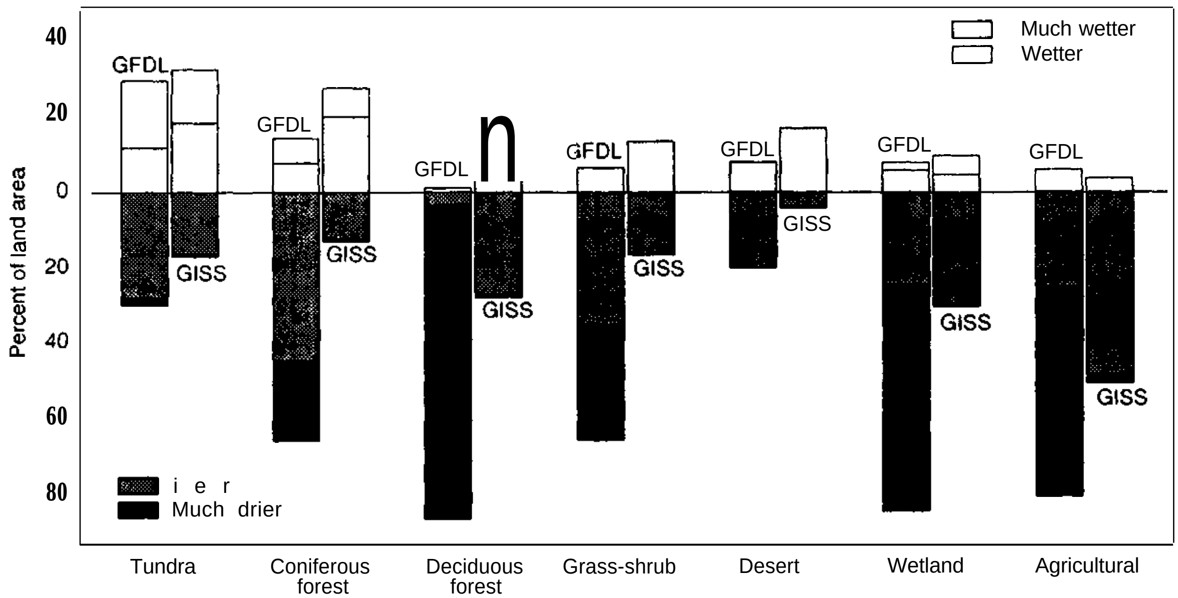
Figure 2-13-Soil-Moisture Changes Under the GFDL and GISS Climate Change Scenarios, by Land-Use and Cover Type



NOTE: Bars above the zero axis represent the percent of land-use area predicted to become wetter bare below the axis chow the percent of land area becoming drier. Drying or wetting is calculated from the change In the ratio of actual evapotranspiration (AET) to potential evapotranspiration (PET). No change is reported If the index changed (up or down) by lees than 0.025; wetter= 0.25 to 0.05; much wetter= > .05; drier= -0.25 to -.05; much drier. <-0.05. GFDL-Geophysical Fluid Dynamics Laboratory, GISS=Goddard Instltute for Space Studies.

SOURCE: P.N. Halpin, "Ecosystems at Risk to Potential Climate Change," contractor report prepared for the Office of Technology Assessment, June 1993.

vulnerability and adaptability of the various resources and the potential management strategies and policies that might assist adaptation.

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Box 2-F–Major Assessments of Climate Change Impacts

Three major assessments by national and international organizations have addressed the potential impacts of climate change: the U.S. Environmental Protection Agency's (EPA's) 1989 report, The Potential *Effects of Climate Change (94),* the three-volume climate change series issued by the Intergovernmental Panel on Climate Change in 1990 *(42, 43, 44,* and the 1992 supplement (45)), and a 1991 report by the National Academy of Sciences, Policy */mplications of Greenhouse Warming (22),* and its 1992 supplement. These reports focus on different aspects of climate change. Taken together, they lay the foundations for OTA's assessment of the adaptability and vulnerability of systems to climate change, and their findings are cited throughout this chapter.[1]

The EPA Report—In 1987, Congress requested that EPA study "the potential health and environmental effects of climate change including, but not. . . limited to, the potential impacts on agriculture, forests, wetlands, human health, rivers, lakes, estuaries, as well as societal impacts." To respond, EPA conducted a massive 2-year effort, hiring more than a hundred contractors to model potential effects on each system, and contracting out several regional case studies to integrate how all impacts might interact in different regions. The results were synthesized in a 400-page report accompanied by 11 appendixes of contractor papers.

EPA used regional predictions of temperature and precipitation generated by four major general circulation models GCMs to examine the sensitivities of managed and unmanaged systems and to evaluate regional effects. The climate predictions were distributed to contractors, who then incorporated the results into their own models for crop growth, forest productivity, farm-level decisionmaking, etc., to predict the potential effects on particular systems and in particular regions.

EPA found that unmanaged systems such as coastal wetlands, parks, and forests "maybe unable to adapt quickly to rapid warming." Effects could include a reduced range for many tree species, changes in forest composition, a decline in cold-water fish and shellfish (although some warm-water species could benefit), an increase in species extinction, loss of coastal wetlands, and an increase in salinization of estuaries. Such impacts could begin in 30 to 80 years. Climate changes may heighten the effects of other stresses (such as pollution, increased radiation accompanying stratospheric ozone depletion, pests and pathogens, and fire). For example, climate-induced stress may make large regions of forests more susceptible to other stresses, such as fire, pests, disease outbreaks, wind damage, and air pollution. Changes in forest species and productivity could lead to secondary effects such as increased soil runoff and erosion, reduced aquifer recharge, reduced biodiversity, and changes in wildlife habitat and recreational opportunities. Species extinctions could increase (and biological diversity could decline), especially in areas where roads, agriculture, and urban development block or restrict migration pathways or habitat, and in areas that harbor heat-or drought-sensitive species. Some forested land could become grassland. As communities and ecosystems are displaced by climate change, it may be necessary to expand scientific knowledge on the practice of ecosystem restoration, so that communities can be rebuilt in degraded sites or relocated to new areas where they have not existed in the past (94) (see also vol. 2, boxes 4-A and 5-M).

Overall, EPA found that managed systems such as water resources and agriculture are more capable than natural systems of withstanding climate change. However, problems may still arise as humans attempt to adapt to the changes to these systems brought about by climate change. Agricultural yields might be reduced, but productivity could shift northward so that overall production could probably meet domestic needs, with some possible reductions in exports. Farmers might have to change their practices, such as beginning or increasing irrigation, which might increase conflicts over water use. If climate change leads to reduced stream flows, water quality may suffer because less water will be available for diluting or flushing pollutants and dissipating heat; these

1 Ail three reports were based on the assumption that there would be no major changes in climate variability.

Changes could affect fish and wildlife populations. The effects on agriculture might vary considerably over regions, with declines, for example, in crop acreage in t he Great Plains potentially offset by increased acreage in the Great Lakes States.

Quality of life may not suffer much in areas where, for example, forests shift from one species to another, and where the shifts are gradual; however, in areas where forests die altogether (such as may occur in some parts of California), people would face severe environmental and land-use effects. Recreation relies on relatively healthy forests; rapid changes that caused stressed or declining forests would Iikely reduce recreational opportunities and demand.

The IPCC Report—The Intergovernmental Panel on Climate Change (IPCC) is an international group of hundreds of scientists from more than 50 countries established in 1988 by the World Meteorological Organization and the United Nations Environment Program. The IPCC setup three working groups: Working Group I to assess the scientific basis for how human activities affect the climate; Working Group II to study the potential impacts of climate change worldwide; and Working Group Ill to formulate possible policy responses. The results were Published in the three-volume Climate Change report in 1990 (The *IPCC Scientific Assessmemt, The IPCC Impacts Assessment* and The /PCC Response *Strategies).* The working groups continue to meet, and issue occasional updates to the 1990 reports.

The scientific assessment predicted that under a ''business-as-usual" scenario (characterized by continued reliance on coal-intensive energy sources and only modest efficiency increases), the global average temperature would increase at a rate of 0.5°F (0.3 °C) per decade, with a likely increaseof2'F (1 °C) over current levels by 2025 and 5.4 °F (3 °C) before the end of the next century. The impact assessment used this business-as-usual prediction for increasing temperature (with accompanying estimates that equivalent atmospheric CO_2 concentrations would double by 2025 to 2050 and sea level would rise about 1 foot (0.3 meter) by 2030) to predict potential impacts on systems including natural terrestrial ecosystems, agriculture, and forestry.

IPCC suggested that climate change could shift climatic zones several hundred miles toward the poles over the next 50 years, requiring natural terrestrial ecosystems to either migrate or adapt to a new climate regime. The rate of change will determine the degree of impacts: some species might be able to keep up with change, but some could become extinct, thus reducing global biodiversity. Ecosystems are unlikely to move as units, but will develop new structures as species abundance and distribution are altered. Most at risk are systems with limited options for adaptability (montane, alpine, and polar areas, island and coastal communities, remnant vegetation, heritage sites or reserves, and areas already under stress). Sea level rise and ocean warming will affect fisheries, potentially reducing habitat for several commercially important species. Coastal wetlands may be inundated by rising seas and forced to migrate inward, though in many areas, this may not be possible. Inland wetland areas may come under increased pressure for agricultural use. As for managed systems, forests may become more susceptible to parasites, and losses from fires will increase. It is urclear whether global agricultural productivity would increase or decrease overall, but many regions are likely to experience shifts or losses in production (for example, a decline in cereal and horticultural production in the southern United States), which will alter trade patterns. Impacts will differ considerably from region to region, as will the socioeconomic effects. Water availability will likely increase in some areas and decrease in others, but regional details are not yet known. There may also be a change in drought risk which could seriously affect agriculture at both the regional and global levels.

The NAS Report—The National Academy of Sciences (NAS) convened three different scientific panels to conduct preliminary analyses of climate change effects, mitigation strategies, and adaptation strategies. Each panel drafted a report that described their analyses and conclusions. A fourth "synthesis" panel drew on the work of the other three panels to formulate a policy report which was published in April 1991.

2 The Cumulative warming effect of all greenhouse gases is equivalent to a doubled $C0_2$ concentration.

(Continued on next page)

Box 2-F-Major Assessments of Climate Change Impacts-(Continued)

The NAS panels assumed greenhouse warming In the range of 2 to 9°F(1 to 5°C), but did not give a specific time frame of reference. Based on this scenario, NAS classified natural resource systems and human activities into one of three categories: low sensitivity to climate change within the given range; sensitive but adaptable at a cost; and sensitive with questionable ability to adjust or adapt. NAS concluded that built systems generally fit into the first or second categories, and managed crop or timber lands fit into the second.

Water resources are quite sensitive to climate because runoff is the "small difference between the larger quantities of precipitation and evaporation," and runoff fluctuates relatively more" than either precipitation or evaporation. Changes in runoff will have adverse impacts only when water supply no longer matches water demand for use and consumption. In the United States, water supply and demand are now closely matched in the Great Basin, Missouri, and California water regions, so these areas maybe particularly vulnerable to decreases in precipitation (and conversely, they would reap large benefits should precipitation increase). Activities such as irrigation are also vulnerable to decreased precipitation because irrigation is most common in areas where precipitation is already light and evaporation is high. Unless climate changes quickly relative to demographic changes that affect water demand, however, the NAS report concludes, "the overall impact of climate change is unlikely to be substantially more serious than that of the vagaries of the current climate" {21).

In contast, NAS suggested that unmanaged ecosystems—the "natural landscape" and marine ecosystems-respond relatively slowly to climate change and that their ability to adapt is questionable and "problematic."

SOURCE : Office of Technology Assessment, 1993.

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