State of Polish Mountain Forests: Past, Present, and Future[1]

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Abstract

*Mountains occupy only 3 percent of Poland. They are the northern part of the European arc of the Carpathian and Sudety Mountains, extending about 700 km along the southern Polish border. They are of medium height (about 1,500 m., maximum 2,600 m. a.s.l.), and diversified in terms of climate, geology, soils, vegetation, and anthropogenic impacts. The forest vegetation of the Sudety and Carpathian Mountains forms three elevational zones. Forests occur in the foothills (as high as 600 m. a.s.l.), the lower mountain forest zone (as high as 1,250 m. a.s.l.) and the upper montane forest zone (as high as 1,500 m. a.s.l.). The original lower mountain forests consist mainly of the fir (*Abies alba *Mill.) and beech (*Fagus sylvatica *L.), while upper montane forests consist of spruce (*Picea abies *[L.] Karst.). Centuries of economic activity have changed the species composition of mountain forests. The share of the spruce has increased considerably, and the percentage of the fir and beech has decreased significantly. In the Sudety and western part of the Carpathian Mountains prevalence of spruce is the highest (83 percent), while in the eastern part of the Carpathians, it does not exceed 10 percent. The percentage of beech in the Sudety and western part of Carpathian forests is below 20 percent, but about 40 percent in the eastern part of the Carpathians. Severe weather conditions, frequently poor habitats and improper management and considerable air pollution occurring in the past 50 years, followed by infestations of primary and secondary insects and spread of parasite fungi, have led to considerable destruction of mountain forests. According to forecasts, the area of totally destroyed and severely damaged mountain forests will increase considerably through the year 2010. Deterioration of forest health will proceed from west to east. Protection of forest health against deterioration requires reduction of industrial emissions, changing existing forests into less sensitive habitats more compatible with their carrying capacity, and recultivation of contaminated forests.*

Introduction

Generally Poland is a lowland country. Mountains occupy only 3 percent of the country. Even though the area occupied by mountains is small, their landscape makes them the most beautiful areas of Poland, and they are valuable in terms of wildlife, with numerous endemic and rare plant and animal species, and specific biocenoses (Denisiuk 1995, Szafer and Zarzycki 1972, Zarzycki and others 1991).

Humans have affected the wildlife of the Polish mountains for centuries. Forms of human intervention have changed over the years, evolving from direct activity (cutting forests, raking duff, grazing) to air pollution, a much more dangerous indirect impact that is difficult to control. Human impacts, exacerbated by specific climatic, orographic and soil conditions, have seriously worsened the condition of mountain ecosystems, including forests, in at least part of the ranges.

General Characteristics of Polish Mountains

Polish mountains form the northern part of the European arc of the Sudety and Carpathian Mountains (*fig. 1*) extending about 700 km along the southern boundary of Poland (*fig. 2*). They are of medium height, with average elevation not exceeding 1500 m. a.s.l. (*fig. 3*). They are diversified in terms of climate, geology, soil and vegetation, and also vary with anthropogenic impacts (Fabiszewski and Jenik 1994, Paschalis 1995, Starkel 1991, Szafer and Zarzycki 1972, Zarzycki and others 1991).

The Carpathian climate is more continental (colder and drier) than that in the Sudety Mountains. Continentalism increases along the west-east transect. The Sudety Mountains are composed mainly of granite, gneiss and basalt, and the Carpathians are comprised of sandstone and shales (Carpathian flysch) with small

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areas occupied by granite and limestone rock (Starkel 1991). Thus, the Sudety have a poor substratum and strongly acidic soils, while the Carpathians have less acidic, more nutrient-rich substratum and soil.

The vegetation of the Sudety and Carpathians is diverse by elevation (*fig. 4*). The foothill zone, as high as 600-700 m. a.s.l., is occupied by deciduous and mixed forests (deciduous and coniferous). The lower montane zone (as high as 1,250 m. a.s.l.) is represented by mixed forests, usually beech and fir, and the upper montane belt (as high as 1,500 m. a.s.l.) consists of spruce. Above the montane forest zones in the higher mountain ranges, there is a dwarf mountain pine zone (up to 1,750 m. a.s.l.), and alpine (up to 2,300 m. a.s.l.) and subalpine zones (>2,300 m. a.s.l.) (*fig. 4*).

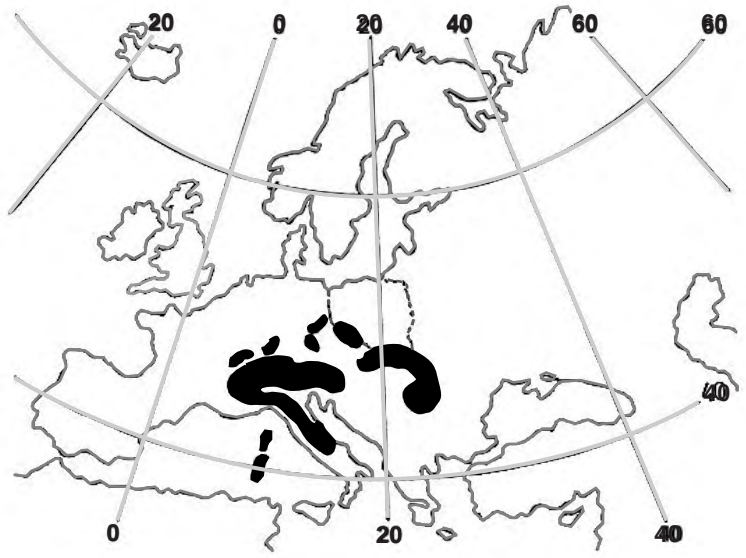


Figure 1 — Central European Mountains Province (Szafer and Zarzycki 1972).

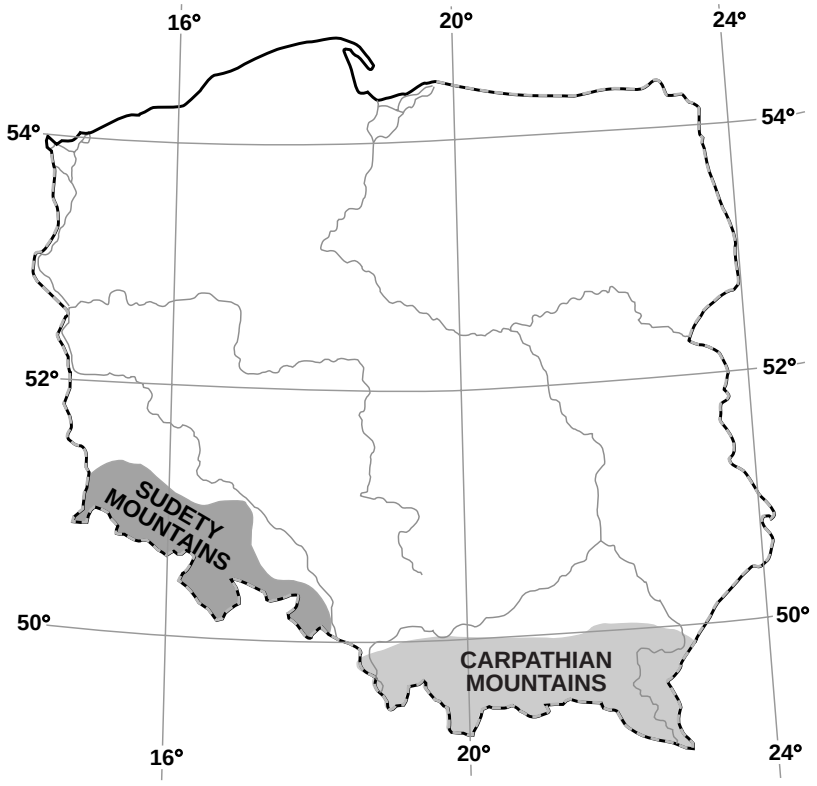


Figure 2 — Polish Mountains: the Sudety and Carpathians.

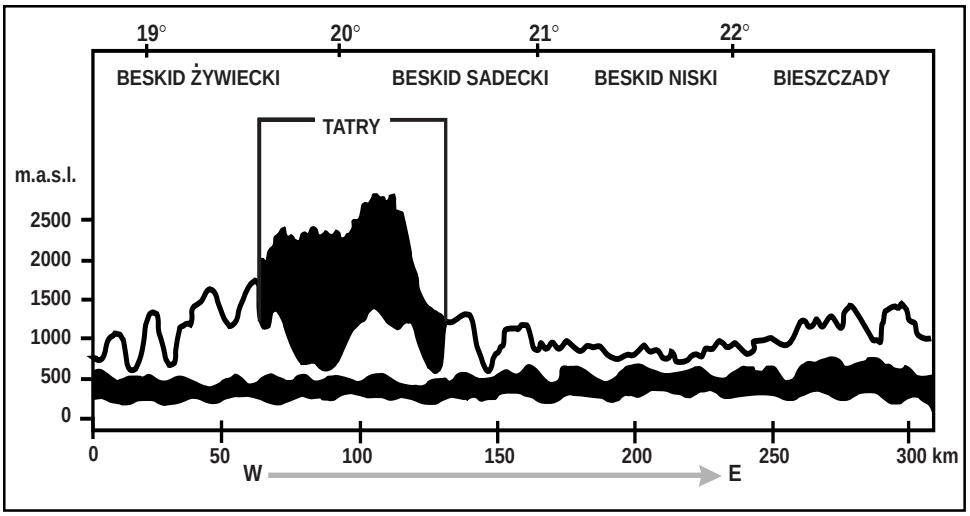


Figure 3 — The Carpathian Mountains (Warszynska 1995).

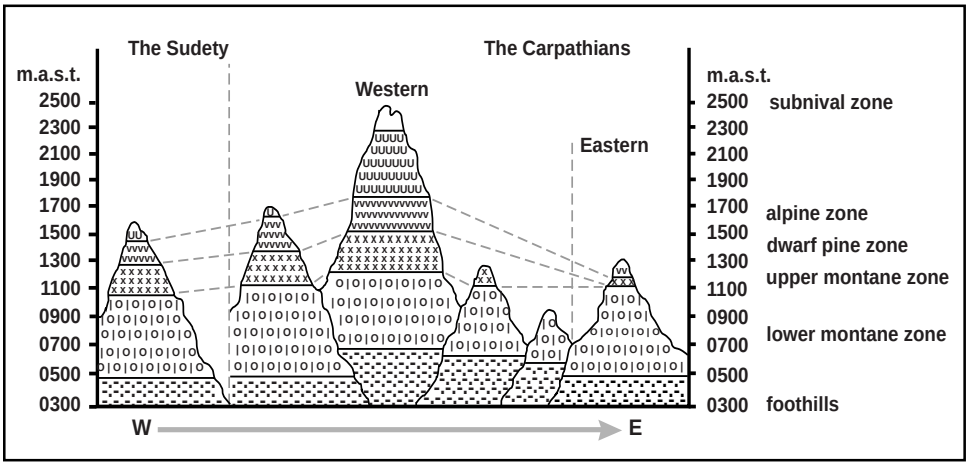


Figure 4 — Vegetation zones in Polish mountains (Denisiuk 1995, Fabiszewski and Janik 1994).

Polish Mountains Forests

The primeval lower montane forests are comprised mainly of the fir (*Abies alba* Mill.) and beech (*Fagus sylvatica* L.), while the upper montane forests have spruce (*Picea abies* [L.] Karst). The first two species are abundant in the Carpathians, and the third species is common in the Sudety. Generally, poor acidophilic forest communities occur in the Sudety, while the Carpathians had more eutrophic communities (Matuszkiewicz 1984).

The current species composition of the forests significantly differs from the primeval one because of centuries-long, often improper management. Currently, spruce stands occupy considerably larger mountain areas, and often the seed source is from non-native plantations. The percentage of the fir and beech in forests in Polish mountains has significantly decreased. In Sudety the current percentage of the spruce in forests is more than 83 percent (Capecki 1989) (*table 1*). In the Carpathians the average percentage of this species does not exceed 22 percent, and beech and fir are about 25 percent each (Fabijanowski and Jaworski 1995). The percentages of these three forest-forming species are different in various parts of the Carpathian arc. In the western part (Silesian Beskid Mountains, Zywiecki Beskid Mountains) the spruce dominates (> 70 percent), while in the eastern part (Beskid Niski and Bieszczady Mountains beech (27 and 41 percent) and fir (31 and 20 percent) dominate (Fabijanowski and Jaworski 1995) (*table 1*).

The average age of Carpathian forest trees is about 50 years, and their volume per hectare is as high as 200 m^3, with average annual growth 2.6 m^3/ha/year. In selected regions of the Carpathians there are considerably older tree stands (> 80 years), with

higher volume and valuable native populations (e.g., Beskid spruce) and ecotypes (Istebnianski spruce), but they occupy small areas.

Mountain forests, both in the Sudety and Carpathians, are affected by severe climatic conditions, including strong winds, low temperatures, frequent mists, and high snowfall. Tree stands, in habitats unsuitable for them and thus weakened, are more easily broken by wind and snow.

In the last 50 years, the severe climatic conditions have been accompanied by gaseous (SO_2, NO_x) and particulate (heavy metals) air pollutants. The Sudety, located closest to large industrial centers in the Czech Republic, Germany, and Poland, are among the most threatened and damaged Polish mountains. In the Sudety the average annual SO_2 concentration reaches 25 µg m^{-3}, fluctuating during the year between 16 and 45 µg m^{-3}; average annual NO_x reaches 32 µg m^{-3} (Godzik and Szdzuj 1994). The average 24-h ozone concentrations reaches in the spring month of May 100 µg m^{-3} (Zwozdziak and others 1994). Annual sulfur deposition is estimated at about 30 kg/ha^{-1}, and nitrogen deposition at 8-9 kg ha^{-1}. Atmospheric precipitation is acidic, below pH 4 (Stachurski and others 1994, Zwozdziak and others 1995). Critical ambient concentrations of sulfur and ammonia compounds are considerably exceeded in the Sudety forests. In the westernmost parts of the Carpathians (Silesian Beskid Mountains), air pollutant concentrations and deposition of these pollutants are nearly the same as those in the Sudety (Godzik and Szdzuj 1994). Air pollution is considerably lower eastwards (Beskid Niski and Bieszczady Mountains) because no large emission sources are found in these areas (Dmuchowski and Wawrzyniak 1994) (*figs. 5, 6*).

The decrease in the air pollution gradient from west to east (from the Sudety Mountains to the Carpathians) is confirmed by sensitive plant indicators (Dmuchowski and Wawrzyniak 1994, Zolnierz and others 1995). Concentrations of and toxic elements (cadmium and aluminum) in the needles of the spruce and pine (*Pinus silvestris* L.) are considerably higher in the Sudety than in the Carpathians (*figs. 7, 8*).

Mountain forests that have altered species composition, improperly managed and affected by industrial emissions are attacked by primary insect pests, such as *Zeiraphera griseana*, *Cephalcia falleni*, and *Lymantria monacha*, and then by secondary pests, such as *Ips typographus* and *Pityogenes chalcographus* as well as by parasite fungi (among others *Armillaria obscura* and *Heterobasidion annosum*). Insects of both groups inflict the greatest damage in the Sudety and western Carpathians (Capecki 1989, Godzik 1995, National Inspectorate for Environmental Protection 1993).

Table 1 *— Main tree species in forest stands in the Sudety and Carpathian Mountains.*

Forest Stand	*Picea abies*	*Abies alba*	*Fagus sylvatica*
	pct		
Sudety	83.4	-	5.0
Carpathians	21.7	25.0	25.3
Beskid Slaski	73.6	3.5	17.2
Beskid Zywiecki	74.8	8.8	12.1
Beskid Makowski, Wyspowy	12.9	43.9	17.2
Gorce, Beskid Sadecki	36.9	28.1	25.9
Tatry	77.6	2.8	2.2
Beskid Niski	3.7	31.0	27.0
Bieszczady	9.3	20.0	40.9

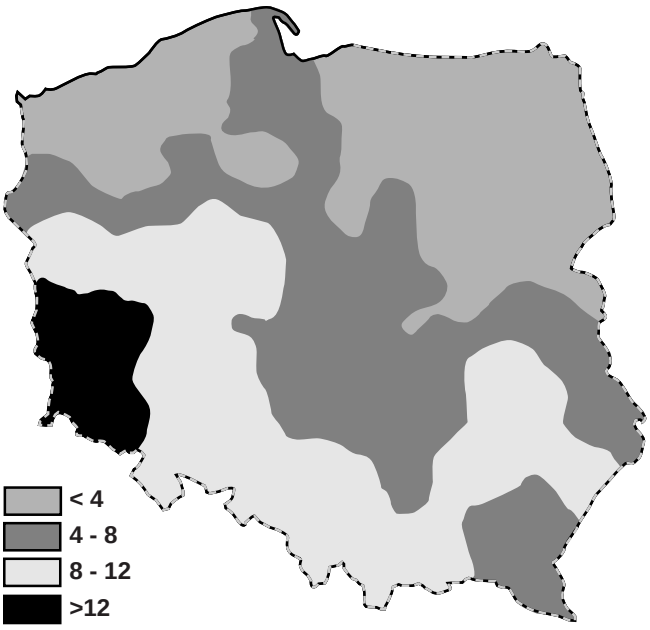


Figure 5 — SO_2 deposition index, average value for 1989-1991, summer period (mg/m²/24 h) (Dmuchowski and Wawrzoniak 1994).

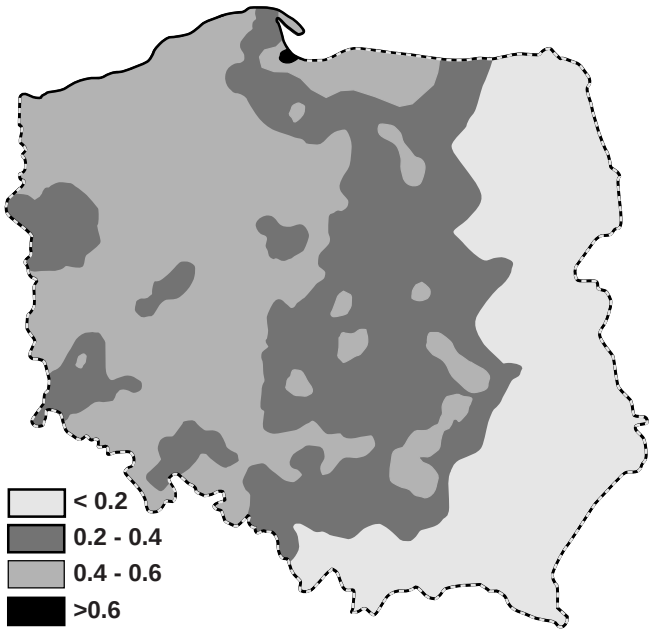


Figure 6 — NO_x deposition index, average value for 1989-1991, summer period (mg/m²/24 h) (Dmuchowski and Wawrzoniak 1994).

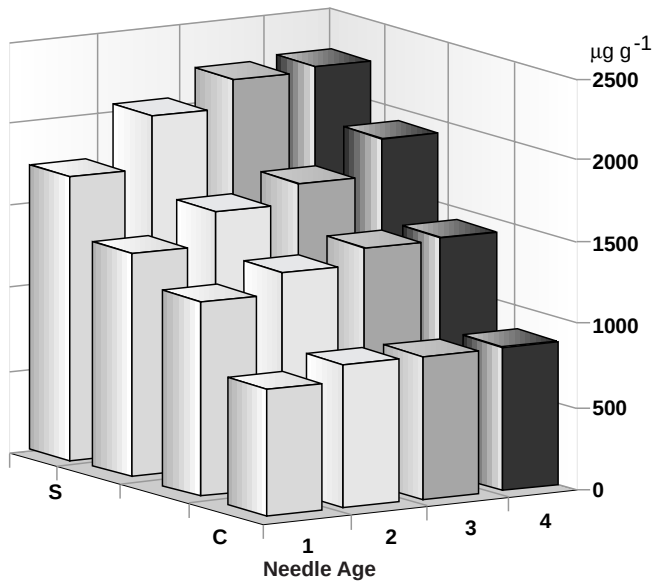


Figure 7 — Total sulfur concentration in spruce needles (Zolnierz and others 1995).

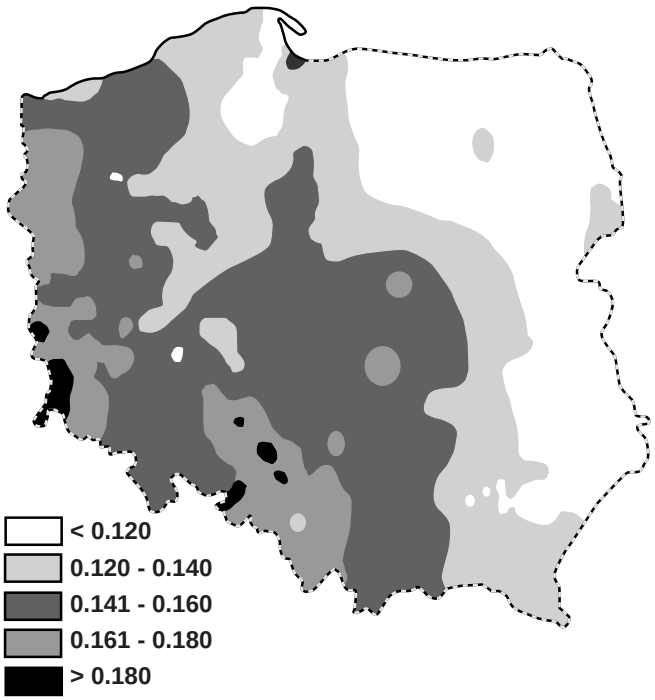


Figure 8 — Total sulfur concentration (percent in d.wt) in Scots pine needles (previous year growth) (Dmuchowski and Wawrzoniak 1994).

The Present Health of Mountain Forests in Poland

According to the general map of forest health by Paschalis (1995), based on data from the Institute of Forest Research, there were no healthy forests in Poland in 1995. The Sudety forests and westernmost Carpathian ranges are in a state of total disaster or very damaged (*fig. 9*). The forests in the central and eastern Carpathians have been classified as strongly damaged. Compared to 1990, the state of the forests has deteriorated considerably (Paschalis 1995).

Factors involved in damage to the mountain forests, which is highest in the western part and lowest in the eastern part of the Sudety-Carpathian arc include climatic, geological, and soil conditions; the intensity of anthropogenic impact; the level of air pollution from industrial emissions; the occurrence of insect pests and parasite fungi (*fig. 10*).

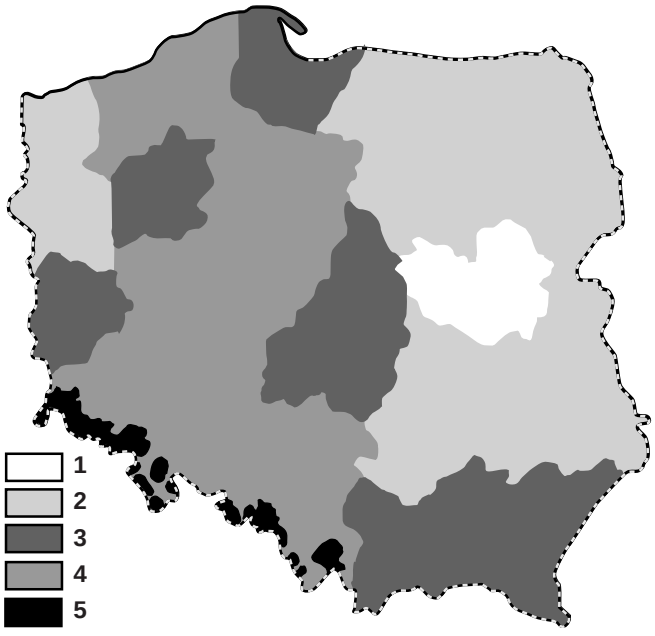
In addition to the horizontal east-west gradient of contamination of the mountain forests, a vertical gradient has been found. Upper montane forests, higher than 1,200 m. a.s.l., are exposed to greater amounts of wet deposited pollutants than lower ones (< 1,000 m a.s.l.). These pollutants are brought there together with orographic mists and clouds that occur more frequently at higher elevations than lower elevations (Zwozdziak and others 1994).

Locally, beautiful stands of forests can be still found in Poland. They are usually under protection from economic activity in national parks. The country's seven mountain national parks are located at regular intervals along the Sudeten-Carpathian arc. Forests occupy between 67 percent and 91 percent of their areas.

Future of Mountain Forests in Poland

According to forecasts of the Institute of Forest Research based on a large-area inventory of damage to tree stands, the area of completely and very damaged forests will increase considerably during the next 15 years (through the year 2010) (Paschalis 1995). Deterioration of forest health will proceed from west to east (*fig. 11*).

To counteract the deterioration of mountain forest health, managers and scientists should reduce both local and transboundary industrial emissions; change existing forests into less sensitive genotypes, more compatible with local habitats; and recultivate contaminated forests.



Fgure 9 — Forest damage in Poland. Damage degree:
1 = low,
2 = moderate,
3 = heavy,
4 = very heavy,
5 = deforestation (Paschalis 1995).

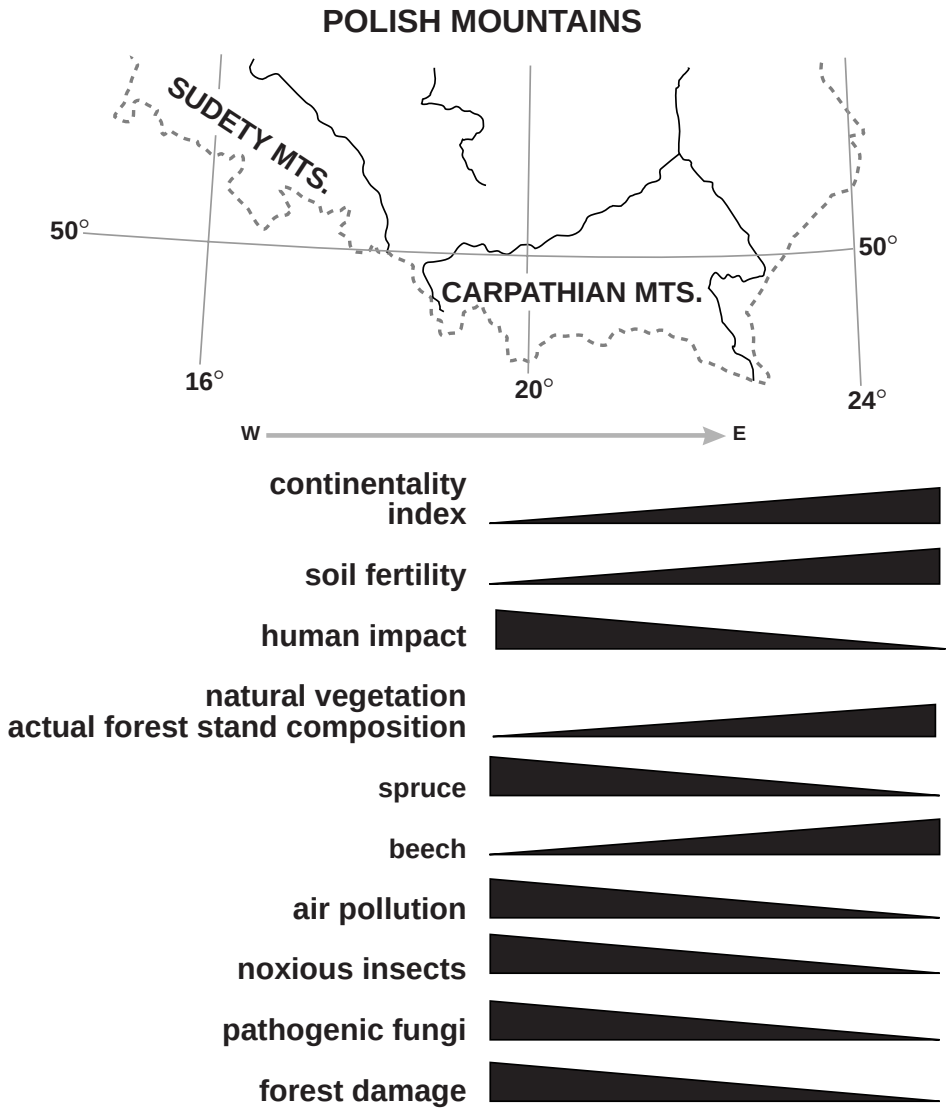


Figure 10 — Factors involving various degree of damage to mountain forests in Poland.

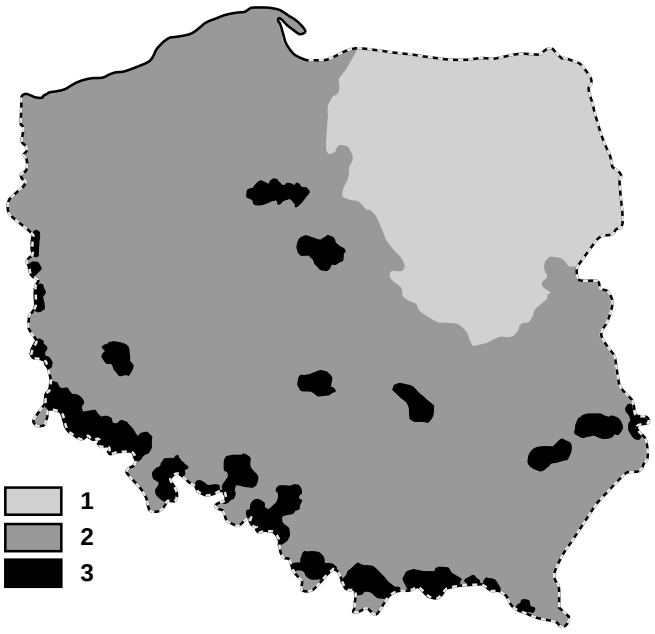


Figure 11 — Forest damage in Poland, prognosis 2010. Damage degree:
1 = moderate,
2 = heavy and very heavy,
3 =deforestation (Paschalis 1995).

The future of mountain forests is a primary concern of Polish ecologists. We are reminded of the consequences of total forest destruction on the environment by an admonition more than a dozen years ago by Keating who stated, "The fate of mountain ecosystems affects half the world's people" (The Earth Summit Agenda for Change 1983).

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