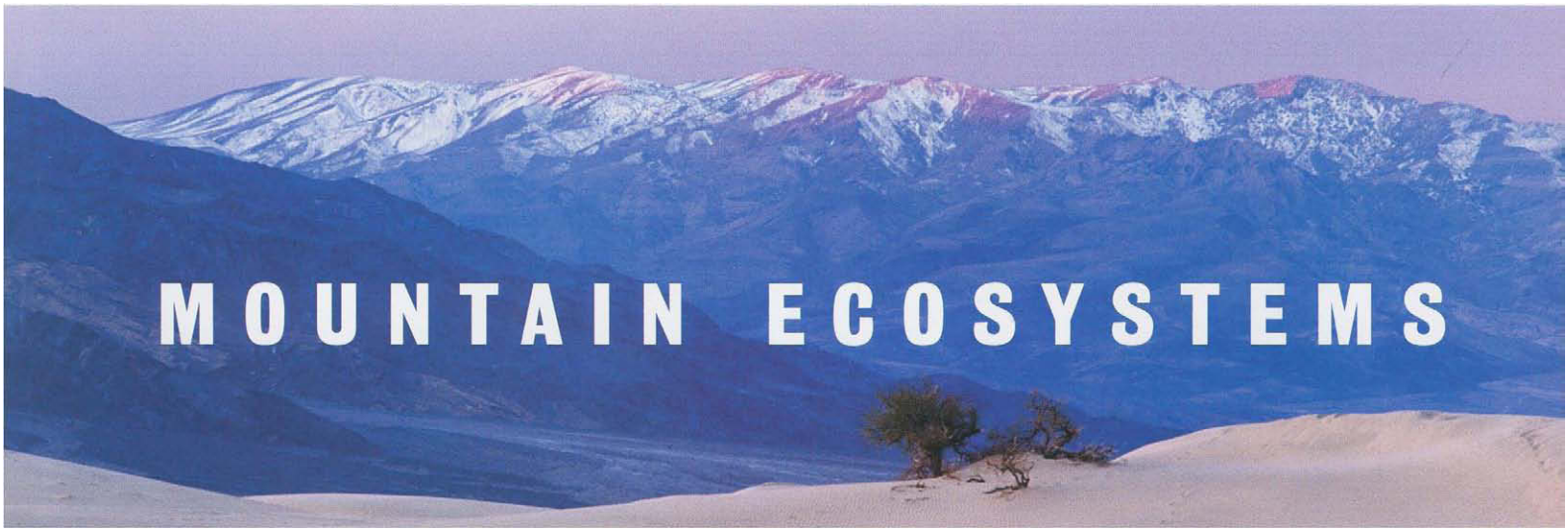
APPENDIX: Although mountain, polar, and urban ecosystems were not included in the PAGE study, they are fundamentally important to human health and well-being. Mountain areas are the source of water for more than half of the world's population. Polar regions play a critical role in controlling global climate and sea level. Urban areas are home to half of all people, and urban populations are rising, especially in the developing world. This appendix gives brief profiles of each of these ecosystems.



MOUNTAIN ECOSYSTEMS

The grandeur of mountain ecosystems belies their delicacy. Weathering processes and gravity constantly pull rocks, soil, snow, and water downhill, inhibiting the development of soils. Thin soils and slope instability, in turn, limit plant growth, raise the vulnerability of mountains to human disturbance, and require lengthy recovery time once damaged. Mountain regions also have a long history of political neglect and economic exploitation.

Nevertheless, millions of people who live far beyond mountains' boundaries benefit from the water, timber, rich biodiversity, and awe-inspiring scenery that mountain ecosystems supply. Yet, it is the people who live in mountain and upland regions, about a tenth of the world's population, who depend most immediately on mountain ecosystems for subsistence (Grötzbach and Stadel 1997:17). Within mountainous regions of developing countries, transport links may be scarce, access to supplies and markets poor, population growth rates high, and employment opportunities limited. Mountain populations in Nepal, Ethiopia, and Peru, for example, rank among the world's poorest (FAO 1995).

Extent of Mountain Ecosystems

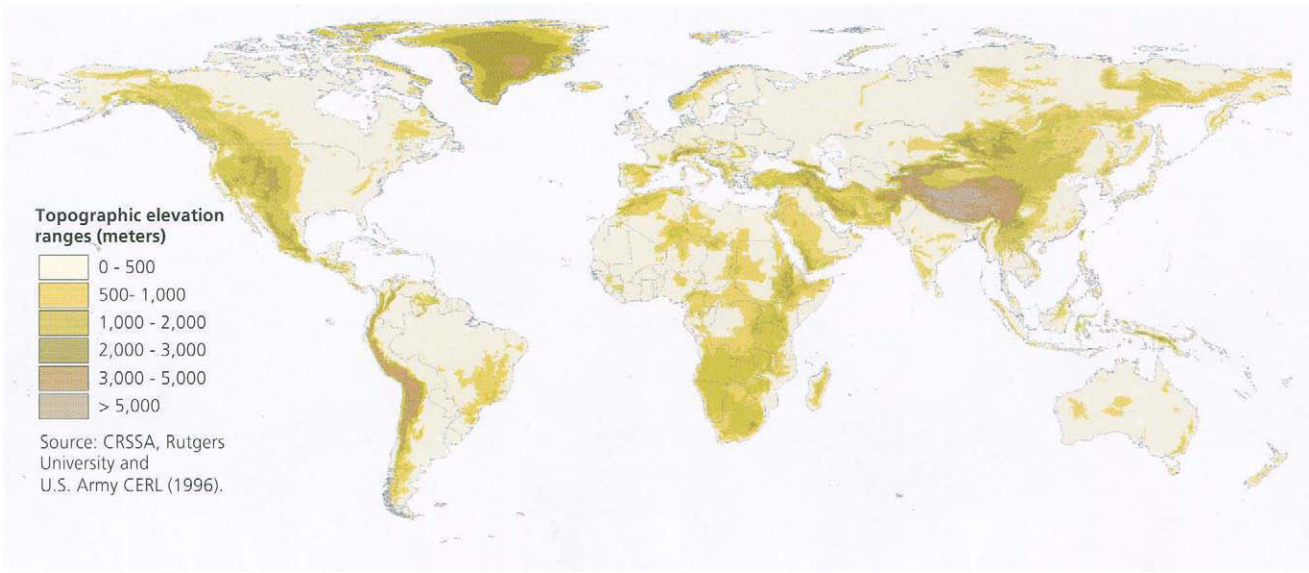
The definition of a *mountain region* can be based on numerous criteria–including height, slope, climate, and vegetation. A simple definition is "areas above 3,000 m"–a category that encompasses about 5 percent of the world's terrestrial surface and an estimated 120 million people. For simplicity, again, upland area is defined as the 27 percent of the world's surface above 1,000 m (Grötzbach and Stadel 1997:17; Ives et al. 1997:6–8). A total of about half a billion people live in uplands and mountains (Ives et al. 1997:8) Mountain ecosystems encompass a range of shapes, climates, and compositions of vegetation and animal species depending on elevation and latitude.

Goods and Services from Mountain Ecosystems

FOOD AND FIBER PRODUCTION

Mountains are not world centers of agriculture in terms of volume, but subsistence agriculture in mountains is the primary food source for most mountain inhabitants in developing countries–millions of people (Messerli and Ives 1997:10). Mountain agroecosystems also are valuable storehouses of food crop genes; many of the major food crops originated in uplands. Much of the world's remaining agricultural genetic diversity is believed to exist in the fields of subsistence mountain farmers or in still more remote areas.

Potatoes are a perfect example. Andean subsistence farmers have actively maintained the genetic diversity of potatoes.



In Paucartambo, Peru, about 21 potato varieties are planted in each field, and the International Potato Center in Lima maintains the world's largest bank of potato germplasm, including some 5,000 distinct types of wild and cultivated potato and more than 160 noncultivated wild species (Tripp and van der Heide 1997; CIP 2000). By comparison, in most producer countries, a few commercial varieties dominate; and these monocultures are susceptible to epidemics of pests and diseases.

Mountains also have traditionally supplied timber resources to the world and fuel to local populations, but deforestation has reduced standing timber in many areas. In the tropics, mountain forests have had the fastest rates of loss over the last decade, compared with all types of lowland forests–about 1.1 percent a year (FAO 1993:ix).

WATER QUALITY AND QUANTITY

Half the world's population depends on mountain water. All the major rivers of the world originate in mountains, which receive high levels of precipitation as rain and snow that they store temporarily as ice, then release during spring and summer melt periods (Liniger et al 1998:5). Mountain forests help filter the water and protect its quality. On average, mountains in semiarid and arid environments provide 70–95 percent of downstream freshwater. In regions with higher rainfall, mountains provide 30–60 percent of the water supply (Liniger et al. 1998:18). High elevation water flows also power many of the world's hydroelectric plants.

Mountain watersheds will be expected to meet much of the projected increase in demand for freshwater by 2025. Will they be able to? Few assessments of the biological integrity of mountain rivers have been attempted, but trends in population growth, inadequate wastewater treatment, global warming, and increasingly extensive montane forest destruction and pollution all suggest that mountain ecosystems' ability to supply ample high-quality water is being degraded.

Mining is one of the greatest threats to the supply of clean water from mountains. Many countries have lax mining laws, regulatory controls, or enforcement, particularly in remote areas where citizens may be uninformed about mining impacts. Water drained or pumped directly from mines is often highly acidic and laden with cyanide and other heavy metals. Liquid wastes may be pumped directly into local waterways, or stored in ponds or behind earthen dams that are vulnerable to overflow or leaks. A partial survey of tailings dam failures by an NGO identified more than 70 spills and accidents in the last several decades, with considerable environmental damage (D'Esposito and Feiler 2000:5).

BIODIVERSITY

Mountains encompass numerous and varied habitats informed by altitude, soil and rock type, temperature, and sun exposure; their isolation has further enabled species diversity and endemism to flourish. The mountains of Central Asia, for example, are home to more than 5,500 species of flowering plants, with more than 4,200 species concentrated in Tajikistan alone (Jeník 1997:201). Mount Kinabalu in Sabah (Borneo) is estimated to harbor more than 4,000 plant species (Price et al. 1999:5).

Mountains also function as sanctuaries for plants and animals whose lowland habitats have been lost to conversion. Tropical montane forests, for example, are refuges for some of the world's rarest species including the mountain gorillas of Central Africa, the Quetzel of Central America, the red panda of the Eastern Himalaya, the Andean spectacled bear, and the European lynx found in isolated parts of Central

Europe. Ten percent of all bird species–already reduced to restricted ranges worldwide–are found solely or primarily in cloud forests, where the atmospheric environment is characterized by persistent, frequent, or seasonal cloud cover, usually on tropical or subtropical mountains exposed to oceanic climates.

Some protection of mountain biodiversity and other services is afforded by the designation of 141 biosphere reserves, 150 parks and reserves (above 1,500 m), and 39 World Heritage Sites in mountain and upland areas–more than in any other major landscape category. Still, numerous pressures–air and water pollutants, people–cross the boundaries of protected areas (Messerli and Ives 1997:20; Schaaf 1999).

Conversion

One sign of the potential decline in the capacity of some mountains to provide biodiversity is the reduction of unique mountain habitats, like tropical montane cloud forests, to just fragments of their original extent. Perhaps 90 percent of mountain forests have disappeared from the northern Andes (WCMC 1997, citing Weutrich 1993). Although half of the world's remaining montane cloud forests have some degree of protection, WCMC reports that many continue to be fragmented or cleared at a rapid rate for agriculture, fuel wood, grazing areas, mining, and road building, and as a result of fires that spread from adjacent cultivated areas (WCMC 1997:4).

Pollution

Air pollution is another pressure with documented impacts on mountain biodiversity. As high land masses, mountains intercept more air currents, and generally receive more precipitation, than other land forms. Most researchers believe that elevated ambient levels of sulfur and nitrogen oxides and ozone are responsible for the death or decline of extensive areas of montane forest in the northeastern United States and Canada. Long-range air pollutants also have damaged the mountain ranges along the border of the Czech Republic, Southeast Germany, and Southwest Poland (FRCFFP 1998:9).

RECREATION

Mountain tourism generates about US$70–$90 billion annually worldwide, about 15–20 percent of the global tourism industry. That total only begins to capture the value of mountains as sites of sacred rituals, sacrifice, and pilgrimage for all the major world religions, many minor ones, and as places for reverence of nature and wilderness (Price et al. 1999:4).

But mountains may have a difficult time sustainably accommodating further growth in tourist numbers. Tourism can significantly increase the employment and income levels of mountain communities, and sometimes provides funds for ecosystem protection. At the same time, tourism can be a primary degradation force. For example, mountains are heavily used by the 65–70 million downhill skiers worldwide (Price et al. 1999:36). They consume local supplies of food and water, generate solid waste and sewage, and require access to once pristine locales via roads, rail lines, airports, and hotels. Skiing also involves forest clearance and consumption of large volumes of water for snowmaking or watering.

High in the San Juan Mountains of Colorado, near the Continental Divide, the Summitville gold mine leaked contaminants into the Alamosa River in 1992, killing all aquatic life along a 27-km stretch. Clean-up is slated to cost $170 million (Carlson 2000:10).

The Bottom Line for Mountain Ecosystems. The demand for mountain areas' mineral resources, timber, scenic beauty, and water is growing. Yet there is a chronic lack of data regarding the state of mountain ecosystems and the extent and growth rates of activities damaging to mountain ecosystems. Agenda 21—the environmental blueprint crafted at the Rio Earth Summit in 1992—argued that mountains, as fragile areas, require integrated ecosystem treatment, like islands, polar regions, or tropical rainforests. Although acceptance of this viewpoint is growing, mountains are still low on the priority list of most national and international agendas. They remain vulnerable to exploitation by lowland populations through damaging extraction of natural resources and tourism development, for example, and by poorly designed government policies that contribute to the demise of traditional mountain farming systems and indigenous knowledge.