Chapter 1
The Global Ecological Situation

"Thirty years ago," zoologist Viktor Dolnik wrote in 1992, "only a few ecologists on the whole planet thought about the approaching ecological catastrophe. The public called them alarmists and had a big laugh at their expense. Today, though, large numbers of ordinary people have felt for themselves the growing pressure of primary factors (affecting human life)"[1] (Dolnik 1992).

Indeed, people have come to think ecologically at a rate unusual by historical standards. The topic frequently appears on television and online. Magazines dealing entirely with ecological problems come out one after the other. Impressive international conferences regularly gather to discuss environmental protection at the highest levels. In 1972, the United Nations formed a permanent body for the issue, the UN Environmental Program (UNEP). The UN Commission on Sustainable Development, a functional commission of the Economic and Social Council, arrived 20 years later with the aim of implementing the international agreements on environmental issues reached at the 1992 Rio de Janeiro Earth Summit. Aside from these, authoritative non-governmental organizations such as the World Wildlife Fund (WWF) and the Global Footprint Network have begun work in most countries.

Ecology has also broken into the worlds of business and politics. By 2010, the market for green technology surpassed the $1 trillion mark. Political party platforms can no longer do without promises to fix one environmental problem or another. Green parties have gained representation not only in European parliaments, but in cabinets (from 1999 to 2005 in Germany, for example), directly influencing government programs and funding nature-friendly projects. Finally, we should recall that in 2007 the Nobel Peace Prize was awarded to former Vice-President Albert Gore and the Intergovernmental Panel on Climate Change (IPCC), "For their efforts to build up and disseminate greater knowledge about man-made climate change, and to lay the foundations for the measures that are needed to counteract such change" (Nobel Prize 2007).

[1] Parentheses ours.

V. I. Danilov-Danil'yan, I. E. Reyf, *The Biosphere and Civilization: In the Throes of a Global Crisis*, https://doi.org/10.1007/978-3-319-67193-2_1

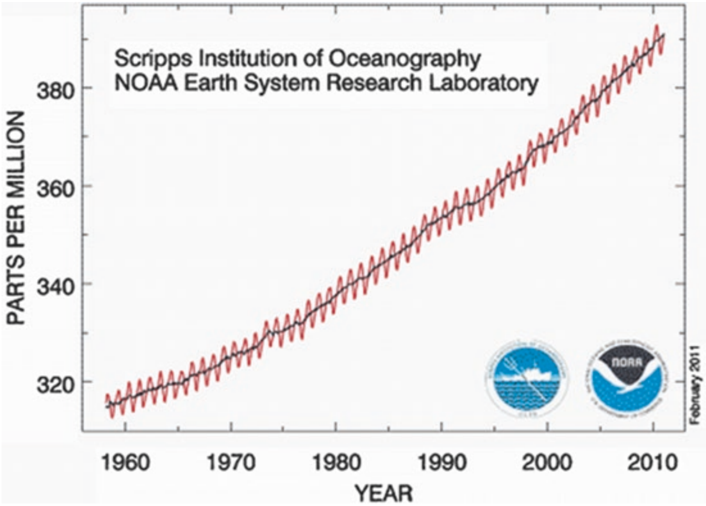

Fig. 1.1 A graph of the increase in CO_2 concentrations in the atmosphere (parts per million), taken at the Mauna Loa Observatory, Hawaii, from 1958 to the present. Slight fluctuations in the course of the overall trend reflect seasonal variations in CO_2 levels connected to intensified photosynthesis and carbon use by vegetation in spring and summer. Source: Scripps Institution of Oceanography NOAA Earth System Research Laboratory

It would seem that all the necessary financial and technological resources have been mobilized. But the problem, like a giant iceberg, is still sitting right in the path of global civilization, and it shows no signs of melting. Meanwhile, people are gradually learning to think of "the environment" as a long-term problem, one that their children and grandchildren will live with. They've learned to think that the relatively carefree days of the recent past are never coming back, and that mankind can go on living with the current troubles (sometimes better, sometimes worse) forever, if need be.

In reality, the ecological situation we are living through is markedly different from anything the human race has dealt with before. If for no other reason, this is because the dangerous changes have taken on a global character. They have spread to every subsystem and component of the environment. They have reached the entirety of the planet's surface from pole to pole as various scientific studies have confirmed, perhaps sparing only the ocean depths.

Particularly telling is the concentration of ***nutrients***—substances that take part in life processes—in the atmosphere. Studies of air bubbles in glacial core samples from Antarctica and Greenland, which keep a record of the atmosphere in long-past epochs, have shown that concentrations of nutrients are changing faster than at any time in hundreds of thousands of years at the least (Barnola et al. 1991; Cannariato et al. 1999) Most of all, this concerns the increase in the concentration of atmospheric carbon dioxide (CO_2).

Since 1958, when consistent monitoring began, the concentration of CO_2 in the atmosphere grew from 315 to 390 parts per million (ppm). (See Fig. 1.1.) At the same time, ice cores from the Vostok Antarctic Research Station show that over the last four ice age cycles (about 400 thousand years), CO_2 levels varied from 190 ppm during glaciation to 280 ppm during interglacial periods (Rapp 2008). During that period, the rate of carbon level increase was lower by two orders of magnitude, while the decrease from peak to trough took up roughly 10,000 years.

A 3 km bore conducted by the European Project for Ice Coring in Antarctica from 1996 to 2006 has allowed us to glimpse an even more distant past, going back 800–850 thousand years. As University of Bern Climatologist Thomas Stocker notes, in the entire period recorded in the core carbon dioxide levels never once rose above 290 ppm. It was only with the approach of the present day that concentrations of CO_2 began rising sharply. In the past 50 years, the rate of increase has surpassed anything in the observed ice record by 200 times(!) (Siegenthaler et al. 2005). Analysis of the ratios of Carbon-14 and Carbon-13 isotopes in atmospheric CO_2 demonstrates with a high degree of certainty that the origin of the increase is connected to fossil fuel combustion and other human economic activity (Vitousek 1994).

Granted, coal was known as early as ancient Rome, but until the mid-nineteenth century, wood, straw and charcoal served most of humanity's energy needs. Only after that point did fossil fuels replace them as a primary source of energy. We trace the skyrocketing increase in CO_2 emissions to that moment, with the process accelerating in the last century. The emissions come from non-industrial as well as industrial sources such as cement production and gas burn-off from oil drilling. They are growing ever faster. The growth rate for CO_2 emissions rose from 1.0% in 1990 to 3.4% in 2008, more than tripling nine billion metric tons per year (Le Quere et al. 2013). The quickly developing economies of China, India and Brazil made up most of that difference, along with the growth of the global automobile park (Oak Ridge National Laboratory 2011).

Unfortunately, fossil fuel carbon emissions continued racing higher into the twenty-first century, reaching about nine billion metric tons (nearly ten billion standard tons)/year in 2008. For this we must thank the quickly developing economies of China, India and Brazil along with the world's ever-growing auto park (Oak Ridge National Laboratory 2011).

By now every grade-schooler probably knows that carbon dioxide plays a major role in what we call **the greenhouse effect**. Less well known is that the greenhouse effect provides just as much support for the conditions of life on earth as the atmosphere itself. Greenhouse gasses "capture" part of the sunlight reflected by the Earth's surface, warming the lower levels of the atmosphere. This results in a roughly 30 °C increase to the surface temperature. So, the greenhouse effect itself does not present a danger, but rather exceeding its baseline level, which has remained unchanged for hundreds of millions of years. Think of it as too much of a good thing.

True, climatologists disagree on the share of human contribution to the global warming confirmed in countless observations over the twentieth Century (Kondratyev and Donchenko 1999; Jaworowski 1997). However, the first decade of the twenty-first century was the warmest on modern meteorological record, and summer of 2015 turned out hotter than any other in the history of the northern hemisphere. The rate of warming was particularly significant in the 30 years from 1980 to 2010 (National Research Council 2011). Over the course of the twentieth century,

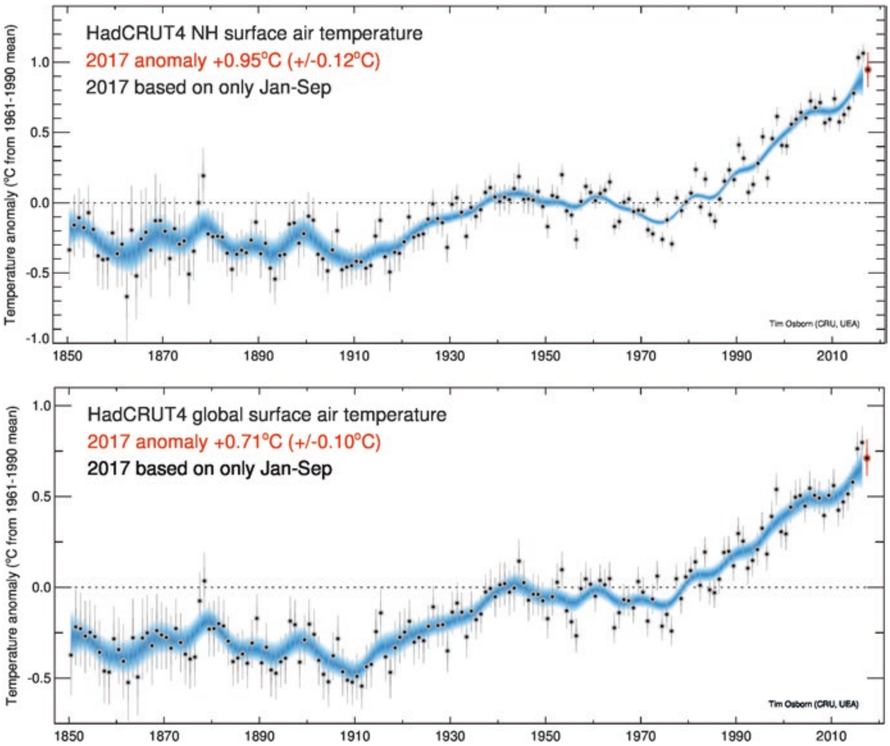

Fig. 1.2 Yearly Anomaly in near-surface temperature for the northern hemisphere (land) and globally from 1850 to 2017. Source: Climatic Research Unit, University of East Anglia https://crudata.uea.ac.uk/~timo/diag/tempdiag.htm

average surface temperatures rose 0.7 °C, surpassing fluctuations for the whole previous millennium (Fig. 1.2).

Of course, the rate of warming varies between regions of the globe. The highest rate is observed in continental areas at middle latitudes of the northern hemisphere. In eastern Siberia west of Lake Baikal, for example, mid-winter temperatures have risen by nearly 2 °C. Warming is less noticeable at oceanic middle latitudes and in the southern hemisphere. In a few areas of the Southern Ocean and Antarctica, we have even observed some cooling.

With this we cannot help but notice the correlation between the increase in surface temperature and the accumulation of carbon dioxide gas in the atmosphere over the course of the twentieth century (Fig. 1.3). While we can expect a slowed increase in the release of CO_2 into the atmosphere in the future as renewable sources of energy replace organic fuel, this is unlikely to happen in the next 20 years. Meanwhile, the thawing of polar icecaps and subarctic Siberian bogs encased in ancient permafrost threatens to further crank up the speed of climate change. The thaw, itself the result of warming, causes a chain reaction of secondary effects such as the release of methane from the melting of long-frozen soils or from gas hydrates in the ocean depths as the World Ocean's temperature rises.

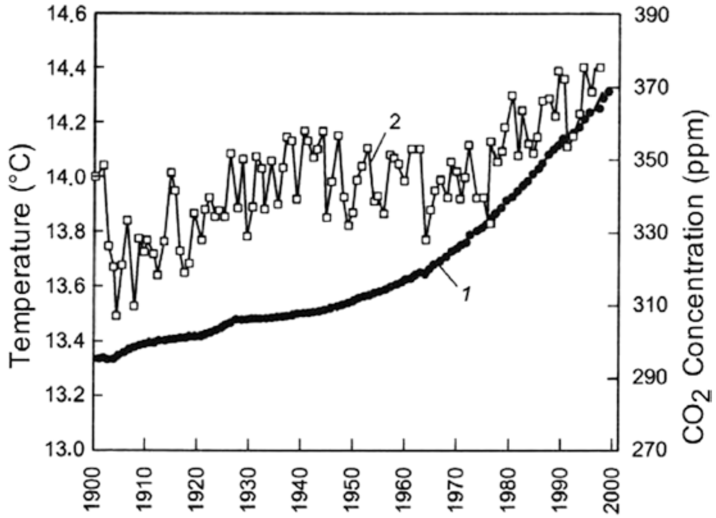

Fig. 1.3 Rate of change to the Earth's near-surface temperature (1) and the concentration of carbon dioxide in the atmosphere (2). Source: Worldwatch Database (2000)

The fact is that for thousands of years roughly 70 billion tons of methane, a fourth of the world's total, has been trapped under the ice of Siberian bogs. Until recently, these reserves were not taken into account in calculations of the rate of global warming, the assumption being that they would make themselves felt much later, when the climate had warmed. Over the past 10–15 years, however, as scientists have observed, the ongoing thaw of Siberian bogs has already become a fait accompli. That, it must be said, is one of the most unpleasant surprises that has awaited humanity due to global warming. The polar regions of western Siberia are warming faster than anywhere else on Earth, and methane's greenhouse effect is 20 times stronger than carbon dioxide's. The journal "New Scientist" quotes Professor Sergey Kirpotin of Tomsk University on this point: "[It is an] ecological landslide that is probably irreversible and is undoubtedly connected to climatic warming" (Pearce 2005).

In this way, assuming that the current rate of acceleration continues, global warming could reach 2 °C by 2060 and atmospheric CO_2 concentrations will surpass 1900 levels by 150% (Joshi et al. 2011; Rogelj et al. 2011). The consequences of these developments are obvious. It means a radical shift in the world climate zones. It means a rising sea level as continental ice sheets in Antarctica and Greenland melt and the World Ocean experiences thermal expansion. By the end of the twentieth century, sea levels were already rising by 2.1 mm/year, more than at any time in the past 2000 years (Kemp et al. 2011). It means the sinking of low-lying coastal territory, where nearly a third of the Earth's population lives. Finally, it means the transformation of the whole natural world, representing a threat to mankind's very survival.

But CO_2 is not the only or even the most important greenhouse gas (water vapor, for example, makes up an order of magnitude more of the atmosphere at 0.5–1%), and industrial pollution is just one source of its migration to the atmosphere. **Land use** plays no less of a role in this, having contributed 180 (198) trillion tons of atmospheric carbon between the Neolithic Revolution and the present day, while by the end of the twentieth century, industrial emissions added up to about 160 (176) trillion (Lashof and Ahuja 1990; Titlyanova 1994). This is because land use has caused *the destruction of ecosystems*, especially the cutting down of forests, which play a vital role in excess carbon fixation through photosynthesis.

Overall, the destruction and degradation of the ecosystem is, without a doubt, the largest and most important component of the global ecological crisis. Ancient agriculture served as the starting point for this process. Thousands of years before the industrial revolution began, the acquisition of new lands for farming was already leading to the destruction of enormous swaths of the natural biota. As historian Lev Gumilyov wrote, "Hard working farmers, thinking only of the next year's harvest, turned the banks of the Hotan and Lake Lop Nur into sand dunes.[2] They churned up the soil of the Sahara and let dust storms blow it away" (Gumilyov 2014). Worst of all, however, was the destruction of **forest ecosystems**, the most important stabilizing factor in the global environment.

The most crushing blow to ecosystems came in the twentieth century. While at the turn of that century, territories with ecosystems partially or entirely destroyed by man took up 20% of land, by the beginning of the twenty-first they occupied about 60% (not including ice-covered or denuded territory). In the meantime, three massive zones of environmental destabilization have formed in the northern hemisphere, covering a total area of 20 million km^2 (12.5 million sq. miles) (Arsky et al. 1997; Danilov-Danil'yan and Losev 2000; Nowinski et al. 2007). (For more on that, see Chap. 15.)

We will have plenty to say throughout this book about forests and their key role in nutrient cycles. Essential photosynthetic production takes place in forests. Among land ecosystems, forests have the greatest ability to absorb the excess carbon oxide gas thrown into the atmosphere during the combustion of fossil fuels. By storing and evaporating water, they provide most of the continental water cycle, support river flow, even out short-term and seasonal fluctuations, reduce the speed of pressurized air fronts that produce extreme weather, work as filters to clean the atmosphere, et cetera.

Currently, forests occupy about 40 million km^2, or 31% of land area. Before the Neolithic Revolution, 10,000 years ago, they had access to over 60 million km^2, or 45% of the land's surface (FAO 2010) Thus, in the course of history, humanity has annihilated no less than a third of the planet's forests. The Neolithic or Agricultural Revolution not only brought a start to farming culture, it also heralded a new stage in the relationship between human beings and nature. Their predecessors, hunter-gatherers, fit naturally into their environment, not unlike other species. Now they set out to conquer the world, acquire new lands and transform them for use by fields and herds.

The forests would have seemed to present a daunting hurdle for the new colonists to cross. But the slash-and-burn method of agriculture and new implements to fell

[2] A dried up river and closed-basin salt lake in western China's Xinjiang province.

trees successfully overcame the problem. True, these primitive and inefficient methods caused the plots to quickly exhaust themselves. This didn't worry the ancient farmer: without any shortage of land, he could move to a new plot whenever he pleased, clearing away the forest as he went.

The process followed a specific, geographically understandable pattern. First, the forests in the ancient civilization zones of India, China and the Near East were annihilated, followed by those around the Mediterranean in the millennium before the common era. The mass felling of European woods began later. Before the seventh century, they covered 75% of the continent. But with the Renaissance and the Age of Discovery, deforestation took on vast dimensions as cities boomed and nations built sailing fleets. Forests were cut to open tillage and pasture. People used wood as both fuel and raw material, for which the 1782 invention of the steam engine added still greater impetus. Meanwhile, the populations of European countries skyrocketed. As immigrants moved west in the eighteenth and nineteenth centuries, deforestation overtook North America as well.

As for deforestation on a global level, its rate and pattern reflected population growth until 1950. At that point, population growth increased sharply and caught up to deforestation, creating a kind of "scissors" shape (Fig. 1.4).

It's worth noting that population growth and deforestation reach their peaks simultaneously in the same regions. This partly coincides with the start of economic growth in a given country. Both rates then typically stabilize or slow once society reaches a certain level of prosperity. The fate of first the northern, then the southern forests illustrates this rule.

The *northern forest zone*, occupying roughly two billion ha (4.94 billion ac), lies mainly in three countries: Russia, Canada and the U.S. Peak eradication of these forests coincided with rapid industrial development in Europe and North America with its corresponding population boom and urban construction. It continued through the early 1900s. As a result, Europe lost the vast majority of its forests, which shrank to a mere 10% of its territory (State of the World's Forests 2012). Only as new technologies improved agricultural yields and food storage, and as new materials replaced lumber in construction and wood as fuel, did the process of deforestation wind down and a period of restorative forestry begin. And while forest coverage of Europe (not including Russia) is approaching 35%, this is, with minor exceptions, cultivated secondary forest and tree farms growing on the ashes and stump holes of dead ecosystems. They are at least four times less productive and biodiverse than primary forests, with which they cannot remotely compete as environmental stabilizers. Old-growth primary forests have hung on only in the mountainous Alps, Pyrenees, Carpathians and the Balkan Peninsula, along with northern Scandinavia and Finland. But one way or another, the main threats to European and North American forests have passed, except for global climate change.

Things stand entirely differently in the *southern forest zone*, where tropical forests have suffered an unprecedented assault since the 1920s. The following numbers will give you some idea of the scale of the assault. From 1990 to 2010, 88 million ha (217 mln ac) of primordial rain forest, 9% of the continent's total forest area, were cut down in South America alone. South America's rainforests shrank to less than

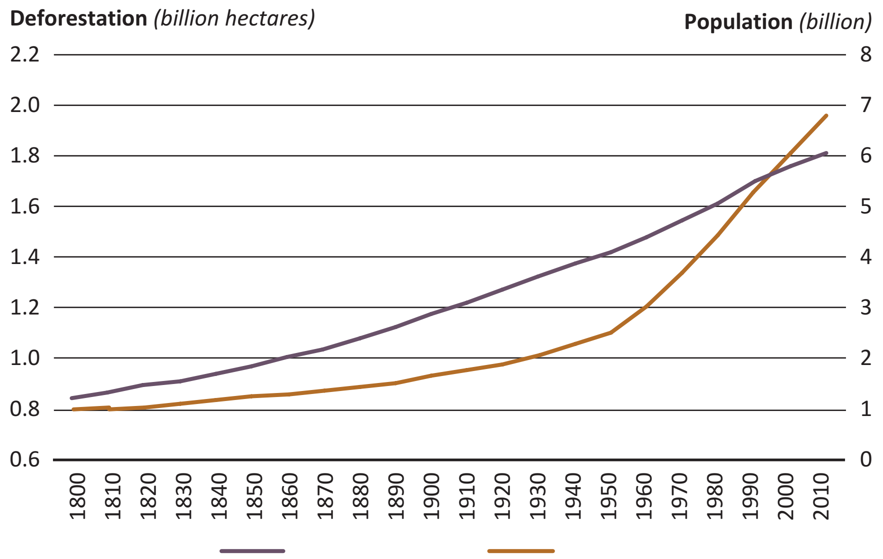

Fig. 1.4 Earth population and total deforestation 1800–2010. Verticals: on the left, deforestation in billions of hectares (ha) (1 hectare = 2.47 acres [ac]); on the right, population in billions. The lower line, forming a "scissors" with the upper, represents population growth. Source: State of the World's Forests (2012)

half of the continent's area for the first time in history. In Africa, where forests cover 23% of the surface, 10% of them were wiped out over the same period, a total of 75 million ha (185 mln ac). Some countries of the southern forest zone—El Salvador, Jamaica, Haiti—have lost their forests altogether. In nine countries forests are being annihilated at 2% per year, and in 20 more the rate of deforestation surpasses 1%. If this trend continues, many of these countries will lose their forests in the next century. At the very least, all will face serious ecological problems (State of the World's Forests 2012).

And so you might say that developing countries are repeating the unlearned lessons of industrialized states with a century's delay. As you can see from the diagram (Fig. 1.5), the latter passed this tragic baton to the former somewhere back in the mid-twentieth century. And while the pace of deforestation worldwide has recently slowed, the situation remains deeply troubling. According to the UN Food and Agriculture Organization (FAO), the area of world forests shrank by 13 million ha (32 mln ac) a year from 2000 to 2010 (primary forests shrank by 5.2 mln ha/12.8 mln ac). This is ten times faster than the process of natural forest recovery. The 130 million ha (321 mln ac) lost over the decade as a whole made up a full 3.2% of all forest areas from 2000 (FAO 2010; State of the World's Forests 2012).

Importantly, the reasons for developing countries' profligate use of forest bounty remain in force. These include inefficient agricultural systems in constant demand for new tillage and pasture. They include a lack of electrification and gas supply, which means that 100 million people depend on wood as their only source of fuel.

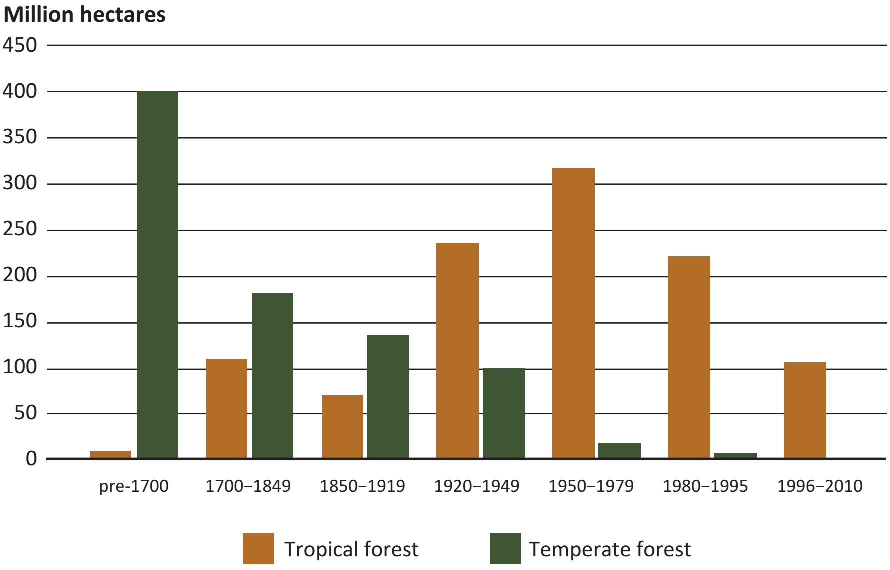

Fig. 1.5 Relative rate of deforestation by year and climate zone. Vertical numbers are in millions of hectares. Source: State of the World's Forests (2012)

Roughly half of the world's cut timber is burned for fuel, including 80% of Africa's. The reasons include a growing export of tropical timber, mainly for the pulp and paper needs of industrialized nations. Per person, developing countries use an average of 6 kg (13 lbs) of paper in a year. The US uses 257 kg (566 lbs) per capita (Zakharov 2014). Furthermore, poor countries are forced to take such measures to improve the balance of trade and reduce debt. As French President Francois Mitterrand said in 1991 at the opening of World Forestry Congress X in Paris, it's hard to criticize the people of tropical regions for allowing the destruction of forests when they must do so to live.

But man's economic activity not only damages the Earth's flora and fauna. It also harms the **soil**—that universal fundament on which all territorial life is based. Plowing up the land and compacting it under agricultural vehicles leads to its degradation, and, without proper soil management, to complete destruction. The cultivation of the virgin soil of Kazakhstan testifies as one example of the irretrievable harm that can be done. By the end of the 50s, after mere decades of cultivation, the country faced horrible ecological consequences such as widespread soil degradation, wind and water erosion, and dust storms. Around the world, 6–7 million ha (15–17 mln ac) of agricultural land are lost each year due to erosion, secondary salinization and other anthropogenic causes. The loss of *humus*, the fertile layer of topsoil, increases constantly.

In all of human history prior to the Industrial Revolution, humus loss added up to roughly 25 million metric tons (27.5 mln standard tons), while in recent centuries—300 (330) million. Over the last 50 years, however, up to 760 (837) million tons of humus have vanished each year (Rosanov et al. 1990) Soil loss, furthermore, is practically irreversible. The recovery of 2.5 cm (1 in.) of topsoil requires 300–1000 years. For 18 cm (7 in.), it takes 2 to 7 thousand years. As a result, according to estimates by the World Resources Institute, the rate of soil degradation exceeds regeneration by anywhere from 16 to 300 times, depending on region (Meadows et al. 2006).

Add to that the area of agricultural land eaten up by transport infrastructure and construction each year. Global statistics concerning this factor do not exist, but there are plenty of localized examples. The Indonesian capital of Jakarta swallows up surrounding land at a pace of 20 thousand ha (49 thousand ac) a year. Vietnamese urbanization likewise uses up that amount of rice paddy over the same period. In China from 1987 to 1992, 6.5 million ha (16 mln ac) of tillage went towards new construction, in exchange for which 3.8 mln ha (9.4 mln ac) of forest and pasture were cleared for the plow. Each year in the US, 170 thousand hectares (420 thousand acres) of farmland are reallocated for roads. And these are just a few of many such examples (Meadows et al. 2006).

This soil is not only an agricultural asset, but a global ecological resource. It plays a vital role in biogeochemical cycles. It serves as a gathering point for water, a veritable ocean on dry land, feeding the plant biota with moisture and supporting the continental water cycle. It also plays host to a plethora of soil organisms. A square meter of topsoil 30 cm (just under a foot) thick contains over a trillion microorganisms and spores. These bacteria, fungi and invertebrates provide for the circulation of decaying organic matter, those biogenic elements (also called nutrients) that the biosphere has limited access to. Normally, the nutrient cycle of a soil ecosystem functions as a **closed loop**, supporting the synthesis and decay of organic matter with a high degree of accuracy which ensures its stability over the course of millennia. In pulling up nutrients along with the harvest, man is constantly exhausting the soil and is forced to support fertility artificially, providing nutrients in the form of fertilizer. If we consider that 11% of land is used for agriculture, and 28% of that (1.4 billion ha/3.46 bln ac) goes under the plow each year, and that disruption to the closed loop biogeochemical cycle on such land goes upwards of 10%, then you must realize the scale of destruction to the biospheric balance that modern agriculture represents.

One of the consequences of ecosystem destruction is the process of **desertification** which now represents a grave problem the world over. Arid, or dry, lands make up 35% of the world's landmass, and over one billion people live on them. Their fates directly depend on the condition of frail and delicate ecosystems, which is what makes desertification such a threat (Fig. 1.6).

This process usually develops as the result of joint actions by man and nature. Elimination of sparse vegetation by overgrazing livestock, chopping down trees and shrubs, and tilling land poorly suited to agriculture all violate the already unstable natural balance. This leads to the degradation of native ecosystems, the drying out and salinization of soil, and then wind erosion. Any ill-considered business in this zone could have disastrous consequences for the natural environment and local populations.

A remarkable example of this is the Aral Sea ecological catastrophe. After many years of using the entire flow of the rivers Amu Darya and Syr Darya for cotton growing, the Aral Sea dropped 20 m from its 1960 level. The salinity in the lakes

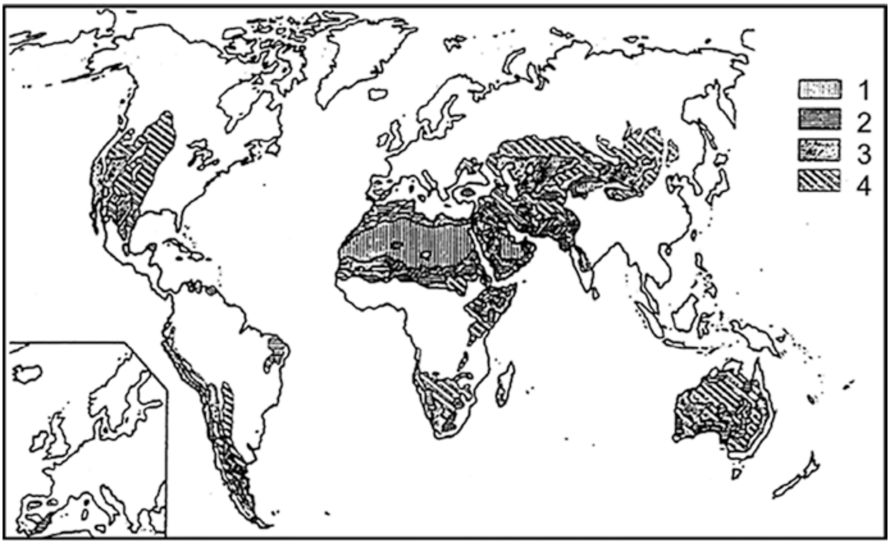

Fig. 1.6 Territories subject to desertification. (1) Deserts; (2) Very High Risk; (3) High Risk; (4) Moderate risk. Source: Maksakovsky (2008) Book 1

that replaced the Aral increased by 5–8 times. The spread of salt by wind and dwindling stocks of groundwater caused a rapid deterioration of ecological wellbeing, salinization and soil degradation over a huge area inhabited by 30 million people.

Another consequence of the misuse of natural resources in these regions has been drought, which has brought disaster to the poorest developing countries of Asia and Africa. These countries, already subject to unfriendly natural forces, are home to 90% of arid zones' residents, half of whom live on the edge of hunger and penury. When drought and famine struck the Sahel, south of the Sahara, in the 1970s and East Africa in the 80s and 90s, hundreds of thousands died. The drought of 2011 dealt a particularly heavy blow to the region (Horn of Africa Drought Crisis…, OCHA 2011). However, the need to feed a large and ever-growing population forces local farmers to abandon developed fields and search out new ones, even though with current agricultural methods the result will likely be the same.

Because of desertification, the world loses about 6 mln ha (14.8 mln ac) of cultivated land yearly. As a rule, these losses are irreversible. UN experts estimate that the desert could claim nearly one third of tillage by the end of the century. By 2025, at the current rate of soil degradation, the continent of Africa will be able to feed a mere 25% of its population (ForexAW.com 2013). These facts have roused the UN to take the initiative. 191 member-states signed the Convention to Combat Desertification in 1996.

Water pollution has already taken on a global scale, and that's just fresh water sources. It has also spread over a large part of closed and semi-closed seas, such as the Caspian, the Baltic, the Sea of Azov and the North Sea. As American ecologist Aldo Leopold wrote in 1941:

"Mechanized man, having rebuilt the landscape, is not rebuilding the waters. The sober citizen who would never submit his watch or his motor to amateur tampering freely submits his lakes to draining, filling, dredging, pollution, stabilization, mosquito control, algae control, swimmer's itch control, and the planting of any fish able to swim. So also for rivers. We constrict them with levees and dams, and then flush them with dredging, channelizations, and the floods and silt of bad farming" (Leopold 1941, p. 17).

Here we must keep in mind that rivers, lakes and the World Ocean mark the final resting place for pollutants that have circulated through city, air and land. Fertilizers and pesticides wash in from farmers' fields. Industrial waste and household waste ends up here. Finally, atmospheric pollutants settle on the surface, deposited by meltwater and rain. So don't be surprised if you find nearly all of Mendeleyev's table in some particularly unfortunate body of water.

Sadly, this applies to many of the arteries of economically developed Europe, despite enormous sums dedicated to their purification. The Elbe, the Oder, the Dnieper, the Southern Bug and the Guadalquivir are all rivers that belong to the category "highly polluted." Pesticides and assorted dangerous organic compounds have accumulated to dangerous levels in them. Concentrations of certain metals such as lead, zinc, chromium and others in the Elbe, for example, are 3–16 times higher than ambient levels (Europe's Environment 1995). The high demand for water further complicates the situation. In some countries, such as Belgium, water processing uses 70% of renewable water resources.

Since 1940 the process of *anthropogenic eutrophication*—the explosive proliferation or "bloom" of blue-green algae[3] due to the accumulation of nutrient elements at the surface—has taken on a massive scope. When an algal bloom occurs, the aerobic bacteria swallows up the oxygen diluted in the water along with dead organic material as they multiply, suffocating the life below and excreting toxins in a wave of death which, furthermore, leads to a sharp decline of water quality.

True, eutrophication also occurs under natural circumstances. But the process in such cases hardly compares with the speed of anthropogenic eutrophication, accelerated by the nitrogen fertilizer that washes off the fields and the phosphorus-rich runoff of urban wastewater. The previous century's hallmark construction of massive dams and reservoirs has deeply compromised the ability of rivers to clean themselves.

Paradoxically, a reservoir can also play a positive role from an ecological point of view. This is particularly apparent at the Volga cascade of hydroelectric stations, which has turned Russia's main water artery into a chain of nearly stagnant reservoirs. These giant basins function largely as cesspools for Volga water. For example, at the Volgograd reservoir, a closed basin 3100 km^2 (1926 mi^2) in area, a bottom sediment 25 cm (9.8 in.) thick had formed by 2007, trapping an enormous mass of harmful and toxic substances (Danilov-Danil'yan and Losev 2006). So, without the reservoirs and at the current catchment area, the Volga would be much dirtier and

[3] Cyanobacteria. The two terms will be used interchangeably in the text. These prokaryotic organisms bear a superficial resemblance to algae, which leads to the layman's term despite being unrelated. -*Translator's note.*

could only very generously be called water at all. Today the Volga is considered a "moderately polluted" river and is classified as "polluted" only in some areas. Thanks to the reservoirs, it has higher water quality in its lower reaches than it does mid-course. This paradox illustrates the complexity of human involvement in natural processes whose unpredictability impacts our very survival.

No less a role in water degradation is played by *acidification* and *secondary salinization* of fresh water. The former directly causes what is known as acid rain and results from emissions of oxidized sulfur and nitrogen compounds formed by the combustion of hydrocarbon fuel. When mixed with drops of rain, these molecules react with the water to form sulfuric and nitric acid. This falls on the surface of land and water, often poisoning all life. In any case, withered forests and dead lakes with neither fish nor plankton began appearing in industrial regions of the US, Europe and Japan in the middle of the last century. By the 1970s, they had become a usual occurrence, most often the result of acid rain.

As concerns salinization, well known from the days of ancient Babylon and Assyria, since the twentieth century it has become the scourge of sedentary agriculture. We now use about 1000 (1100) tons of water to produce one metric ton of grain for the worldwide market. If you consider that rice-producing countries use up to 80% of renewable surface and groundwater on agriculture, the result is entirely predictable: a catastrophic lowering of the water table, and salinization of reservoirs thereafter.[4]

In some farming regions of China, the water table is lowering by roughly 1 m per year due to overuse of groundwater. Around Beijing the aquifer has fallen to a depth of 40 m. India is facing similar problems (Maksakovsky 2008, Book 2). Under the twin burdens of booming cities and pollution to surface water, the role of underground water sources has increased dramatically, reaching 50% of overall use in several countries. In many regions of the world, aquifer depletion has already led to serious shortages of fresh water. Meanwhile, demand for this resource is growing faster than population. In order to satisfy the growing demand for food, for example, the share of harvests grown with the aid of irrigation worldwide will have to be 50% higher in 2025 than it was at the end of the last century.

But we already have a deficit of fresh water today equal to the Nile's entire flow of 8 years. According to scientific estimates, 2.7 billion people currently live in river basins subject to severe drought for at least 1 month a year. A particularly difficult "water stress" situation occurs when a period of low water levels coincides with agriculture's seasonal peak demand for water. According to the International Water Management Institute, over a billion people will live in countries with an absolute water scarcity by 2025. The worst effects are in regions of the Middle East, South

[4] Along with primary salinization of surface water, it's worth noting secondary, anthropogenic salinization. This arises as the result of irrigation and drainage projects on dry grasslands situated over deep-lying groundwater that rests on saline bedrock. The application of water to the surface opens up previously defunct capillary connections to the aquifer below, drawing up highly-mineralized groundwater. After water has circulated from top to bottom and back, it evaporates, leaving behind a growing layer of salt on the farmland.

Asia, most of Africa and northern China. Even if these regions had highly efficient irrigation systems, they would still not be able to produce enough food on irrigated lands to satisfy their industrial, household and ecological needs. As the authors of the book *Beyond Malthus* noted, "Indeed, the spreading water scarcity may be the most underrated resource issue in the world today" (Brown et al. 1999, p. 37).

Most of Earth's landmass, from the arctic tundra to the burning desert sands, is covered by a continuous membrane of life, **the biota**. This unbroken living quilt resulted from a long process of evolution in which the various species and their communities diverged and adapted to the whole range of geographically and climactically diverse conditions on Earth, as well as their roles within them. This is what we call *biodiversity*, a term well known today even outside academic circles. This is what allows each living being to use the resources available to them within their habitat and *ecological niche*, the "profession" of an organism.

And while the membrane may have ripped in one spot or another at various times during the past due to catastrophic shifts in the planet's crust, volcanic activity or asteroids colliding with the Earth, there have always been forms of life capable of surviving the crisis and filling the breach. This uninterrupted development of life owes itself to biodiversity, the most important factor supporting the biosphere and the efficiency of biogenic processes. By providing the necessary adaptive potential of the biota, biodiversity ensures its survival and future development in a constantly changing environment.

With the beginning of active human economic activity, this priceless evolutionary accomplishment came under threat. The destruction of ecosystems and technological reshaping of the landscape disrupts the ongoing existence of many species and communities, some of which have disappeared from the Earth, and others of which are near extinction. Many species, especially insects and protozoa dwelling under the canopy of tropical forests, die out without even being identified. Even if we limit ourselves to vertebrates, 23 species of fish, two of amphibians, 13 of birds and 83 of mammals have disappeared from the Earth since 1600 (McNeely 1992).

Each extinct species is a final and irreversible loss for the biosphere, and evolution offers no way back. But there are far higher numbers under threat of extinction: 24% of mammal species, 12% of birds and 30% of fish (Species Survival Commission 2001). If this morbid trend continues, it's not hard to imagine what kind of species desert we masters of the planet will have to lord over. Such a biota would also stand little chance of survival after continued material changes to the environment in this degree.

Over the past 20 years, the WWF has developed a program for monitoring global biodiversity on a permanent basis. This "Living Planet Index" allows us to judge the ecological state of the biosphere based on aggregate data for populations of vertebrates in various countries and climate zones. Here in Fig. 1.7 is what the trend looks like of the global Living Planet Index for the period from 1970 to 2008 (1970 is taken as the starting point, so we use it as the baseline value "1").

As you can see from the graph, over the past 40 years the quantitative indicator has declined by almost 30%. That is, the number of wild animals shrank by nearly a third. The situation is especially troubling in the tropical zone, where the index has declined by 60%. Freshwater species of fish declined by 70% (WWF Living Planet

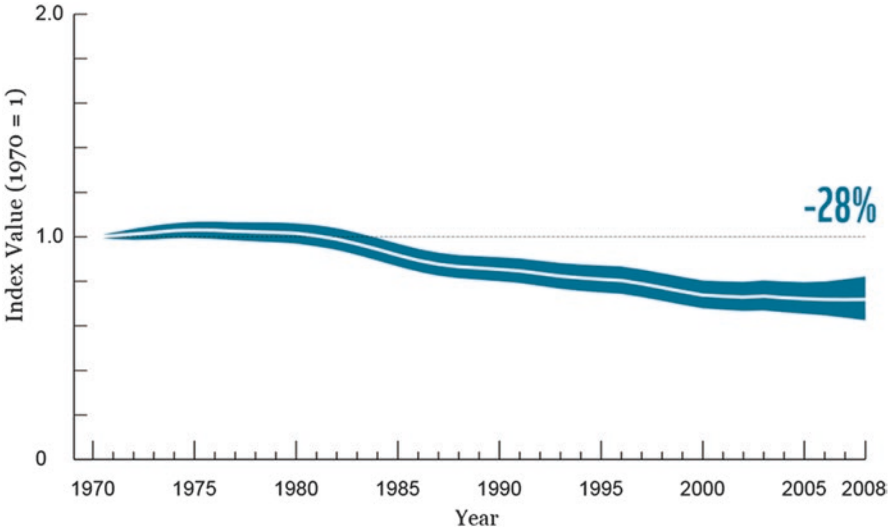

Fig. 1.7 Global Living Planet Index 1970–2008. Source: http://panda.org/downloads/1_lpr_2012_online_full_size_single_pages_final_120516.pdf

2012). At the same time, the index for the temperate climate zone increased by 30%.[5] That does not mean, however, that ecosystems from that zone are in significantly better shape than those in the tropics. The population index doesn't account for the tremendous losses suffered in biodiversity prior to 1970. If we could follow the trend line back several centuries, rather than decades, you would surely see a drop much like that of the tropical zone today, only extended over a longer period.

Still, growth in the index for the temperate zone tells us about an important change. People managed to reverse the negative trend by undertaking nature-friendly programs and events. Since the whaling industry was shut down 40 years ago, the number of Greenland whales has grown from 1–3 thousand to 10 thousand head. Wetland and aquatic birds have started recovering in the US. The same is true for sea birds and migratory birds in the UK (Angliss and Outlaw 2006; Birdlife International 2008). These welcome tendencies indicate a degree of stewardship and responsibility towards nature protection by these countries and their neighbors. Most developing countries lack this emphasis. This is partly due, of course, to limited economic resources, but mainly because there is not the priority placed on ecology which, as a rule, corresponds to the prosperity of the country (Fig. 1.8).

No matter the amount of wrangling there's been over the problem of global warming, scientists agree that humans are responsible for no less than 50% of the effect. The lion's share of attention, however, goes to anthropogenic carbon emissions. The role of ecosystems—forests, steppes, wetlands, etc.—that serve as a

[5] This data mainly characterizes the state of European and North American populations. Information concerning wildlife in Central Asia is hard to come by.

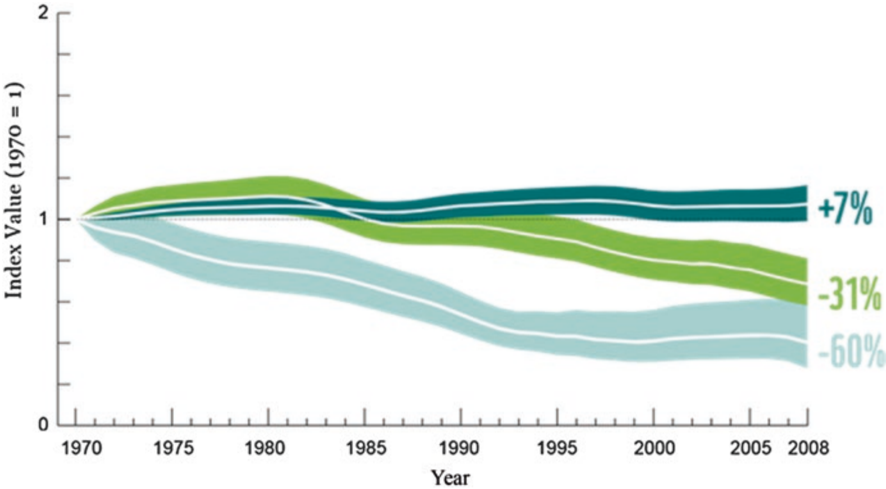

Fig. 1.8 Living Planet Index for three groups of countries according to per-capita income. Source: http://panda.org/downloads/1_lpr_2012_online_full_size_single_pages_final_120516.pdf

natural reservoir for absorbing excess CO_2 and that mankind has efficiently decimated for millennia, unfortunately remains a footnote of popular ecology. You can understand the logic behind that. The chain of cause and effect you typically see when climate change is discussed (increased greenhouse gasses>raised concentrations in the atmosphere>intensification of the greenhouse effect>global warming) is straightforward and quite demonstrative. Most importantly, it provides a clear prescription for the situation: limit the amount of fossil fuels we burn, use alternative sources of energy, encourage energy-saving technology and so forth. But what can be done for ploughed-up steppes and chopped-down forests, which require tens or hundreds of years to recover, assuming we stopped utilizing these lands? What do we do with the deserts that happen to form on the site of forests razed, grown back and razed again until the soil disappears, as is typical of slash-and-burn agriculture? Furthermore, while solving this problem we should remember that the role of the biota in climate change is intricate and complex, involving much more than the absorption of carbon.

Take, for example, the process of active evaporation, or *transpiration*. Clouds form over a forest and water vapor condenses. As it does that, air pressure falls in an atmospheric column and an air mass flows in from the ocean. (For more on this, see Chap. 11.) In this way, violating the ecosystem influences not only the continental water cycle, but the climate system as a whole. The collapse of this mechanism is certain to make itself felt in the most unpredictable ways. We shouldn't only be talking about warming, but of unbalancing the entire climactic machine—a colossal machine so complicated that no computer can model its responses.

Of course, climate systems are highly flexible by their very natures, and their parameters are defined by constant variation around a mean that may itself change over extended periods of time. A totally sustained climate would only be possible on

Table 1.1 Statistics on the largest natural disasters in the second half of the twentieth century

	1950–59	1960–69	1970–79	1980–89	1990–99
Number of natural disasters	20	27	47	63	91
Economic losses in $billions	42.1	75.5	138.4	213.9	654.9

Source: Kondratyev et al. (2005), pp. 57–76

Mars or on the Moon, if only we could apply the idea of a "climate" to them. But in recent decades on Earth, anomalies have become the norm. Cyclones and anticyclones have grown more powerful. They move across larger swathes of land and replace each other less often. Regional irregularity and inconsistency in the climate situation have become typical. Thus, in the US, over the same summer of 1994, scientists noted lowest-ever temperatures on the eastern seaboard while heat records broke on the California coast, reaching 48 °C (118 °F) (Kondratyev et al. 2005).

Add to this picture the anomaly of seasonal shift in the northern hemisphere noted in the middle of the last century. While the timing of change between seasons never varied by more than a day in the previous 350 years, over the past 50 years seasons have come an average of 1.7 days earlier on land than in the first half of the 1900s. Over the ocean, they have begun a day later over the same period. The difference in temperature between seasons has decreased by 2.5 °C. All of these changes are beyond the range of chance variation (Stine et al. 2009).

Most telling of all may be the increasing frequency of natural disasters—floods, droughts, hurricanes, tornadoes, wildfires and others. Each year, upwards of 200 million people suffer their effects, particularly in developing countries. Table 1.1 shows the rate of the most extreme natural disasters in the second half of the twentieth century. As you can see, the number of cataclysms has increased geometrically, claiming tens of thousands of human lives and costing many billions of dollars to clean up. From 1990 to 2015, the yearly number of victims to these catastrophes increased 450%.

This unflagging growth cannot be a coincidence, either. Most climatologists consider this to be the result of climate destabilization connected to human economic activity. According to research conducted by the insurance company Travelers (and insurers take the first monetary losses after tornadoes, hurricanes and floods), raising the surface temperature by a mere 0.9 °C is enough to increase the number of hurricanes on the US coast by a third (van Aalst 2006).

Figure 1.9 uses data from German insurance company "Munich Re" on the increase in natural disasters in the second half of the twentieth century and the accompanying material damages. A decrease in the final years of the twentieth century was paid back with interest in the first years of the twenty-first century. New catastrophes have since created countless victims along with destruction and losses high into the billions.

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One particular aspect of the global ecological crisis is the stubborn accumulation of waste from human economic activity in the environment, including chemical products with pronounced toxic qualities.

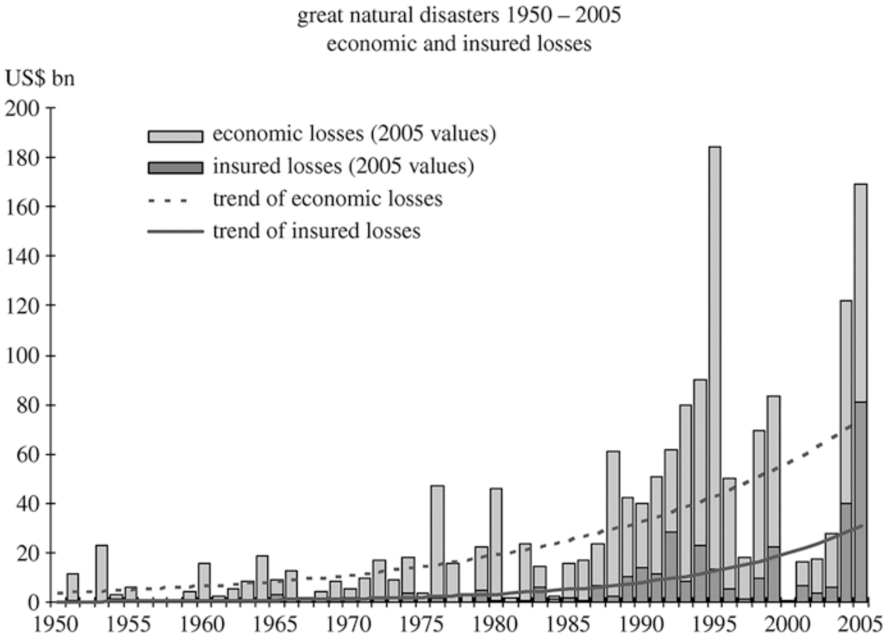

Fig. 1.9 Economic losses from natural disasters. Source: Münich Re

Many people think that pollution itself makes up the greatest threat to modern civilization (justifiably or not we'll determine later on). Indeed, the amount of waste has reached cyclopean proportions that beggar the imagination. For each person on earth, 50 (55) tons of raw materials are yearly called forth from the earth, of which a mere two metric tons goes into the finished product. Therefore, having undertaken this enormous labor, humanity gets almost as much back in waste—48 (53) tons, 0.1 tons of it toxic. In developed countries alone, that is 0.5 (0.55) tons of toxic waste per person (Arsky et al. 1997; Danilov-Danil'yan and Losev 2000).

But the two tons of finished production is also waste, in fact, only transferred to the future, like a gift for our children and grandchildren. From the ecologist's point of view, practically everything physically made by man will sooner or later become a waste product. Just as the Egyptian pyramids and other archaeological sites represent a kind of persistent garbage that allows people to acquaint themselves with their own history.

Naturally, different forms of waste do not have the same effect on environmental pollution. In that sense, chemically active substances and their products are beyond comparison.

Some of them, possessed of high persistency and long half-lives, accumulate in every medium, including the human body. Others are destroyed in the course of biological processes, making themselves known only when their intake surpasses the biochemical ability to destroy them (Odum 1983). Short-lived pollutants (which dissipate in a matter of weeks) cause regional pollution when they rise into the atmosphere. If they persist longer than 6 months, the pollution takes on a global character.

Aerosols—tiny, suspended particles between 0.1 and 10 μm in size—are a common contaminant in the atmosphere. They are made up of both solid (dust, ash, soot) and liquid components (sulfur and nitrogen dioxide, ammonia and light hydrocarbons). They absorb toxic high-molecular-weight components and many metals including lead. When introduced to the human respiratory tract, some of them cause irritation or allergic reactions. Others, finding their way into the bloodstream, have a generally toxic effect. Especially dangerous is photochemical smog, a "brown haze" of exhaust and industrial emissions which reacts to solar radiation by producing ethylene, ozone and other unstable molecules.

Hazardous waste and *supertoxicants* represent a special category of contaminants. Industrialized countries produce 90% of these substances, with the USA taking home the gold. However, in recent years, intensive production of hazardous waste has spread to many developing countries, including the rising giants of China, India and Brazil, as well as post-Soviet states such as Russia and Ukraine.

As a rule, countries tend to conceal or keep mum on data about hazardous waste. But, thanks to the efforts of the press, many substances in this group are now household words, including heavy metals and pesticides, as well as related compounds belonging to the chlorohydrocarbon group—dioxins, biphenyls, furans, and others. All of these are very persistent in the environment and, being unknown to the biota, resist chemical or biological breakdown. And so they linger on for decades, invading every sphere and embedding themselves in the food chain that links all earthly species. Dioxins, for example, formed as a byproduct by many technological processes, can be found not only in the atmosphere, soil and water, but also in food, including breast milk from humans and other mammals. As evidence of the truly global proliferation of these pollutants, we witness their discovery even beyond the Arctic Circle, thousands of kilometers from the source emissions. Some of them impact the endocrine, nervous and reproductive systems, for which they are called supertoxicants (The Environment 1993; Colborn et al. 1996; Baranowska et al. 2005).

You probably have some familiarity with the role of pesticides in soil and water pollution. They began their triumphal march with the 1938 discovery of the famed DDT (Dichlorodiphenyltrichloroethane) by Swiss Chemist Paul Muller, who won the Nobel Prize. Mass production began immediately after the Second World War. About 180 brands of pesticide are used in the world today, adding up to 3.2 (3.5) million tons (or just short of 1 1/3 pounds per person) in the 1990s. Developed countries have taken a harder line on pesticides in recent decades, including bans on DDT. Farmers now apply less dangerous forms of pest control. In Third World Countries, however, use of pesticides is not only failing to wind down, but is continuing to increase.

In environmental pathology, pesticides sit at the top of the stress index (followed by heavy metals, transported waste from nuclear plants and toxic waste solids). Generally, between 0.5 and 11 kilos of chemical pesticide are used per hectare (0.44 to 9.8 lbs per acre) of tillage, half of which immediately seeps down into the soil and ground water. In the then-controversial book "Silent Spring" (1962)—one of the first ecological warning sirens—journalist Rachael Carson wrote that the whole human race had come under the influence of chemicals, and no one knew what the long-term consequences might be. Now, 50 years later, the consequences are coming into view.

We've seen, in part, that ecotoxins—whether agricultural herbicides and pesticides (beyond the now-illegal DDT), industry and transport byproducts, such as polychlorinated biphenyls, dioxins, furan etc. or metals such as cadmium, lead and mercury—wind various paths into human bodies, where they wreck untold harm upon the endocrine system, including hormone-associated cancer of the breast and prostate, sperm degeneration, infertility, birth defects and more.

Many of these substances decay slowly and so tend to accumulate in the body. Lead builds up in bone tissue, where in modern humans its concentrations surpass those of our first-millenium ancestors by nearly a thousand times (Khudoley and Mizgiryov 1996). Chlorinated biphenyls build up in fat cells and work their way into breast milk in drops of lipids. As analyses of raw milk samples have shown, even in well-to-do Bavaria, every third sample contains biphenyls at concentrations beyond the acceptable limit (The Environment 1993).

As we've said concerning other issues in this chapter, the "chemicalization of the biosphere" is already a done deal. There are from 100 to 200 thousand different substances floating around the world market, including synthetics and counterfeits. For 80% of them, their effects on living organisms are unknown and unlikely to be completely studied. Passed up the food chain, some of them will accumulate in the upper links (including humans) at concentrations exceeding the initial dose a hundred or a thousand times. So you could very justifiably compare our civilization to a giant animal lab, where the rats are human beings testing upon themselves the effects of some unknown medicine (Coman et al. 2007).

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But is there any hope in forcing back the raging tide of chemicals that threatens humanity's very existence? And couldn't we use modern technology to somehow overcome the ocean of waste that brought it forth? The first question, we're sorry to say, remains unanswered for now. But as for the widely prevalent illusion that some new technology, even one still in the works, could liberate us from our garbage, we ought to discuss that in more detail.[6]

Let's start with garbage incineration, seeing as it is the most direct and obvious way to eliminate solid waste. It's also tried and true, at over 140 years old. But since the mid-80s many governments in Europe and the Americas have begun winding down this method. Why?

It turns out, first of all, that solid waste simultaneously contains chlorine compounds and transition metals, so the process of incineration produces highly-toxic dioxins. Furthermore, while incineration reduces waste to ashes and slag with a volume ten times lower than before, it produces clouds of gaseous smoke—an average of 6000 m^2 for every metric ton—which contains sulfur dioxide, nitrogen oxides, hydrocarbons and heavy metals in addition to the above-mentioned dioxins. And the whole plume of smoke goes up through the smokestacks into the atmosphere. From there, the air currents carry it for hundreds or thousands of miles.

[6] The following section of Chap. 1 was written using materials from K. S. Losev.

Granted, some countries have once again turned to incineration with new technological plant. They presort the garbage and use special filters, along with high temperature incineration technology that prevents the creation of dioxins, benzo(a)pyrene and other burn-off products.

Garbage incineration is but one illustration of the fundamental law of conservation of mass, according to which waste, once produced, can never be eliminated. And clearly it's no coincidence that wildlife produces no garbage as such. The organic byproducts of natural life find their way into a closed food chain, participating one way or another in nutrient cycles. Human waste (aside from that which is universal to the Animal Kingdom, of course) cannot participate in these cycles and thus serves as empty ballast within the biosphere. We can only hide it, bury it, transform it from one phase of matter to another, litter the environment with it, shoot it into space, or, finally, rework it into some new, less-toxic product which, in its turn, will also become waste.

With this in mind, another conventional solution is to create resource-saving technologies or to organize the production system in such a way that one business' waste becomes another's raw material. The famed eco-industrial park of Kalundborg, Denmark, brought such a scheme into existence. Behind the promising facade, however, a portion of unused garbage remains. More importantly, Kalundborg's production is still a form of waste, only put off for another day. The circle, then, has not quite closed. Recycling overall has spread worldwide, with Japan demonstrating the greatest success. Japanese industry reuses about 210 (231) million tons of the country's waste each year, 10% of the total.

Unfortunately, however, all such technologies are expensive and, worse, associated with high usage of energy. All energy production means unavoidable pressure on the environment, and ultimately its deformation and destruction to a degree that negates any positive result.

Japan, again a recognized leader in this field, undertook a structural reform of its economy from the 1970s to the 90s, greatly reducing the role of raw materials and so-called "dirty" industries. Priority was transferred to the information and service industries, high-tech and eco-friendly production built on the principles of recycling, resource conservation and extended product life-cycles. So, what happened? Despite cutting out its own raw materials industry, consumption not only failed to shrink, but even grew. With it grew the mass of accompanying waste. Furthermore, energy usage per capita rose by 15% (Quality of the Environment in Japan 1999). Analogous situations arose in the USA and the countries of Western Europe. Clearly it's no coincidence that the enormous expenditures of the last 40 years on environmental protection and transitioning from "dirty" inefficient economies to "clean" and efficient have not materially reduced per-capita energy usage. On the contrary, in many countries, it just kept going up. Once again, this is a bad sign for the environment.

The widely advertised efforts of various countries to clean local environments have made little difference to the overall global effect. Yes, there have been great successes, such as with the American Great Lakes or the Rhine in Germany, which were in truly horrible shape a half century ago.[7] But, has anyone added up the over-

[7] After the second World War, increasing pollution led to a shortage of oxygen in the waters of the Rhine. Levels hit a nadir in 1970, when practically all life in the river was eliminated. By 1980,

all balance of the local clean-ups? How much energy and material was spent upon them, and what were the ecological consequences for the countries they were taken from? Or for the countries the "dirty" industries were taken to?

According to the Law of Communicating Vessels, the ecological gains of one country are often compensated by the losses of others, and so the overall ecological costs, as a rule, surpass the benefits of local cleanups. The WWF's report, "Living Planet 2012," indirectly acknowledges this fact when it says that the ability of rich countries to import resources from poorer ones results in "degrading the biodiversity in those countries while maintaining the remaining biodiversity and ecosystems in their own 'back yard'" (WWF 2012, p. 57). And if the global ecological situation continues to worsen against the background of improvements in a few territories, it resembles nothing so much as "sweeping the problem under the rug" at a planetary level.

And so, it might be time to rethink the second half of the club of Rome's famous slogan: "Think Globally, Act Locally." We need not only to think, but to act globally. Or, at the very least, to review the effectiveness of local actions with a global eye.

As we have seen, in the entire course of its existence Human Civilization has not invented one technology that failed to deform the environment in one way or another. For many long centuries, the biosphere successfully resisted the destructive (business) activity of man. But from the beginning of the twentieth century, the effect of humans upon nature entered a qualitatively different stage; from every side, change toward a decisive end arose as never before witnessed, and it continues to tirelessly accelerate. This means that the compensatory power of the biosphere no longer has the power to resist the influence of civilization, which has grown to ruinous proportions. And this unprecedented ecological crisis has unfolded before our very eyes, in the space of two generations.

References

Angliss, R. P., Outlaw, R. B. (2006). Bowhead whale (Balaena mysticetus): Western Arctic Stock. NOAA's National Marine Fisheries Service, Alaska, National Marine Fisheries Service.

Arsky, Y. M., Danilov-Danil'yan, V. I., Zalikhanov, M. C., Kondratyev, K. Y., Kotlyakov, V. M., & Losyev, K. S. (1997). Ecological problems. In *What is going on? Who is to blame? What is to be done?* Moscow: MNEPU. [in Russian].

Baranowska, I., Barchanska, H., & Pyrsz, A. (2005). Distribution of pesticides and heavy metals in trophic chain. *Chemosphere, 60*, 1590–1589.

after major financial investments in purification, things had improved. However, the purification equipment could not deal with toxic heavy metals. This improved only after all of the Rhine countries agreed to harsh laws against environmental pollution. As a result, heavy metals had largely disappeared from the river by 2000, though they remain in silt and riverbeds. A high concentration of chlorine remains, as well as nitrates from farm field runoff. Nonetheless, in 1996 the first salmon was discovered after disappearing 60 years earlier (Weber 2000).

Barnola, J. M., Pimienta, P., Raynaud, D., & Korotkevich, Y. S. (1991). CO2 climate relationship as deduced from Vostok Ice Core: A re-examination based on new measurements and on re-evolution of the air dating. *Tellus, 43B*(2), 83–90.

BirdLife International. (2008). State of the world's birds: indicators for our changing world. Cambridge, UK: BirdLife International. Retrieved from http://datazone.birdlife.org/userfiles/docs/SOWB2008_en.pdf.

Brown, L., Gardner, G., & Halweil, B. (1999). *Beyond Malthus: Nineteen dimensions of the population challenge*. New York: W. W. Norton.

Cannariato, K. G., Kennett, J. P., & Behl, R. J. (1999). Biotic response to late quaternary rapid climate switches in Santa Barbara Basin; ecological and evolutionary implications. *Geology, 27*(1), 63–66.

Colborn, T., Dumanoski, D., & Myers, J. P. (1996). *Our stolen future*. New York: Dutton.

Coman, G., Draghici, C., Chirila, E., & Sica, M. (2007). Pollutants effects on human body: Toxicological approach. In *Chemicals as intentional and accidental global environmental threats*. Dordrecht: Springer.

Danilov-Danil'yan, V. I., & Losev, K. S. (2000). *The ecological challenge and sustainable development*. Moscow: Progress-Traditsia. [in Russian].

Danilov-Danil'yan, V. I., & Losev, K. S. (2006). *Water usage: ecological, econonomic, social and political aspects*. Moscow: Nauka. [in Russian].

Dolnik, V. T. (1992). Are there biological mechanisms for regulating human population numbers? *Priroda, 6*, 3–16. Retrieved from http://vivovoco.astronet.ru/VV/PAPERS/ECCE/VV_EH13W.HTM. [in Russian].

Europe's Environment. (1995). *Statistical compendium for the Dobris assessment*. Eurostat: Luxemburg.

FAO. (2010). *Global Forest Resources Assessment: Key findings*. Rome (Italy): FAO. Retrieved from http://www.fao.org/docrep/013/i1757e/i1757e.pdf.

ForexAW.com. (2013). Retrieved from http://forexaw.com/TERMs/Society/Shocks_and_disasters/Economic_Crisis/l983_%D0%91%D0%B5%D0%B4%D0%BD%D0%BE%D1%81%D1%82%D1%8C_Poverty_%D1%8D%D1%82%D0%BE

Gumilyov, L. N. (2014). An end and a new beginning. Moscow: Ayric-press. Retrieved from http://royallib.com/get/rtf/gumilyov_lev/konets_i_vnov_nachalo_populyarnie_lektsii_po_narodovedeniyu.zip. [in Russian].

Jaworowski, Z. (1997). Another global warming fraud exposed: Ice core data show no carbon dioxide increase. 21st century. *Science and Technology, 10*(1), 42–52.

Joshi, M., Hawkins, E., Sutton, R., Lowe, J., & Frame, D. (2011). Projections of when temperature change will exceed 2°C above pre-industrial levels. *Nature Climate Change*, 407–412.

Kemp, A. C., Horton, B. P., Donnelly, J. P., Mann, M. E., Vermeer, M., & Rahmstorf, S. (2011). Climate related sea-level variations over the past two millennia. *Proceedings of the National Acadamy of Sciences of the United States, 108*(27), 11017–11022.

Khudoley, V. V., & Mizgiryov, I. V. (1996). *Ecologically dangerous factors*. St. Petersburg: Izdatel'stvo "Bank Petrovsky". [in Russian].

Kondratyev, K. Y., & Donchenko, V. K. (1999). *Ecodynamics and geopolitics. Vol. 1: Global problems*. Saint Petersburg. [in Russian].

Kondratyev, K. Y., Krapivin, V. F., & Potapov, I. I. (2005). *Natural disaster statistics. Problems of the environment and natural resourses: General information* (Vol. 5, pp. 55–76). Moscow. [in Russian].

Lashof, D. A., & Ahuja, D. R. (1990). Relative global warming potentials of greenhouse gas emissions. *Nature, 344*, 529–531.

Le Quere, C., et al. (2013). The global carbon budget 1959–2011. *Earth System Science Data, 5*, 165–185. Retrieved from https://spiral.imperial.ac.uk/bitstream/10044/1/41754/3/essd-5-165-2013.pdf

Leopold, A. (1941). Lakes in relation to terrestrial life patterns. In *A symposium on hydrology* (pp. 17–22). Madison: University of Wisconsin Press.

Maksakovsky, V. P. (2008). *A geographical portrait of the world (in two books)*. Moscow: DROFA. [in Russian]. Book 1. Retrieved from http://www.twirpx.com/file/997779/. Book 2. Retrieved from http://www.twirpx.com/file/997899/

McNeely, J. A. (1992). The sinking ark: Pollution and the worldwide loss of biodiversity. *Biodiversity and Conservation, 1*, 2–18.

Meadows, D., Randers., J., & Meadows., D. (2006). *The limits of growth: The 30 year update* (pp. 57–61). London: Earthscan.

National Research Council. (2011). *Climate stabilization targets: Emissions, concentrations, and impacts over. Decades to millennia*. Washington: National Academies Press.

Nobel Prize. (2007). 2007 Nobel Peace Prize Laureates. Retrieved from http://www.nobelprize.org/nobel_prizes/peace/laureates/2007/

Nowinski, N. S., Trumbore, S. E., Schuur, E. A. G., Mack, M. C., & Shaver, G. R. (2007). Nutrient addition prompts rapid destabilization of organic matter in an Arctic tundra ecosystem. *Ecosystems, 2007*. https://doi.org/10.1007/s10021-007-9104-1. Retrieved from http://www.springerlink.com/content/t5650v8x5711l87k/

Oak Ridge National Laboratory. (2011). *Carbon dioxide emissions rebound quickly after global financial crisis*. Tennessee, USA.

OCHA. (2011). Horn of Africa Drought Crisis Situation Report No. 5. Retrieved from http://reliefweb.int/sites/reliefweb.int/files/resources/Full_report_166.pdf

Odum, E. (1983). *Basic ecology* (p. 518). Philadelphia: Saunders.

Pearce, F. (2005). Climate warning as Siberia melts. *New Scientist*. Aug 11.

Quality of the Environment in Japan. (1999). Tokyo: Institute for Global Environmental Strategies.

Rapp, D. (2008). *Assessing climate change*. Chichester: Springer/Praxis.

Rogelj, J., Hare, W., Lowe, J., Van Vuuren, D. P., Riahi, K., Matthews, B., Hanaoka, T., Jiang, K., & Meinshausen, M. (2011). Emission pathways consistent with a 2_C global temperature limit. *Nature Climate Change, 1*, 413–418.

Rosanov, B. G., Targulian, V., & Orlov, D. S. (1990). Soils. In B. L. Turner et al. (Eds.), *The earth as transformed by human action: Global and regional changes in the biosphere over the past 30 years*. Cambridge: Cambridge University Press.

Siegenthaler, U., Stocker, T. F., Monnin, E., Lüthi, D., Schwander, J., Stauffer, B., Raynaud, D., Barnola, J. M., Fischer, H., Masson-Delmotte, V., & Jouzel, J. (2005). Stable carbon cycle—Climate relationship during the Late Pleistocene. *Science, 310*(5752), 1313–1317.

Species Survival Commission. (2001). *2000 IUCN Red List of threatened species* (p. 2000). Gland, Switzerland: International Union for the Conservation of Nature.

State of the World's forests. (2012). Rome: FAO. Retrieved from http://www.fao.org/3/a-i3010e.pdf

Stine, A. R., Huybers, P., & Fung, I. Y. (2009). Changes in the phase of the annual cycle of surface temperature. *Nature, 457*, 435–441.

The Environment. (1993). *Encyclopedic dictionary and reference*. Moscow: Pangea. [in Russian].

Titlyanova, A. A. (1994). Carbon dioxide and methane emissions into the atmosphere. *Review of Applied and Industrial Mathematics, 6*, 974–978. [in Russian].

van Aalst, M. K. (2006). The impacts of climate change on the risk of natural disasters. *Disasters, 30*(1), 5–18.

Vitousek, P. M. (1994). Beyond global warming: Ecology and global change. *Ecology, 75*(7), 1861–1876.

Weber, U. (2000, June). *The miracle of the Rhine*. UNESCO Courier.

Worldwatch Database. (2000). Retrieved from http://www.worldwatch.org/

WWF Living Planet Report 2012. (2012). In M. Grooten (Ed.). Retrieved from http://www.footprintnetwork.org/content/images/uploads/LPR_2012.pdf

Zakharov, A. N. (2014). *Development tendencies of real capital in the world and the world economy* (Vol. 4). Russian International Economic Vestnik.