

### 3. ENVIRONMENTAL ISSUES AND THEIR IMPACTS ON NATIONAL SECURITY

This chapter provides an overview of critical environmental issues. It serves as a basis for the strategic analysis of the national security implications of these issues presented in the next chapter.

The term “critical environmental issues” reflects two realities:

1. there are more environmental issues than can be covered effectively in this study and, more fundamentally,
2. not all environmental issues are national security concerns.

The latter reality is simple enough, but actually deciding which environmental issues relate to national security is a challenging task. Conflict over scarce resources, water for example, is easily defined as a problem area. There is, however, a thread of logic that can perceive a threat in nearly every environmental issue, if not as a primary effect, certainly as a secondary or tertiary impact influencing national security. For example, as we see often in today’s world, human suffering from floods, mud slides, drought, or any of a long list of calamities may cause the national command authority to select a military response as a component of our aid in times of international humanitarian crises. Although a natural disaster is not in itself a security issue, any use of military forces has national security implications. It impacts the readiness of the troops by depriving them of time to train for their war-fighting mission, in diversion of resources from training, by causing wear and tear of military equipment (particularly air transportation assets), and through numerous other spillover impacts.

The issues selected for this analysis are a compilation of environmental stresses identified in works published by the U.S. Environmental Protection Agency (USEPA),<sup>1</sup> the Army Environmental Policy Institute (AEPI),<sup>2</sup> and a variety of authors included in the bibliography. Note that population trends analyses are included here even though population has not generally been considered an environmental issue. Strong arguments are being made by specialists in the field of human geography that it should be so viewed, since humans are part of the

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<sup>1</sup> USEPA, *Environmental Security* (Washington, D.C., 1999).

<sup>2</sup> Jerome Glenn and others, *Defining Environmental Security: Implications for the U.S. Army* (Atlanta, Ga.: AEPI, 1998).

ecosystem. It is becoming increasingly clear that one cannot consider environmental security issues without concurrently examining population trends, particularly in a regional context. For example, consider the water scarcity issues in several regions of the U.S. Water scarcity is caused by pollution of existing sources, reduction of available supplies, or increases in demand from either per capita demand increase or more people consuming at the same rate. In reality, most cases of regional water scarcity result from all of these factors occurring at the same time. Clearly, then, population trends must be examined in predicting water demand and determining scarcity issues.

Because population trends are an important variable in nearly all environmental security issues, we will begin this analysis by discussing population trends on a regional scale. We will then proceed to consider three major environmental areas:

- Global Climate Change
  - Global Warming (the greenhouse effect, greenhouse gases, the carbon cycle)
  - El Niño / La Niña
  - Ozone Depletion in the Stratosphere
- Land Use
  - Deforestation
  - Desertification
  - Hazardous Wastes
- Water Use
  - Fresh Water
  - Oceans

### 3.1 Population

Figure 3-1 depicts the increase in the human population of the Earth over the last 250 years and adds projections for the trends until the year 2100.<sup>3</sup> Clearly, an increasing population will have environmental impacts. We can use the concept of “carrying capacity” to help focus our understanding of the fundamental interrelationship between overpopulation and environmental security. Ecology and environmental geography share the concept of carrying capacity, which, defined in general terms, is the total population that the resources of an area can support over an indefinite period of time.<sup>4</sup>

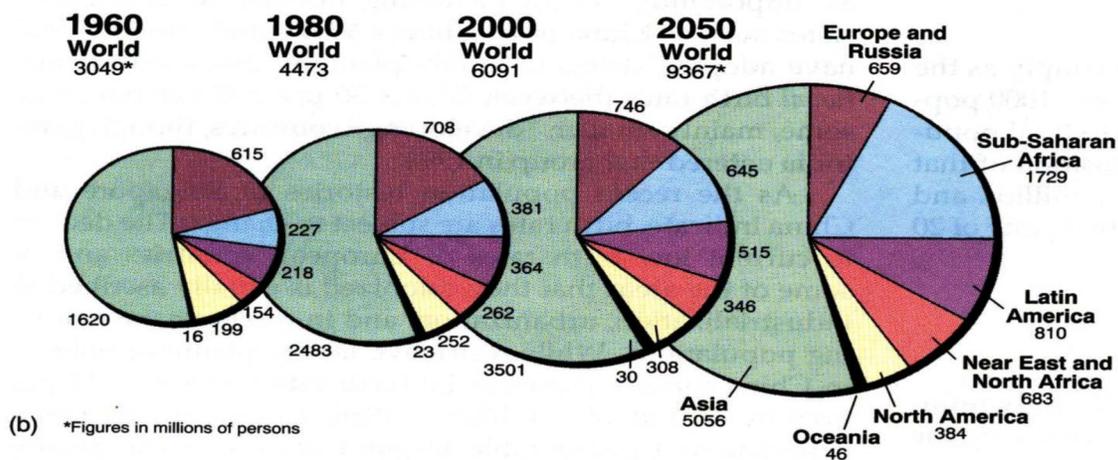
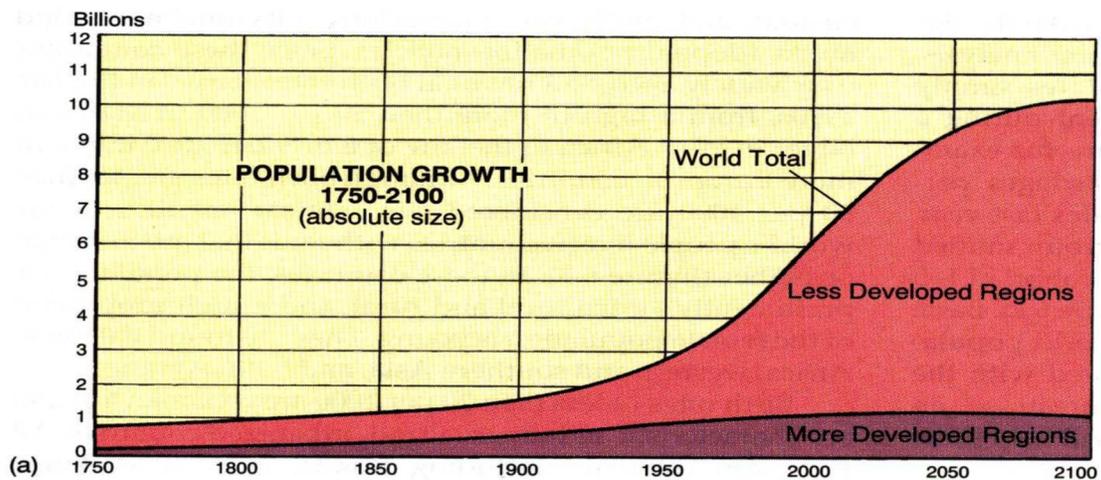
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<sup>3</sup> Arthur Getis and others, *Introduction to Geography* (Boston: McGraw-Hill, 1998), 192.

<sup>4</sup> *Ibid.*, 217.

The concept of carrying capacity is readily reflected in livestock management practices. Ranchers understand that a grazing area can sustain only a certain number of cattle or sheep per acre without long-term damage to the supporting vegetation. In the context of a specific geographical region, carrying capacity is a function of the soils, the climate, the availability of water, and several other natural system variables. The magnitude of carrying capacity can be influenced positively by technology with irrigation and fertilization, and it can also be impacted in both directions by weather, such as drought or increased rainfall. Over the long term, however, *only a finite number of animals* can be supported without damaging the land's ability to sustain its natural state.

**FIGURE 3 – 1**  
**World Populations, 1750–2100**



SOURCE: Arthur Getis and others, *Introduction to Geography* (Boston: McGraw-Hill, 1998), 142.

From a human perspective, this principle is equally valid—even with the marvelous products of human ingenuity. Technology can change the relative value of human carrying capacity by enabling us to resource one region at the expense of another, changing efficiency of use, and providing solutions to many other specific problems. However, there are finite limits to the number of people any region can support and, by extension, the total population the entire world can support.<sup>5</sup> Some of the more academic philosophies of human activity espouse the belief that technology can overcome the fundamentals of carrying capacity; to date this belief has not proven valid. The critical resources of water and energy<sup>6</sup> are renewable at finite rates, which humankind can impact only in minor percentages of total use. In the final analysis, we remain one of the more fragile organisms on the planet, bound to a relatively constrained set of environmental conditions of landscape, temperature, oxygen, moisture, and available energy sources.

### 3.1.1 Population Issues

When one considers the concept of carrying capacity in the context of Figure 3-1, the question immediately arises: what is the total carrying capacity of the Earth? Figure 3-1 predicts a steady-state world population of slightly over 11 billion people by 2100, nearly double the current world population. Will the Earth be able to sustain this many people?

We cannot even attempt to answer the questions without first considering the spatial distribution of both people and resources. Where will these 11 or so billion people be located and how well aligned will the people be with essential resources? Another issue that complicates any analysis of regional or world carrying capacity is the ability to share or transfer resources effectively. All great modern cities now operate through a worldwide supply network. Countries such as Japan and the United Kingdom thrive at a very high standard of living, while providing only a small portion of consumed natural resources from within their geographic boundaries. Further, there is no assurance that this transfer process can be sustained over time.

Whether it is 8 billion, 11-12 billion, or 50 billion people, no one truly knows how many people the Earth can sustain. Many scientists studying the issue are quite concerned

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<sup>5</sup> Lester Brown and Hal Kane, *Full House: Reassessing the Earth's Carrying Capacity* (New York: Norton, 1994).

<sup>6</sup> Energy is used in the broadest sense in this context. It includes food, heating fuel, and power used to support human activities such as transportation and many other energy consuming activities.

about the currently predicted human population increases and are acutely fearful about several rapidly growing regions with limited resources. If they are correct in their worries about regions with rapid growth, two scenarios seem plausible. First, renewable resources are mined (withdrawn at a faster rate than they are replenished by natural systems) until population far exceeds carrying capacity. This initial population surge then leads to a population die-off. The pressure of a burgeoning population often damages the natural resources to such an extent that there can be a loss in carrying capacity for the region. The large-scale chaos produced by this type of an event would result in a highly insecure world for all nations.

The second scenario is just a bit less threatening, but still involves serious security concerns. Here, resource limitations affect the rate of population growth so that the predicted population is not reached. Famine, disease, increased infant mortality, and the reduction of life expectancy could come to bear as a region reaches the limits of its ability to support the existing population. This scenario may even now be playing out in Africa, where over the last ten years population predictions for sub-Saharan Africa have been reduced to reflect the impacts of disease and other constraining factors.

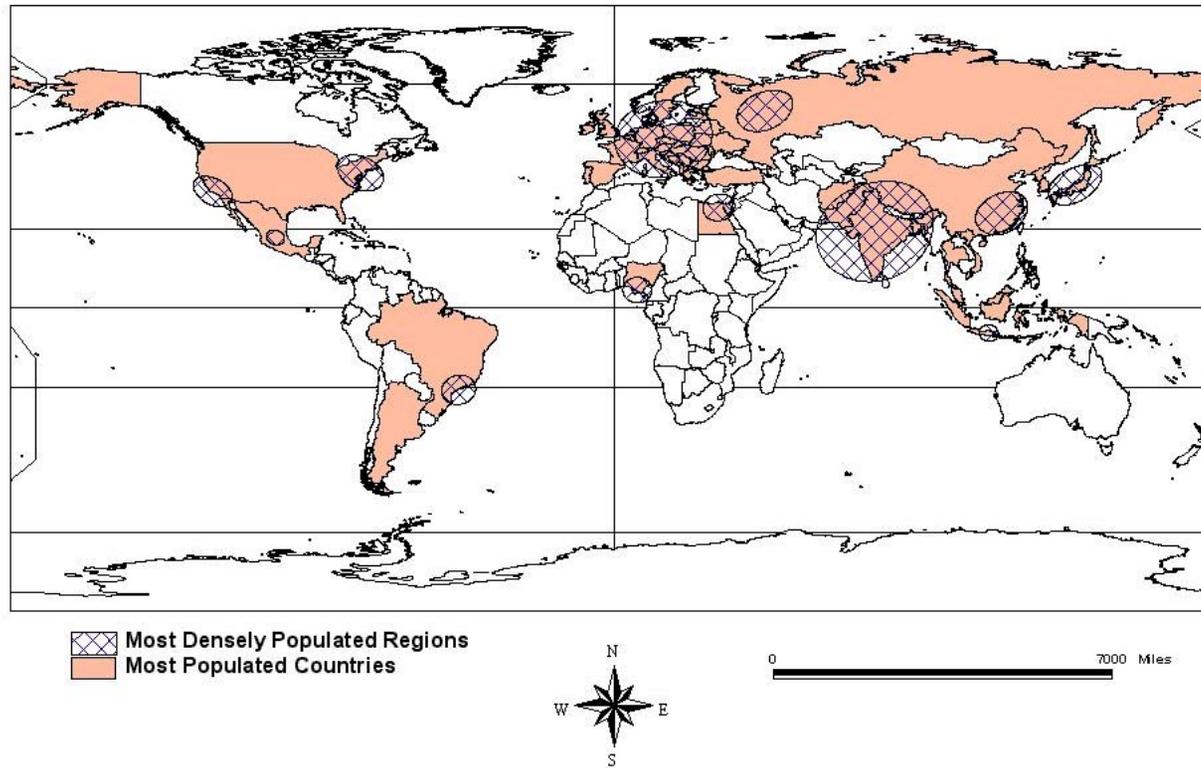
The obvious follow-on question and one that immediately relates to our environmental security analysis is: are there regions of the world that have already exceeded their carrying capacity or are in danger of doing so in the near term?

To begin to address this question it is necessary to examine existing and predicted population growth in a geospatial context. Figure 3-2 is a representation of the most heavily populated regions of the world; Figure 3-3 shows the countries with the highest natural growth rates. Natural growth rate (rate of natural increase) reflects the difference between yearly births and deaths reported as an annual percent change. This statistic does not include changes in a country's population resulting from migrations and therefore may differ from total rate of population growth. Because neither Figure 3-2 nor Figure 3-3 can be interpreted as defining regional carrying capacity, they do not directly answer the question posed. Much more detailed analysis of specific regions will be required, but the data provided in these two figures allow for certain summary inferences. For example, by overlaying areas of high population density with areas of high growth rates we can see the regions that are likely to experience problems in the future.

It is obvious that the west coast of Africa from Cote D'Ivoire to Nigeria, areas of Bangladesh and east India, and the Philippines are areas of high concern. A complete analysis of this type will be conducted in Chapter 4, where, having used environmental issues data to locate areas with resource limitations, we will be able to overlay our population data to identify areas with large and growing populations that also have resource limitations. Such an approach enables us to begin to identify areas where the carrying capacity concept may come into play.

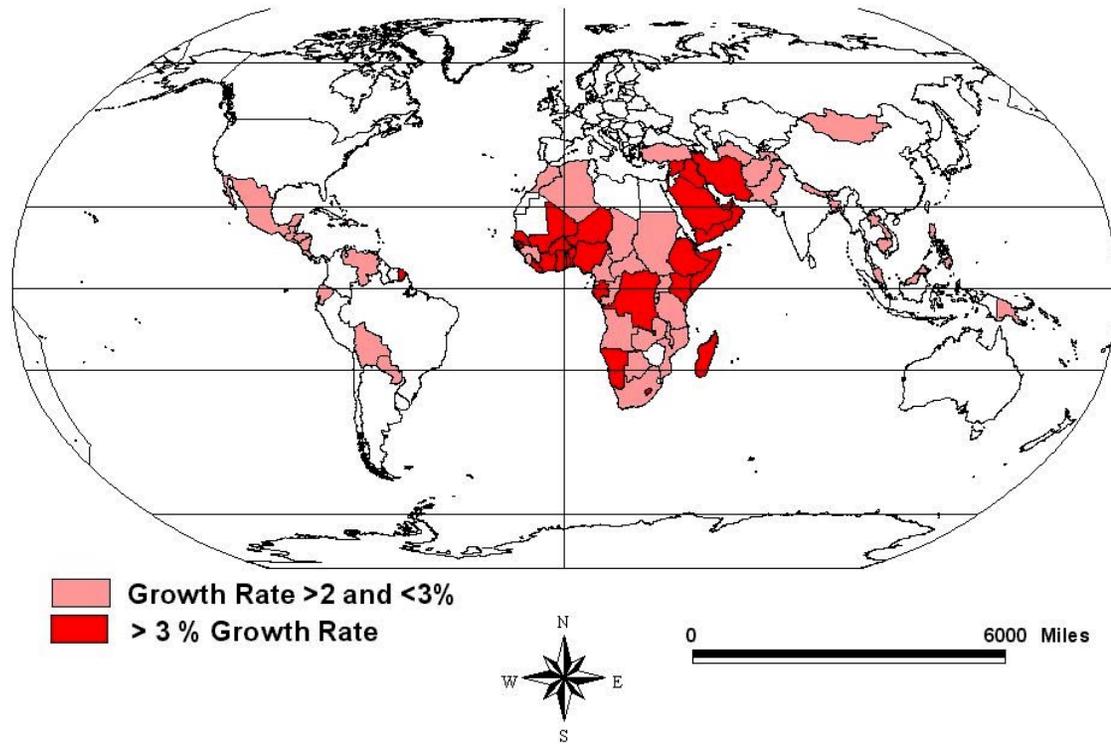
**FIGURE 3 – 2**

**World's Most Populated Countries with High Density Regions**



SOURCE: *Goode's World Atlas*, ed. Edward B. Espenshade and others (New York: Rand McNally, 1995), 25.

**FIGURE 3 – 3**  
**Population Natural Growth Rates**



SOURCE: *Goode's World Atlas*, ed. Edward B. Espenshade and others (New York: Rand McNally, 1995), 27.

This technique of spatial representation and matching of data is the basis of the geographic information system process that has evolved within geospatial sciences and which will be a primary tool for the analysis section of this paper. To the extent that the data are available, environmental issues will be quantified in the same spatial scale, as seen in Figures 3-2 and 3-3, thus allowing for a comparative analysis of regions. The power of this process will be discussed as the data are presented, but a caution must also be issued. All data found in this report are at the macro scale and cannot be used in too precise a manner. This report is meant to help identify areas where theater commanders should focus their detailed analyses. Further, it proposes a methodology that is applicable at any scale where data are available.

A major factor that complicates rigorous application of the principle of carrying capacity to human populations is the perturbing impact of global trends in urbanization. Figure 3-4 shows the results of a trend through which the world population has been transformed from 80 percent rural in 1925 to 52 percent rural today.<sup>7</sup> In some ways, urbanization increases the efficiency of a society in energy and resource use. At the same time, however, it creates high demand areas in regions that may not be capable of sustaining the population. Consider the air pollution problems of major cities such as Los Angeles, Mexico City, or Santiago, Chile, or the water concerns in such places as Tucson, Phoenix, and numerous other towns in the southwestern U.S. These are regions that have exceeded the carrying capacity of at least a part of their natural environment. Depending on the stage of economic development of the society, these types of issues have a greater or lesser impact on the population, but all represent the possibility of environmentally induced strain. The specifics of these problems will be addressed in Chapter 4.

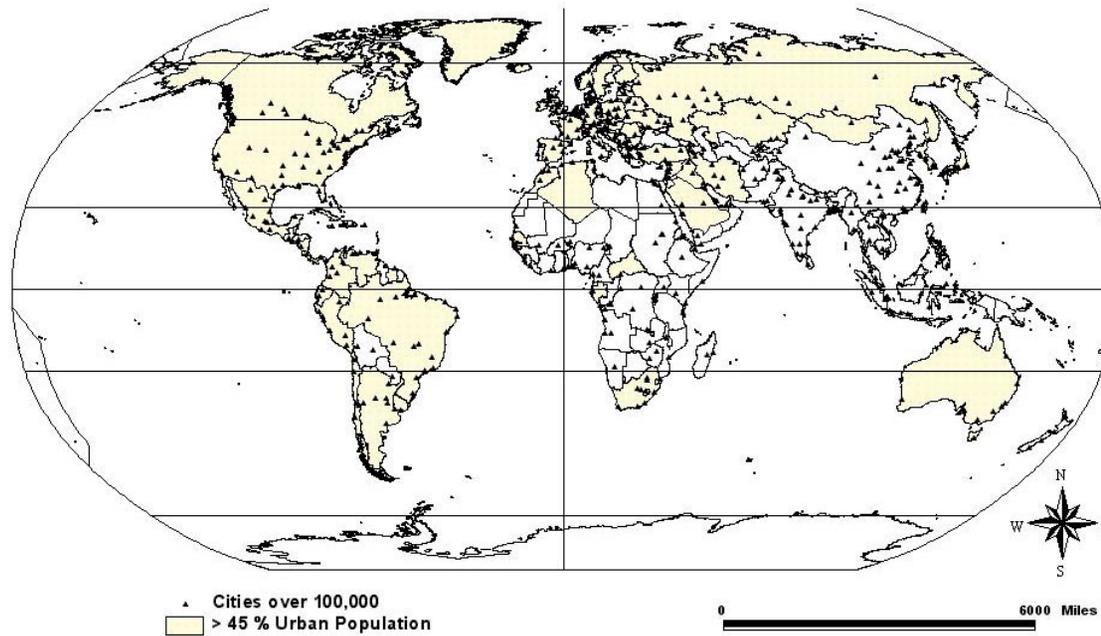
### **3.1.2 Population Impacts**

Most of the analysis of population increase impacts will be done in the following sections on environmental factors, but this section concludes with the hypothesis that there are regions of the world that cannot, even under normal environmental conditions for these regions, support the population that now exists. Such regions lack one or more critical resources—whether water, clean air, or energy (in the broadest sense, including food and power for transportation and other energy-consuming activities)—to provide for the basic requirements of the current population. This seems to be the case for parts of Africa today.

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<sup>7</sup> *Goode's World Atlas*, ed. Edward Espenshade and others (New York: Rand McNally, 1995), 27.

**FIGURE 3 – 4**  
**Urbanized Countries and Large Cities**



SOURCE: *Goode's World Atlas*, ed. Edward B. Espenshade and others (New York: Rand McNally, 1995). Cities from ESRI Data Base, 1999.

In this situation, people first mine the natural resources, consuming water, wood, and other renewable resources at a rate faster than they can be regenerated. Next, people may migrate to a region where they can be better supported, but such opportunities are found less and less in a world of 6 billion. In natural systems, the final stage of this process is the die-off phase described earlier. The human response is much more difficult to predict because more variables come into play. Humanitarian relief to stressed regions is one example of a variable, while human conflict or war is another. In any event, the population must align with the sustainable level of resources and this can mean reduction of the population. Often die-off is precipitated by some environmental event such as a drought or flood. The net impact is that the population suffers a significant reduction over a short period of time. Obviously, each level of this hopeless cycle will increase the insecurity in a region until complete chaos exists.

The term “hopeless” is employed in the sense that the basic principle of carrying capacity cannot be violated over the long term; thus, it is hopeless to expect a region to long support more than its capacity for people. Worse, the first phase, the mining of renewable resources can actually reduce the existing carrying capacity of a land for some period—which can be a very long period for a fragile environment such as a desert or a cold region. To illustrate this concept, we can use the example of agricultural crop rotation, which involves cultivating the land for a period and then allowing a fallow time for the soil to recover. It has been proven that without this recovery period the land produces less and less until it becomes unusable. As will be discussed in the section on desertification, people’s actions can critically damage the entire ecosystem of an area.

Many authors continue to suggest that it is the resource side of the problem that must be addressed. Paul Simon’s excellent book on water, *Tapped Out—The Coming World Crisis in Water and What We Can Do About It*,<sup>8</sup> takes this general approach, i.e., fix the water problems and we can avoid the crisis. While his concern with water and his solutions are all valid, the underlying principle of carrying capacity cannot be violated. In the water context, the climate provides a watershed with only a fixed amount of water. There is a minimum amount of water required per person each day for survival. The equation then becomes straightforward:

$$\text{Human carrying capacity} = \frac{\text{Gallons of water available per year}}{\text{Gallons per person per year}} \quad (3-1)$$

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<sup>8</sup> Paul Simon, *Tapped Out* (Champaign, Ill.: Welcome Rain Pub., 1998).

Conservation and other management tools can to some degree change the values in both the numerator and denominator, but cannot change the reality that a given environmental setting can support only a certain number of people.

### **3.2 Global Climate Change**

This environmental security analysis begins with the issue of global climate change because of the high risk of the consequences associated with it. The issue itself is complex and fraught with uncertainties. Some authors writing on global climate change immediately describe the issue as global warming, although their discussions admit a great deal of existing uncertainty. There is a lack of agreement regarding the degree to which human activities are affecting global climate. Further, as is demonstrated in the following discussion, there is little certainty in predicting future climate change. Nevertheless, based on documented anthropogenically produced changes to the atmosphere and employing the risk model of Equation 1-1 (p. 9), there is a sufficiently high probability of occurrence and the potential severity of the consequence is high enough to pose significant risk. Thus, the issue must be seriously considered.

Understanding global climate change is technically complex because of the many dependent variables in the defining equation and because of the natural variability of weather even without anthropogenically induced change. Breaking the impasse on the science of global climate change has required considerable international cooperation, and in a sense can be considered as progress in security because of the many fruitful and cooperative discussions that have ensued. In 1988, the Intergovernmental Panel on Climate Change (IPCC) was formed. Over time the IPCC has produced several significant studies on this subject and has contributed to building consensus and reducing uncertainty. The IPCC results will be the basis for discussion at several points in this review and analysis, particularly in areas where a wide diversity of opinion exists.

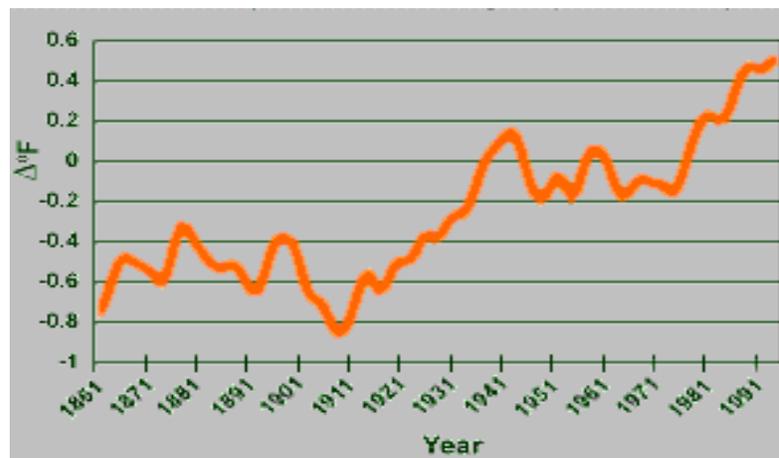
#### **3.2.1 Global Warming**

Many scientists, as will be shown shortly, now believe that global climate change in the form of global warming caused by anthropogenic activity is occurring. Driving global climate change is a series of interwoven phenomena including, but not limited to, deforestation,

burning of fossil fuels, and industrial pollution. Assessing each of these factors independently in a static model is within our scientific capability today, but does not yield realistic results. Each activity occurs independently at different rates and concurrently with the natural variability in weather.

Figure 3-5 shows changes in world temperature over the past 135 years, the period for which accurate measured data are available.

**FIGURE 3 – 5**  
**Global Temperature Changes (1861–1996)**



Source: IPCC (1995), updated.

Many look at these data and conclude that global warming is an acute issue brought on by human abuse of the environment.<sup>9</sup> Others, however, point out that this change over such a minute period in the history of the Earth is well within the statistical bounds of natural fluctuations.<sup>10</sup> Logically, the change illustrated in Figure 3-5 must be the result of both, i.e., the forced changes caused by human inputs imbedded in the natural variability for that period. Unfortunately, there is insufficient scientific understanding to precisely separate the two components at this time.

In attempting to understand global climate change, this study begins by presenting the known factors in the equation, which are primarily the greenhouse effect, the increase in greenhouse gases produced by human activities, and the carbon cycle. With these as a

<sup>9</sup> Rodney White, *North, South, and the Environmental Crisis* (Toronto: University of Toronto Press, 1993), 39.

<sup>10</sup> John Horel and Jack Geisler, *Global Environmental Change* (New York: John Wiley, 1997), 9.

basis one can build on the known science to more competently examine the feasible range of measured changes in the environment and then apply this perspective to determine possible human impacts.

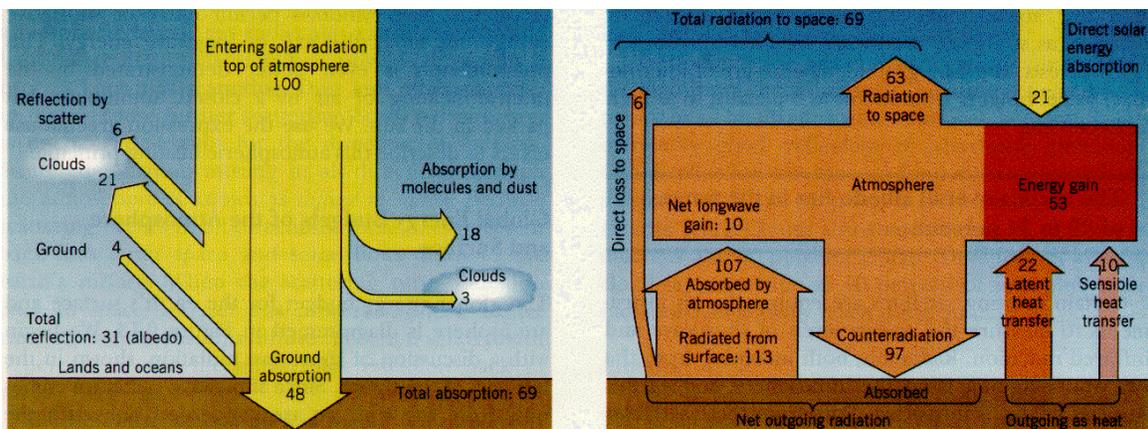
### *The Greenhouse Effect*

The “greenhouse effect” is a term used to describe the natural process by which the Earth’s atmosphere converts the sun’s light energy into heat to warm the surface of the Earth and make our planet habitable for all living organisms. The process inherited this name because what occurs in the Earth’s atmosphere is not unlike what occurs in a greenhouse, where the sun’s energy is naturally collected and retained to help plants grow.

Before beginning our discussion, we must first address and discard a common error: the greenhouse effect is not the “bad” process that causes global warming, though many authors suggest that it is by misusing the term. The greenhouse effect is an essential function of the biosphere without which humans could not inhabit the Earth.

Figure 3-6 is a simple model of the heating of the Earth’s surface by the sun. The sun’s energy arrives at the top of the atmosphere as visible or short wavelength radiation, with most energy in the range of 0.3 to 0.7 micrometers. Each component (whether gas or particle) of the atmosphere has as one of its basic material properties a specific way of interacting with the

**FIGURE 3 – 6**  
**Global Energy Balance**



SOURCE: Alan Strahler and Arthur Strahler, *Introducing Physical Geography* (New York: John Wiley, 2000), 43.

electromagnetic energy that strikes it; each element of energy will be reflected, absorbed, or transmitted (pass through the component). For example, oxygen, which makes up just over 20 percent by weight of our atmosphere, absorbs most light below 0.3 micrometers wavelength and is transparent to all longer wavelength energy. Nitrogen (80 percent of air) is transparent to all visible (short wavelength) and heat radiation (long wavelength or infrared). As indicated in Figure 3-6, clouds, the ground, and the air reflect a small percentage of light; the atmosphere absorbs a small amount; but the ground absorbs about half of the sun's light energy. The light directly reflected by the ground does not change wavelengths; therefore, it will travel back into space because it remains transparent to the atmospheric gases. The unreflected energy reaching the Earth's surface is either absorbed at the surface or is captured for use by photosynthetic plants. The absorption of energy by soil, rocks, and other materials warms Earth's surface. Since all warm bodies emit heat energy (see the right side of Figure 3-6) as longer wavelength radiation (4–20 micrometers), the Earth's surface becomes a source for infrared radiation. This long wavelength energy is transmitted through oxygen and nitrogen, but is absorbed at different rates by several of the minor constituents of the atmosphere, both those that are naturally occurring and anthropogenically generated substances.

### ***Greenhouse Gases***

Gases that have the ability to absorb thermal wavelength energy have been defined as “greenhouse gases.” Table 3-1 lists the greenhouse gases, their current atmospheric concentrations, their relative absorptive capacities, and other important properties that will further our understanding of the greenhouse effect.

The greenhouse effect is, then, the warming of the atmosphere close to the ground by certain gases absorbing heat radiated from surface materials. Since the amount of energy input by the sun is relatively constant from year to year, the temperature of the Earth's atmosphere is regulated by the concentration of the greenhouse gases listed in Table 3-1. Each gas enters and leaves the atmosphere at a rate determined by both natural cycles and inputs from human activity. Increases in the quantity of these gases present in the atmosphere disturb the balance and could influence atmospheric temperatures. Many knowledgeable scientists have concluded that the increase of greenhouse gases, particularly carbon dioxide, is causing an “enhanced greenhouse effect” and that this is the cause of the global warming reflected in Figure 3-5.<sup>11</sup>

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<sup>11</sup> John Houghton, *Global Warming* (Oxford, England: Lion Publ., 1994).

**TABLE 3 – 1**  
**Properties of Greenhouse Gases**

Chemical	Preindustrial Atmospheric Concentration	Concentration in 1994	Absorption wavelengths in the thermal range (micrometers)	Residence Time in the Atmosphere (years)	Strength of Absorption Relative to Carbon Dioxide
Carbon Dioxide, CO <sub>2</sub>	280 ppm	360 ppm	>10	3	1
Methane, CH <sub>4</sub>	0.8 ppm	1.7 ppm	3 & 7	10	20
Freon, CFC-11&12	0	0.76 ppb	8 – 12	100	12,000
Nitrous Oxide, N <sub>2</sub> O	0.288 ppb	0.31 ppb	8	150	200
Water, H <sub>2</sub> O	Varies	Varies	3, 6, & 11	-	-

Notes: ppm = parts per million in volume to volume ratio; ppb = parts per billion by volume

SOURCES: Compiled from Noel de Nevers, *Air Pollution Control Engineering* (Boston: McGraw-Hill, 2000), 523; John Horel and Jack Geisler, *Global Environmental Change* (New York: John Wiley, 1997), 98; and John Houghton, *Global Warming* (Oxford, England: Lion Publ., 1994), 22.

At this point, an examination of the greenhouse gases on an individual basis will allow for a better interpretation of their impacts on the environment. We will begin with the gases that have the least impact and work up to our major concern, carbon dioxide (CO<sub>2</sub>).

Nitrous oxide (also known as laughing gas) is a relatively minor component of the environment and one that has grown only slightly with industrialization. There are both natural and human sources for nitrous oxide; these include natural biological processes, chemical manufacturing, and motor vehicle emissions. The rate of production from all of these sources is not large enough to suggest big changes in atmospheric nitrous oxide concentration in the future. Nitrous oxide is a gas that persists in the environment and is a strong energy absorber; therefore, any new major sources would be of concern. But again, without significant changes in atmospheric concentration, nitrous oxide is not expected to further impact the global climate.

Freon is a common name for the most important forms of a class of chemicals more precisely described as chlorinated fluorocarbons (CFCs). CFCs are a class of synthetic chemicals used in the past as carrier gases for aerosol spray cans and, more important, as gases used to produce the cooling reaction in refrigeration compressors. Much more attention will be given to CFCs when the problem of the hole in the ozone layer is discussed, but CFCs are also greenhouse gases because they very efficiently absorb thermal energy. Table 3-1 shows that CFCs are also highly persistent. Thus, at even small concentrations, they can contribute to the enhanced greenhouse effect. Noel de Nevers estimates that 24 percent of the anthropogenic

enhanced greenhouse effect is the result of CFCs.<sup>12</sup> If the concentration of CFCs were to continue to increase, they would be of major environmental concern. Later in this chapter we will discuss the good news story of a worldwide effort to phase out the use of CFCs. The bad news, however, is that even though the concentration of CFCs in the atmosphere is being reduced, an atmospheric residence time of 100 years is going to make recovery very slow.

Methane is a naturally occurring gas that is also a by-product of many industrial processes and is the major component of the fuel called “natural gas.” Biochemical reactions that proceed in the absence of oxygen produce methane (swamp gas) as a by-product. Wetlands and paddy agriculture are the major sources of methane, followed by sources from the livestock production industry. Because methane is 20 times stronger than CO<sub>2</sub> in its greenhouse impact, is increasing, and has sources that are crosslinked to population, methane is a concern in the enhanced greenhouse effect.

With regard to anthropogenic sources of the enhanced greenhouse effect, CO<sub>2</sub> concentration in the atmosphere is the big issue. There is complete certainty that, over the short term of atmospheric measurement available, the concentration of CO<sub>2</sub> in the air is increasing and burning of fossil fuels is the cause. Figure 3-7 shows the trend in carbon dioxide concentration over the past 300 years with an expanded view since 1960. One cannot but notice the striking similarity in shape between this figure and Figure 3-5 (global temperature changes). Is this merely a coincidence? A mass balance of the total carbon in the environment as depicted in Figure 3-8 shows that fossil fuel burning and deforestation (which will be discussed later in this chapter) are adding CO<sub>2</sub> to the air faster than natural systems can remove it, with a net increase of 3.5 gigatonnes per year.

A common misconception about global warming arising from poor science reported in the news media is that CO<sub>2</sub> is produced because of improper burning of fossil fuels. Carbon dioxide is the clean by-product of the complete combustion of all fossil fuels and is not created by improper burning. This can be represented chemically as,



Poor combustion processes produce carbon monoxide (CO), which is an air pollutant because of its deleterious health impacts, asphyxiation being the most acute. The only way of reducing CO<sub>2</sub> production in burning coal, gasoline, or natural gas is to burn less fuel.

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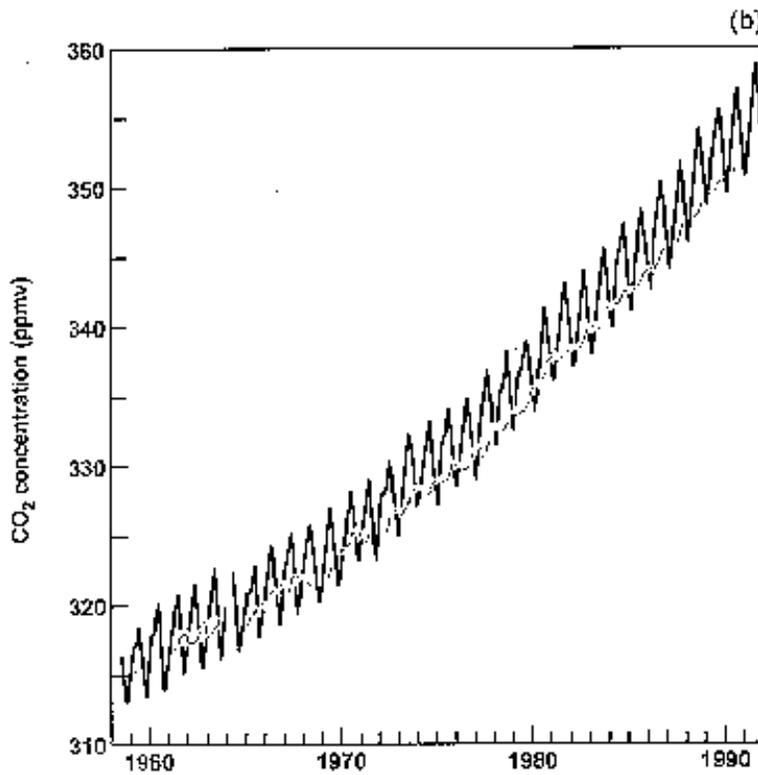
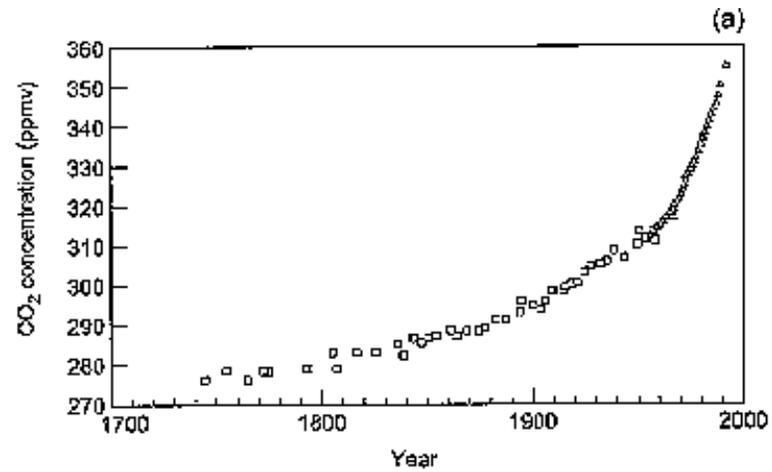
<sup>12</sup> Noel de Nevers, *Air Pollution Control Engineering* (Boston: McGraw-Hill, 2000), 517.

# FIGURE 3 – 7

## Carbon Dioxide Concentrations

a) 1700 – 1990s

b) 1960 to 1994 as measured at Mauna Loa Hawaii



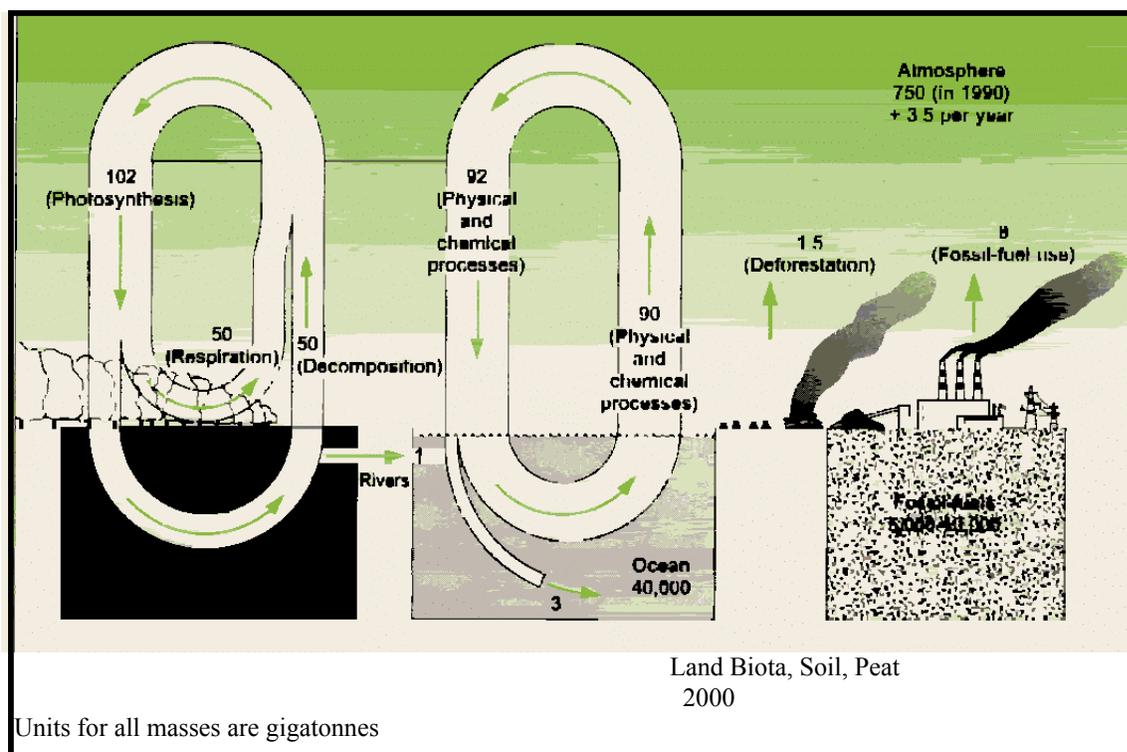
SOURCE: John Houghton, *Global Warming* (Oxford, England: Lion Publ., 1994), 31.

## The Carbon Cycle

The fate of the carbon dioxide in the air is described as a part of the carbon cycle, a complex, dynamic system of chemical and biological processes illustrated in Figure 3-8. First, we need to recognize that there is a natural or good concentration of CO<sub>2</sub> in air that is essential for photosynthetic reactions in green plants. On land, photosynthesis captures CO<sub>2</sub>, storing carbon in plant biomass and releasing oxygen back to the environment. The carbon can be re-released back to the atmosphere by natural decomposition or human activities (such as burning of fuels). The reactions in the ocean are more complex because both chemical and biological processes come into play in transporting CO<sub>2</sub> from the air to the water and through living organisms, with waste products either returning to the air or sinking to the bottom of the ocean where they are retained for long periods.

One of the uncertainties in global warming has to do with the role played by chemical reaction kinetics. It is known that for all chemical and biological reactions, an increase in one

**FIGURE 3 – 8**  
**The Carbon Cycle**  
(1990 data)



SOURCE: John Houghton, *Global Warming* (Oxford, England: Lion Publ., 1994), 30.

of the inputs (reactants) increases the rate at which reactions occur and the quantity of products produced. This leads to the hypothesis that an increase of CO<sub>2</sub> in the air can/will cause an increase in the uptake rate of CO<sub>2</sub> and thereby compensate for or moderate the rate of increase of CO<sub>2</sub> in the atmosphere. Whether or not this theory proves true, Figure 3-7 indicates that this type of regulation has not occurred or, if it has occurred, its effects have not been strong enough to counterbalance the large CO<sub>2</sub> inputs occurring today.

John Houghton and others provide excellent discussions of the many different scenarios that can be used to predict carbon dioxide concentrations in the year 2100.<sup>13</sup> Even with the uncertainties in the science, all models indicate that the rate of fossil fuel burning regulates CO<sub>2</sub> levels. The optimistic predictions are for CO<sub>2</sub> to level off at just over 400 parts per million (ppm) and pessimistic estimates predict CO<sub>2</sub> exceeding 700 ppm by 2100. This is the first major uncertainty in understanding global warming: how will carbon dioxide produced by man-made and natural processes impact the global climate, and what will the concentration of CO<sub>2</sub> in the air be in the future?

Table 3-2 presents the release rates for greenhouse gases (GHG) as self-reported by the major producers in the world.<sup>14</sup> The United States produces 25 percent of the world's carbon releases and our burning of carbon fuels continues to increase over time. Without a paradigm shift in use patterns in the predictable future, there will continue to be a growth in greenhouse gases, dominated by CO<sub>2</sub> production.

### **3.2.2 Impacts of Global Climate Change**

The preceding discussion alluded to the fact that the uncertainty challenging scientists' understanding of the enhanced greenhouse effect has to do with defining the relationship between changes in GHG concentrations in the air and changes in global climate. The consensus of scientists today is that increases in CO<sub>2</sub> will have a direct impact on temperature. Specifically, increases in CO<sub>2</sub> will produce increases in global temperatures. We have already noted that a comparison of Figure 3-5 (global temperature change) with Figure 3-7 (CO<sub>2</sub> concentrations) suggests a very strong correlation between the two, but it would be simplistic to draw rigorous scientific conclusions from this observation. Predicting temperature change within the dynamics of greenhouse gas behavior and natural climate processes

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<sup>13</sup> Houghton, 37.

<sup>14</sup> USEPA, website: [www.epa.gov/globalwarming/emissions/international/inventories.html](http://www.epa.gov/globalwarming/emissions/international/inventories.html), April 2000.

**TABLE 3 – 2**  
**Aggregate Greenhouse Gas Emissions,**  
**Excluding Land-Use Change and Forestry**  
(MMTCE)

Country	1990	1991	1992	1993	1994	1995	1996
Australia	113.4	113.4	114.5	114.5	115.6	118.8	121.6
Austria	21.1	22.3	20.7	20.4	20.4	21.5	21.9
Belgium	37.9	39.0	38.3	37.9	39.4	39.6	41.4
Canada	163.1	161.5	164.7	168.0	172.9	178.2	183.1
Czech Republic	52.4	48.2	44.5	43.0	40.9	41.2	41.9
Denmark	19.5	22.5	21.1	21.5	22.5	21.5	25.3
France	151.9	158.0	155.0	147.4	147.4	149.4	153.3
Germany	329.8	316.6	303.4	300.1	296.8	292.8	297.6
Greece	28.7	28.7	29.0	29.3	29.8	30.6	31.3
Ireland	15.5	15.4	15.5	15.5	16.0	16.2	16.3
Japan	333.2	339.9	346.5	343.2	363.2	368.8	-
Latvia	9.7	8.0	7.0	6.0	5.3	5.2	4.9
Monaco	0.03	0.04	0.04	0.04	0.04	0.04	0.04
Netherlands	59.2	61.0	60.4	61.0	61.6	63.9	66.3
New Zealand	19.8	19.8	19.9	19.9	19.8	19.8	20.4
Norway	15.0	14.4	14.0	14.6	15.2	15.3	16.1
Slovakia	19.8	17.4	16.0	15.2	14.2	14.8	15.0
Sweden	17.8	17.6	17.9	17.9	18.5	18.3	19.8
Switzerland	14.7	15.1	14.8	14.4	14.2	14.4	14.6
United Kingdom	206.7	206.7	200.5	194.3	192.2	189.6	195.5
United States*	1,632.1	1,620.0	1,645.2	1,675.0	1,713.2	1,733.9	1,790.5

- Data not available

\* Emissions data taken from the latest "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-1997."

Source: USEPA website: [www.epa.gov/globalwarming/emissions/international/inventories.html](http://www.epa.gov/globalwarming/emissions/international/inventories.html), April 2000.

is a key area of uncertainty in the global warming debate. Several complex computer models have been developed and are being continually updated, but each has its strengths and weaknesses. Here we come to yet another major area of uncertainty, knowing how much the temperature will change as greenhouse gases increase.

A wide range of temperature predictions exists, but they generally fall in the 0.5 – 5.0° C range. To proceed further with this analysis of estimates of impacts from the enhanced greenhouse effect, we will need to choose a temperature prediction from this range. This study will use the figures projected by the IPCC and supported by the USEPA, or a 1 to 3.5 °

C temperature increase by 2100.<sup>15</sup> The reason for our choice is that these figures represent the consensus values of scientists worldwide and have received the most scrutiny.

This introduces another area of uncertainty into the global warming debate, and arguably the one of greatest contention in the scientific community. Again, complex interactions between systems, actions, and counteractions of the carbon cycle and other processes make it difficult to determine exactly how atmospheric warming will change the Earth's atmosphere. Based on our current understanding of climate and weather, a rise in temperatures worldwide and changes in temperature distribution, spatially and temporally, will change weather and climate over large areas of the Earth. Weather is primarily driven by the sun's energy being unequally distributed over space and time. Higher temperatures will produce more evaporation from the oceans and this will increase rains somewhere. Higher temperatures over land will increase evaporation of soil moisture, raise dry soil temperatures, and melt ice. All of these factors will combine to change the weather patterns of a particular region, in both frequency and intensity of events. These can over time sum to changes in climate regions in many parts of the world. Grasslands, forests, and deserts may shift due to evolving climates.

Sea level rise as a direct response to global warming has been the issue that seems to have captured the most public attention, although there are many other equally important possibilities that must be assessed, particularly in considering environmental security. Based on scientific analysis to date, the range of sea level rise is predicted to be between -1 and +6 meters, not a particularly informative range to use in assessing impacts. However, the factors that enter into this calculation are fairly well defined.

First, warm water occupies a larger volume than cold water, so as ocean surface temperatures warm because of contact with the warmer air, the volume of the ocean will increase, resulting in a rise in sea level. The more difficult factor to calculate is the depth change attributable to warmer air temperatures occurring in regions with snow and ice cover. Uncertainty about whether and how much ice will melt under different warming predictions accounts for the wide range in the sea level rise estimates. Using the IPCC warming estimate as a basis for temperature rise,<sup>16</sup> Houghton predicts a 50-centimeter (1.65 feet) sea level rise by the year 2100. The most detailed statistical analysis of sea rise predicts a 35 cm rise by 2100 as the most likely result, with a 10 percent chance of sea rise reaching 65 centimeters, and a 1 percent chance of a 1 meter rise.<sup>17</sup> This rise, coupled with natural land subsidence in some lowland regions, could have large impacts in several critical areas of the world, such as

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<sup>15</sup> USEPA, website: [www.epa.gov/globalwarming/publications/reference/ipcc/summary/page4.html](http://www.epa.gov/globalwarming/publications/reference/ipcc/summary/page4.html), April 2000.

<sup>16</sup> IPCC, *Climate Change 1992* (Geneva: United Nations, 1992).

<sup>17</sup> James Titus and Vijay Narayanan, *The Probability of Sea Level Rise* (Washington, D.C.: USEPA, 1995).

Bangladesh and Egypt.<sup>18</sup> The significance of this with regard to security will be discussed in the next chapter.

There is some scientific certainty that changes in weather will impact water resources, food production, human health, weather events such as floods and other “natural disasters,” and coastal processes, all of which have peace and security implications. In this researcher’s view, these are more difficult impacts to predict than sea level rise. In order to realistically predict the impacts of global climate change it will be necessary to input the variables with the accumulated uncertainties mentioned above into the same weather and climate models that are now employed to predict the weather.

Figure 3-9 is one estimate of climate change based on continued discharge of greenhouse gases at the IPCC predicted “business as usual” rate. This figure characterizes changes in climate that could occur in five regions of the world. Looking at the area of the United States depicted in this figure as a familiar example, we can see the impacts such a climate change might produce. The central U.S. is a rich agricultural area that relies extensively on irrigation, primarily using groundwater to increase production. The predicted drier summer months would cause either lower production rates or increase the need for irrigation, assuming the water was available. The groundwater source for this region is the Ogallala aquifer. This massive aquifer is the primary water source for a large part of the middle U.S., from Minnesota all the way to the Texas/Mexico border. Water levels are already dropping rapidly in this aquifer, largely as a result of agricultural uses in the upper Midwest that actively mine the aquifer. Current use rates threaten water supplies over this entire region.<sup>19</sup>

The difficulties in predicting impacts of climate change can be appreciated by considering the two questions below:

- a. Will the predicted increases in rain in the winter recharge the aquifer sufficiently so that additional water can be used in irrigation in the summer over an indefinite period and possibly increase production through a longer growing season?

Or

- b. Will the needed additional summer withdrawals further deplete the aquifer and endanger water supplies throughout the aquifer, ultimately drying up much of southern Texas?

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<sup>18</sup> Houghton, 91.

<sup>19</sup> Simon, 43-45.

## FIGURE 3 – 9

### Houghton's Predictions of Climate Change

#### Estimates of regional changes by 2030<sup>8</sup>

In the IPCC 1990 report, estimates were given for climate changes by the year 2030 under a business-as-usual scenario of greenhouse gas emissions, for the five regions shown in the map of Fig. 6.4. These regional estimates can be summarized as follows:

**Central North America**  
Warming varies from 2 to 4°C in winter and 2 to 3°C in summer. Precipitation increases up to 15 per cent in winter whereas there are decreases of 5 to 10 per cent in summer. Soil moisture decreases in summer by 15 to 20 per cent.

**Southern Asia**  
Warming varies from 1 to 2°C throughout the year.

Precipitation changes little in winter, but in the summer monsoon increases by 5 to 15 per cent<sup>9</sup>. Summer soil moisture increases by 5 to 10 per cent.

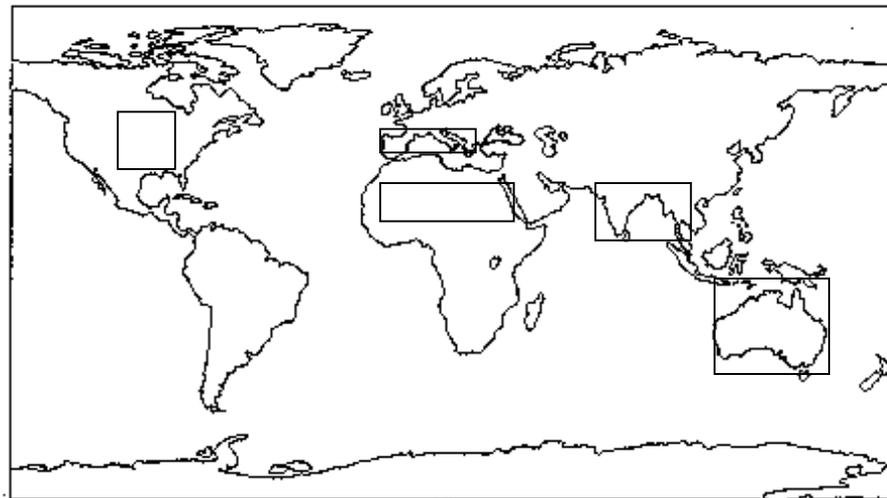
**Sahel region of Africa**  
Warming ranges from 1 to 3°C. Area mean rainfall increases and area mean soil moisture decreases marginally in summer. However, within the region, there are areas of both increase and decrease in rainfall and soil moisture.

**Southern Europe**  
Warming is about 2°C in winter and varies from 2 to 3°C in summer. There is some indication of increased precipitation in

winter, but summer precipitation decreases by 5 to 15 per cent, and summer soil moisture by 15 to 25 per cent.

**Australia**  
The warming ranges from 1 to 2°C in summer and is about 2°C in winter. Summer precipitation increases by about 10 per cent, but the models do not produce any consistent estimates of the changes in soil moisture. The area averages hide large variations at the sub-continental level.

FIG. 6.4 Map of regions chosen for estimates of regional climate change.



SOURCE: John Houghton, *Global Warming* (Oxford, England: Lion Publ., 1994), 84. After the IPCC, 1990.

Current scientific understanding does not provide a definitive answer to these questions today, although this is one of the most studied geohydrologic systems in the world. Clearly, even in the country of the world most capable of mitigating change, the impacts on economics, quality of life, and other secondary elements could be immense.

Table 3-3 presents a synthesis of predicted worldwide impacts from regional climate change based upon IPCC Global Climate Change studies, as summarized by the USEPA. As indicated in the table, regions relying on single-crop agriculture and subsistence farming, such as tropical Asia and Africa, are particularly vulnerable to changes in weather patterns. Vector and water-borne disease is expected to rise in the developing regions of the world and areas where more extremes in weather will increase the frequency of weather-driven disasters. The strategic significance of the data contained in the table will be analyzed in the next chapter.

Many of the environmental issues discussed later in this chapter are inexorably linked to global climate change—water as a scarce resource, desertification, and deforestation being prime examples. While the data are not specific in terms of exactly where impacts will be seen, they do suggest that the basic carrying capacities of many regions will change, which implies that populations will need to shift in response. Overall, the impacts of global warming as predicted by this review will be a major destabilizing influence on the security of the world and will constitute a major causative factor in population migration.

### **3.2.3 El Niño / La Niña**

Occasionally “news and information reporting” associate the climate phenomena El Niño and La Niña with the enhanced greenhouse effect and global climate change, but scientists now better understand that these phenomena are natural. El Niño is a period of unusually warm water temperatures and increased early winter rain along the western coast of South America centered on Peru. Historically, the local residents named this periodic change in weather El Niño because it generally appeared around Christmas, and thus they associated it with the birth of “The Child,” El Niño. The term La Niña came from scientists who coined the expression to refer to the periods of normal (cold) water temperatures in the Pacific and thus, normal weather patterns along the coast of South America.

The world became concerned with El Niño as these rains, combined with the impacts of deforestation in some areas, produced floods and mudslides, occasionally causing great destruction in the region and killing or injuring many people. A second concern related to El

**TABLE 3 – 3**  
**Regional Impacts of Enhanced Greenhouse Effects on Climate**

<b>IMPACTS</b>	<b>North America</b>	<b>Tropical Asia</b>	<b>Temperate Asia</b>	<b>Arid Western Asia</b>	<b>Europe</b>	<b>Africa</b>	<b>Australasia</b>
<b>Geographic Area</b>	Canada, US, and Arctic Circle	India, Pakistan, Bangladesh, Vietnam, Malaysia, and inclusive counties.	Japan, Korea, Mongolia, most of China, and Russian Siberia	Turkey in the west to Kazakhstan in the east.	West of Ural Mountains	The continent	Australia, New Zealand, and islands
<b>Ecosystem</b>	Shifts in location of forests and croplands; change of vegetation types; loss of water-fowl habitat	Changes in distribution of rainforest; drying of wetlands.	Reduction in the boreal forests, expanded grasslands, decrease in the tundra zone.	No large changes.	Mostly disturbed environment now. Alter wetlands through lower ground water levels	Desertification in north, loss of forests in SubSahara; deterioration of land cover. Major impacts expected throughout.	Alterations of soils and vegetation could be large.
<b>Hydrology and Water Resources</b>	Increased Spring and Winter runoff; decreased rain and soil moisture in summer.	Glaciers recede in Himalayas; more seasonal impacts,	Net decrease in water supply; glacier melt; North China water supplies vulnerable.	Continued water shortages in the region.	Increased precipitation in high latitudes and reduced in lower; loss of glaciers with water storage processes.	Reduction in supplies in Sahel and southern Africa. Acute concern in many already water scarce countries of the region.	Reduce water could be critical in drought prone areas; loss of snow and glaciers in New Zealand; flooding.
<b>Food and Fiber Production</b>	Small changes, plus and minus inputs	Vulnerable to natural disasters. Changes in production and yield very difficult to predict, but crops are sensitive to temperature and moisture.	Not agreement in predicted change;	No large net change.	Shift of growing seasons and patterns. Possible increased production.	Water shortages could be acute to farming in the North. Winter wheat growing in north hurt. Could have moderate increases in the south.	Early increased production predicted, but uncertain long-term impacts.
<b>Human settlements</b>	Changes in energy use; increased natural hazards.	Inundation of lowland cities.; salt water intrusion into water supplies in lowlands	Land subsidence in lowlands, salt water intrusion in water supplies	No large impacts	Flooding of more inhabited areas. Cooling demands higher, heating demands lower.	Increased exposure to natural disasters; urban water supplies threatened. Sanitation and waste disposal problems expand.	No large impacts expected
<b>Coastal Systems</b>	Up to 19,000 km <sup>2</sup> inundated; 23,000km <sup>2</sup> added to floodplain	Large and productive lowlands flooded; more natural hazards impacts; millions displaced by 1 m sea rise.	Japanese industry in coastal zones; large areas inundated	No large issues.	Risk of storm surges in lowland coasts of Holland, Germany, Russia, and Ukraine.	Coastal erosion in central coastal areas, particularly in storm impacted west Africa. Flooding of Nile delta of concern.	Highly vulnerable to flooding and inundation
<b>Human Health</b>	None predicted	Increase in vector and water borne disease, malaria, dengue, and schistosomiasis	Increased transmission of vector borne disease.	Small increases in disease and heat induced health problems	No major changes	All types of disease exacerbated by malnutrition would further damage the overall health of the people of Africa.	Small increases in disease and heat induced health problems.

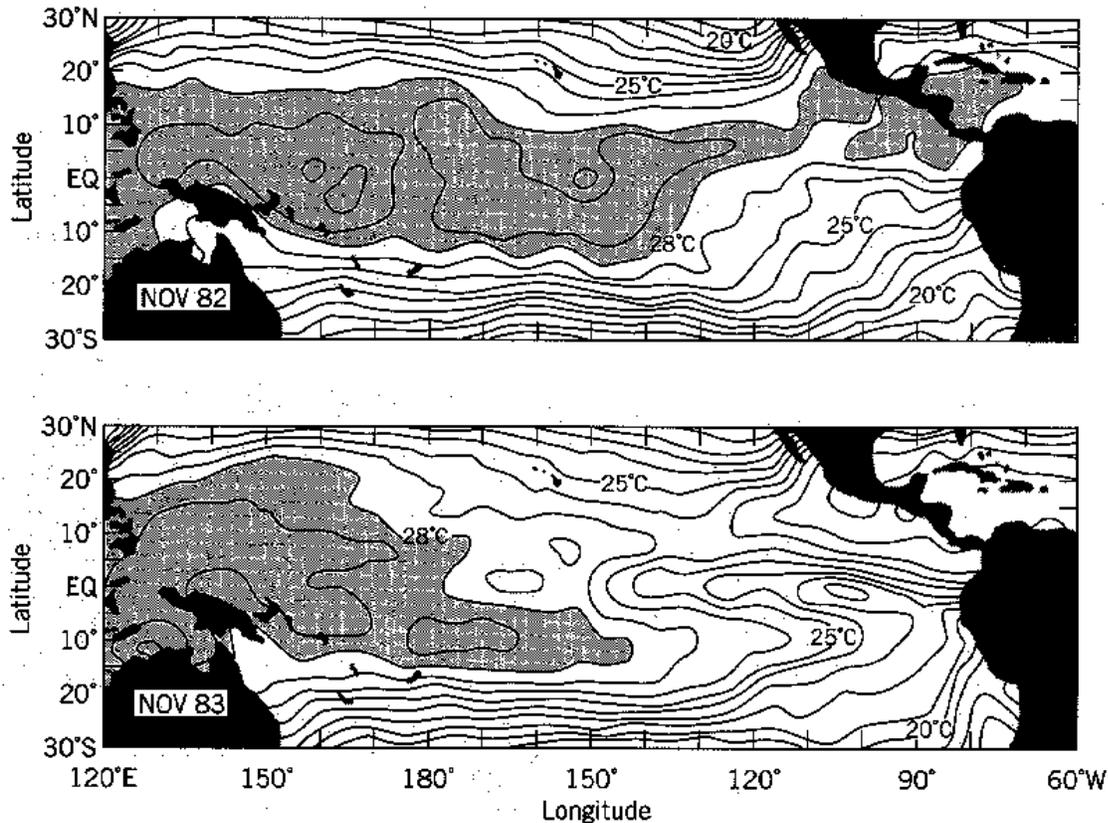
SOURCE: USEPA, website: [www.epa.gov/globalwarming/publications/reference/ipcc/summary/page4.html](http://www.epa.gov/globalwarming/publications/reference/ipcc/summary/page4.html)

Niño is the impact that the unusually warm water temperature has on the rich fishing waters off the coast of Peru. The warmer waters result in a depletion of the nutrient supply, which causes fish die-off; further, many valuable natural species intolerant of the warmer water may migrate from the region.<sup>20</sup>

The frequency of El Niño events and the exact reasons for their timing remains unknown, but the conditions required to produce an El Niño have been identified. Figure 3-10 shows the surface water temperature profiles of the Pacific for El Niño and La Niña conditions.

**FIGURE 3 – 10**  
**Surface Water Temperatures**  
**in the Pacific Ocean**

Top view shows El Niño conditions  
 Bottom view shows normal conditions (La Niña)



Note: The gray area shows the extent of the warm waters (28 C°)

SOURCE: John Horel and Jack Geisler, *Global Environmental Change* (New York: John Wiley, 1997), 60.

<sup>20</sup> Horel and Geisler, 59-63.

It is known that the size of the warm water pool in the Pacific grows at times when the normally cool easterly winds along the equator slow, thereby reducing the cooling impact they have on water temperatures in the Pacific Ocean and bringing the warmer waters closer to South America. As water temperatures rise over a larger area of the Pacific, net evaporation increases greatly. This produces more moisture in the atmosphere—moisture that eventually becomes rain—and intensifies the low-pressure cells created by the rising warm moist air. These large low-pressure areas become the engines inducing air movements throughout the region. The net result is intense rainfall events over areas of the west coast of South America. There are data suggesting that El Niño also produces corresponding drier areas in Central America, but the evidence for this impact is not as conclusive.

The El Niño/La Niña cycle is of special interest to scientists for two reasons. First, there are questions as to whether global warming may change the frequency and magnitude of El Niño occurrences, and thus the weather patterns that result. Second, El Niño is a natural weather experiment that can be studied to advance understanding of the scientific relationships between ocean behavior and terrestrial weather. By watching and measuring the cause and effect relationships of the weather generated during El Niño and La Niña periods, it may be possible to build and test better weather models.

From an environmental security standpoint, the military is concerned primarily with the impacts of El Niño. The military has already been involved in humanitarian relief missions in South America in response to the floods and mudslides associated with El Niño, therefore, the better understood the science, the better the military can prepare and respond. Further, if global warming makes El Niño occurrences more common, as some predict, this could become a significant issue for the U.S. Southern Command.

### **3.2.4 Ozone Depletion in the Stratosphere**

It is important to begin by recognizing that there are two kinds of ozone, which can be referred to as “good ozone” and “bad ozone”—and it is very easy to confuse the two. “Bad ozone,” which is really not the subject of this discussion, is the ozone that exists in the lower atmosphere within the living space of plants and animals. Chemically, ozone (O<sub>3</sub>) is a highly reactive oxidizing agent, similar in properties to chlorine bleach, with the ability to damage most organic materials. This “bad ozone” kills vegetation, burns the lungs of mammals at even small concentrations, contributes to the production of photochemical smog, and has

several other negative impacts—so much so that it is a primary air pollutant strictly regulated by the USEPA.

The “good ozone,” which is the subject of our concern here, is the ozone that exists in the upper atmosphere. It is primarily produced in the upper stratosphere (25–50 kilometers) and stored in the lower stratosphere in a band 10 to 20 kilometers above the Earth. Recall the earlier discussion of the photochemical properties of the greenhouse gases and how each gas absorbs specific wavelengths of radiant energy at different rates. Ozone is a strong absorber of ultraviolet light (UV), wavelengths below 0.28 micrometers. The sun emits a large quantity of this energy spectrum into the Earth’s upper atmosphere. If allowed to reach the ground, the UV radiation would cause significant harm to many of the living organisms on earth—including humans. Large doses of radiation at these wavelengths are known to increase the incidence of cancer in humans, and we have documented evidence of deleterious impacts on other animals and many plants.

Depletion of stratospheric ozone became an issue when a hole in the ozone layer over the South Pole was first detected in 1985 through the use of new space-based remote sensing technologies. Since then, considerable effort has gone into understanding the complex chemistry involved in ozone depletion and determining its causes. Scientists have identified chlorine compounds, particularly chlorinated fluorocarbons (CFCs) as the primary culprits in this mystery. CFCs and specifically freons had become ubiquitous in home and commercial use as refrigerants. Since there was no known harm from them, they were routinely discharged to the environment after use. The chemical reactions that take place in the atmosphere are complex, light-activated processes where ozone is broken down into oxygen ( $O_2$ ) with chlorine serving as a catalyst in the reaction. Since chlorine is only a catalyst, it is not consumed in the reaction. These reactions occur at higher rates in the South Pole region because in extremely cold temperatures ice crystals form which further catalyze or enhance the reactions.

Because chlorine is not bound into the products of the reaction, a small amount of chlorine continues to propagate these reactions for long periods. Freons, which represent more than 50 percent of the ozone depleting chemicals already in the stratosphere, have an atmospheric lifetime of 80 years.<sup>21</sup>

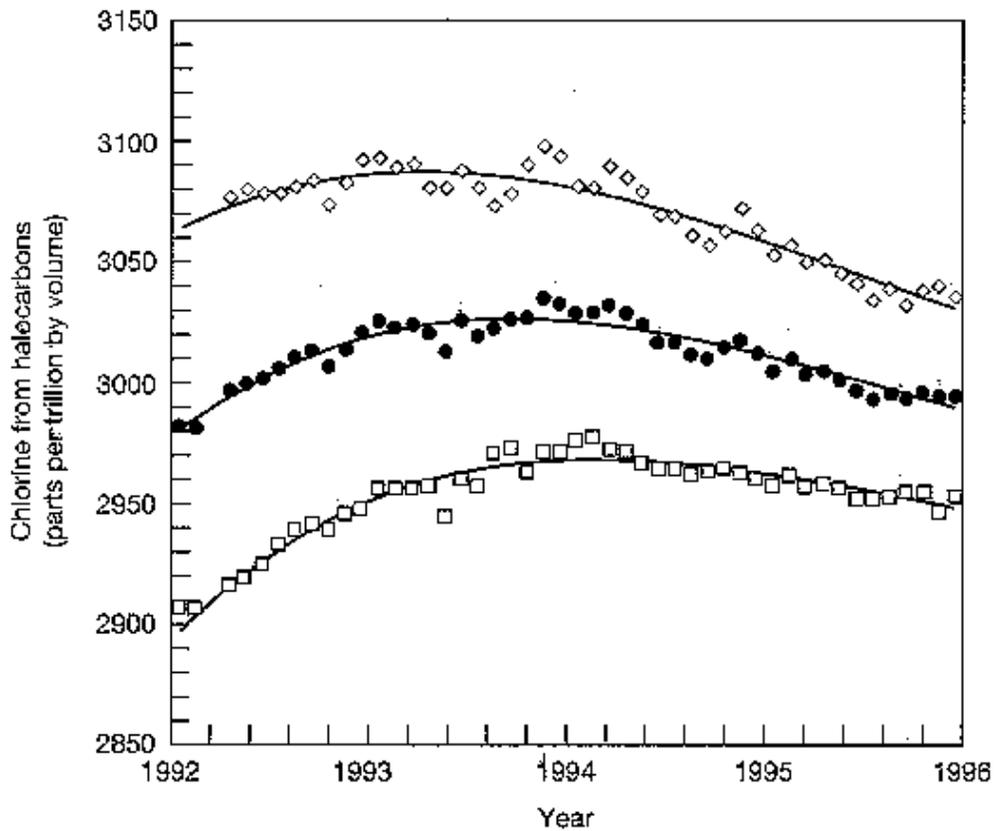
There is, however, some good news in this story, news that should be considered very important from the environmental security standpoint because it proves that global environmental problems can be resolved at the international level. As the scientific understanding of the causes of ozone depletion and its consequences developed within the inter-

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<sup>21</sup> de Nevers, 526.

national scientific community, and as people came to realize that the technical solutions needed to reduce dependence on ozone depleting substances existed, the world was able to reach agreement in the Montreal Protocol of 1987 to phase out the use of CFCs. Figure 3-11 provides a graphic depiction of the fact that the chlorine concentrations in the atmosphere have indeed begun to decline. However, the long residence times of many of the different ozone depleting compounds suggests that full recovery will not occur until well into the next century.

**FIGURE 3 – 11**  
**Chlorine in the Upper Atmosphere**



- = Measured in Southern Hemisphere
- = Measured in Global Average
- ◇ = Northern Hemisphere

SOURCE: Fred T. Mackenzie, *Our Changing Planet* (New Jersey: Prentice Hall, 1998), 414.

## ***Impacts of Ozone Depletion***

There is certainty that a reduction of the stratospheric ozone layer has a direct impact on the quantity of UV light reaching the ground. All research to date strongly suggests that environmental harm, such as damage to DNA material in organisms, is occurring in areas under the existing ozone hole. In the inhabited areas under the Antarctic ozone hole, southern South America and Australia, biologists are documenting damage to light sensitive plant and animal species. The strategic implications of this issue will be analyzed in Chapter 4.

### **3.3 Land Use**

#### **3.3.1 Deforestation**

This section deals with the relationship between the reduction in the amount of forest area in the world and environmental security. On a global scale, forests are important for the uptake of carbon dioxide as part of the global carbon cycle, which then serves to regulate the greenhouse effect. This alone would be sufficient reason to consider the security implications of deforestation, but there are more direct issues that result from the widespread loss of forest areas in a region. Before discussing the impacts of deforestation, it is necessary to look at exactly what deforestation is and where and why it is occurring.

Explaining deforestation begins with a definition of the term “forest.” As defined by the Food and Agriculture Organization of the United Nations (FAO), a forest is an area where the tree crowns cover at least 20 percent of the surface area in a developed country and 10 percent of the surface area in a developing country. There is no scientific basis for defining a forest in terms of the economic state of a country, but it is necessary to defer to this definition because the FAO has the best available worldwide data on the state of the world’s forests and these data apply this definition.<sup>22</sup>

Scientifically, there are many ways to classify forests. Different forest types are identified by their requirements for temperature, soil types, and moisture. For example, Alan and Arthur Strahler in their physical geography text divide forests into six separate classifications.<sup>23</sup> Because data describing deforestation are not available at such a level of detail, this

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<sup>22</sup> FAO, *Forest Resources Assessment 1990: Global Synthesis*, as reported at: [www.igc.apc.org/wri/wr-96-97/lc\\_ttxt2.html](http://www.igc.apc.org/wri/wr-96-97/lc_ttxt2.html), April 2000.

<sup>23</sup> Alan Strahler and Arthur Strahler, *Introducing Physical Geography* (New York: John Wiley, 2000), 207-216.

analysis will consider forests as either temperate or tropical. Figure 3-12a depicts the worldwide distribution of forests and highlights regions of tropical growth climate with a rectangular box across the center of the figure. These classifications generalize the effects of temperature and moisture based on the latitude of the region, but cannot deal with localized impacts, such as altitude.

Tropical forests, located in the wet, always warm mid-latitude belt centered around the equator, occupied 1.8 billion hectares in 1990.<sup>24</sup> As seen in Figure 3-12a, nearly all tropical forests in the world today exist in the developing countries. These forests include both the rainforests with constant leaf cover and monsoon forests that lose their leaves in a dry season. Rainforests, which have literally thousands of species per hectare, are the most biologically diverse biome on Earth. Because of the thickness of the vegetation and the perennial biological activity, tropical forests are the world's most productive regions for removing carbon dioxide from the atmosphere.

Temperate forests contain a much wider variety of both deciduous and evergreen forest types and cover a much larger area of the world, 2.4 billion hectares as reported in the FAO 1990 study.<sup>25</sup> Temperate forests contain both deciduous and evergreen species of trees capable of survival in all but the coldest and/or highest altitudes in the world. Though not as productive in carbon cycling or as diverse in species as tropical forests, temperate forests have the ability to propagate over large areas of the world, thus making them a critically important worldwide resource.

Deforestation, throughout time, has been the most fundamental and ongoing action of human modification of the environment. Trees are removed to clear land for farming, to provide lumber for building and energy for heating, cooking, and many economic activities. In a sense, a primary difference between developed and developing countries is that developed countries have reached equilibrium with respect to their renewable forest resources while developing countries continue to reduce forest areas.

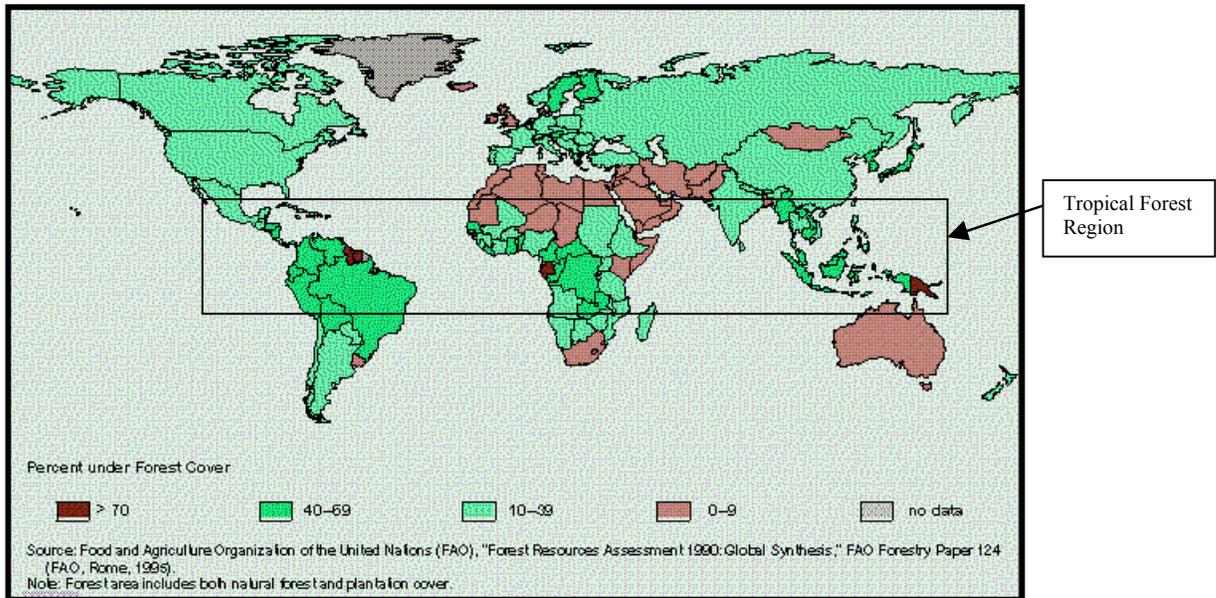
Deforestation is defined by the FAO as the loss of tree cover to below 10 or 20 percent crown coverage. On the basis of this definition, Figure 3-12b shows the rate of worldwide deforestation for 1980–1990. It is important to point out, however, that Figure 3-12b depicts as areas of stable growth some areas without forests. Mongolia, for example, is shown as stable in rate of deforestation in Figure 3-12b, but, as seen in Figure 3-12a, there are few existing forests to cut. This fact requires caution in the use of these data.

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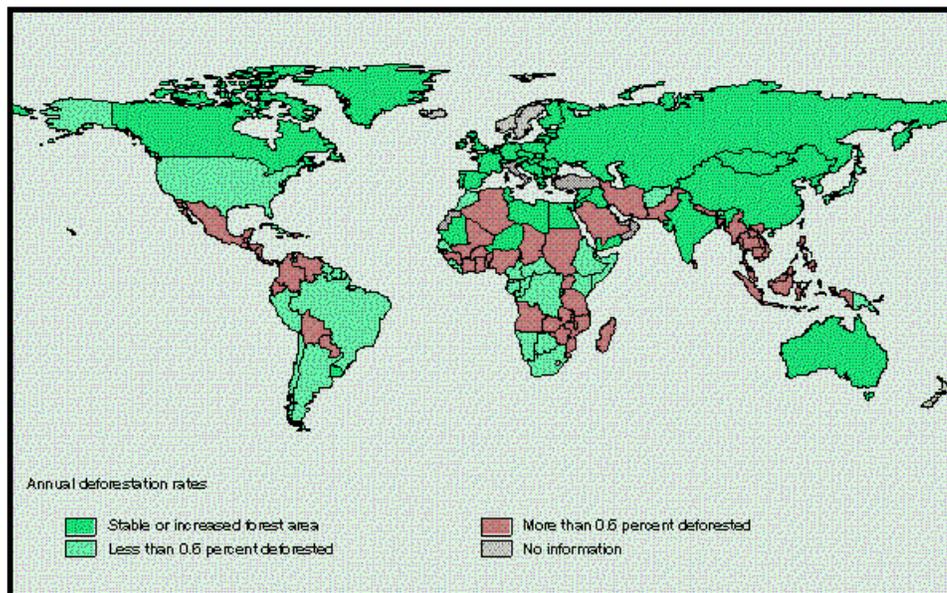
<sup>24</sup> FAO, *Forest Resources Assessment 1990: Global Synthesis*.

<sup>25</sup> *Ibid.*

**FIGURE 3 –12a**  
**Distribution of Forests Worldwide**



**FIGURE 3 – 12b**  
**Estimated Annual Deforestation Rates, 1980-1990**



SOURCE: FAO, *Forest Resources Assessment 1990: Global Synthesis*, as reported at: [www.igc.apc.org/wri/wr-96-97/lc\\_txt2.html](http://www.igc.apc.org/wri/wr-96-97/lc_txt2.html), April, 2000.

Figure 3-12b indicates that deforestation is occurring at the highest rates in the developing countries and within the tropical forests. In contrast, over the period 1990–1995, developed countries showed a net growth in forest area of 0.12 percent per year.<sup>26</sup> Some caution must be taken when considering this number, because it hides a loss in natural forest. In the FAO data calculations, losses in natural forest can be compensated for by increases in plantation acreage. This same source reports the total annual deforestation percentage in the tropics as 0.8 percent or 15.4 million hectares lost per year from 1980 to 1990 (that is an area about the size of the state of Georgia each year).

Deforestation has both a natural component and one of anthropogenically induced change; the discussion here is limited to the latter. In the developing countries, trees are removed to expand farm and grazing lands, provide fuel wood, and obtain the economic benefits of logging. Population pressure is a direct and acute factor affecting the rate of deforestation for the first two purposes. The need for more land for food production is the obvious driver, but with 35 percent of the world's population relying on wood for cooking and heating—and most of these people in areas without good options to replace wood fuels—the pressure is doubly intense.<sup>27</sup>

Economically, trees are a primary export for many of the developing countries, particularly in the tropics. Logging may be conducted by the government or by international logging companies working under some contractual arrangement with the government. For many of these countries, the profits from logging are essential to help pay the costs of modernization and, in many cases, the costs of a growing and urbanizing population.

It should not be overlooked that most of the wood generated from logging in developing countries is utilized by developed countries. The FAO deforestation data indicate that developed countries have reached a sustaining level in forest management, but the reality is that they are maintaining their forests by satisfying their need for wood from the forests of the developing countries. Japan, for example, a country with more than 60 percent forest cover and showing no net change in forest area, annually consumes 50 percent of all tropical wood cut.<sup>28</sup>

In the developed countries, deforestation results from economic pressures to sustain an often-dying logging industry, but it is further exacerbated by the impacts of air pollution. Air pollution not only kills trees directly, but also can damage trees by making them more susceptible to insect and microbial infestation, which eventually leads to die-off. The damage

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<sup>26</sup> Fred T. MacKenzie, *Our Changing Planet* (New Jersey: Prentice Hall, 1998), 254-257.

<sup>27</sup> *Ibid.*, 267.

<sup>28</sup> *World Resources 1996-1997*, [www.igc.apc.org/wri/wr-96-97](http://www.igc.apc.org/wri/wr-96-97), 217.

that emissions from large power plants cause to forests in the eastern United States is well documented; many regions in central Europe are experiencing similar problems.<sup>29</sup>

In both developing and developed countries, global climate change may affect the size and distribution of forests. Over time, climate change can impact temperature, the quantity and temporal distribution of water, and soil structure, all of which help determine the type of vegetation, including forests, that an area can naturally sustain. The facts are irrefutable; however, actual regional impacts are very difficult to differentiate from naturally occurring change and, therefore, are difficult to predict.

### ***Impacts of Deforestation***

The impacts of deforestation range from the very subtle changes in climate that loss of forest areas may induce to the dire life-threatening issues that the absence of fuel wood can cause. In the context of environmental security, consider the examples of Ethiopia and Haiti. In 1900 Ethiopia was 45 percent forested,<sup>30</sup> while today only 2.5 percent of the country remains forest and woodland.<sup>31</sup> Likewise, Haiti has gone from a mostly tree covered to a nearly barren landscape. The strategic discussion of linkages between security and environment are the subject of the next chapter, but it is reasonable to surmise that there is a correlation between the unrest in these countries and these drastic changes in their environments.

Deforestation is not a completely anthropogenic process. Natural changes in climate and weather, forest fires and forest disease all occur at natural rates, producing changes in the types and locations of the world's forests. By observing natural changes, we can get a better understanding of how human-induced deforestation will impact an area. There is no question that numerous serious consequences will result from deforestation. In relation to environmental security, the most critical concerns are:

- Reduced carrying capacity of the land
- Fewer forests as a component of the carbon cycle, resulting in loss of CO<sub>2</sub> removal capacity
- Loss of biodiversity with all of its known and unknown implications

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<sup>29</sup> MacKenzie, 327.

<sup>30</sup> Ibid., 257.

<sup>31</sup> *World Resources 1996-1997*, 216.

- Increased flooding and loss of soils, with resultant mudslides and waterway siltation
- Lost economic benefits from loss of forests as a renewable resource

It is well beyond the scope of this paper to discuss the scientific basis for each of the complex concerns attributed to deforestation. In an effort to summarize these concerns in a format that will support strategic analysis later, Table 3-4 describes the possible impacts of deforestation on tropical and temperate regions of the world, further divided into developed and developing countries. In each of the impact boxes, an arbitrary qualitative rating has been assigned based on the severity of impact should deforestation continue at the rates predicted in Figure 3-12b.

What is clearly evident in the table is that the impacts from deforestation will be most severe in the tropical regions, not unexpectedly because these are the regions of highest deforestation rates. It appears the tropical regions are trading short-term economic benefits for an unknown future. From a world perspective, the developed countries share a portion of the blame for global climate change caused by tropical deforestation because they provide the markets for the wood being harvested at a rate much faster than it is being regenerated. Furthermore, developed countries understand how good management practices would allow trees to be harvested without the damage done by large-scale clear cuttings, but pursuit of higher profits by international business is hindering the use of best forestry practices.

When considering security issues in the developing temperate forest countries, impacts on carrying capacity have the most direct and dire effects. In the developing world, the land must provide water, food, and energy for heating and cooking. Loss of fuel wood reduces the ability to properly process food, and this could lead to both malnutrition and disease. Thus, the clearing of former forestlands for grazing and farming can have effects opposite to those intended.

In many parts of the world, forests are the only appropriate use for the land because of shallow soils and high rainfall rates. Removing the trees destroys the root structure that holds soil, thus increasing the intensity of the runoff and causing the soil to be quickly eroded and washed away. In addition to affecting rates of storage of rainfall, deforestation has other detrimental effects on regional hydrologic cycles, with a net effect of less available water over time.

**TABLE 3 – 4**

**Potential Impacts of Deforestation**

Possible Issues	IMPACTS Tropical, only Developing Countries	IMPACTS Temperate, Developing Countries	IMPACTS Temperate, Developed Countries
Carrying Capacity - Loss of soil from erosion - Less fuel wood - Less water available - Loss of soil moisture for crops - Land cannot sustain crops	- Increased disease - Food production reduced - Famine - Drought/flooding - Population migrations - Reduced water supply  {MODERATE}	- Loss of fuel wood increases disease - Reduced water supply - Reduced soil moisture impacts food supply  {HIGH}	- Water supply reduced - Soil moisture loss reduces food production  {SMALL}
Carbon Cycle / Global Climate Change - Global warming - Storm frequency and intensity - El Niño / La Niña - Sea level rise	- Less Carbon dioxide absorption - Slash and burn releases carbon dioxide inputs - Change in evaporation rates causes shifts in water availability - Storm frequency impacts - Loss of farmlands  {MODERATE}	- Population migrations - Lower soil moisture in growing season - Higher temperatures impact health  {HIGH}	- Storm frequency impacts - Minor impacts and shifts in land use  {MODERATE}
Biodiversity - Loss of species - Loss of habitat	- Thousands of species lost each year - Critical habitat lost - Loss of indigenous native tribes  {HIGH}	- Species die-off - Habitat lost for endangered species  {SMALL}	- Loss of natural forests could impact a number of species  {SMALL}
Hazards - Loss of life - Increased disease - Economic costs of response	- Increased runoff rates produce floods - Mudslides and siltation of streams  {MODERATE}	- Increased flooding damage - Loss of life - Drought more common  {MODERATE}	- Increased storm frequency  {SMALL}
Economics - Short-term cost/benefits - Long-term costs/benefits	- Debt payment possible - Development funds created - Long-term loss of sustainable resource - Unknown value of biodiversity lost  {HIGH}	- Long-term loss of sustainable resource  {MODERATE}	- Mitigation of storm impacts - Quality of life impacts  {SMALL}

HIGH - Potential to significantly alter existing environmental setting

MODERATE - Measurable negative impacts expected

SMALL - Small net change in environmental conditions, well within capacity for adjustment

### 3.3.2 Desertification

Today, some 40 percent or 60 million square kilometers of the world's land area is classified as having a dry climate, with some 10 million square kilometers of this land being considered desert.<sup>32</sup> Figure 3-13 represents the distribution of desert areas across the world.

This paper defines "desertification" as the process whereby both water and soil become scarce to the point of being unable to sustain a vegetative cover. The process has both natural and human causes. In the scientific literature, the precise terms used are "desertification" when the process has human causes and "desertization" when the causes are natural. Since this paper is most concerned with human-produced changes, we will use the term "desertification."

When desertification occurs, the loss of vegetative cover allows for increased soil erosion, primarily by wind, further reducing the carrying capacity of the land, even if water were again to be available. Natural fluctuations in rainfall can change the shape of a desert, usually working around the boundaries of an existing desert. Overgrazing, mining of groundwater, and overuse in farming can also produce desertification of an area.

The African Sahel is the most striking example of desertification or land degradation seen in modern times. The Sahel is the belt that extends across Africa at about 15 degrees north latitude and forms the southern extent of the Sahara desert. An increase in the nomadic herding population of the region in combination with a drought lasting from 1968 to 1991 has produced desertification in the area.<sup>33</sup> Desertification has resulted in a drastic reduction of regional grazing capacity until conditions and time allow regeneration of the vegetative cover, if erosion and the other impacts of desertification have not been so severe as to irreversibly damage the land.

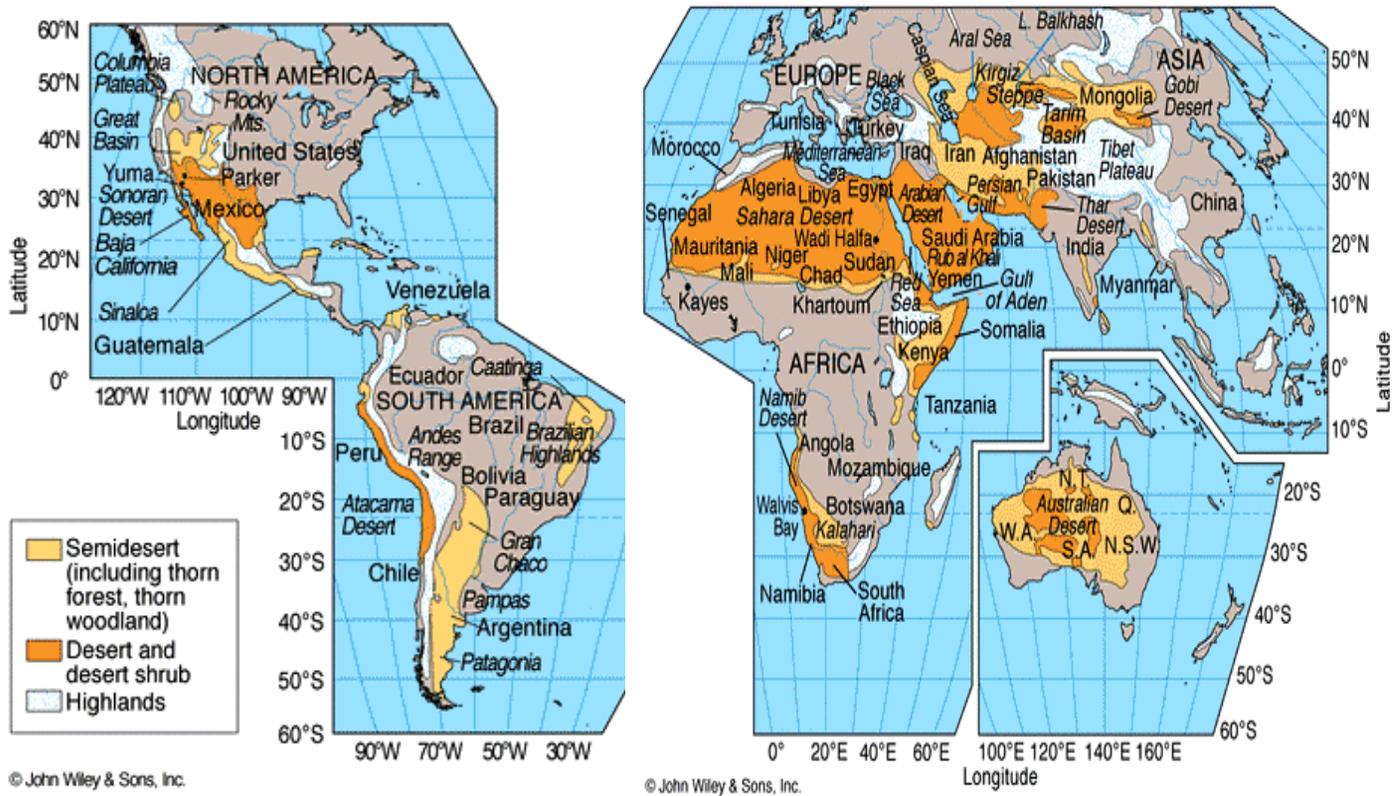
Global climate change can produce desertification in the same way that natural climate change does. A major challenge today involves distinguishing natural desertization from human-induced desertification; even more difficult is predicting the changes resulting from the enhanced greenhouse effect. Based on experience to date, we can expect that changes will occur within existing dry climates and on the margins of existing deserts. In some places the result may be a receding of the existing desert because of increased rainfall, while in others the result is likely to be desertification.

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<sup>32</sup> Houghton, 101.

<sup>33</sup> Stahler and Strahler, 170.

**FIGURE 3 – 13**  
**Desert Regions of the World**



SOURCE: Alan Strahler and Arthur Strahler, *Introducing Physical Geography*, Visualization- Version 2.0 (New York: John Wiley, 2000).

### ***Impacts of Desertification***

The ultimate direct impact of desertification is the complete loss of carrying capacity of an already fragile biome, and the primary indirect effect is the migration of people previously supported by that area. Our ability to predict desertification is limited by our inability to predict long-term natural regional climate patterns. Adding to the problem is our lack of understanding of the impacts of anthropogenically induced global climate change, primarily from the enhanced greenhouse effect.

Expansion of the world's deserts will be at the expense of steppe-type environments, which have grass and scrub vegetation and most commonly support sparsely populated herding cultures. Variations in migration and settlement patterns for these people make it difficult to determine the impacts of desertification on humans. More human pressure in these regions could accelerate the desertification process because of increased grazing and fuel wood gathering. Overall, the spiraling impact of desertification displacing people has been seen in the Sahara regions already and it has the potential to affect other parts of the world as a result of global warming.

### **3.3.3 Hazardous Waste Disposal**

Toxic and hazardous materials are a uniquely modern reality. Today, millions of tons of thousands of different chemicals are manufactured for some "beneficial" use. These organic and inorganic chemicals have become ubiquitous throughout the world. Most of these chemicals and the billions of pounds of waste generated as by-products in their manufacturing processes are toxic, carcinogenic, mutagenic, or teratogenic, making their use and disposal hazardous to living organisms. Many of these chemicals biodegrade very slowly, and therefore, when released into the environment, they have the capacity to cause harm for a long time.

The sequence of events that can lead to environmental damage and human harm is as follows: (1) the intentional or accidental release of these chemicals; (2) human exposure through direct contact, ingestion of contaminated food or water, or inhalation of airborne chemicals; and finally; (3) accumulation of enough of the toxin to produce a physiologic response.

A widely known environmental contaminant, PCBs (polychlorinated biphenyls), can be used to illustrate the hazards posed by modern chemicals. PCBs are a group of organic

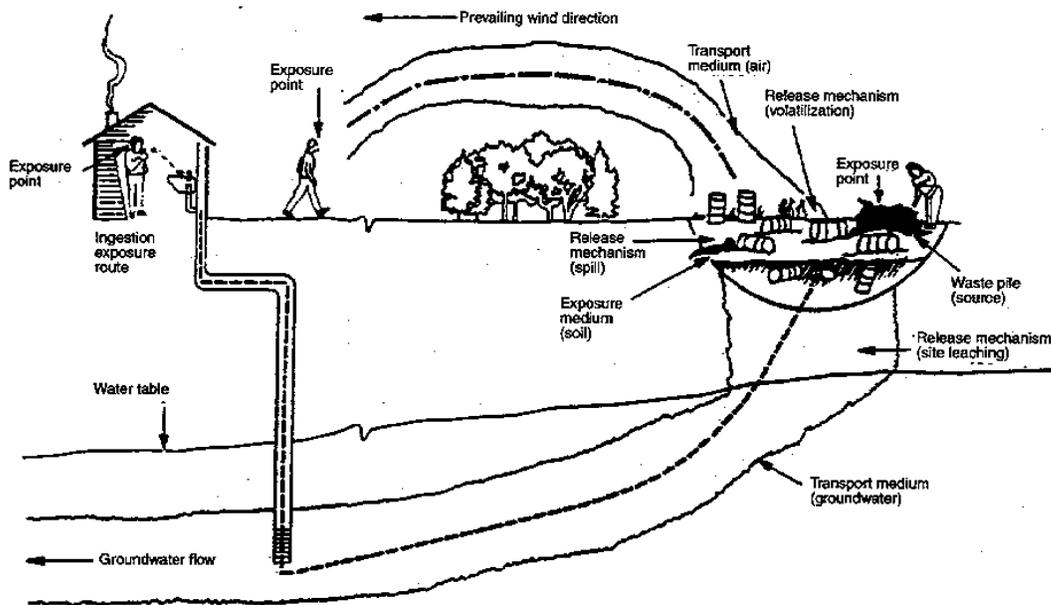
chemicals long utilized as insulating fluids in electrical devices because these chemicals possess the appropriate electrical properties while not being volatile or flammable. Over the past 50 years, nearly all large transformers installed on electrical poles and in substations have been filled with this pale yellow liquid.

Using PCBs as an example, we can examine the sequence of events outlined above.

*Step 1* — As a result of maintenance activities, accidents causing spills, and improper disposal activities, a large quantity of PCBs are released to the environment over many years. Also, PCB manufacturing waste by-products are disposed of in ways that contaminate soil and drinking water supplies. In just one case, a large manufacturing operation dumped thousands of tons of PCBs into the Hudson River in New York State. As a result, the fish in the river today remain dangerous for human consumption years after dumping has ceased.

*Step 2* — The pathways through which chemicals released to the environment reach humans are illustrated in Figure 3-14.

**FIGURE 3 – 14**  
**Pathways of Human Exposure to Hazardous Substances**



SOURCE: W. C. King, *Environmental Engineering* (AAEE, Annapolis, 1999), 436. USEPA 1989.

The most common exposure pathway is through a drinking water source, where contaminants can collect and be transported to unknowing consumers. The figure depicts the drinking water source as a water well, but it is more often a public water supply system. For most of the chemicals that dissolve in water at harmful levels—and this a large number of chemicals—standard drinking water treatment practices DO NOT remove the toxicity. Public water supplies in the U.S. are monitored for hundreds of common contaminants to prevent and protect against these types of problems. However, with thousands of existing chemicals and more being created every day, it is possible for many toxins to go undetected. In the developing world, monitoring involves an expense that typically cannot be afforded.

*Step 3* — Except in the case of a catastrophic occurrence, such as the one in Bhopal, India, where thousands were killed or injured from a toxic cloud, most toxins act in an insidious manner, requiring long periods of time for the body to accumulate sufficient concentrations to manifest symptoms. In the case of human beings exposed to contaminated water, food, or air, this time is available. PCBs have an **Immediately Dangerous to Life or Health (IDLH)** level of 5 milligrams per cubic meter (mg/M<sup>3</sup>),<sup>34</sup> because of their known carcinogenic risk. This extreme toxicity is further exacerbated by the long persistence of PCBs in the environment.<sup>35</sup> PCBs ingested in water or fish can accumulate in the body until, often decades later, cancer results.<sup>36</sup>

The military has its own unique hazardous materials that have the potential to pollute the environment. These include explosives and weapons materials, waste oils, fuel from spills, waste cleaning solutions and other maintenance fluids, chemical agents, and nuclear material. The DOD now spends billions of dollars a year to clean up past indiscretions in disposal and spillage of hazardous materials. Chapter 4 discusses opportunities to share lessons learned with other military forces, so that they do not make the same costly mistakes or can benefit from U.S. experience to expedite remediation efforts.

### ***Hazardous Waste Issues***

Hazardous waste issues all relate directly or indirectly to human and environmental health. Just as Chernobyl made thousands of square kilometers uninhabitable for years, toxic releases from industrial manufacturing and waste dumping directly impact people all over the

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<sup>34</sup> NIOSH, *Pocket Guide to Chemical Hazards* (Washington, D.C.: U.S. Public Health Service, 1990), 68.

<sup>35</sup> C. W. Fetter, *Contaminant Hydrogeology* (New York: Macmillan, 1993), 301.

<sup>36</sup> Figure 3-18 explains the process of environmental contamination on the basis of disease transmission.

world. This occurs primarily through pollution of groundwater, making it dangerous to drink. In the developed world this water would not be consumed or would be treated to safe standards. However, in the developing world, conditions are such that contamination may not be detected, there may be no alternative source of drinking water, or treatment may be too expensive—all of which adds up to an extremely hazardous situation for people in the developing world.

Air exposures to toxic chemicals occur in the developing world where modern pollution abatement technology is not applied to industrial smokestacks. A senior Russian environmental scientist in 1995 reported areas of his country where the infant mortality rate had reached 50 percent because of toxic metals released to the air from smelting operations.<sup>37</sup> Land use for farming and living can also be degraded or lost as a result of toxic contamination events. Overall, toxic pollution can severely stress people and the environment, and may pose a threat to the security of a region.

## **3.4 Water Use**

### **3.4.1 Fresh Water**

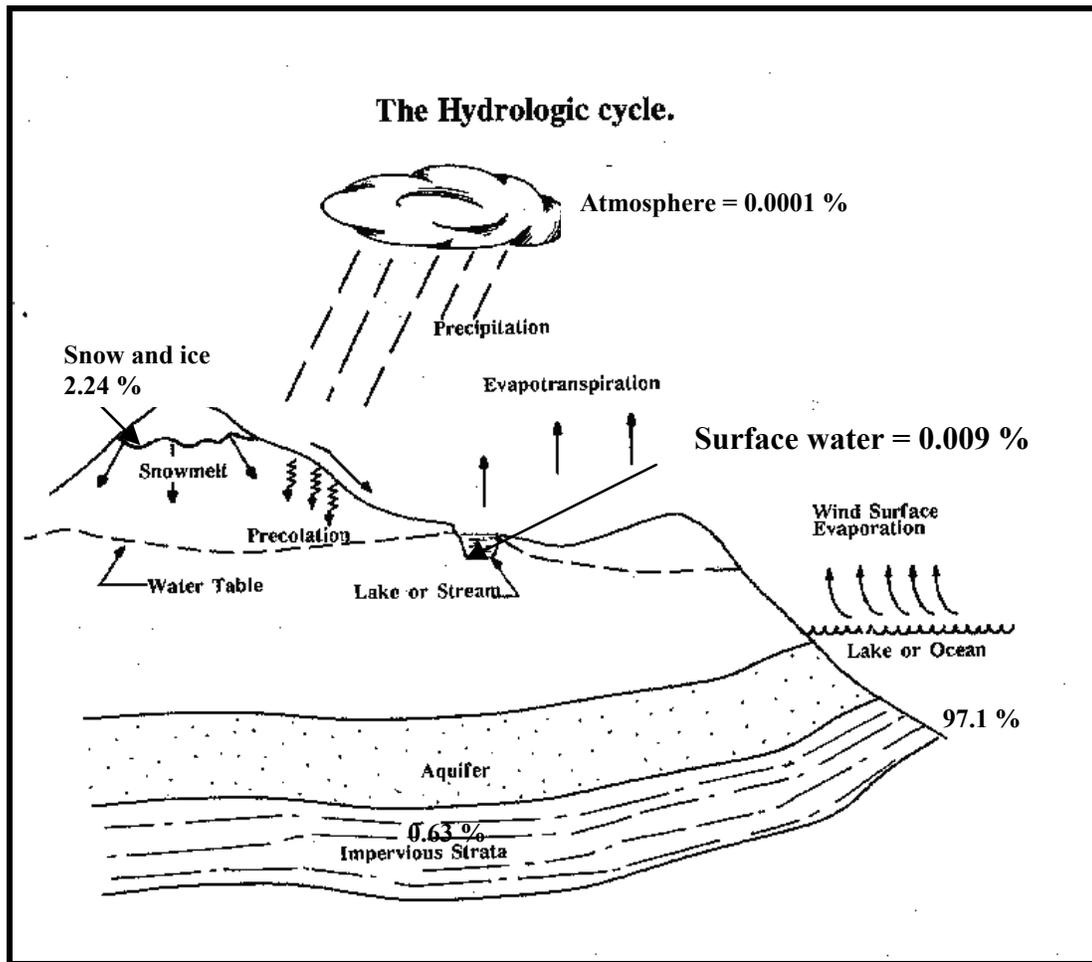
Water is a critical resource for life and essential for economic success in a modern developed society.

Most people are familiar with the hydrologic cycle depicted in Figure 3-15, which shows the relative quantities of water stored in different segments of the environment. This figure is a good reminder of the relatively small quantity of fresh water available for many demands—domestic consumption, sanitary use, industrial use, electric power generating cooling water, hydroelectric generation, and agricultural irrigation. Water quantity can be measured in terms of total demand, but is better represented in terms of the quantity per person over some period of time (daily or yearly). Figure 3-16 shows world water consumption over the past century in both of these units of measure. Clearly, the eight-fold increase in total water demand is driven by population increases, but demand per person has also doubled over the century.

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<sup>37</sup> Non-attribution lecture by a member of the Russian Academy of Science at the United States Military Academy, 1994.

**FIGURE 3 – 15**  
**Distribution of Water in the Environment**

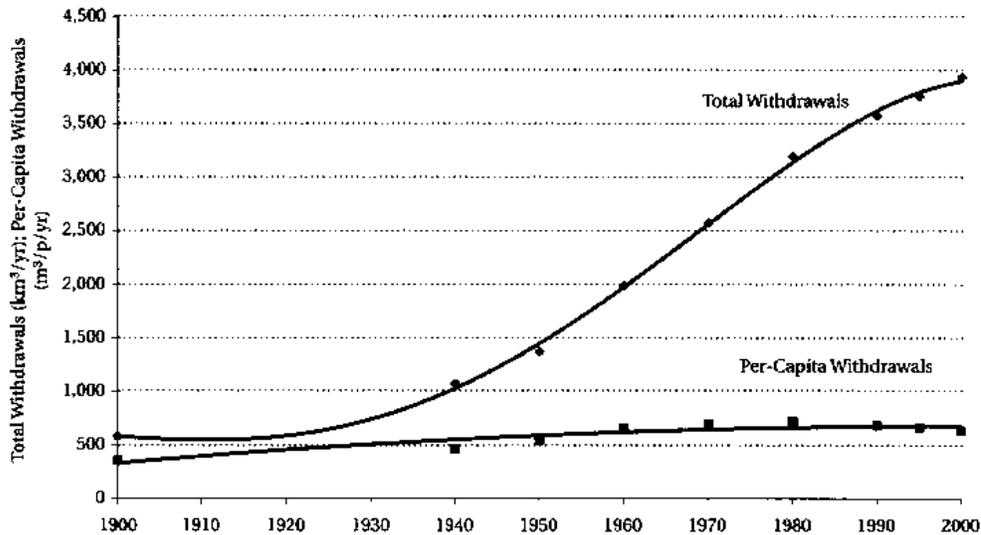


SOURCE: Andrew Dzurik, *Water Resource Planning* (Savage, Md.: Rowman & Littlefield, 1990), 13.

An example of the impact that development has on water use can be seen by comparing water use in the U.S. with world water use. In 1900, world demand was approximately 300 cubic meters per person per year ( $M^3/p/yr$ ) while in the same units U.S. demand was 700. In 1980, world consumption had grown to 700  $M^3/p/yr$ , while in the U.S. demand had reached 2700  $M^3/p/yr$ . In terms of these units, which factor population growth out of the equation, water demand in the U.S. had grown by a factor of four while world demand had increased by a factor of only two.<sup>38</sup> The important point here is that transforming from a developing to a developed society, to this point in history, has greatly increased the requirement for water.

<sup>38</sup> Peter Gleick, *The World's Water* (Washington, D.C.: Island Press, 1998), 10-13.

**FIGURE 3 – 16**  
**World Water Use Rates, Total and Per Capita**



SOURCE: Peter Gleick, *The World's Water* (Washington, D.C.: Island Press, 1998), 11.

The problem is one of trying to reconcile supply (Figure 3-15) with demand (Figure 3-16). Supplies are fixed, while demand continues to grow rapidly. There has been progress in improving management practices, but these have reduced the rate of growth in demand per person, not total consumption. In this context, the U.S. can be considered a recent good news story. By 1995, demand in the U.S. had dropped to 2,200 cubic meters per person per year, resulting in a flattening of total demand over the past 20 years. This was achievable only in concert with a small population growth rate over the same period.

The bottom-line for water as a resource is:

- Demand will continue to increase steadily and in direct proportion to population growth.
- Modernization (development) will increase demand, not reduce it.
- It can be expected that, in areas experiencing water shortages now, conditions will worsen, while many more areas of the world will reach their limits of available water resources.

Figure 3-15 shows that water resources are renewed by precipitation which recharges surface water streams and lakes and water stored in the ground. This recharge is temporally

and spatially dependent, or, in simpler terms, we don't have water problems—it just comes in the wrong places at the wrong times. To overcome this problem, dams are constructed to store water for use during drier periods and aqueducts are built to transmit water to areas without sufficient resources to meet their demands, but these mitigative actions are less than fully effective. Dams are expensive solutions; they have limited life spans and are feasible only in ideal circumstances of available space, high seasonal flows, and no conflicting water uses. Aqueducts are also expensive, requiring that some region be willing to supply water to another region and that access between the two areas can be assured. In a military context, there is some concern about the security issue of having water supplies that are vulnerable to the actions of others or can serve as a possible critical target in a conflict.

In terms of environmental security, an important question is: what is the basic water requirement for a person to sustain life? This value must include water for drinking, cooking, and basic sanitation requirements such as personal hygiene and cleaning. One widely accepted estimate is 50 liters per day per person.<sup>39</sup> Table 3-5 identifies those countries of the world not providing this quantity of water as of 1990.

**TABLE 3 – 5**  
**Water Data for Countries with Low Domestic Supplies**

COUNTRY	Total Domestic Water Use (Liter/per/d)	Total Water Withdrawal (km <sup>3</sup> /yr)	Total Renewable Supply (km <sup>3</sup> /yr)	Total Use (M <sup>3</sup> /per/yr)	Domestic Use (%)
Gambia	4.5	0.02	8	23	7
Mali	8	1.36	67	148	2
Somalia	8.9	0.81	15.7	108	3
Mozambique	9.3	0.6	216	39	9
Uganda	9.3	0.2	66	11	32
Cambodia	9.5	0.52	498	69	5
Tanzania	10.5	1.17	89	43	9
Central African Rep.	13.2	0.07	141	23	21
Ethiopia	13.3	2.2	110	45	11
Rwanda	13.6	0.77	6.3	106	5
Chad	13.9	0.18	43	32	16
Bhutan	14.8	0.02	95	15	36
Albania	15.5	0.2	21	94	6
Zaire	16.7	0.36	1019	10	61

<sup>39</sup> Ibid., 44.

COUNTRY	Total Domestic Water Use (Liter/per/d)	Total Water Withdrawal (Km <sup>3</sup> /yr)	Total Renewable Supply (Km <sup>3</sup> /yr)	Total Use (M <sup>3</sup> /per/yr)	Domestic Use (%)
Nepal	17	2.68	170	103	7
Lesotho	17	0.05	5.2	28	22
Sierra Leone	17.1	0.37	160	89	7
Bangladesh	17.3	22.5	2357	211	3
Burundi	18	0.1	3.6	18	36
Angola	18.3	0.48	184	48	14
Djibouti	18.7	0.01	0.3	24	13
Ghana	19.1	0.3	53	20	35
Benin	19.5	0.14	25.8	31	23
Solomon Islands	19.7	0.001	44.7	18	40
Myanmar	19.8	3.96	1082	103	7
Papua New Guinea	19.9	0.1	801	25	29
Cape Verde	20	0.03	0.3	70	10
Fiji	20.3	0.03	28.6	37	20
Burkina Faso	22.2	0.38	17.5	42	19
Senegal	25.4	1.36	39.4	186	5
Oman	26.7	1.22	1	325	5
Sri Lanka	27.6	6.3	43.2	503	2
Niger	28.4	0.5	32.5	65	16
Nigeria	28.4	3.63	280	33	31
Guinea-Bissau	28.5	0.02	27	17	60
Vietnam	28.8	5.07	376	81	13
Malawi	29.7	0.94	18.7	107	10
Congo	29.9	0.04	832	18	62
Jamaica	30.1	0.32	8	157	7
Haiti	30.2	0.04	11	46	24
Indonesia	34.2	16.6	2530	96	13
Guatemala	34.3	0.73	116	139	9
Guinea	35.2	0.74	226	128	10
Cote d'Ivoire	35.6	0.71	78	59	22
Swaziland	36.4	0.66	4.5	830	2
Madagascar	37.2	16.3	337	1358	1
Liberia	37.3	0.13	232	50	27
Afghanistan	39.3	26.11	65	1436	1
Uruguay	39.6	0.65	66	241	6
Cameroon	42.6	0.4	268	34	46
Togo	43.5	0.09	11.5	25	62
Paraguay	45.6	0.43	314	111	15
Kenya	46	2.05	30	85	20
El Salvador	46.2	1	19	241	7
Zimbabwe	48.2	1.22	20	126	14

SOURCE: Peter Gleick, *The World's Water* (Washington, D.C.: Island Press, 1998), 235-244.

Understanding the causes of the shortfall requires analyzing both the available supply and rates of withdrawal and use. First, only a small portion of the annual renewable supply is actually usable in the sense that it is available in the right place at the right time. Analysis even on a country scale may not account for the maldistribution of people and resources. Accepting this shortcoming, Table 3-5 shows the renewable water supply, the total withdrawal per person per year, and the percent domestic use rate. These data will later provide the basis for interpretation of the causes of domestic water shortages in the 50 countries listed in Table 3-5.

Quality is an often-overlooked issue that must be addressed in any discussion of water supply. The World Health Organization estimates that 1 billion people a year contract a water-borne diarrheal disease and that 3.3 million of these people die, per year!<sup>40</sup> This does not account for many other water-borne diseases that inflict pain and suffering pandemically throughout the world. A primary quality concern in the developing world is human waste being disposed of in surface waters which contaminate drinking water supplies and this water then being consumed without adequate treatment. The current state of safe drinking water and adequate sanitation in the world is depicted in Figure 3-17. Clean water is a critical issue for parts of South and Central America, most of Africa, and much of Asia.

The developed world is not without its problems with water quality. A water-borne disease outbreak in Minneapolis in 1993 caused over 400,000 cases of disease and 100 deaths, this in a region rich in water resources.<sup>41</sup> While we have the technical capability to treat any polluted water to a standard that makes it again safe for consumption, this technology is very expensive. Great improvements have been made over the past 30 years in safeguarding the developed world's drinking water. In the developing world, however, water-borne disease, toxic waste disposal, and other forms of pollution continue to degrade fresh water resources.

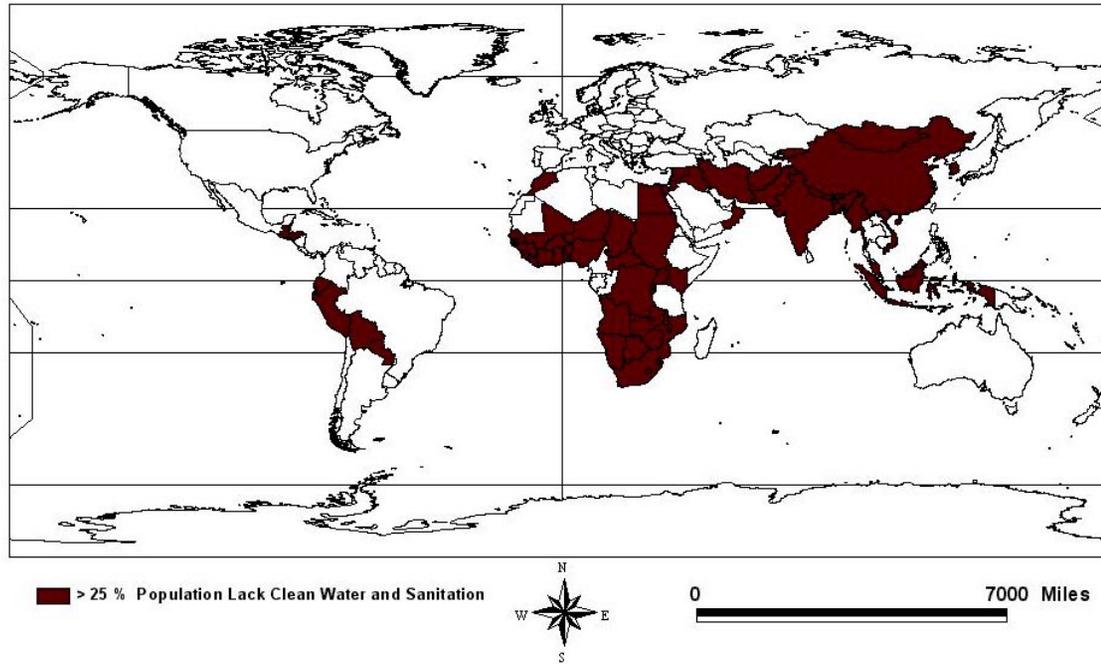
After basic human needs for water are satisfied, other uses for water can be met with the available supplies. These higher-level uses include irrigation, power generation, and the many industrial processes (such as food processing) that are high volume users of water. In Table 3-5, non-domestic use can be determined as the percent difference from the amount shown in the last column. For example, even though Afghanistan and Madagascar fall short of recommended domestic supplies, 99 percent of their total water use is diverted to other purposes; in these two countries this water all goes to agricultural use. One of the great uncertainties relating to global climate change is how weather shifts will impact food production by changing water supplies during growing seasons.

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<sup>40</sup> WHO, *Community Water Supply and Sanitation* (A48/EOS/96.15), 48<sup>th</sup> World Health Assembly, Geneva 1995.

<sup>41</sup> Gleick, 48.

**FIGURE 3 – 17**  
**Countries Without Clean Water and Adequate Sanitation**



SOURCE: Peter Gleick, *The World's Water* (Washington, D.C.: Island Press, 1998).

Salinity in water is another major quality issue of concern in agriculture and industry. Salts present in irrigation water are retained and concentrated in the soil as water naturally evaporates from the upper layers. Over time, without adequate rain to dissolve these salts back into the water for transport away, salt levels in soil build up to concentrations toxic to many plants. These lands are then lost to production or must be used for crops more tolerant of salt. Such crop choices are quite limited. Salination is reducing food production rates in many parts of the world today, mostly in arid regions where lack of rainfall makes soil recovery times very long. The U.S. is experiencing this problem in isolated parts of the arid West and Southwest.

Overall, water is a problem affecting basic survival in at least one third of the world and a limiting factor in development for most of the world. As an anonymous American sage once said, “People argue over politics; they fight over water.”

### ***Water Scarcity Issues***

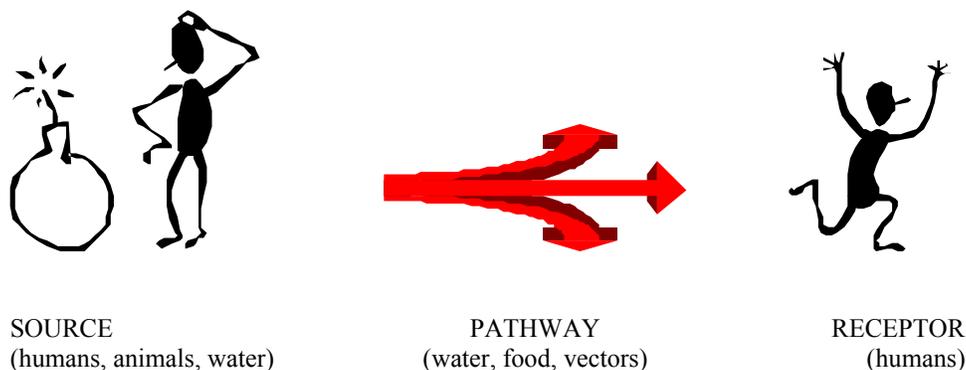
The issues having to do with sufficient quality and quantity of fresh water are obvious, but current and anticipated impacts on the world need to be addressed. Foremost is the impact on health resulting from inadequate and/or contaminated water. This is a two-part problem, the first part being sanitation and the second being clean water sources for drinking.

Nearly all infectious diseases and thus epidemics in the world today have poor sanitation as their root cause. Figure 3-18 presents a description of this process. Human wastes serve as a reservoir of disease. Depending on the disease, the mode of transmission can be water, food, or vectors, but contaminated water is by far the most common vehicle for disease agents. In most of the world, water in open or contained sewers is used to convey human wastes away from susceptible human populations to eventually discharge into the nearest naturally flowing stream. In the developed world, sewage is treated to reduce the level of pathogenic organisms before discharge. In most cities of the developing world, sewage flows, untreated or partially treated, directly into the surface water system. Water scarcity reduces the amount of water available to safely remove the waste from populated areas. This affords exposure opportunities through direct contact with vectors such as flies and mosquitoes transmitting the disease or numerous other pathways for disease transmission.

The second part of this problem has to do with the water supply. In water-scarce regions, all available resources—even those contaminated with human and animal wastes—must serve as human water sources. As noted earlier, the technology exists to clean

## FIGURE 3 – 18

### A Primer in Epidemic Disease



There has long been a basic understanding of the disease transmission and the epidemic process, as evidenced by guidance on personal hygiene to prevent illness dating back to the Bible and the Koran. Disease is transmitted following the source-pathway-receptor model illustrated above. The source or reservoir is the location of the active disease agent, typically bacteria or viruses. In most cases of infectious disease, humans are the reservoir. “Pathway” indicates that there must be a mode of transmission from the source to the receptor. This is the function that water accomplishes most often, but disease can also be transmitted by food as well as person-to-person contact. The receptor is a person who is susceptible to the contagious agent.

Not all people exposed to an agent will contract the disease; incidence of disease is heavily dependent on the dose received and the susceptibility of the receptor (victim). In disasters where the population has been weakened by malnutrition, stress, and exertion, people are much more susceptible to disease; thus, epidemic diseases following disasters are commonplace. In addition, the breakdown of public sanitation in disaster situations further accelerates disease transmission through the source-pathway-receptor model. Crowding in squalid camps exacerbates the situation by bringing large numbers of susceptible people into close proximity with disease sources and unsanitary conditions. Breaking the disease cycle following natural or human-caused disasters is a difficult problem for the military as we are called to provide humanitarian relief to refugees and displaced people all around the world.

this water to safe standards, but the cost of high technology treatment is out of reach for most developing countries. In fact, much of the world's population uses untreated water directly from the source.

Consider again the example of Minneapolis mentioned earlier in the chapter, the case in which *Cryptosporidium*, a water-borne microorganism transmitted through a treated public water system, killed over 100 people. In the developing world, water-borne cholera, salmonellosis, and *E. coli* are constant security threats. The World Health Organization (WHO) estimates that 2.6 billion people live without proper sanitation, while 1.3 billion people are without safe drinking water.<sup>42</sup> Figure 3-17 shows the areas of the world where more than 25 percent of the population lack proper sanitation and safe drinking water. As the figure makes clear, in terms of both mortality/morbidity and the cost drain of health care for preventable disease, water scarcity can have a debilitating impact in much of the developing world.

As a major contributor to population migration, water scarcity also poses a major threat to security in many regions of the world. The impacts of recurring droughts in Saharan Africa have shown this to the world. Overall, water is a resource essential for food production, power, and transportation, and it is critical for many industries. Because all of these are significantly impacted when water is "shared" by different countries or different peoples, water scarcity is a security issue.

### 3.4.2 Oceans

The oceans are considered an environmental security issue primarily because of their role in feeding the world's population and the regional economic importance of fishing for some countries. Annual fish harvesting increased from 22 million tons in 1950 to just over 90 million tons in 1995. This was down from a peak harvest of 100 million tons in 1989.<sup>43</sup> There is strong evidence that overfishing in many regions of the world has caused these recent declines. Fish as food now represents 20 percent of the protein consumed by humans and is the primary source of protein for more than 1 billion people.<sup>44</sup> The increased harvesting is caused by the demand as populations grow and by increased per capita consumption of fish as it is substituted for other meat sources that have become more expensive.

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<sup>42</sup> Ibid., 40.

<sup>43</sup> Getis, 429.

<sup>44</sup> Ibid., 427.

A secondary impact of the water quality issues described above is damage to estuaries, which causes a reduction in the production of food for the ocean's fauna. Discharge of domestic and industrial sewage into closed waters, the Mediterranean Sea, for example, is also reducing the number of fish in these waters.