

## "Mining" Australia

Australia's significance ■ Soils ■ Water ■ Distance ■ Early history ■ Imported values ■ Trade and immigration ■ Land degradation ■ Other environmental problems ■ Signs of hope and change ■

**M**ining in the literal sense—i.e., the mining of coal, iron, and so on—is a key to Australia's economy today, providing the largest share of its export earnings. In a metaphorical sense, however, mining is also a key to Australia's environmental history and to its current predicament. That's because the essence of mining is to exploit resources that do not renew themselves with time, and hence to deplete those resources. Since gold in the ground doesn't breed more gold and one thus has no need to take account of gold renewal rates, miners extract gold from a gold lode as rapidly as is economically feasible, until the lode is exhausted. Mining minerals may thus be contrasted with exploiting renewable resources—such as forests, fish, and topsoil—that do regenerate themselves by biological reproduction or by soil formation. Renewable resources can be exploited indefinitely, provided that one removes them at a rate less than the rate at which they regenerate. If however one exploits forests, fish, or topsoil at rates exceeding their renewal rates, they too will eventually be depleted to extinction, like the gold in a gold mine.

Australia has been and still is "mining" its renewable resources as if they were mined minerals. That is, they are being overexploited at rates faster than their renewal rates, with the result that they are declining. At present rates, Australia's forests and fisheries will disappear long before its coal and iron reserves, which is ironic in view of the fact that the former are renewable but the latter aren't.

While many other countries today besides Australia are mining their environments, Australia is an especially suitable choice for this final case study of past and present societies, for several reasons. It is a First World country, unlike Rwanda, Haiti, the Dominican Republic, and China, but like the countries in which most of the likely readers of this book live. Among First World countries, its population and economy are much smaller and less

complex than are those of the U.S., Europe, or Japan, so that the Australian situation is more easily grasped. Ecologically, the Australian environment is exceptionally fragile, the most fragile of any First World country except perhaps Iceland. As a consequence, many problems that could eventually become crippling in other First World countries and already are so in some Third World countries—such as overgrazing, salinization, soil erosion, introduced species, water shortages, and man-made droughts—have already become severe in Australia. That is, while Australia shows no prospects of collapsing like Rwanda and Haiti, it instead gives us a foretaste of problems that actually will arise elsewhere in the First World if present trends continue. Yet Australia's prospects for solving those problems give me hope and are not depressing. Then, too, Australia has a well educated populace, a high standard of living, and relatively honest political and economic institutions by world standards. Hence Australia's environmental problems cannot be dismissed as products of ecological mismanagement by an uneducated, desperately impoverished populace and grossly corrupt government and business, as one might perhaps be inclined to explain away environmental problems in some other countries.

Still another virtue of Australia as the subject of this chapter is that it illustrates strongly the five factors whose interplay I have identified throughout this book as useful for understanding possible ecological declines or collapses of societies. Humans have had obvious massive impacts on the Australian environment. Climate change is exacerbating those impacts today. Australia's friendly relations with Britain as a trade partner and model society have shaped Australian environmental and population policies. While modern Australia has not been invaded by outside enemies—bombed, yes, but not invaded—Australian perception of actual and potential overseas enemies has also shaped Australian environmental and population policies. Australia also displays the importance of cultural values, including some imported ones that could be viewed as inappropriate to the Australian landscape, for understanding environmental impacts. Perhaps more than any other First World citizens known to me, Australians are beginning to think radically about the central question: which of our traditional core values can we retain, and which ones instead no longer serve us well in today's world?

A final reason for my choosing Australia for this chapter is that it's a country that I love, of which I have long experience, and which I can describe both from firsthand knowledge and sympathetically. I first visited Australia in 1964, en route to New Guinea. Since then I have returned

dozens of times, including for a sabbatical at Australian National University in Australia's capital city of Canberra. During that sabbatical I bonded to and imprinted on Australia's beautiful eucalyptus woodlands, which continue to fill me with a sense of peace and wonder as do just two other of the world's habitats, Montana coniferous forest and New Guinea rainforest. Australia and Britain are the only countries to which I have seriously considered emigrating. Thus, after beginning this book's series of case studies with the Montana environment that I learned to love as a teenager, I wanted to close the series with another that I came to love later in my life.

For purposes of understanding modern human impacts on the Australian environment, three features of that environment are particularly important: Australian soils, especially their nutrient and salt levels; availability of freshwater; and distances, both within Australia and also between Australia and its overseas trading partners and potential enemies.

When one starts to think of Australian environmental problems, the first thing that comes to mind is water shortage and deserts. In fact, Australia's soils have caused even bigger problems than has its water availability. Australia is the most unproductive continent: the one whose soils have on the average the lowest nutrient levels, the lowest plant growth rates, and the lowest productivity. That's because Australian soils are mostly so old that they have become leached of their nutrients by rain over the course of billions of years. The oldest surviving rocks in the Earth's crust, nearly four billion years old, are in the Murchison Range of Western Australia.

Soils that have been leached of nutrients can have their nutrient levels renewed by three major processes, all of which have been deficient in Australia compared to other continents. First, nutrients can be renewed by volcanic eruptions spewing fresh material from within the Earth onto the Earth's surface. While this has been a major factor in creating fertile soils in many countries, such as Java, Japan, and Hawaii, only a few small areas of eastern Australia have had volcanic activity within the last hundred million years. Second, advances and retreats of glaciers strip, dig up, grind up, and redeposit the Earth's crust, and those soils redeposited by glaciers (or else blown by the wind from glacial redeposits) tend to be fertile. Almost half of North America's area, about 7 million square miles, has been glaciated within the last million years, but less than 1% of the Australian mainland: just about 20 square miles in the southeastern Alps, plus a thousand square

miles of the Australian offshore island of Tasmania. Finally, slow uplift of crust also brings up new soils and has contributed to the fertility of large parts of North America, India, and Europe. However, again only a few small areas of Australia have been uplifted within the last hundred million years, mainly in the Great Dividing Range of southeastern Australia and in the area of South Australia around Adelaide (map, p. 386). As we shall see, those small fractions of the Australian landscape that have recently had their soils renewed by volcanism, glaciation, or uplift are exceptions to Australia's otherwise prevalent pattern of unproductive soils, and contribute disproportionately today to modern Australia's agricultural productivity.

The low average productivity of Australian soils has had major economic consequences for Australian agriculture, forestry, and fisheries. Such nutrients as were present in arable soils at the onset of European agriculture quickly became exhausted. In effect, Australia's first farmers were inadvertently mining their soils for nutrients. Thereafter, nutrients have had to be supplied artificially in the form of fertilizer, thus increasing agricultural production costs compared to those in more fertile soils overseas. Low soil productivity means low growth rates and low average yields of crops. Hence a larger area of land has to be cultivated in Australia than elsewhere to obtain equivalent crop yields, so that fuel costs for agricultural machinery such as tractors and sowers and harvesters (approximately proportional to the area of land that must be covered by the machines) also tend to be relatively high. An extreme case of infertile soils occurs in southwestern Australia, part of Australia's so-called wheat belt and one of its most valuable agricultural areas, where wheat is grown on sandy soils leached of nutrients and essentially all nutrients must be added artificially as fertilizer. In effect, the Australian wheat belt is a gigantic flowerpot in which (just as in a real flowerpot) the sand provides nothing more than the physical substrate, and where the nutrients have to be supplied.

As a result of the extra expenses for Australian agriculture due to disproportionately high fertilizer and fuel costs, Australian farmers selling to local Australian markets sometimes cannot compete against overseas growers who ship the same crops across the ocean to Australia, despite the added costs of that overseas transport. For example, with modern globalization, it is cheaper to grow oranges in Brazil and ship the resulting orange juice concentrate 8,000 miles to Australia than to buy orange juice produced from Australian citrus trees. The same is true of Canadian pork and bacon compared to their Australian equivalents. Conversely, in some specialized "niche markets"—i.e., crops and animal products with high added value beyond

ordinary growing costs, such as wine—Australian farmers compete successfully in overseas markets.

A second economic consequence of low Australian soil productivity involves agroforestry, or tree agriculture, as discussed for Japan in Chapter 9. In Australian forests most of the nutrients are actually in the trees themselves, not in the soils. Hence when the native forests that the first European settlers encountered had been cut down, and when modern Australians had either logged the regrowing natural forests or invested in agroforestry by establishing tree plantations, tree growth rates have been low in Australia compared to those in other timber-producing countries. Ironically, Australia's leading native timber tree (the blue gum of Tasmania) is now being grown more cheaply in many overseas countries than in Australia itself.

The third consequence surprised me and may surprise many readers. One doesn't immediately think of fisheries as dependent on soil productivity; after all, fish live in rivers and in the ocean, not in soils. However, all of the nutrients in rivers, and at least some of those in oceans near the coastline, come from the soils drained by the rivers and then carried out into the ocean. Hence Australia's rivers and coastal waters are also relatively unproductive, with the result that Australia's fisheries have been quickly mined and overexploited like its farmlands and its forests. One Australian marine fishery after another has been overfished to the point of becoming uneconomic, often within just a few years of the fishery's discovery. Today, out of the nearly 200 countries in the world, Australia has the third-largest exclusive marine zone surrounding it, but it ranks only 55th among the world's countries in the value of its marine fisheries, while the value of its freshwater fisheries is now negligible.

A further feature of Australia's low soil productivity is that the problem was not perceptible to the first European settlers. Instead, when they encountered magnificent extensive woodlands that included what may have been the tallest trees in the modern world (the blue gums of Victoria's Gippsland, up to 400 feet tall), they were deceived by appearances into thinking that the land was highly productive. But after loggers had removed the first standing crop of trees, and after sheep had grazed the standing crop of grass, the settlers were surprised to discover that trees and grass grew back very slowly, that the land was agriculturally uneconomic, and that in many areas it had to be abandoned after farmers and pastoralists had made big capital investments in building homes, fences, and buildings and making other agricultural improvements. From early colonial times continuing

until today, Australian land use has gone through many such cycles of land clearance, investment, bankruptcy, and abandonment.

All those economic problems of Australian agriculture, forestry, fisheries, and failed land development are consequences of the low productivity of Australian soils. The other big problem of Australia's soils is that in many areas they are not only low in nutrients but also high in salt, from three causes. In southwestern Australia's wheat belt the salt in the ground arises from its having been carried inland over the course of millions of years by sea breezes off the adjacent Indian Ocean. In southeastern Australia, Australia's other area of most productive farmland rivaling the wheat belt, the basin of Australia's largest river system, the Murray and Darling Rivers, lies at low elevations and has been repeatedly inundated by the sea and then drained again, leaving much of the salt behind. Still another low-lying basin in Australia's inland was formerly filled by a freshwater lake that did not drain to the sea, became salty by evaporation (like Utah's Great Salt Lake and Israel's and Jordan's Dead Sea), and eventually dried out, leaving behind salt deposits that became carried by winds to other parts of eastern Australia. Some Australian soils contain more than 200 pounds of salt per square yard of surface area. We shall discuss later the consequences of all that salt in the soil: briefly, they include the problem that the salt is easily brought to the surface by land clearance and irrigation agriculture, resulting in salty topsoils in which no crop can grow (Plate 28). Just as Australia's first farmers, without modern analyses of soil chemistry, could not be aware of the nutrient poverty of Australian soils, they similarly could not be aware of all that salt in the ground. They could no more anticipate the problem of salinization than of nutrient depletion resulting from agriculture.

Whereas the infertility and salinity of Australia's soils were invisible to the first farmers and are not well known outside Australia among the lay public today, Australia's water problems are obvious and familiar, such that "desert" is the first association of most people overseas to mention of the Australian environment. That reputation is justified: a disproportionately large fraction of Australia's area has low rainfall or is extreme desert where agriculture would be impossible without irrigation. Much of Australia's area remains useless today for any form of agriculture or pastoralism. In those areas where food production is nevertheless possible, the usual pattern is that rainfall is higher near the coast than inland, so that as one proceeds inland one first encounters farmland for growing crops, plus half of

Australia's cattle maintained at high stocking rates; farther inland, sheep stations; still farther inland, cattle stations (the other half of Australia's cattle, maintained at very low stocking rates), because it remains economic to raise cattle in areas with lower rainfall than sheep; and finally, still farther inland, the desert where there is no food production of any sort.

A more subtle problem with Australia's rainfall than its low average values is its unpredictability. In many parts of the world supporting agriculture, the season in which rain falls is predictable from year to year: for example, in Southern California where I live, one can be virtually certain that whatever rain falls will be concentrated in the winter, and that there will be little or no rain in the summer. In many of those productive overseas agriculture areas, not only rain's seasonality but also its occurrence is relatively reliable from year to year: major droughts are infrequent, and a farmer can go to the effort and expense of plowing and planting each year with the expectation that there will be enough rain for that crop to mature.

Over most of Australia, however, rainfall depends upon the so-called ENSO (the El Niño Southern Oscillation), which means that rain is unpredictable from year to year within a decade, and is even more unpredictable from decade to decade. The first European farmers and herders to settle in Australia had no way of knowing about Australia's ENSO-driven climate, because the phenomenon is difficult to detect in Europe, and it is only within recent decades that it has become recognized even by professional climatologists. In many areas of Australia the first farmers and herders had the misfortune to arrive during a string of wet years. Hence they were deceived into misjudging the Australian climate, and they commenced raising crops or sheep in the expectation that the favorable conditions greeting their eyes were the norm. In fact, in most of Australia's farmlands the rainfall is sufficient to raise crops to maturity in only a fraction of all years: not more than half of all years at most locations, and in some agricultural areas only in two years out of 10. That contributes to making Australian agriculture expensive and uneconomic: the farmer goes to the expense of plowing and sowing, and then in half or more of years there is no resulting crop. An additional unfortunate consequence is that, when the farmer plows the ground and plows underground whatever cover of weeds has sprung up since the last harvest, bare soil becomes exposed. If the crops that the farmer then sows do not mature, the soil is left bare, not even covered by weeds, and thus exposed to erosion. Thus, the unpredictability of Australia's rain-

fall makes growing crops more expensive in the short run, and increases erosion in the long run.

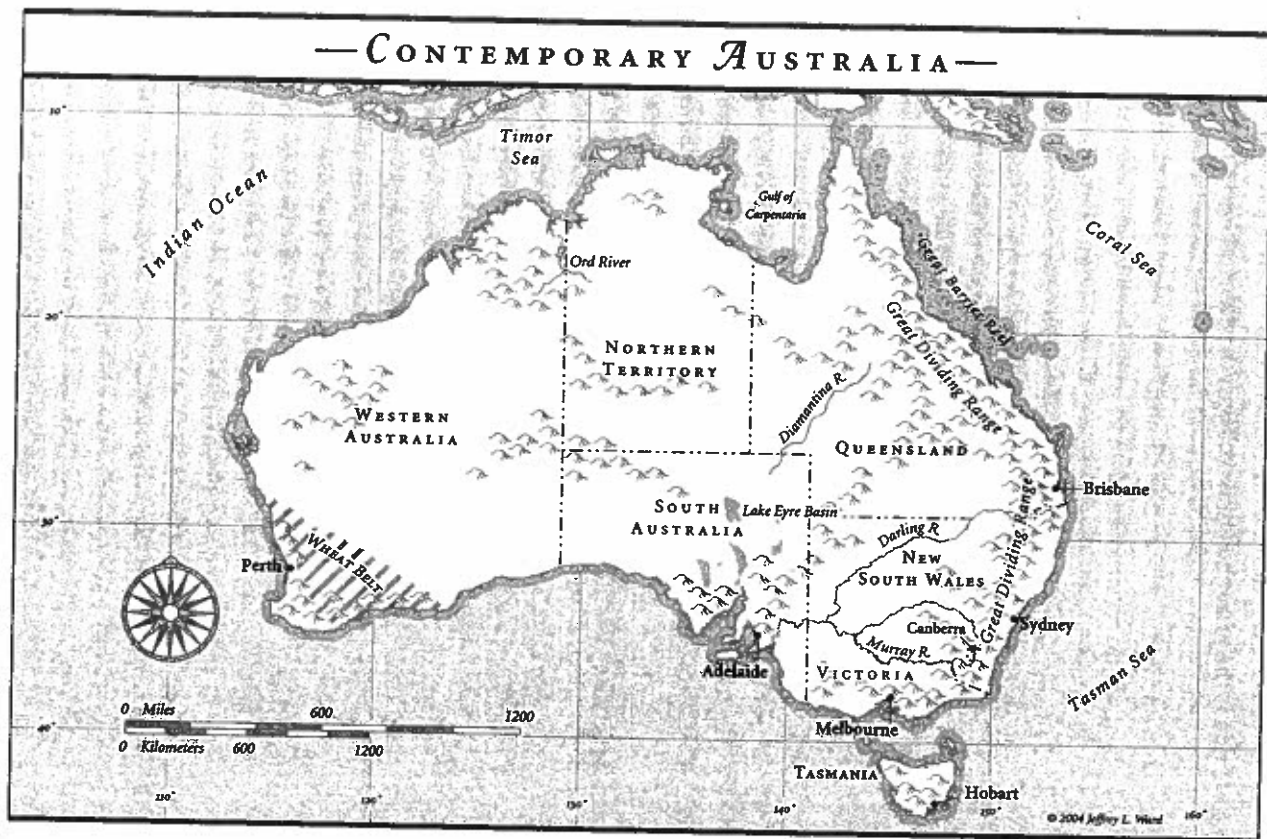
The principal exception to Australia's ENSO-driven pattern of unpredictable rain is the wheat belt of its southwest, where (at least until recently) the winter rains came reliably from year to year, and where a farmer could count on a successful wheat crop almost every year. That reliability propelled wheat within recent decades to overtake both wool and meat as Australia's most valuable agricultural export. As already mentioned, that wheat belt also happens to be the area with particularly extreme problems of low soil fertility and high salinity. But global climate change in recent years has been undermining even that compensating advantage of predictable winter rains: they have declined dramatically in the wheat belt since 1973, while increasingly frequent summer rains there fall on harvested bare ground and cause increased salinization. Thus, as I mentioned for Montana in Chapter 1, global climate change is producing both winners and losers, and Australia will be a loser even more than will Montana.

Australia lies largely within the temperate zones, but it lies thousands of miles overseas from other temperate-zone countries that are potential export markets for Australian products. Hence Australian historians speak of the "tyranny of distance" as an important factor in Australia's development. That expression refers to the long overseas ship journeys making transport costs per pound or per unit of volume for Australian exports higher than for exports from the New World to Europe, so that only products with low bulk and high value could be exported economically from Australia. Originally in the 19th century, minerals and wool were the main such exports. Around 1900, when refrigeration of ship cargo became economic, Australia also began to export meat overseas, particularly to England. (I recall an Australian friend who disliked the British, and who worked in a meat-processing factory, telling me that he and his mates occasionally dropped a gallbladder or two into boxes of frozen liver marked for export to Britain, and that his factory defined "lamb" as a sheep under six months old if it was destined for local consumption, but defined it as any sheep up to 18 months old if it was destined for export to Britain.) Today, Australia's principal exports remain low-bulk, high-value items, including steel, minerals, wool, and wheat; increasingly within the last few decades, wine and macadamia nuts as well; and also some specialty crops that are bulky but that have high

value because Australia produces unique crops aimed at specialty niche markets for which some consumers are willing to pay a premium, such as durum wheat and other special wheat varieties, and wheat and beef raised without pesticides or other chemicals.

But there is an additional tyranny of distance, one within Australia itself. Australia's productive or settled areas are few and scattered: the country has a population only  $1/14$  that of the U.S., scattered over an area equal to that of the U.S.'s lower 48 states. The resulting high costs of transportation within Australia make it expensive to sustain a First World civilization there. For example, the Australian government pays for telephone connection to the national phone grid for any Australian home or business at any location within Australia, even for outback stations hundreds of miles from the nearest such station. Today, Australia is the most urbanized country in the world, with 58% of its population concentrated in just five large cities (Sydney with 4.0 million people, Melbourne 3.4 million, Brisbane 1.6 million, Perth 1.4 million, and Adelaide 1.1 million as of 1999). Among those five cities, Perth is the world's most isolated large city, lying farther than any other from the next large city (Adelaide, 1,300 miles to the east). It is no accident that two of Australia's largest companies, its national airline Qantas and its telecommunications company Telstra, are based on bridging those distances.

Australia's internal tyranny of distance, in combination with its droughts, is also responsible for the fact that banks and other businesses are closing their branches in Australia's isolated towns, because those branches have become uneconomic. Doctors are leaving those towns for the same reason. As a result, whereas the U.S. and Europe have a continuous distribution of settlement sizes—large cities, medium-sized towns, and small villages—Australia is increasingly without medium-sized towns. Instead, most Australians today live either in a few large cities with all the amenities of the modern First World, or in smaller villages or else outback stations without banks, doctors, or other amenities. Australia's small villages of a few hundred people can survive a five-year drought, such as arises often in Australia's unpredictable climate, because the village has so little economic activity anyway. Big cities can also survive a five-year drought, because they integrate the economy over a huge catchment area. But a five-year drought tends to wipe out medium-sized towns, whose existence depends on their ability to provide enough business branches and services to compete with more distant cities, but which aren't big enough to integrate over a huge catchment. Increasingly, most Australians don't depend on or really live in





the Australian environment: they live instead in those five big cities, which are connected to the outside world rather than to the Australian landscape.

Europe claimed most of its overseas colonies in hopes of financial gain or supposed strategic advantages. Locations of those colonies to which many Europeans actually emigrated—i.e., excluding trading stations where only relatively few Europeans settled in order to trade with the local population—were chosen on the basis of the land's perceived suitability for the successful founding of an economically prosperous or at least self-supporting society. The unique exception was Australia, whose immigrants for many decades arrived not to seek their fortunes but because they were compelled to go there.

Britain's principal motive for settling Australia was to relieve its festering problem of large numbers of jailed poor people, and to forestall a rebellion that might otherwise break out if they could not somehow be disposed of. In the 18th century British law prescribed the death penalty for stealing 40 shillings or more, so judges preferred to find thieves guilty of stealing 39 shillings in order to avoid imposing the death penalty. That resulted in prisons and moored ship hulks filling with people convicted of petty crimes such as theft and debt. Until 1783, that pressure on the available jail space was relieved by sending convicts as indentured servants to North America, which was also being settled by voluntary emigrants seeking improvement of their economic lot or else religious freedom.

But the American Revolution cut off that escape valve, forcing Britain to seek some other place to dump its convicts. Initially, the two leading candidate locations under consideration were either 400 miles up the Gambia River in tropical West Africa, or else in desert at the mouth of the Orange River on the boundary between modern South Africa and Namibia. It was the impossibility of both of those proposals, evident on sober reflection, that led to the fallback choice of Australia's Botany Bay near the site of modern Sydney, known at the time only from Captain Cook's visit in 1770. That was how the First Fleet brought to Australia in 1788 its first European settlers, consisting of convicts plus soldiers to guard them. Convict shipments went on until 1868, and through the 1840s they comprised most of Australia's European settlers.

With time, four other scattered Australian coastal sites besides Sydney, near the sites of the modern cities of Melbourne, Brisbane, Perth, and Ho-

bart, were chosen as locations of other convict dumps. Those settlements became the nucleus of five colonies, governed separately by Britain, that eventually became five of the six states of modern Australia: New South Wales, Victoria, Queensland, Western Australia, and Tasmania, respectively. All five of those initial settlements were at locations chosen for advantages of their harbors or locations on rivers, rather than for any agricultural advantages. In fact, all proved to be sites poor for agriculture and incapable of becoming self-supporting in food production. Instead, Britain had to send out food subsidies to the colonies in order to feed the convicts and their guards and governors. That was not the case, however, for the area around Adelaide that became the nucleus of the remaining modern Australian state, South Australia. There, good soil resulting from geological uplift, plus fairly reliable winter rains, attracted German farmers as the sole early group of emigrants not from Britain. Melbourne also has good soils west of the city that became the site of a successful agricultural settlement in 1835, after a convict dump founded in 1803 in poor soils east of the city quickly failed.

The first economic payoff from British settlement of Australia came from sealing and whaling. The next payoff came from sheep, when a route across the Blue Mountains 60 miles west of Sydney was finally discovered in 1813, giving access to productive pasture land beyond. However, Australia did not become self-supporting, and Britain's food subsidies did not cease, until the 1840s, just before Australia's first gold rush of 1851 at last brought some prosperity.

When that European settlement of Australia began in 1788, Australia had of course been settled for over 40,000 years by Aborigines, who had worked out successful sustainable solutions to the continent's daunting environmental problems. At the sites of initial European occupation (the convict dumps) and in subsequently settled areas suitable for farming, Australian whites had even less use for Aborigines than white Americans had for Indians: the Indians in the eastern United States were at least farmers and provided crops critical for survival of European settlers during the first years, until Europeans began to grow their own crops. Thereafter, Indian farmers were merely competition for American farmers and were killed or driven out. Aboriginal Australians, however, did not farm, hence could not provide food for settlements, and were killed or driven out of the initial white settled areas. That remained Australian policy as whites expanded into areas suitable for farming. However, when whites reached areas too dry for farming but suitable for pastoralism, they found Aborigines

useful as stockmen to look after sheep: unlike Iceland and New Zealand, two sheep-raising countries that have no native predators on sheep, Australia had dingos which do prey on sheep, so that Australian sheep farmers needed shepherds and employed Aborigines because of the shortage of white labor in Australia. Some Aborigines also worked with whalers, sealers, fishermen, and coastal traders.

Just as the Norse settlers of Iceland and Greenland brought over the cultural values of their Norwegian homeland (Chapters 6-8), so too did the British settlers of Australia carry British cultural values. Just as was the case in Iceland and Greenland, in Australia as well some of those imported cultural values proved inappropriate to the Australian environment, and some of those inappropriate values continue to have legacies today. Five sets of cultural values were particularly important: those involving sheep, rabbits and foxes, native Australian vegetation, land values, and British identity.

In the 18th century Britain produced little wool itself but instead imported it from Spain and Saxony. Those continental sources of wool were cut off during the Napoleonic Wars, raging during the first decades of British settlement in Australia. Britain's King George III was particularly interested in this problem, and with his support the British succeeded in smuggling merino sheep from Spain into Britain and then sending some to Australia to become the founders of Australia's wool flock. Australia evolved into Britain's main source of wool. Conversely, wool was Australia's main export from about 1820 to 1950, because its low bulk and high value overcame the tyranny-of-distance problem preventing bulkier potential Australian exports from competing in overseas markets.

Today, a significant fraction of all food-producing land in Australia is still used for sheep. Sheep farming is ingrained into Australia's cultural identity, and rural voters whose livelihood depends on sheep are disproportionately influential in Australian politics. But the appropriateness of Australian land for sheep is deceptive: while it initially supported lush grass, or could be cleared to support lush grass, its soil productivity was (as already mentioned) very low, so the sheep farmers were in effect mining the land's fertility. Many sheep properties had to be quickly abandoned; Australia's existing sheep industry is a money-losing proposition (to be discussed below); and its legacy is ruinous land degradation through overgrazing (Plate 29).

In recent years there have been suggestions that, instead of raising sheep, Australia should be raising kangaroos, which (unlike sheep) are native Aus-

tralian species that are adapted to Australian plants and climates. It is claimed that the soft paws of kangaroos are less damaging to soil than are the hard hooves of sheep. Kangaroo meat is lean, healthy, and (in my opinion) absolutely delicious. In addition to their meat, kangaroos yield valuable hides. All of those points are cited as arguments to support replacing sheep herding with kangaroo ranching.

However, that proposal faces real obstacles, both biological and cultural ones. Unlike sheep, kangaroos are not herd animals that will docilely obey one shepherd and a dog, or that can be rounded up and marched obediently up ramps into trucks for shipment to the slaughterhouse. Instead, would-be kangaroo ranchers have to hire hunters to chase down and shoot their kangaroos one by one. Further strikes against kangaroos are their mobility and fence-jumping prowess: if you invest in promoting growth of a kangaroo population on your property, and if your kangaroos perceive some inducement to move (such as rain falling somewhere else), your valuable crop of kangaroos may end up 30 miles away on somebody else's property. While kangaroo meat is accepted in Germany and some is exported there, sales of kangaroo meat face cultural obstacles elsewhere. Australians think of kangaroos as vermin holding little appeal for displacing good old British mutton and beef from the dinner plate. Many Australian animal welfare advocates oppose kangaroo harvesting, overlooking the facts that living conditions and slaughter methods are much crueler for domestic sheep and cattle than for wild kangaroos. The U.S. explicitly forbids the importation of kangaroo meat because we find the beasts cute, and because a congressman's wife heard that kangaroos are endangered. Some kangaroo species are indeed endangered, but ironically the species actually harvested for meat are abundant pest animals in Australia. The Australian government strictly regulates their harvest and sets a quota.

Whereas introduced sheep have undoubtedly been of great economic benefit (as well as harm) to Australia, introduced rabbits and foxes have been unmitigated disasters. British colonists found Australia's environment, plants, and animals alien and wanted to be surrounded by familiar European plants and animals. Hence they attempted to introduce many European bird species, only two of which, the House Sparrow and Starling, became widespread, while others (the Blackbird, Song Thrush, Tree Sparrow, Goldfinch, and Greenfinch) became established only locally. At least, those introduced bird species have not done much harm, while Australia's rabbits in plague numbers cause enormous economic damage and land degradation by consuming about half of the pasture vegetation that would

otherwise have been available to sheep and cattle (Plate 30). Along with habitat changes through sheep grazing and suppression of Aboriginal land burning, the combination of introduced rabbits and introduced foxes has been a major cause of the extinctions or population crashes of most species of small native Australian mammals: foxes prey on them, and rabbits compete with native herbivorous mammals for food.

European rabbits and foxes were introduced to Australia almost simultaneously. It is unclear whether foxes were introduced first to permit traditional British fox hunting, then rabbits introduced later to provide additional food for the foxes, or whether rabbits were introduced first for hunting or to make the countryside look more like Britain and then foxes introduced later to control the rabbits. In any case, both have been such expensive disasters that it now seems incredible that they were introduced for such trivial reasons. Even more incredible are the efforts to which Australians went to establish rabbits: the first four attempts failed (because the rabbits released were tame white rabbits that died), and not until wild Spanish rabbits were used for the fifth attempt did success follow.

Ever since those rabbits and foxes did become established and Australians realized the consequences, they have been trying to eliminate or reduce their populations. The war against foxes involves poisoning or trapping them. One method in the war against rabbits, memorable to all non-Australians who saw the recent film *Rabbit Proof Fence*, is to divide up the landscape by long fences and attempt to eliminate rabbits from one side of the fence. Farmer Bill McIntosh told me how he makes a map of his property to mark the locations of every one of its thousands of rabbit burrows, which he destroys individually with a bulldozer. He then returns to a burrow later, and if it shows any fresh sign of rabbit activity, he drops dynamite down the burrow to kill the rabbits and then seals up the burrow. In this laborious way he has destroyed 3,000 rabbit burrows. Such expensive measures led Australians several decades ago to place great hopes in introducing a rabbit disease called myxomatosis, which initially did reduce the population by over 90% until rabbits became resistant and rebounded. Current efforts to control rabbits are using another microbe called the calicivirus.

Just as British colonists preferred their familiar rabbits and blackbirds and felt uncomfortable amidst Australia's strange-looking kangaroos and friarbirds, they also felt uncomfortable among Australia's eucalyptus and acacia trees, so different in appearance, color, and leaves from British woodland trees. Settlers cleared the land of vegetation partly because they didn't like its appearance, but also for agriculture. Until about 20 years ago, the

Australian government not only subsidized land clearance but actually required it of lease holders. (Much agricultural land in Australia is not owned outright by farmers, as in the U.S., but is owned by the government and leased to farmers.) Leaseholders were given tax deductions for agricultural machinery and labor involved in land clearance, were assigned quotas of land to clear as a condition of retaining their lease, and forfeited the lease if they did not fulfill those quotas. Farmers and businesses were able to make a profit just by buying or leasing land covered with native vegetation and unsuitable for sustained agriculture, clearing that vegetation, planting one or two wheat crops that exhausted the soil, and then abandoning the property. Today, when Australian plant communities are recognized as unique and endangered, and when land clearance is regarded as one of the two major causes of land degradation by salinization, it is sad to recall that the government until recently paid and required farmers to destroy native vegetation. The ecological economist Mike Young, whose job for the Australian government now includes the task of figuring out how much land has been rendered worthless by land clearance, told me of his childhood memories of clearing land with his father on their family farm. Mike and his father would each drive a tractor, the two tractors advancing in parallel and connected by a chain, with the chain dragging over the ground to remove native vegetation and replace it with crops, in return for which his father received a big tax deduction. Without that deduction provided by the government as an incentive, much of the land would never have been cleared.

As settlers arrived in Australia and began buying or leasing land from each other or from the government, land prices were set according to values prevailing back home in England, and justified there by the returns that could be obtained from England's productive soils. In Australia that has meant that land is "overcapitalized": that is, it sells or leases for more than can be justified by the financial returns from agricultural use of the land. When a farmer then buys or leases land and takes out a mortgage, the need to pay the interest on that high mortgage resulting from land overcapitalization pressures the farmer to try to extract more profit from the land than it could sustainably yield. That practice, termed "flogging the land," has meant stocking too many sheep per acre, or planting too much land in wheat. Land overcapitalization resulting from British cultural values (monetary values and belief systems) has been a major contributor to the Australian practice of overstocking, which has led to overgrazing, soil erosion, and farmer bankruptcies and abandonments.

More generally, high valuation on land has translated into Australians'



embracing rural agricultural values justified by their British background but not justified by Australia's low agricultural productivity. Those rural values continue to pose an obstacle to solving one of modern Australia's built-in political problems: the often disproportionate influence of rural voters. In the Australian mystique even more than in Europe and the U.S., rural people are considered honest, and city-dwellers are considered dishonest. If a farmer goes bankrupt, it's assumed to be the misfortune of a virtuous person overcome by forces beyond his control (such as a drought), while a city-dweller who goes bankrupt is assumed to have brought it on himself through dishonesty. This rural hagiography and disproportionately strong rural vote ignore the already-mentioned reality that Australia is the most highly urbanized nation. They have contributed to the government's long-continued perverse support for measures mining rather than sustaining the environment, such as land clearance and indirect subsidies of uneconomic rural areas.

Until 50 years ago, emigration to Australia was overwhelmingly from Britain and Ireland. Many Australians today still feel strongly connected to their British heritage and would indignantly reject any suggestion that they treasure it inordinately. Yet that heritage has led Australians to do things that they consider admirable but that would strike a dispassionate outsider as inappropriate and not necessarily in Australia's best interest. In both World War I and World War II Australia declared war upon Germany as soon as Britain and Germany declared war on each other, though Australia's own interests were never affected in World War I (except for giving Australians an excuse to conquer Germany's New Guinea colony) and did not become affected in World War II until the outbreak of war with Japan, more than two years after the outbreak of war between Britain and Germany. The major national holiday of Australia (and also of New Zealand) is Anzac Day, April 25, commemorating a disastrous slaughter of Australian and New Zealand troops on Turkey's remote Gallipoli Peninsula on that date in 1915, as a result of incompetent British leadership of those troops who were joining British forces in an unsuccessful attempt to attack Turkey. The blood-bath at Gallipoli became for Australians a symbol of their country's "coming of age," supporting its British motherland, and assuming its place among nations as a united federation rather than as half-a-dozen colonies with separate governor-generals. For Americans of my generation, the closest parallel to Gallipoli's meaning to Australians is the meaning to us of the disastrous Japanese attack of December 7, 1941, on our Pearl Harbor base, which overnight united Americans and pulled us out of our foreign policy

based on isolation. Yet people other than Australians cannot escape the irony of Australia's national holiday being associated with the Gallipoli Peninsula, situated one-third of the way around the world and on the opposite side of the equator: no other geographic location could be more irrelevant to Australia's interests.

Those emotional ties to Britain continue today. When I first visited Australia in 1964, having lived previously in Britain for four years, I found Australia more British than modern Britain itself in its architecture and attitudes. Until 1973, the Australian government still submitted to Britain each year a list of Australians to be knighted, and those honors were considered the highest possible ones for an Australian. Britain still appoints an Australian-nominated governor general for Australia, with the power to fire the Australian prime minister, and the governor general actually did so in 1975. Until the early 1970s, Australia maintained a "White Australia policy" and virtually banned immigration from its Asian neighbors, a policy that understandably angered them. Only within the last 25 years has Australia belatedly become engaged with its Asian neighbors, come to recognize its place as being in Asia, accepted Asian immigrants, and cultivated Asian trade partners. Britain has now fallen to a ranking in eighth place among Australia's export markets, behind Japan, China, Korea, Singapore, and Taiwan.

That discussion of Australia's self-image as a British country or as an Asian country raises an issue that has recurred throughout this book: the importance of friends and enemies to a society's stability. What countries has Australia perceived as its friends, its trade partners, and its enemies, and what has been the influence of those perceptions? Let's start with trade and then proceed to immigration.

For over a century until 1950, agricultural products, especially wool, were Australia's main exports, followed by minerals. Today Australia is still the world's largest wool producer, but Australian production and overseas demand are both decreasing because of increasing competition from synthetic fibers to fill wool's former uses. Australia's number of sheep peaked in 1970 at 180 million (representing an average of 14 sheep for every Australian then) and has been declining steadily ever since. Almost all of Australia's wool production is exported, especially to China and Hong Kong. Other important agricultural exports include wheat (sold especially to Russia, China, and India), specialty durum wheat, wine, and chemical-free beef. At present, Australia produces more food than it consumes and is a net food

exporter, but Australia's domestic food consumption is increasing as its population grows. If that trend continues, Australia could become a net importer rather than exporter of food.

Wool and other agricultural products now rank only in third place among Australia's earners of foreign exchange, behind tourism (number two) and minerals (number one). The minerals highest in export value are coal, gold, iron, and aluminum in that sequence. Australia is the world's leading exporter of coal. It has the world's largest reserves of uranium, lead, silver, zinc, titanium, and tantalum and is among the world's top six countries in its reserves of coal, iron, aluminum, copper, nickel, and diamonds. Especially its reserves of coal and iron are huge and not expected to run out in the foreseeable future. While Australia's largest export customers for its minerals used to be Britain and other European countries, Asian countries now import nearly five times more minerals from Australia than do European countries. The top three customers are presently Japan, South Korea, and Taiwan in that order: for instance, Japan buys nearly half of Australia's exported coal, iron, and aluminum.

In short, over the last half century Australia's exports have shifted from predominantly agricultural products to minerals, while its trade partners have shifted from Europe to Asia. The U.S. remains Australia's largest source of imports and (after Japan) its second largest export customer.

Those shifts in trade patterns have been accompanied by shifts in immigration. With an area similar to that of the U.S., Australia has a much smaller population (currently about 20 million), for the obvious good reason that the Australian environment is far less productive and can support far fewer people. Nevertheless, in the 1950s many Australians, including government leaders, looked fearfully at Australia's much more populous Asian neighbors, especially Indonesia with its 200 million people. Australians were also strongly influenced by their World War II experience of being menaced and bombed by populous but more distant Japan. Many Australians concluded that their country suffered from a dangerous problem of being greatly underpopulated compared to those Asian neighbors, and that it would become a tempting target for Indonesian expansion unless it quickly filled all that empty space. Hence the 1950s and 1960s brought a crash program to attract immigrants as a matter of public policy.

That program involved abandoning the country's former White Australia Policy, under which (as one of the first acts of the Australian Commonwealth formed in 1901) immigration was not only virtually restricted to people of European origin but even predominantly to people from

Britain and Ireland. In the words of the official government yearbook, there was concern that "non-Anglo-Celtic background people would not be able to adjust." The perceived population shortage led the government first to accept, and then actively to recruit, immigrants from other European countries—especially Italy, Greece, and Germany, then the Netherlands and the former Yugoslavia. Not until the 1970s did the desire to attract more immigrants than could be recruited from Europe, combined with growing recognition of Australia's Pacific rather than just British identity, induce the government to remove legal obstacles to Asian immigration. While Britain, Ireland, and New Zealand are still Australia's major sources of immigrants, one-quarter of all immigrants now come from Asian countries, with Vietnam, the Philippines, Hong Kong, and (currently) China variously predominating in recent years. Immigration reached its all-time peak in the late 1980s, with the result that nearly one-quarter of all Australians today are immigrants born overseas, as compared to only 12% of Americans and 3% of Dutch.

The fallacy behind this policy of "filling up" Australia is that there are compelling environmental reasons why, even after more than two centuries of European settlement, Australia has not "filled itself up" to the population density of the U.S. Given Australia's limited supplies of water and limited potential for food production, it lacks the capacity to support a significantly larger population. An increase in population would also dilute its earnings from mineral exports on a per-capita basis. Australia has recently been receiving immigrants only at the net rate of about 100,000 per year, which yields an annual population growth by immigration of only 0.5%.

Nevertheless, many influential Australians, including the recent Prime Minister Malcolm Fraser, the leaders of both major political parties, and the Australian Business Council, still argue that Australia should try to increase its population to 50 million people. The reasoning invokes a combination of continued fear of the "Yellow Peril" from overpopulated Asian countries, the aspiration for Australia to become a major world power, and the belief that that goal could not be achieved if Australia had only 20 million people. But those aspirations of a few decades ago have receded to the point where Australians today no longer expect to become a major world power. Even if they did have that expectation, Israel, Sweden, Denmark, Finland, and Singapore provide examples of countries with populations far less than that of Australia (only a few million each) that nevertheless are major economic powers and make big contributions to world technological innovation and culture. Contrary to their government and business leaders, 70% of

Australians say that they want less rather than more immigration. In the long run it is doubtful that Australia can even support its present population: the best estimate of a population sustainable at the present standard of living is 8 million people, less than half of the present population.

Driving inland from the state capital of Adelaide in South Australia, the only Australian state to have originated as a self-supporting colony because of its soils' decent productivity (high by Australian standards, modest by standards outside Australia), I saw in this prime farmland of Australia one ruin after another of abandoned farms. I was able to visit one of those ruins preserved as a tourist attraction: Kanyaka, a large manor developed as a sheep farm at considerable expense by English nobility in the 1850s, only to fail in 1869, to become abandoned, and never to be reoccupied. Much of that area of inland South Australia was developed for sheep farming during the wet years of the 1850s and early 1860s, when the land was covered with grass and looked lush. With droughts beginning in 1864, the overgrazed landscape became littered with the bodies of dead sheep, and those sheep farms were abandoned. That disaster stimulated the government to send the surveyor-general G. W. Goyder to identify how far inland from the coast the area with rainfall sufficiently reliable to justify farming extended. He defined a line that became known as the Goyder Line, north of which the likelihood of drought made attempts at farming imprudent. Unfortunately, a series of wet years in the 1870s encouraged the government to resell at high prices the abandoned sheep farms of the 1860s, as small overcapitalized wheat farms. Towns sprang up beyond the Goyder Line, railways expanded, and those wheat farms in turn succeeded for a few years of abnormally high rainfall until they too failed and became consolidated into larger holdings that reverted to being large sheep farms in the late 1870s. With the return of drought, many of those sheep farms subsequently failed once again, and those that still survive today cannot support themselves based on sheep: their farmer/owners require second jobs, tourism, or outside investments to make a living.

There have been more or less similar histories in most other food-producing areas of Australia. What made so many initially profitable food-producing properties become less profitable? The reason is Australia's number-one environmental problem, land degradation, resulting from a set of nine types of damaging environmental impacts: clearance of native vegetation, overgrazing by sheep, rabbits, soil nutrient exhaustion, soil erosion,

man-made droughts, weeds, misguided government policies, and salinization. All of these damaging phenomena operate elsewhere in the world, in some cases with even greater individual impact than in Australia. Briefly, these impacts are as follows:

I mentioned above that the Australian government formerly required tenants leasing government land to clear native vegetation. While that requirement has now been dropped, Australia still clears more native vegetation per year than any other First World country, and its clearance rates are exceeded in the world only by Brazil, Indonesia, the Congo, and Bolivia. Most of Australia's current land clearance is going on in the state of Queensland for the purpose of creating pasture land for beef cattle. The Queensland government has announced that it will phase out large-scale clearing—but not until 2006. The resulting damage to Australia includes land degradation through dryland salinization and soil erosion, impairment of water quality by runoff of salt and sediment, loss of agricultural productivity and land values, and damage to the Great Barrier Reef (see below). Rotting and burning of the bulldozed vegetation contribute to Australia's annual greenhouse gas emissions a gas quantity approximately equal to the country's total motor vehicle emissions.

A second major cause of land degradation is overstocking of sheep in numbers that graze down the vegetation faster than it can regrow. In some areas such as in parts of the Murchison District of Western Australia, overgrazing was ruinous and irreversible because it led to loss of the soil. Today, now that overgrazing's effects are recognized, the Australian government imposes *maximum* stocking rates for sheep: i.e., farmers are *forbidden* to stock more than a certain number of sheep per acre on leased land. Formerly, however, the government imposed *minimum* stocking rates: farmers were *obliged* to stock a certain minimum number of sheep per acre as a condition of holding the lease. When sheep stocking rates first became well documented in the late 19th century, they were three times higher than the rates considered sustainable today, and before documentation began in the 1890s sheep stocking rates were apparently up to 10 times higher than sustainable rates. That is, the first settlers mined the standing crop of grass, rather than treating it as a potentially renewable resource. Just as was true for land clearance, the government thus required farmers to damage the land and cancelled leases of farmers who failed to damage the land.

Three other causes of land degradation have already been mentioned. Rabbits remove vegetation as do sheep, cost farmers by reducing the pasture available to sheep and cattle, and also cost farmers through the

expense of the bulldozers, dynamite, fences, and virus release measures that farms adopt to control rabbit populations. Nutrient exhaustion of soils often develops within the first few years of agriculture, because of the low initial nutrient content of Australian soils. Erosion of topsoil by water and wind increases after its cover of vegetation has been thinned or cleared. The resulting runoff of soil via rivers into the sea, by making coastal waters turbid, is now damaging and killing the Great Barrier Reef, one of Australia's major tourist attractions (not to mention its biological value in its own right and as a nursery of fish).

The term "man-made drought" refers to a form of land degradation secondary to land clearance, sheep overgrazing, and rabbits. When the cover of vegetation is removed by any of these means, land that the vegetation had previously shaded now becomes directly exposed to the sun, thereby making the soil hotter and drier. That is, the secondary effects creating hot and dry soil conditions impede plant growth in much the same way as does a natural drought.

Weeds, discussed in Chapter 1 in connection with Montana, are defined as plants of low value to farmers, either because they are less palatable (or totally unpalatable) to sheep and cattle than preferred pasture plants, or because they compete with useful crops. Some weeds are plant species unintentionally introduced from overseas; about 15% were intentionally but misguidedly introduced for use in agriculture; one-third escaped into the wild from gardens where they had been intentionally introduced as ornamentals; and other weed species are Australian native plants. Because grazing animals prefer to eat certain plants, the action of grazing animals tends to increase the abundance of weeds and to convert pasture cover to plant species that are less utilized or unutilizable (in some cases, poisonous to animals). Weeds vary in the ease with which they can be combated: some weed species are easy to remove and to replace with palatable species or crops, but other weed species are very expensive or prohibitively difficult to eliminate once they have become established.

About 3,000 plant species are considered weeds in Australia today and cause economic losses of about \$2 billion per year. One of the worst is *Mimosa*, which threatens an especially valuable area, the Kakadu National Park and the World Heritage Area. It is prickly, grows up to 20 feet tall, and produces so many seeds that it can double the area that it covers within a year. Even worse is rubber vine, introduced in the 1870s as an ornamental shrub from Madagascar to make Queensland mining towns prettier. It escaped to become a plant monster of a type depicted in science fiction:

besides being poisonous to livestock, smothering other vegetation, and growing into impenetrable thickets, it drops pods that disperse far by floating down rivers, and that eventually pop open to release 300 seeds carried far by the wind. The seeds within one pod suffice to cover two-and-a-half acres with new rubber vines.

To the misguided government policies of land clearance and sheep overstocking previously mentioned may be added the policies of the government's Wheat Board. It has tended to make rosy predictions of higher world wheat prices, thereby encouraging farmers to incur debt for capital investments in machinery to plant wheat on land marginal for wheat growing. Many farmers then discovered, to their misfortune after investing much money, that the land could support wheat for only a few years, and that wheat prices dropped.

The remaining cause of land degradation in Australia, salinization, is the most complex and requires the most explanation. I mentioned previously that large areas of Australia contain much salt in the soil, as legacies of salty sea breezes, former ocean basins, or dried-out lakes. While a few plants can tolerate salty soils, most plants, including almost all of our crops, cannot. If the salt below the root zone just stayed there, it wouldn't be a problem. But two processes can bring it up towards the surface and start causing problems: irrigation salinization and dryland salinization.

Irrigation salinization has the potential for arising in dry areas where rainfall is too low or too unreliable for agriculture, and where irrigation is necessary instead, as in parts of southeastern Australia. If a farmer "drip-irrigates," i.e., installs a small irrigation water fixture at the base of each fruit tree or crop row and allows just enough water to drip out as the tree's or crop's roots can absorb, then little water is wasted, and there is no problem. But if the farmer instead follows the commoner practice of "broadcast irrigation," i.e., flooding the land or else using a sprinkler to distribute the water over a large area, then the ground gets saturated with more water than the roots can absorb. The unabsorbed excess water percolates down to that deeper layer of salty soil, thereby establishing a continuous column of wetted soil through which the deep-lying salt can percolate either up to the shallow root zone and the surface, where it will inhibit or prevent growth of plants other than salt-tolerant species, or else down to the groundwater table and from there into a river. In that sense, the water problems of Australia, which we think of as (and which is) a dry continent, are not problems of too little water but of too much water: water is still sufficiently cheap and available to permit its use in some areas for broadcast irrigation. More

exactly, parts of Australia have enough water to permit broadcast irrigation, but not enough water to flush out all the resulting mobilized salt. In principle, problems of irrigation salinization can be partly mitigated by going to the expense of installing drip irrigation instead of broadcast irrigation.

The other process responsible for salinization, besides irrigation salinization, is dryland salinization, potentially operating in areas where rainfall suffices for agriculture. That's true especially in the areas of Western Australia and parts of South Australia with reliable (or formerly reliable) winter rains. As long as ground in such areas is still covered with its natural vegetation, which is present all year, the plants' roots take up most of the rain falling, and little rainwater remains to percolate down through the soil to establish contact with the deeper salt layers. But suppose a farmer clears the natural vegetation and replaces it with crops, which are planted seasonally and then harvested, leaving the ground bare for part of the year. Rain soaking the ground when it is bare does percolate down to the deep-lying salt, permitting it to diffuse up to the surface. Unlike irrigation salinization, dryland salinization is difficult, expensive, or essentially impossible to reverse once the natural vegetation has been cleared.

One can think of salt mobilized by either irrigation or dryland salinization into soil water as like a salty underground river, which in some parts of Australia has salt concentrations three times those of the ocean. That underground river flows downhill just as does a normal above-ground river, but much more slowly. Eventually, it may seep out into a downhill depression, creating hypersaline ponds that I saw in South Australia. If a farmer on a hilltop adopts bad land management practices that cause his land to become salinized, the salt may slowly flow through the ground to the land of farms lying downhill, even if those farms are well managed. In Australia there is no mechanism whereby the owner of a downhill farm that has been thus ruined can collect compensation from the owner of an uphill farm responsible for his ruin. Some of the underground river doesn't emerge in downhill depressions but instead flows down into above-ground rivers, including Australia's largest river system, the Murray/Darling.

Salinization inflicts heavy financial losses on the Australian economy, in three ways. First, it is rendering much farmland, including some of the most valuable land in Australia, less productive or useless to grow crops and raise livestock. Second, some of the salt is carried into city drinking water supplies. For instance, the Murray/Darling River provides between 40% and 90% of the drinking water of Adelaide. South Australia's capital, but the river's rising salt levels could eventually make it unsuitable for human con-

sumption or crop irrigation without the added expense of desalination. Even more expensive than either of those two problems are the damages caused by salt corroding infrastructure, including roads, railroads, airfields, bridges, buildings, water pipes, hot water systems, rainwater systems, sewers, household and industrial appliances, power and telecommunication lines, and water treatment plants. Overall, it is estimated that only about a third of Australia's economic losses arising from salinization are the direct costs to Australian agriculture; the losses "beyond the farm gate" and downstream, to Australia's water supplies and infrastructure, cost twice as much.

As for the extent of salinization, it already affects about 9% of all cleared land in Australia, and that percentage is projected under present trends to rise to about 25%. Salinization is currently especially serious in the states of Western Australia and South Australia; the former state's wheat belt is considered one of the worst examples of dryland salinization in the world. Of its original native vegetation, 90% has now been cleared, mostly between 1920 and 1980, culminating in the "Million Acres a Year" program pushed by the Western Australia state government in the 1960s. No other equally large area of land in the world was cleared of its natural vegetation so quickly. The proportion of the wheat belt sterilized by salinization is expected to reach one-third within the next two decades.

The total area in Australia to which salinization has the potential for spreading is more than 6 times the current extent and includes a 4-fold increase in Western Australia, 7-fold increase in Queensland, 10-fold increase in Victoria, and 60-fold increase in New South Wales. In addition to the wheat belt, another major problem area is the basin of the Murray/Darling River, which accounts for nearly half of Australia's agricultural production but which now gets progressively saltier downstream towards Adelaide because of more salty underground water entering and more water being extracted for irrigation by humans along its length. (In some years so much water is extracted that no water is left in the river to enter the ocean.) That salt input into the Murray/Darling arises not just from irrigation practices along the river's lower reaches but also from the impact of increasingly extensive industrial-scale cotton farming along its headwaters in Queensland and New South Wales. Those cotton operations are considered Australia's biggest single dilemma of land and water management, because on the one hand cotton by itself is Australia's most valuable crop after wheat, but on the other hand the mobilized salt and applied pesticides associated with the cotton-growing damage other types of agriculture downstream in the Murray/Darling Basin.



Once salinization has been initiated, it is often either poorly reversible (especially in the case of dryland salinization), or prohibitively expensive to solve, or solutions take a prohibitively long time. Underground rivers flow very slowly, such that once one has mobilized salt through bad land management, it may take 500 years to flush that mobilized salt out of the ground even if one switches overnight to drip irrigation and stops mobilizing further salt.

While land degradation resulting from all those causes is Australia's most expensive environmental problem, five other sets of serious problems deserve briefer mention: those involving forestry, marine fisheries, freshwater fisheries, freshwater itself, and alien species.

Apart from Antarctica, Australia is the continent with proportionately the least area covered by forests: only about 20% of the continent's total area. They used to include possibly the world's tallest trees, now-felled Victorian Mountain Ash, rivaling or topping California Coast Redwoods in height. Of Australia's forests standing at the time of European settlement in 1788, 40% have already been cleared, 35% have been partly logged, and only 25% remain intact. Nevertheless, logging of that small area of remaining old-growth forests is continuing and constitutes yet another instance of mining the Australian landscape.

The export uses (in addition to domestic consumption) to which timber logged from Australia's remnant forests is being put are remarkable. Of forest product exports, half are not in the form of logs or finished materials but are turned into wood chips and sent mostly to Japan, where they are used to produce paper and its products and make up one-quarter of the material in Japanese paper. While the price that Japan pays to Australia for those wood chips has dropped to \$7 per ton, the resulting paper sells in Japan for \$1,000 per ton, so that almost all of the value added to the timber after it is cut accrues to Japan rather than to Australia. At the same time as it exports wood chips, Australia imports nearly three times more forest products than it exports, with more than half of those imports being in the form of paper and paperboard products.

Thus, the Australian forest products trade involves a double irony. On the one hand, Australia, one of the First World countries with the least forest, is still logging those shrinking forests to export their products to Japan, the First World country with the highest percentage of its land under forest (74%) and with that percentage still growing. Second, Australia's forest

products trade in effect consists of exporting raw material at a low price, to be converted in another country into finished material at a high price and with high added value, and then importing finished materials. One expects to encounter that particular type of asymmetry not in the trade relations between two First World countries, but instead when an economically backward, non-industrialized Third World colony unsophisticated at negotiations deals with a First World country sophisticated at exploiting Third World countries, buying their raw materials cheaply, adding value to the materials at home, and exporting expensive manufactured goods to the colony. (Japan's major exports to Australia include cars, telecommunications equipment, and computing equipment, while coal and minerals are Australia's other major exports to Japan.) That is, it would appear that Australia is squandering a valuable resource and receiving little money for it.

The continued logging of old-growth forests is giving rise to one of the most passionate environmental debates in Australia today. Most of the logging and the fiercest debate are going on in the state of Tasmania, where Tasmania Mountain Ash, at up to 305 feet tall some of the world's tallest remaining trees outside of California, are now being logged faster than ever. Both of Australia's major political parties, at both the state and federal levels, favor continued logging of Tasmanian old-growth forests. A possible reason is suggested by the fact that, after the National Party announced its strong support for Tasmanian logging in 1995, it became known that the party's three biggest financial contributors were logging companies.

In addition to mining its old-growth forests, Australia has also planted agroforestry plantations, both of native and of non-native tree species. For all the reasons mentioned previously—low soil nutrient levels, low and unpredictable rainfall, and resulting low growth rates of trees—agroforestry is much less profitable and faces higher costs in Australia than in 12 out of the 13 countries that are among its principal competitors. Even Australia's most valuable commercially surviving timber tree species, the Tasmanian Blue Gum, grows faster and more profitably in overseas plantations where it has been planted (in Brazil, Chile, Portugal, South Africa, Spain, and Vietnam) than in Tasmania itself.

The mining of Australia's marine fisheries resembles that of its forests. Basically, Australia's tall trees and lush grass deceived the first European settlers into overrating Australia's potential for food production on land: in technical terms used by ecologists, the land supported large standing crops but low productivity. The same is true of Australia's oceans, whose productivity is low because it depends on nutrient runoff from that same

unproductive land, and because Australian coastal waters lack nutrient-rich upwellings comparable to the Humboldt current off the west coast of South America. Australia's marine populations tend to have low growth rates, so that they are easily overfished. For example, within the last two decades there has been a worldwide boom in a fish called Orange Roughy, caught in Australian and New Zealand waters and providing the basis of a fishery that has been profitable in the short term. Unfortunately, closer studies showed that Orange Roughy are very slow-growing, they do not start to breed until they are about 40 years old, and the fish caught and eaten are often 100 years old. Hence Orange Roughy populations cannot possibly breed fast enough to replace the adults being removed by fishermen, and that fishery is now in decline.

Australia has exhibited a history of marine overfishing: mining one stock until it is depleted to uneconomically low levels, then discovering a new fishery and switching to it until it too collapses within a short time, like a gold rush. After a new fishery opens, a scientific study by marine biologists may be initiated to determine the maximal sustainable harvesting rates, but the fishery is at risk of collapsing before recommendations from the study become available. Australian victims of such overfishing, besides Orange Roughy, include Coral Trout, Eastern Gemfish, Exmouth Gulf Tiger Prawns, School Sharks, Southern Bluefin Tuna, and Tiger Flathead. The only Australian marine fishery for which there are well-supported claims of sustainable harvesting involves the Western Australian rock lobster population, which is currently Australia's most valuable seafood export and whose healthy status has been evaluated independently by the Marine Stewardship Council (to be discussed in Chapter 15).

Like its marine fisheries, Australia's freshwater fisheries as well are limited by low productivity because of low nutrient runoff from the unproductive land. Also like the marine fisheries, the freshwater fisheries have deceptively large standing crops but low production. For example, Australia's largest freshwater fish species is the Murray Cod, up to three feet long and confined to the Murray/Darling river system. It is good eating, highly valued, and formerly so abundant that it used to be caught and shipped to markets by the truckload. Now, the Murray Cod fishery has been closed because of the decline and collapse of the catch. Among the causes of that collapse are the overharvesting of a slow-growing fish species, as in the case of Orange Roughy; effects of introduced carp, which increase water turbidity; and several consequences of dams built on the Murray River in the 1930s, which interrupted fish spawning movements, decreased river wa-

ter temperature (because dam managers released cold bottom water too cold for the fish's reproduction, rather than warmer surface water), and converted a river formerly receiving periodic nutrient inputs from floods into permanent bodies of water with little nutrient renewal.

Today, the financial yield from Australia's freshwater fisheries is trivial. For instance, all freshwater fisheries in the state of South Australia generate only \$450,000 per year, divided among 30 people who fish only as a part-time occupation. A properly managed sustainable fishery for Murray Cod and Golden Perch, the Murray/Darling's other economically valuable fish species, could surely yield far more money than that, but it is unknown whether damage to Murray/Darling fisheries is now irreversible.

As for freshwater itself, Australia is the continent with the least of it. Most of that little freshwater that is readily accessible to populated areas is already utilized for drinking or agriculture. Even the country's largest river, the Murray/Darling, has two-thirds of its total water flow drawn off by humans in an average year, and in some years virtually all of its water. Australia's freshwater sources that remain unutilized consist mainly of rivers in remote northern areas, far from human settlements or agricultural lands where they could be put to use. As Australia's population grows, and as its unutilized supplies of freshwater dwindle, some settled areas may be forced to turn to more expensive desalinization for their freshwater. There is already a desalinization plant on Kangaroo Island, and one may be needed soon on the Eyre Peninsula.

Several major projects in the past to modify unutilized Australian rivers have turned out to be costly failures. For instance, in the 1930s it was proposed to build several dozen dams along the Murray River in order to permit freight traffic by ship, and about half of those planned dams were built by the U.S. Army Corps of Engineers before the plan was abandoned. There is now no commercial freight traffic on the Murray River, but the dams did contribute to the already-mentioned collapse of the Murray Cod fishery. One of the most expensive failures was the Ord River Scheme, which involved damming a river in a remote and sparsely populated area of northwestern Australia in order to irrigate land for growing barley, corn, cotton, safflower, soybeans, and wheat. Eventually, only cotton among all those crops was grown on a small scale and failed after 10 years. Sugar and melons are now being produced there, but the value of their yield does not come close to matching the project's great expense.

In addition to those problems of water quantity, accessibility, and use, there are also issues of water quality. Utilized rivers contain toxins,

pesticides, or salts from upstream that reach urban drinking areas and agricultural irrigation areas downstream. Examples that I already mentioned are the salt and agricultural chemicals from the Murray River, which furnishes much of Adelaide's drinking water, and the pesticides from New South Wales and Queensland cotton fields, which jeopardize the marketability of downstream attempts to grow chemical-free wheat and beef.

In part because Australia itself has fewer native animal species than the other continents, it has been especially vulnerable to exotic species from overseas becoming intentionally or accidentally established, and then depleting or exterminating populations of native animals and plants without evolved defenses against such alien species. Notorious examples that I already mentioned are rabbits, which consume about half of the pasture that could otherwise be consumed by sheep and cattle; foxes, which have preyed on and exterminated many native mammal species; several thousand species of plant weeds, which have transformed habitats, crowded out native plants, degraded pasture quality, and occasionally poisoned livestock; and carp, which have damaged water quality in the Murray/Darling River.

A few other horror stories involving introduced pests deserve briefer mention. Domestic buffalo, camels, donkeys, goats, and horses that have gone feral trample, browse, and otherwise damage large areas of habitat. Hundreds of species of insect pests have established themselves more easily in Australia than in temperate-zone countries with cold winters. Among them, blowflies, mites, and ticks have been especially damaging to livestock and pastures, while caterpillars, fruit flies, and many others are damaging to crops. Cane Toads, introduced in 1935 to control two insect pests of sugarcane, failed to do that but did spread over an area of 100,000 square miles, assisted by the fact that they can live for up to 20 years and that females annually lay 30,000 eggs. The toads are poisonous, inedible to all native Australian animals, and rate as one of the worst mistakes ever committed in the name of pest control.

Finally, Australia's isolation by the oceans, and hence its heavy reliance on ship transport from overseas, has resulted in many marine pests arriving in discharged ballast water and dry ballast of ships, on ship hulls, and in materials imported for aquaculture. Among those marine pests are comb jellies, crabs, toxic dinoflagellates, shellfish, worms, and a Japanese starfish that depleted the Spotted Handfish native only to southeastern Australia. Many of these pests are enormously expensive in the damage that they cause and in the annual control costs that they necessitate every year: e.g., a few hundred million dollars per year for rabbits, \$600 million for flies and

ticks of livestock, \$200 million for a pasture mite, \$2.5 billion for other insect pests, over \$3 billion for weeds, and so on.

Thus, Australia has an exceptionally fragile environment, damaged in a multitude of ways incurring enormous economic costs. Some of those costs stem from past damage that is now irreversible, such as some forms of land degradation and the extinctions of native species (relatively more species in recent times in Australia than on any other continent). Most of the types of damage are still ongoing today, or even increasing or accelerating as in the case of old-growth forest logging in Tasmania. Some of the damaging processes are virtually impossible to halt now because of long built-in time delays, such as the effects of slow underground downhill flows of already-mobilized saline groundwater that will continue to spread for centuries. Many Australian cultural attitudes, as well as government policies, remain the ones that caused damage in the past and are still continuing to cause it. For instance, among the political obstacles to a reform of water policies are obstacles arising from a market for "water licenses" (rights to extract water for irrigation). The purchasers of those licenses understandably feel that they actually own the water that they have paid dearly to extract, even though full exercise of the licenses is impossible because the total amount of water for which licenses have been issued may exceed the amount of water available in a normal year.

To those of us inclined to pessimism or even just to realistic sober thinking, all those facts give us reason to wonder whether Australians are doomed to a declining standard of living in a steadily deteriorating environment. That is an entirely realistic scenario for Australia's future—much more likely than either a plunge into an Easter Island-like population crash and political collapse as prophesized by doomsday advocates, or a continuation of current consumption rates and population growth as blithely assumed by many of Australia's current politicians and business leaders. The implausibility of the latter two scenarios, and the realistic prospects of the first scenario, apply to the rest of the First World as well, with the sole difference that Australia could end up in the first scenario sooner.

Fortunately, there are signs of hope. They involve changing attitudes, rethinking by Australia's farmers, private initiatives, and the beginnings of radical governmental initiatives. All that rethinking illustrates a theme that we already encountered in connection with the Greenland Norse (Chapter 8), and to which we shall return in Chapters 14 and 16: the challenge

of deciding which of a society's deeply held core values are compatible with the society's survival, and which ones instead have to be given up.

When I first visited Australia 40 years ago, many Australian landowners responded to criticism that they were damaging their land for future generations or producing damage for other people by responding, "It's my land, and I can bloody well do with it whatever I bloody please." While one still hears such attitudes today, they are becoming less frequent and less publicly acceptable. Whereas the government until a few decades ago faced little resistance to its enforcing environmentally destructive regulations (e.g., *requiring* land clearance) and putting through environmentally destructive schemes (e.g., the Murray River dams and the Ord River Scheme), the Australian public today, like the public in Europe, North America, and other areas, is increasingly vocal on environmental matters. Public opposition has been especially loud to land clearance, river development, and old-growth logging. At the moment that I write these lines, those public attitudes have just resulted in the South Australian state government's instituting a new tax (thereby breaking an election promise) to raise \$300 million to undo damage to the Murray River; the Western Australian state government's proceeding with the phasing-out of old-growth logging; the New South Wales state government and its farmers' reaching agreement on a \$406 million plan to streamline resource management and end large-scale land clearing; and the state government in Queensland, historically the most conservative Australian state, announcing a joint proposal with the national (Commonwealth) government to end large-scale clearing of mature bushland by the year 2006. All of these measures were unimaginable 40 years ago.

These signs of hope include changed attitudes of the voting public as a whole, resulting in changed governmental policies. Another sign of hope involves changed attitudes of farmers in particular, who are increasingly realizing that the farming methods of the past cannot be sustained and wouldn't permit them to pass on their farms in good condition to their children. That prospect hurts Australian farmers, because (like the Montana farmers whom I interviewed for Chapter 1) it's love for the farming lifestyle, rather than farming's meager financial rewards, that motivates them to carry on with the hard work of being farmers. Symbolic of those changed attitudes was a conversation that I had with sheep farmer Bill McIntosh, the one whom I mentioned as having mapped, bulldozed, and dynamited the rabbit warrens on his farm, which had belonged to his family since 1879. He showed me photos of the same hill, taken in 1937 and in 1999, and illus-

trating dramatically the sparse vegetation in 1937 due to sheep overstocking and the vegetation's subsequent recovery. Among his own measures to keep his farm sustainable, he is stocking sheep at levels below those considered as an acceptable maximum by the government, and is thinking about switching to wool-less sheep kept just for meat production (because they require less attention and less land). As one method of coping with the weed problem and preventing less palatable plant species from taking over pasture, he has adopted a practice termed "cell grazing," under which sheep are not permitted to eat just the most palatable plants and then moved to the next pasture, but are instead left in the same pasture until they have been forced to consume its less palatable as well as its more palatable plants. Astonishingly to me, he keeps costs down and manages the entire farm without any full-time employee besides himself, by herding his several thousand sheep while riding on his motorbike, carrying binoculars and a radio and accompanied by his dog. Simultaneously, he somehow makes time for trying to develop other sources of business income, such as bed-and-breakfast tourism, because he recognizes that his farm alone would be marginal in the long run.

Farmer peer pressure, in combination with recently changed government policies, is reducing stocking rates and improving pasture conditions. In inland parts of South Australia where the government owns land fit for pastoralism and leases it to farmers on 42-year leases, an agency called the Pastoral Board assesses the land's condition every 14 years, reduces the permissible stocking rate if the vegetation's condition is not improving, and revokes the lease if it decides that the farmer/tenant was managing the property unsatisfactorily. Closer to the coast, land tends to be owned outright (as freehold) or under perpetual lease, so that such direct governmental control is not possible, but there is still indirect control enforced in two ways. By law, landowners or leaseholders still bear a "duty-of-care" obligation to prevent land degradation. The first stage of enforcement involves local farmer boards that monitor degradation and apply peer pressure to try to achieve compliance. The second stage depends on soil conservators who can intervene if the local board is not effective. Bill McIntosh related to me four cases in which local boards or soil conservators in his area ordered farmers to reduce sheep stocking rates, or actually confiscated the property when the farmer did not obey.

Among Australia's many innovative private initiatives to address environmental problems are several that I encountered while visiting a former sheep and farm property of nearly 1,000 square miles near the Murray River, called Calperum Station. First leased for grazing in 1851, it fell victim

to the usual panoply of Australian environmental problems: deforestation, foxes, land clearance by chaining and burning, overirrigation, overstocking, rabbits, salinization, weeds, wind erosion, and so on. In 1993 it was bought by the Australian Commonwealth Government and the Chicago Zoological Society, the latter (despite being U.S.-based) already attracted by Australia's pioneering efforts in developing ecologically sustainable land practices. For some years after that purchase, government managers applied top-down control and gave orders to local community volunteers, who became increasingly frustrated, until in 1998 control was turned over to the private Australian Landscape Trust mobilizing 400 local volunteers for bottom-up community management. The trust is funded in large degree by Australia's largest private philanthropic organization, The Potter Foundation, which is expressly concerned with reversing the degradation of Australia's farmland.

Under the trust's management, local volunteers at Calperum threw themselves into whatever projects appealed to each volunteer's own interest. By thus enlisting volunteers, this private initiative has been able to accomplish far more than would have been possible with the limited available government funds alone. Volunteers trained at Calperum have then gone on to use those skills to undertake other conservation projects elsewhere. Among the projects that I saw, one volunteer was devoting herself to a small endangered kangaroo species whose population she was trying to restore; another volunteer preferred to poison foxes, one of the area's most damaging introduced pest species; and still other volunteers were attacking the ubiquitous problem of rabbits, seeking ways to control introduced carp in the Murray River, perfecting a strategy for non-chemical control of insect pests of citrus trees, restoring lakes that had become sterile, revegetating overgrazed land, and developing markets for growing and selling local wildflowers and plants controlling erosion. These efforts deserve a prize for imagination and enthusiasm. Literally tens of thousands of other such private initiatives are operating around Australia: for instance, another organization that also grew in part out of The Potter Foundation's Potter Farmland Plan, called Landcare, is helping 15,000 individual farmers wanting to help themselves to pass on their farms in decent condition to their children.

Complementing these imaginative private initiatives are government initiatives that include a radical rethinking of Australian agriculture, in response to growing awareness of the seriousness of Australia's problems. It is too early to guess whether any of these radical plans will be adopted, but the fact that salaried government employees are being permitted and even paid to develop them is remarkable. The proposals are not coming from idealis-

tic bird-loving environmentalists but from hard-nosed economists, who are asking themselves: would Australia be better off economically without much of its present agricultural enterprise?

The background to this rethinking is the realization that only tiny areas of Australian land currently being used for agriculture are productive and suitable for sustained agricultural operations. While 60% of Australia's land area and 80% of its human water use are dedicated to agriculture, the value of agriculture relative to other sectors of the Australian economy has been shrinking to the point where it now contributes less than 3% of the gross national product. That's a huge allocation of land and scarce water to an enterprise of such low value. Furthermore, it is astonishing to realize that over 99% of that agricultural land makes little or no positive contribution to Australia's economy. It turns out that about 80% of Australia's agricultural profits are derived from less than 0.8% of its agricultural land, virtually all of it in the southwestern corner, on the south coast around Adelaide, in the southeastern corner, and in eastern Queensland. Those are the few areas favored by volcanic or recently uplifted soils, reliable winter rains, or both. Most of Australia's remaining agriculture is in effect a mining operation that does not add to Australia's wealth but merely converts environmental capital of soil and native vegetation irreversibly into cash, with the help of indirect government subsidies in the forms of below-cost water, tax concessions, and free telephone linkups and other infrastructure. Is it a good use of Australian taxpayers' money to subsidize so much unprofitable or destructive land use?

Even from the narrowest point of view, some Australian agriculture is uneconomic to the individual consumer, who can buy its products (such as orange juice concentrate and pork) more cheaply as imports from overseas than as domestic produce. Much agriculture is also uneconomic to the individual farmer, as measured by what is termed "profit at full equity." That is, if one counts among a farm's expenses not only its cash expenditures but also the value of the farmer's labor, two-thirds of Australia's agricultural land (mainly land used for raising sheep and beef cattle) operates at a net loss to the farmer.

For instance, consider Australian pastoralists raising sheep for their wool. On the average, pastoralists' farm income is lower than the national minimum wage, and they are accumulating debts. The farm's capital plant of its buildings and fences is running down because the farm doesn't yield enough money to maintain the plant in good condition. Nor does wool yield enough profit to pay the interest costs on the farm's mortgage. The



means by which the average wool-grower survives economically are through non-farm income, earned by holding a second job as a nurse or in a store, operating a bed-and-breakfast, or other ways. In effect, those second jobs, plus the farmers' willingness to work on their farms for little or no pay, are subsidizing their own money-losing farm operations. Many in the current generation of farmers pursue the profession because they grew up to admire the rural life, even though they could earn more money doing something else. In Australia as in Montana, the children of the current generation of farmers are unlikely to make that same choice when they will be facing the decision whether they want to take over the family farm from their parents. Only 29% of current Australian farmers expect that their children will run the farm.

That's the economic value of much Australian farming to the individual consumer and the individual farmer. What about its value to Australia as a whole? For any given piece of the farming enterprise, one has to take into account a broadened view of its costs to the entire economy, as well as its benefits. One big piece of those broadened costs is government support to farmers through means such as tax subsidies and expenditures for drought assistance, research, advising, and agricultural extension services. Those government expenditures eat up about one-third of Australian agriculture's nominal net profits. Another big piece of those broadened costs is the losses that agriculture imposes on other segments of the Australian economy. In effect, agricultural uses of land compete with other potential uses of the same land, and using one piece of land for agriculture may damage the value of another piece of land for tourism, forestry, fisheries, recreation, or even for agriculture itself. For instance, soil runoff caused by land clearance for agriculture is damaging and locally killing the Great Barrier Reef, one of Australia's major tourist attractions, but tourism is already more important to Australia than agriculture as a source of foreign-exchange earnings. Or suppose one wheat farmer on uphill land can make a profit for a few years by growing irrigated wheat that causes massive salinization of larger properties lying downhill, ruining those properties in perpetuity. In those cases the farmer clearing land in the reef's watershed, or operating the uphill farm, may show a profit to himself as a result of his activities, but Australia as a whole shows a loss.

Another case that has come in for much recent discussion involves industrial-scale cotton-growing in southern Queensland and in northern New South Wales, on the upper reaches of tributaries of the Darling River (flowing down through agricultural districts of southern New South Wales

and South Australia) and of the Diamantina River (flowing down into the Lake Eyre Basin). In a narrow sense, cotton is Australia's second most profitable agricultural export, after wheat. But cotton-growing depends on irrigation water provided at low cost or no cost by the government. In addition, all major cotton-growing areas pollute the water with their heavy applications of pesticides, herbicides, defoliants, and high-phosphorus and high-nitrogen fertilizers (causing algal blooms). Those pollutants even include DDT and its metabolites, last used about 25 years ago but still persisting in the environment because they resist breakdown. In the downstream reaches of those polluted rivers are wheat and cattle growers who appeal to a high-value niche market by raising wheat and beef without adding their own chemicals. They have been protesting vigorously, because their ability to sell their supposedly chemical-free produce is being undermined by those side effects of the cotton industry. Thus, while growing cotton unquestionably brings profits to the owners of the cotton agribusinesses, one would have to calculate indirect costs, such as those of subsidized water and damage to other agricultural sectors, if one wanted to evaluate whether cotton produces a gain or a loss to Australia as a whole.

The remaining example considers Australia's agricultural production of the greenhouse gases carbon dioxide and methane. That's an especially serious problem for Australia, because global warming (thought to result in large degree from greenhouse gases) is breaking down the pattern of reliable winter rains that turned wheat grown in southwestern Australia's wheat belt into Australia's single most valuable agricultural export. The carbon dioxide emissions from Australian agriculture exceed those produced by motor vehicles and all the rest of the transport industry. Even worse are cows, whose digestion produces methane, 20 times more potent than carbon dioxide in causing global warming. The simplest way for Australia to fulfill its stated commitment to reduce its greenhouse gas emissions would be to eliminate its cattle!

While that and other radical suggestions have been put forward, there are currently no signs of their being adopted soon. It would be a "first" for the modern world if a government voluntarily decided to phase out much of its agricultural enterprise, in anticipation of future problems, before being forced in desperation to do so. Nevertheless, even the mere existence of these suggestions raises a larger point. Australia illustrates in extreme form the exponentially accelerating horse race in which the world now finds itself. ("Accelerating" means going faster and faster; "exponentially accelerating" means accelerating in the manner of a nuclear chain reaction, twice as

fast and then 4, 8, 16, 32 . . . times faster after equal time intervals.) On the one hand, the development of environmental problems in Australia, as in the whole world, is accelerating exponentially. On the other hand, the development of public environmental concern, and of private and governmental countermeasures, is also accelerating exponentially. Which horse will win the race? Many readers of this book are young enough, and will live long enough, to see the outcome.

#### PART FOUR

## PRACTICAL LESSONS

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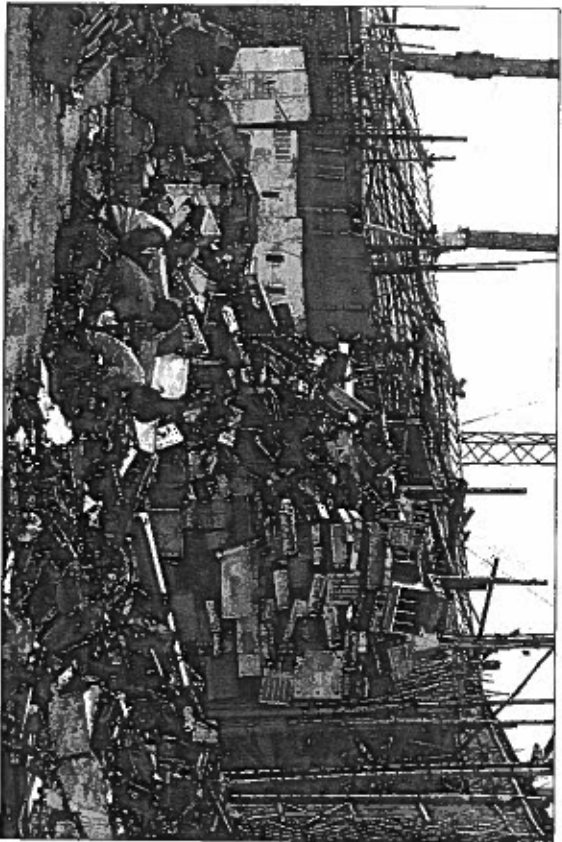


Plate 27. Imported electronic garbage in China represents a direct transfer of pollution from the First World to the Third World.

Plate 28. Surface salt deposits, a form of salinization, along Australia's largest river, the Murray River.

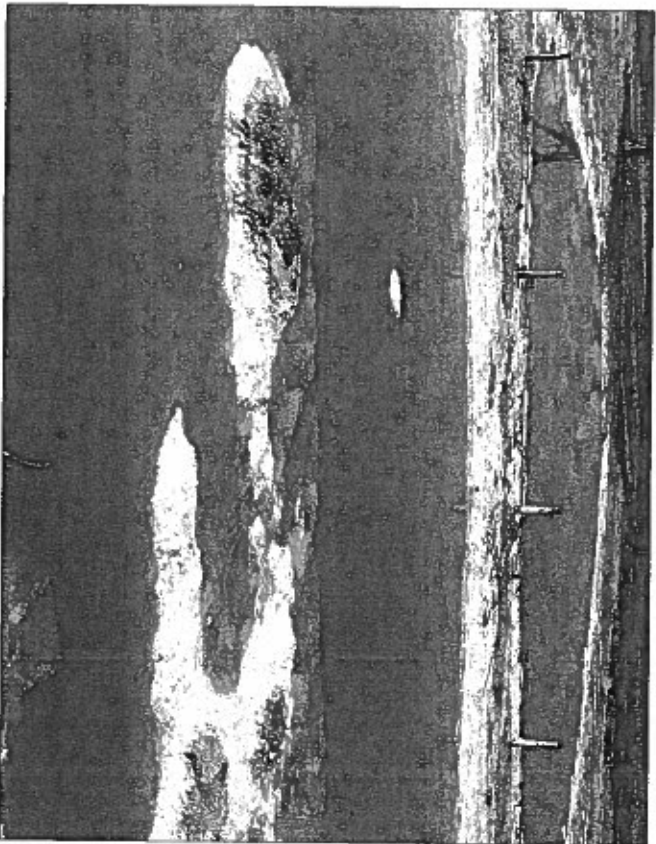


Plate 29. The plague of sheep that consume vegetation and contribute to erosion in Australia.

Plate 30. The plague of introduced rabbits that consume vegetation and contribute to erosion in Australia.

