likely to reduce snowpack, cause earlier runoff in river basins and lakes fed by snowpack, and increase evapotranspiration in all water basins. In addition, sea level rise could increase salinity in estuaries. However, for any given region, whether runoff will increase or decrease as a result of climate change is uncertain. In addition, there are uncertainties about changes in seasonal runoff patterns. Thus, it is not possible to forecast whether specific water basins will be wetter or drier. It is possible that more intense precipitation events could lead to more flooding. The IPCC concluded many regional water systems could become more stressed in the 21st century because of population and economic growth. Arid and semi-arid basins are at greatest risk to climate change. Water demand management and institutional adaptation are the primary means for reducing risks from climate change (Watson et al., 1996a).

Table 18 displays the range of change in runoff for some of the countries assessing water resources. Most countries considered multiple river basins, and the results varied between basins. Generally, scenarios assuming an increase in temperature and no change in precipitation resulted in a drop in runoff. However, changes in precipitation appear to have a greater influence on runoff than changes in temperature. In many countries, if precipitation were to increase, runoff would increase, even with higher temperatures, and if precipitation were to decrease, runoff would decrease. For example, in The Gambia, for each 1 percent change in precipitation, there is a 3 percent change in the same direction of runoff.

Most countries showed mixed results in terms of increases and decreases in runoff. One striking aspect of this table is the range of estimated changes in runoff and the estimated high sensitivity of runoff to changes in climate. For example, estimated changes in runoff in The Gambia ranged from –69 percent to +63 percent. Such large changes in runoff are likely to substantially increase the risk of drought or flood. Two countries, Estonia and Mongolia, estimated no change to increases in runoff under all the scenarios tested. It is interesting that both of these countries are in high latitudes. Since they are likely to receive more precipitation and may not have as large an increase in evapotranspiration as low-latitude countries, high-latitude countries may be more likely to have increased runoff (Rind et al., 1990; Houghton et al., 1996).

Table 18 Change on Annual Runoff for Selected Countries Based on Results from GCM Models

Country	Change in Annual Runoff Minimum	Maximum
Africa & the Middle East		
Botswana	-53%	+17%
Côte d'Ivoire	-22%	-4%
Ethiopia	-33%	+40%
The Gambia	-69%	+63%
Malawi	-40%	+162%
Asia & the Pacific		
Kazakhstan	-29%	+25%
Mongolia	-0.3%	+26%
Philippines	-12%	+32%
China	-15%	+17%
Latin America		
Mexico	-42%	+123%
Transition Countries		
Czech Republic	-10%	+3%
Estonia	+2%	+68%
Kazakhstan	-29%	+25%
Romania[a]	-24%	-3%
Slovak Republic	-100%	+5%
Ukraine	-20%	+128%

[a] Based only on CCCM scenario.

Only two countries, Côte d'Ivoire and Romania, found a reduction in runoff under all scenarios, and a few others, such as the Slovak Republic and Kazakhstan, showed a tendency toward decreased runoff. Kenya conducted only a sensitivity analysis, and its results show a high sensitivity to change in temperature (i.e., a tendency toward reduced runoff). This may not be surprising, given that the country is in a semi-arid climate and already has high temperatures.

Those countries that examined the effects of changes in runoff on the adequacy of the water supply to meet demand found that baseline changes in population would have a much greater effect than climate change. They also found that changes in runoff might be magnified in supply and demand. For example, Ethiopia estimated changes in runoff varying from –33 percent to +40 percent. The estimated change in supply was slightly less negative and more positive than the changes in runoff (e.g., the scenario with a 33 percent reduction in runoff resulted in a 25 percent reduction in supply). Ethiopia found that population and economic growth by 2075 could result in demand exceeding supply.[10] This situation would be made worse if runoff declined and even the 40 percent increase in runoff would not completely meet the higher demand.

In general, the effect of climate change on runoff is difficult to predict. A few areas might see increased runoff (which can alleviate water shortages but increase flood risks), but for most areas the change is uncertain. Change in precipitation, which is uncertain at the regional level, is the most important factor affecting runoff. Until scientists are certain about how precipitation will change, it will remain difficult to reliably forecast future water supplies.

[3] Demand was estimate to increase by twentyfold.

Adaptation

Developing adaptation strategies for water resources affected by climate change is complicated by the fact that climate change could both reduce and increase water supplies. Therefore, countries may need to plan adaptation strategies for both drought and flooding conditions. In spite of the uncertainties about climate change impacts on water resources, there are many adaptation strategies that are likely to reduce the vulnerability of water resources to climate change as well as to current climate variability, regardless of whether runoff increases or decreases (Frederick et al., 1997).

Table 19 summarizes the types of adaptation options evaluated by Bolivia, Botswana, Kazakhstan, Romania, the Russian Federation, and Ukraine. These assessments were made accounting for uncertainties about future water supply and quality. Five countries evaluated options to increase domestic water supply, either nationwide by adding or upgrading storage capacity, or locally through interbasin transfers. Interestingly, four of the countries noted the possibility of increasing water use from international river basins, but Kazakhstan and Ukraine both assumed that this option was not feasible. Implementing such an option would require international cooperation.

Botswana, Kazakhstan, the Russian Federation, and Ukraine also considered technological or outreach options to decrease the demand for water. These options involved programs to either increase efficiency in use or find ways to decrease demand, such as decreasing irrigated farmland or switching to crops that require less water. Botswana also considered a policy option to increase the cost of water, and Bolivia considered use of water metering and direct billing to reduce demand.

The Russian Federation proposed addressing increased risks of flooding by building flood control works in a number of basins that are identified as being at particular risk from flooding (including flooding from sea level rise). The Russian Federation also proposed including Lake Baikal on the World Heritage List to protect the quality of its water. In 1999, the Lake Baikal basin was declared a special water protection zone (A. Kokorin, Institute of Global Climate and Ecology of the Russian Academy of Science and Russian Federal Service for Hydrometeorology, personal communication, 1999). Bolivia proposed generally improving water quality.

Two countries, Romania and Ukraine, proposed changing water management practices, thereby reduc-

Table 19 Examples of Water Resource Adaptation Options

Option	Option Type	Bolivia	Botswana	Kazakhstan	Romania	Russian Federation	Ukraine
Increase water supply (domestic)	Technological	✓	✓	✓	✓		✓
Increase water supply (international)	Technological or policy		✓		✓		
Decrease demand (by efficiency programs or substitution)	Technological or outreach		✓	✓		✓	✓
Increase water price	Policy	✓	✓				
Build flood controls	Technological					✓	
Address ecological risks	Outreach					✓	
Reduce water pollution	Technological and outreach	✓					
Institute drought and flood planning and monitoring	Policy and technological	✓					
Change water basin management practices	Policy	✓			✓	✓	✓

ing hydropower generation, as a way to help offset potential water supply shortfalls. The proposals noted that increasing fossil fuel generation, which would increase greenhouse gas emissions, would make up the power deficit. The studies did not assess the potential for using other renewable power supplies to make up for the reductions in hydropower. It will be important to ensure that adaptation options such as these are consistent with greenhouse gas mitigation strategies.

Bolivia also proposed using river basin planning and drought and flood preparedness and monitoring. Among the options it considered, Bolivia found these options to be the most cost-effective.

3.2.5 Forests

Vulnerability

Most countries evaluated the vulnerability of their forest sector in terms of changes in the land area of different forest types or projected changes in biomass (Box 26). Most countries used the Holdridge Life Zone classification, which allows for a first cut analysis of potential impacts on forest resources under the various climate scenarios. This approach does not consider CO_2 fertilization, which enhances forest growth and reduces water demand (Neilson et al., 1998).

> **Box 26 Vulnerability of Forests to Climate Change**
>
> *Climate change is likely to have a substantial impact on the world's forests. Under a doubling of atmospheric CO_2 concentrations, one-third or more of global forests could be in a new climate, outside the range of climate they currently exist in. Suitable climates for many species could shift faster than many species can migrate. Slow-growing species may be replaced with faster-growing species. Tropical forests are more likely to be affected by changes in land use in coming years than climate change. Since warming is likely to be greatest at the poles, boreal forests may be subject to the greatest shift in climate zones (Watson et al., 1996a).*

Most countries reported a general shift in forest types to those more amenable to warmer climates (e.g., subtropical shifting toward tropical forests). Countries found that changes from dry to moist forest or vice versa were largely driven by changes in precipitation rather than temperature. Table 20 shows estimated changes in biomass from forest sector studies for regions within countries and for whole countries using a number of different climate change scenarios. While it is difficult to draw specific conclusions from the country studies because of the different models and approaches used, a general impression (as seen in Table 20) is that there could be a decline in biomass. However, it is interesting that some countries such as The Gambia found potential increases in biomass.

For some countries, climate change may exacerbate current deleterious conditions. For instance, in Zambia, more than 80 percent of households use either fuelwood or charcoal for their domestic energy requirements. Zambia is currently losing 250,000-300,000 ha of its forest cover annually to human activities, and a decrease in forest productivity could make the situation worse. Based on this, Zambia concludes that climatic changes that affect the resilience of forest vegetation types could grossly affect income and welfare.

Other interesting results of forest vulnerability assessments under the USCSP include the following:

- Even where the dominant ecosystem type is not expected to change, conditions may change to allow the introduction of invasive species. For example, Estonia found that while the climate change scenarios would not change the primary ecosystem type, they could increase the spread of invasive species, including *Fagus sylvatica*, *Carpimus betulus*, and *Quercus petrea*.
- In some cases, simulations indicate that the estimated climate change would be significant for individual tree species even when the Holdridge model does not estimate shifts in forest type.
- If warming increased potential evapotranspiration, there would be a tendency toward more drought stress.
- Impacts on specific forest reserves or national parks may be important. For example, Sri Lanka found that the most vulnerable forest areas would be the Sinharaja Forest Reserve and the Peak Wilderness Forest Reserve, and Venezuela found that most of

Table 20 Examples of Forest Sector Vulnerability Results

Country	Region	Scenario	Percent Change in Biomass
Bolivia	Nationwide	GISS	-92% to -32%
		UK89	-44% to +34%
		+2°C/ + 10% P	-81% to -13%
		+2°C/ -10%P	-83% to -19%
Estonia	Tudu	Four different scenarios	+5.3% to+13.2%
	Võhma		-33.5% to -28.0%
	Virstu		-47.4% to 9.6%
	Kärevere		-75.9% to -23.5%
	Risti		-42.1% to 1.6%
The Gambia	Nationwide	GFD3	+72.0%
		GISS	+0.2%
		UKMO	-46%
		OSU	-75%[a]
Mongolia	Nationwide	UK89	-27.2% larch
			-35.3% Siberian pine
			-5.1% birch
			-4.2% scotch pine
Romania	Bistrita—2060	GF01	-4.8% red maple
	Predeal—2060		-16.7% red maple
Slovak Republic	Pilsko	CCCM	+17%
	Dobrocsky		+5%
	Sitno		-38%

[a] Estimate is an approximation based on examination of figure in Gambian vulnerability and adaptation report.

the country's natural forest reserve would be affected.

- While the USCSP studies for the most part did not model societal-forest interactions, population pressures were generally recognized. For example, as noted above, Zambia reports that given the country's reliance on forest products, climatic changes could affect the resilience of forest vegetation types and could adversely affect society.

The finding that composition of forests could change with a shift to warmer climate species is consistent with the IPCC. However, the IPCC found that, in general, it is not clear whether forest biomass will increase or decrease (Neilson et al., 1998).

3.2.6 Fisheries

Vulnerability

Few countries examined the vulnerability of fisheries to climate change as part of the USCSP, and we do not attempt to generalize results. For many areas, a lack of location-specific information on species response to potential climate change makes it difficult to assess fishery vulnerability (Box 27). For instance, in Bangladesh, there has been very little or no work on the physiology and ecology of indigenous species of finfish or prawn. As a result, it is difficult to estimate the likely effects of climate change on different fish or prawn populations.

In general, changes in temperature and salinity were estimated to result in changes in species mix and both increases and decreases in different species' productivity. Sea level rise would lead to flooding and loss of productive habitat for many species (e.g., shrimp), generally resulting in decreased productivity. The net result for the fishery sector depends on which effects are stronger. In some developing and transition countries, a significant number of people depend on fish in their diet, especially for protein, so impacts on the fishery sector may also affect the health of the population.

Box 27 Vulnerability of Fisheries to Climate Change

Fisheries will be affected in a number of ways by climate change. Climate change will alter water temperatures, water chemistry (higher temperatures reduce dissolved oxygen levels in water), and circulation. Fish tend to survive only in certain thermal niches and will generally need to migrate or be transplanted poleward. Higher temperatures could result in increased productivity of streams and lakes, especially if terrestrial productivity increases. Fish in small rivers and lakes or where temperature or precipitation changes are greatest may be most at risk. Marine and estuarine fisheries will face higher temperatures and change in the location of thermal niches, but may have increased production if current fisheries management problems are corrected. Estuarine fisheries could also be affected by sea level rise, which could inundate wetlands and move saline water further upstream in estuaries. Loss of coral reefs could adversely affect fish. Coastal protection measures such as bulkheads or dikes can result in additional loss of wetlands by blocking their inland migration (Watson et al., 1996a).

3.2.7 Wildlife

Vulnerability

Two countries, Malawi and Zambia, used the Habitat Suitability Indices to examine the vulnerability of key species to climate change. Although it is difficult to generalize from only two country studies, the vulnerability of wildlife to climate change primarily appears to be a function of changing habitat. Current human activities may be causing habitat fragmentation, which is probably the greatest current stress on wildlife. This could be exacerbated under climate change (Box 28).

Box 28 Vulnerability of Wildlife to Climate Change

The impacts of climate change on wildlife have not been studied as much as impacts on other sectors such as forests. Wildlife is likely to be affected by changes in temperature as well as by shifts in ecosystems. Animals dependent on ice cover may be at particular risk. Migratory species such as birds are likely to alter the timing of their migrations and could be at risk if prey and other food are no longer available. In addition, wildlife is likely to be affected by ecosystem changes such as shifts in vegetation and availability of prey. The IPCC concluded that wildlife populations in Africa are at particular risk from drought (Watson et al., 1998).

For Malawi, vulnerability studies suggest that there would be declines in nyala and zebra in the Lengwe and Nyika National Parks. Nyala is a vulnerable species that may not adapt easily to climate-induced habitat changes. On the other hand, if increased temperature is accompanied by lower precipitation, as is the case in two of the scenarios, tourism might increase because increased ambient temperature could improve accessibility to drier parks. Whether tourists would be less likely to go to the parks because of the loss of nyala was apparently not assessed.

In Zambia, increased or decreased rainfall could significantly affect wildlife through changes from open grasslands and scattered bushlands to denser bushlands (under increased precipitation) or desert-like conditions (under decreased rainfall). In addition, increased or decreased rainfall would significantly affect the behavior and habitat of migratory wetland species. Given the vulnerability of Zambian wildlife to drought and habitat disturbance, it is likely that climate change, whether it leads to increased or decreased rainfall, could dramatically affect both the size and diversity of many populations.

3.2.8 Human Health

Vulnerability

Zambia and Sri Lanka completed assessments of the potential health effects of climate change (Box 29). Although it is difficult to draw generalizations from only

Box 29 Vulnerability of Human Health to Climate Change

Human health is very sensitive to climate, because many maladies are related to temperature. Higher temperatures can increase cases of heat stress and areas where infectious diseases such as malaria and dengue could spread. For example, because of their cooler temperatures, the East African highlands have low risk of malaria. Higher temperatures would make the climate suitable for the survival of malaria-carrying mosquitoes. On the other hand, higher temperatures would also reduce risks of health problems related to cold, such as cardiovascular mortality (Martens, 1998). A key factor affecting the vulnerability of human health is the strength of the public health systems. Countries with weak systems may be at more risk because they would be less able to prevent or contain outbreaks of diseases or other health problems associated with climate change (Watson et al., 1996a; McMichael et al., 1998).

two countries, these countries found that climate change could increase risks to human health. Zambia qualitatively considered characteristics of malaria, bilharzia/schistosomiasis, cholera, dysentery, bubonic plague, and malnutrition. The assessment of health effects was limited largely by the lack of available data. Consequently, no models were run to assess impacts of particular diseases, and potential impacts can only be speculated. In Zambia, the health effects of climate change would appear to affect poorer populations for a variety of reasons, including poorly ventilated structures being conducive to mosquitoes and lack of good water and sanitation services. Existing conditions such as environmental degradation, quarrying, poor drainage systems, and inadequate water taps would exacerbate health impacts from climate change.

Sri Lanka also studied the potential effects of climate change on the incidence of malaria, and found that malaria could become more prevalent in areas where it is not currently a significant risk.

3.3 Assessment Conclusions

3.3.1 Conclusions on Vulnerability Assessments

The IPCC distinguishes between sensitivity, how a system is directly affected by climate change (e.g., change in crop yields), adaptability, how a system could respond to climate change (e.g., switch crops), and vulnerability, the net effect after sensitivity and adaptability are considered (Watson et al., 1996a). Although dozens of countries assessed climate change impacts under the USCSP, one should be cautious about using these studies to draw sweeping conclusions about the vulnerability of developing and transition countries to climate change. The USCSP studies tended to focus on identifying sensitivities of systems, i.e., first-order biophysical effects, and adaptability was assessed only for coastal resources and some of the agriculture, forests, and water resources. Without thorough consideration of underlying socioeconomic changes, integrated impacts, and adaptability in all sensitive sectors, it is difficult to draw firm conclusions about vulnerability.

Nonetheless, some preliminary conclusions about sensitivity and vulnerability can be drawn, although these conclusions do not necessarily apply to all countries. In general, it appears that more heavily managed systems are less at risk than relatively unmanaged systems. For the managed systems, the USCSP studies found the following:

- Sea level rise could cause substantial inundation and erosion of valuable lands, but as is discussed below, protecting developed areas would be economically sound. Countries conducted limited assessment of the ecological consequences of sea level rise.
- The studies tend to show mixed results for changes in crop yields. African and Asian countries, particularly southern Asian countries, tended to estimate decreases in yields. Many countries found mixed results and some even estimated increases in yield of some crops, particularly Europe and Latin America. Adaptation could significantly affect yields, but it is not clear whether these adaptations are affordable or feasible (e.g., whether farmers could afford fertilizers or pesticides). On the whole, some countries may lose while others may win. These conclusions are consistent with those of the IPCC, which found that global agriculture will most likely provide enough food to feed the world, but there are likely to be geographic shifts in production (Watson et al., 1996a).
- Impacts on water resources are uncertain, mainly because of uncertainty about regional change in precipitation patterns. The studies show a high sensitivity of runoff to climate change, which could result in increases in droughts or floods. The ability of water resource systems to adapt was not thoroughly assessed.
- The impacts on grasslands and livestock are mixed, but for the few countries studied, there appears to be a large capacity for adaptation.

For the more unmanaged systems, the USCSP assessments found the following:

- Climate change could result in increased human health problems, particularly for populations in low-latitude countries with inadequate access to health care.

- The composition of forests is likely to change. Many of the assessments found that biomass could be reduced, although this latter finding is not necessarily supported by other assessments (e.g., IPCC).
- There are potential negative impacts on wildlife, with some species possibly having reduced populations.
- The effects on fisheries are indeterminate.

These latter effects were studied in only a few countries, so one should be careful about over-interpreting results. Interestingly, a key factor affecting wildlife and human health is baseline socioeconomic changes. Current baseline issues such as continued destruction of wildlife habitat and lack of healthcare infrastructure may exacerbate the potential vulnerability to climate change. One common theme from many of the assessments is that the impacts of baseline changes may be much greater than the impacts of climate change.

On the whole, it appears that there is high sensitivity to climate change in many developing countries. However, vulnerability is harder to determine. It appears that many unmanaged systems could be quite vulnerable to climate change. Thus, the USCSP has substantially expanded the knowledge about potential impacts of climate change on developing and transition countries, but more work needs to be done to better understand their ultimate vulnerability.

3.3.2 Conclusions on Adaptation Assessments

Table 21 summarizes the results from a number of USCSP adaptation assessments. Since few adaptation assessments have been done to date, these results should be considered preliminary.

- Results for the coastal resources sector (Table 14) show that countries evaluated protection for a variety of sea level rise values and protection options. They also show that most of the benefit-cost ratios are greater than one, indicating that the benefits (e.g., avoided land and infrastructure losses) generally exceeded the costs for most of the locations studied. However, researchers found that costs could outweigh benefits along less-developed shoreline segments.
- In the agricultural sector, seed banks (called regional centers in the Kazakhstan study) were among the more cost-effective options in Kazakhstan and Uruguay, according to Adaptation Decision Matrix (ADM) analyses.[11] In Egypt, switching crops or cultivars was the best option, according to Adaptation Strategy Evaluator (ASE) evaluations.
- In the water resources sector, differences in cost assessment methodology prevent direct comparisons of cost-effectiveness across countries. However, there is some consistency in the way different projects are ranked within a country's assessment. For example, groundwater options tended to be least cost-effective in both Kazakhstan and Botswana.

Countries evaluated a broad mix of policy, technology, research, and education/outreach adaptation options. There do appear to be some sectoral trends. Technological options were more common in the coastal and water resource sectors than were other types of options, and options in the agriculture sector focused on educational or outreach activities to alter farm-level management practices. This suggests that the first reaction in adaptation may be to examine technological or operator changes that could enable activities such as farming or living in coastal areas to continue as before. Addressing policies that change these activities appears not to be the first choice of these countries. The results, however, are too preliminary to draw any conclusions about whether these trends indicate that technological or educational/outreach options are the best adaptation approaches in these sectors.

The adaptation options across sectors primarily affected domestic activities. However, there were some options pertaining to uses of international rivers that would benefit from, if not require, international coordination. This suggests that it will be important to coordinate some adaptation assessments and activities at the international level. It will also be important to ensure that adaptation options are consistent with other policy objectives such as greenhouse gas emissions reduction.

11 See Appendix A for an explanation of the models used to assess adaptation options in each sector.

Table 21 Summary of Adaptation Evaluation Methods and Results

Sector and Country	Cost-Effectiveness	Multi-Attribute	Benefit-Cost	Key Evaluation Results by Country
Agriculture				Best performing adaption options:
Kazakhstan	✓			Market transition and regional centers
Uruguay	✓			Seed bank and soil conservation
Egypt		✓		Change crops or cultivars
Water Resources				Most cost-effective/least cost-effective options:
Kazakhstan	✓			Diversions/groundwater
Romania	✓			Diversions/diversions and added storage
Botswana	✓			Recycling/groundwater
Ukraine	✓[a]			Dredge navigation routes/switch to rail transport
Bolivia	✓			Planning and drought or flood preparedness/water metering
Coastal Resources				
China			✓	B/C > 0 for full protection and all scenarios
Estonia			✓	B/C > 0 for full protection of Pämu, not Tallinn
Poland			✓	B/C > 0 for full and partial protection for entire coast
				B/C < 0 for some areas
				B/C > 0 most likely for projects in capital city
The Gambia			✓	B/C < 0 for all protection options
Venezuela	✓		✓	B/C > 0 for entire coast, B/C < 0 for some areas
Uruguay	✓	✓	✓[b]	Beach nourishment and ICZM had ASE and ADM best sources
Egypt				Beach nourishment and ICZM had ASE and ADM best scores

[a] The Ukrainian study did not include formal cost-effectiveness estimates like the other water resource studies, but their text indicates some comparison of relative costs across options for navigation.
[b] The Uruguayan coastal zone benefit-cost analysis was performed only for protection measures.

3.3.3 Challenges of Assessing Vulnerability and Adaptation

Although assessments of vulnerability have been conducted for almost two decades in developed countries, assessments of vulnerability in developing and transition countries have only recently begun. The USCSP has broadly expanded the number of developing and transition countries assessing impacts and the sectors being considered. This program has substantially expanded knowledge of potential climate change impacts, but there are a number of important limitations, including the following:

- General circulation models (GCMs) often do not adequately simulate current regional climates, so their estimates of future climate should not be treated as predictions. All methods for creating regional climate change scenarios should be treated as tools in identifying potential changes in climate and sensitivities of sectors to climate change. This uncertainty about regional climate change may be the greatest impediment to predicting the effects of climate change.
- Changes in baseline socioeconomic conditions need to be better integrated into vulnerability assessments. Baseline changes could significantly change vulnerability. Of those countries that developed baseline socioeconomic scenarios, only a few integrated the baseline scenarios into their analyses of vulnerability to climate change.
- Integration of impacts across sectors is important to understanding vulnerability. For example, a reduction in water supplies may limit the availability of water for irrigation. Most of the assessments addressed each sector in isolation, and addressed interactions among sectors only qualitatively, if at all.

Assessing climate change adaptation options is an emerging field. Very little work has been done on this topic in either developed or developing countries. It is probably reasonable to conclude that, to date, the USCSP, including the SNAP Program, is the most extensive assessment of adaptation to climate change.

The assessments done for the USCSP raise a number of analytic issues that should be addressed to aid countries in evaluating, selecting, and implementing adaptation options. Among these issues are the following:

(1) Uncertainties about climate change, particularly at the regional scale, make it difficult to select adaptation policies. Not knowing whether it will be wetter or drier, stormier or calmer, makes it difficult to determine what kinds of adaptations are needed. Should the emphasis be on droughts or floods, wet conditions that may result in spread of many infectious diseases, or dry conditions that increase the risk of fire? As long as this uncertainty continues, proposed policies need to be effective under a wide variety of climate change situations. Policies that address only one type of change may have too low a probability of occurrence to justify their adoption. On the other hand, the assessments of adaptation have identified many policies that have many benefits under the current climate as well as under climate change scenarios.

(2) Estimating the cost of adaptation options is often difficult. Many of the options for adaptation were unfamiliar to a number of USCSP participants, and techniques for cost estimation were not readily available. Future technical assistance should include the development of, and training in, techniques for estimating costs of adaptation options.

(3) Quantification of benefits of adaptation options can be difficult. Most of the assessments of adaptation benefits relied on expert judgment to assess the benefits of adopting measures. This is particularly true for the assessments of water resources and some of the assessments of agriculture. On the other hand, assessments of sea level rise adaptation options often yielded quantitative, even monetary estimates of benefits. This discrepancy is probably a result of a difference in the types of assessment tools made available to program participants. Coastal resource assessments used the Common Methodology, which emphasized analysis and quantification of adaptation costs and benefits. Assessments of other sectors tended to focus on identifying biophysical effects such as changes in crop yields and runoff, and had less capability to evaluate the costs and benefits of adaptation. For example, the DSSAT methodology allows users to assess the effect of farm-level adaptations on crop yields, but it does not estimate costs.

The first limitation, which is also the most important limitation for vulnerability assessment, will take time to resolve. Better science and improved climate models will be needed to make more certain forecasts about regional climate change. The last two limitations can be addressed by applying more sophisticated techniques to adaptation assessments. More sophisticated outputs such as monetary estimates of benefits and costs may well be needed before multilateral funding agencies are in a position to provide financial assistance for adoption of adaptation measures.

Despite these challenges, a number of USCSP countries participating in the SNAP Program have already undertaken extensive analyses of methods for implementing adaptation options as part of national action plans. These analyses serve as useful models for policy makers, nongovernment organizations, and researchers in other countries that are exploring methods for implementing adaptation measures. Examples of two of these analyses are provided in Box 30.

3.4 Suggestions for Future Work

The vulnerability and adaptation assessments conducted by 49 countries under USCSP significantly strengthened the capacity of developing and transition countries to assess their vulnerability to climate change and potential adaptive responses. The countries were able to develop scenarios and apply a variety of biophysical impact assessment methods and models in key sectors. These results significantly expand the literature on climate change impacts. In addition, the countries used a variety of methods to evaluate a wide range of adaptation options, including policy, technology, research, and education/outreach activities.

The preliminary results suggest that future vulnerability assessments can be improved by:

- developing better regional or local climate change scenarios, but still interpreting outputs from GCMs

Box 30 Implementation of Adaptation Measures

Kazakhstan and Egypt are two of the countries participating in the USCSP that assessed adaptation options under the SNAP Program. Kazakhstan has incorporated adaptation measures into its national action plan, and Egypt has begun to implement several adaptation measures.

Kazakhstan

Kazakhstan included the results of its water resource and agriculture adaptation assessments in its national action plan and its national communication as well. Kazakhstan also adopted activities as part of its "Plan on Social and Economy Development of the Republic of Kazakhstan for 1998-2000" that are consistent with recommendations from its adaptation assessment. The findings of the adaptation assessment were considered during the development of the plan, in part because a member of the assessment team was also involved in its development (Pilifosova, 1999). As a result, three pilot projects, which can be considered as the "first step" in implementing a program to reduce soil erosion, were included in the plan:

- *an inventory of land and a program to exclude ecologically damaged and low producing areas from arable lands*
- *development and implementation of measures to raise productivity of arable land*
- *creation of a center to handle land degradation problems in the Akmola administrative region.*

Although these measures are part of national action plans, there is currently no funding or plans for actually implementing them (Pilifosova, 1999).

Egypt

Egypt has begun implementing adaptation measures to address sea level rise and impacts on agriculture.

Over the last two years, Egypt has undertaken the following specific activities on adaptation to sea level rise:

- *An Integrated Coastal Zone Management Committee was formed by the Egyptian Environment Affairs Agency and charged with coordination among stakeholders.*
- *Many developments in the coastal zones of the Mediterranean and the Red Sea have considered the integrated approach and have carried out plans that take into account adaptation to sea level rise. A number of environmental impact assessments of projects also considered future adaptation to impacts of sea level rise.*
- *Periodic nourishment of some specific beaches at Alexandria and Port Said against erosion and sea level rise is in progress.*
- *Because of the SNAP Program, awareness of the effects of sea level rise among stakeholders on those specific beaches has increased. Questionnaires provided these stakeholders with basic information on the problem and its possible implications (El-Raey, 1999).[a]*

[a] Dr. El-Raey recommends that a "strategic impact assessment" be required by law such that plans and programs of development on the coastal areas be evaluated on the long term for adaptation to sea level rise.

as indicators, not predictors, of regional climate change

- encouraging countries to use incremental scenarios in addition to GCM scenarios because incremental scenarios are not sensitive to improvements in climate modeling techniques
- refining techniques for developing baseline socio-economic scenarios and incorporating them into vulnerability and adaptation assessments
- applying state-of-the-art assessment models that can be readily used by analysts
- designing vulnerability assessments to produce results that can feed directly into adaptation assessments.

Future adaptation assessments can be improved by:

- undertaking research on more consistent and reliable techniques for quantifying benefits and costs of adaptation
- developing protocols for assessing adaptation so applications and results are more consistent across countries
- examining implementation of adaptation to determine what types of analyses are useful to decision makers and to assess the accuracy of the analyses
- conducting an assessment of country's adaptive capacity (at the national scale as well as at regional and sector scales) and identifying conditions that enhance or impede adaptive capacity.

Finally, future vulnerability and adaptation assessments can be improved by providing continued technical assistance to analysts throughout the assessment.

Several changes in resource management would lead not only to adaptation to climate change but also to overall improvement of the Egyptian agriculture system. The vulnerability assessment for Egypt found that rice yields could decrease by 11 percent and water demand could increase by 16 percent. Based on this, the Delta (12 Governorates) and Middle Egypt (Fayoum Governorate) are trying to reduce the area under rice cultivation by approximately 40 percent. One set of adaptation measures involves the careful selection and/or breeding of heat-tolerant, salinity-tolerant water conserving crops, as well as controlled environmental production methods that minimize water use while maximizing the production of high-value crops (e.g., planting all-season vegetables and fruits, shifting to more cotton plantation instead of some maize in summer crops and to more planting of tomatoes, onions, and potatoes as winter crops before cotton and instead of wheat). Trials are being done on these options across Egypt through the Agricultural Research Centers and the universities (Eid, 1999).[12]

[12] Dr. Eid recommends that efforts be made to promote the preferential adoption of high-return, specialized and water-conserving crops instead of the presently grown water-profligate crops such as rice and sugarcane and /or reducing the area under cultivation with high water consumer crops and/or using early maturing and high yielding cultivars.