Chapter 8

Four Scenarios

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BOXES

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*This appears in Appendix A at the end of this volume.

Main Messages

This chapter presents four internally consistent scenarios that explore aspects of plausible global futures and their implications for ecosystem services. Scenario development is a way to explore possibilities for the future that cannot be predicted by extrapolation of past and current trends. The four scenarios in this chapter are structured around the assumptions and rationale described in Chapter 5, the methods described in Chapter 6, and the drivers described in Chapter 7. The probability of any one of these scenarios being the real future is very small. Each scenario might resemble some people's ideal world, but one lesson to us as we developed them was that all four scenarios have both strengths and potentially serious weaknesses. An ideal future would probably involve a mix of all four, with different elements dominating at different times and in different places. The future could be far better or far worse than any of the scenarios, depending on choices made by key decision-makers and other people in society who bring about change. Our purpose in developing the stories is to encourage decision-makers to consider some positive and negative implications of the different development trajectories.

The Global Orchestration scenario depicts a worldwide connected society in which global markets are well developed. Supra-national institutions are well placed to deal with global environmental problems, such as climate change and fisheries. However, their reactive approach to ecosystem management makes them vulnerable to surprises arising from delayed action or unexpected regional changes. The scenario is about global cooperation not only to improve the social and economic well-being of all people but also to protect and enhance global public goods and services (such as public education, health, and infrastructure). There is a focus on the individual rather than the state, inclusion of all impacts of development in markets (internalization of externalities), and use of regulation only where appropriate. Environmental problems that threaten human well-being (such as pollution, erosion, and climate change) are dealt with only after they become apparent. Problems that have little apparent or direct impact on human well-being are given a low priority in favor of policies that directly improve well-being. People are generally confident that the necessary knowledge and technology to address environmental challenges will emerge or can be developed as needed, just as it has in the past. The scenario highlights the risks from ecological surprises under such an approach. Examples are emerging infectious diseases and other slowly emerging problems that are hard to control once they are established. Other benefits and risks also emerge from the inevitable and increasing connections among people and nations at social, economic, and environmental scales.

The Order from Strength scenario represents a regionalized and fragmented world concerned with security and protection, emphasizing primarily regional markets, and paying little attention to the common goods, and with an individualistic attitude toward ecosystem management. Nations see looking after their own interests as the best defense against economic insecurity. They reluctantly accept the argument that a militarily and economically strong liberal democratic nation could maintain global order and protect the lifestyles of the richer world and provide some benefits for any poorer countries that elect to become allies. Just as the focus of nations turns to protecting their borders and their people, so too their environmental policies focus on securing natural resources seen as critical for human well-being. But, as in Global Orchestration, people in this scenario see the environment as secondary to their other challenges. They believe in the ability of humans to bring technological innovations to bear as solutions to environmental challenges after these challenges emerge.

The Adapting Mosaic scenario depicts a fragmented world resulting from discredited global institutions. It sees the rise of local ecosystem management strategies and the strengthening of local institutions. Investments in human and social capital are geared toward improving knowledge about ecosystem functioning and management, resulting in a better understanding of the importance of resilience, fragility, and local flexibility of ecosystems. There is optimism that we can learn, but humility about preparing for surprises and about our ability to know all there is to know about managing socioecological systems. Initially, trade barriers for goods and products are increased, but barriers for information (for those who are motivated to use it) nearly disappear due to improving communication technologies and rapidly decreasing costs of access to information. There is great regional variation in management techniques. Some local areas explore adaptive management, using experimentation, while others manage with command and control or focus on economic measures. Eventually, the focus on local governance leads to failures in managing the global commons. Problems like climate change, marine fisheries, and pollution grow worse, and global environmental surprises become common. Communities slowly realize that they cannot manage their local areas because global problems are infringing, and they begin to develop networks among communities, regions, and even nations to better manage the global commons. The rebuilding is more focused on ecological units, as opposed to the earlier type of management based on political borders that did not necessarily align with ecosystem boundaries.

The TechnoGarden scenario depicts a globally connected world relying strongly on technology and on highly managed and often-engineered ecosystems to deliver needed goods and services. Overall, eco-efficiency improves, but it is shadowed by the risks inherent in large-scale human-made solutions. Technology and market-oriented institutional reform are used to achieve solutions to environmental problems. In many cases, reforms and new policy initiatives benefit from the strong feel for international cooperation that is part of this scenario. As a result, conditions are good for finding solutions for global environmental problems such as climate change. These solutions are designed to benefit both the economy and the environment. Technological improvements that reduce the environmental impact of goods and services are combined with improvements in ecological engineering that optimize the production of ecosystem services. These changes co-develop with the expansion and development of property rights to ecosystem services, such as requiring people to pay for pollution they create or paying people for providing key ecosystem services through actions such as preservation of key watersheds. These rights are generally created and allocated following the identification of ecological problems. Because understanding of ecosystem function is high, property rights regimes are usually assigned long before the problem becomes serious. These property rights are assigned to a diversity of individuals, corporations, communal groups, and states that act to optimize the value of their property. We assume that ecological management and engineering can be successful, although it does produce some ecological surprises that affect many people due to an over-reliance on highly engineered systems.

Some additional insights emerge from the scenarios, as follows:

A path of accelerated global cooperation and a focus on global public good is likely to improve overall human well-being, but it may have costly consequences for ecosystem services and some aspects of human well-being. Local problems can become unmanageable due to complacency and delayed action; ecological crises can accentuate inequalities as they tend to affect poor regions and countries; reactive solutions can carry unbearable social costs for less favorable areas.

A global development that emphasizes environmental technology and engineered ecosystems will contribute to sustainable development by allowing for greater efficiency and optimal control of ecosystems, but possibly at the cost of loss in local, rural, and indigenous knowledge and

cultural values. Increasing confidence in human ability to manage, tame, and improve nature may lead people to overlook factors that sometimes cause breakdowns of ecosystem services. Large-scale technological solutions carry the internal risks of failure and can engender technology-related ecological surprises.

Emphasis on adaptive management and learning at local scales may be achieved at the cost of overlooking global problems that may result in global environmental surprises with serious local repercussions. While local problems become more tractable, and can be addressed by citizens, attention to global problems such as climate change and marine fisheries may decrease, leading to increasing magnitude of their impacts.

Strategies that focus on local and regional safety and protection may disregard cross-border and global issues, restrict trade and movement of people, and increase inequalities, but protection of key natural resources in richer regions could see an improvement. Such a world encourages boundaries at all levels. It might offer security in the face of aggression, environmental pests, and diseases, but increases risks of longer-term internal and international conflict, ecosystem degradation, and declining human well-being. Alleviation of problems in poorer countries through strategic intervention by richer countries to reduce inequalities and environmental degradation would be likely to occur in cycles, leading to a fluctuating and unstable world for many people.

Institutional development, feedbacks between local and global processes, and the risks entailed by the substitution of ecosystem services by human, social, or manufactured capital determine society's ability to cope with ecological surprises. Globally controlled institutions can be too large and rigid to respond effectively to ecological surprises, yet local institutions may neglect important linkages for anticipating and managing such surprises. Concentrating ecosystem management on a single level of control (local, regional, national, continental, or global) is highly likely to fail to manage cross-scale ecological feedbacks in appropriate way. Solutions that substitute for ecosystem services carry risks, due to limited rates of learning, barriers to development, or the inherent brittleness of human-made solutions, including human or technical failures.

Local management of ecosystems provides better opportunities for more effective and fairer access to ecosystem services on local scales, but local strategies are more likely to be effective when accompanied by measures to ensure regional and global coordination. Local management can be particularly relevant when learning about ecosystems is adaptive and management is more proactive. If risks or surprises are to be reduced, however, local strategies should be accompanied by regional and global coordination measures (such as international treaties like the Convention on Biological Diversity or the Convention on Combating Desertification) that focus on the management of common pool resources and public goods.

A globally compartmentalized, environmentally reactive world could mask developing ecological and social disasters for several decades. The Scenarios Working Group agreed that Order from Strength is ultimately unsustainable in terms of ecosystems and the societies they support, but the group was surprised at the diversity of viewpoints on how such a scenario could unfold and over what time scale. It is plausible that if current trends toward increasing compartmentalization continue, the world could develop a false sense of security in coming decades unless efforts are made to understand and monitor ecosystems and their services.

Current understanding of ecological and social systems is inadequate to predict when and how ecological-social systems will produce adverse feedbacks or unpleasant surprises. There is considerable evidence of adverse cross-scale interactions between ecological processes and human activities (including interventions intended to fix problems). There also is emerging understanding of how these adverse outcomes have been caused. However, we found it surprisingly difficult to locate when within the next five decades the impacts would emerge or precisely what combinations of policies and interventions are most likely to produce them.

8.1. Introduction

The four major components of this chapter are the four scenarios: Global Orchestration, Order from Strength, Adapting Mosaic, and TechnoGarden. Interspersed among the scenarios are boxes drawing out specific issues relating to individual scenarios or comparing issues across scenarios.

The scenarios are fictional stories written from the point of view of someone looking back from 2050 at what has happened in the world since 2000. The stories are designed to draw out key aspects of the questions raised in Chapter 5; these are recapped later in this section. The storylines are based on the logic—or guidelines—developed in Chapter 5, but they do not try to include all elements of these guidelines. The stories would be too complex and the messages would be lost if they did.

The scenarios have been developed from input from all members of the Scenarios Working Group, but they have been woven into storylines by a smaller number of writers. The writers have researched elements of the stories and placed their own interpretation on this research. While our primary aim was to draw out the consequences of several plausible future worlds for ecosystem services, we needed to provide plausible explanations that considered social and economic drivers of change.

The explanations given in the scenarios are only some of the ways in which the worlds could develop. Each member of the Scenarios Working Group would have written each scenario differently if it had been his or her task. The purpose of the scenarios is to get the reader thinking about how the world might develop rather than to provide predictions. The writers of later chapters of this report have drawn their own conclusions based partly on the scenario storylines but also on their own imagination of how the logic behind the scenarios could have played out.

The logic of the scenarios was developed in Chapter 5. The key question addressed in the MA scenarios is:

- What are the consequences of plausible changes in development paths for ecosystems and their services over the next 50 years and what will be the consequences of those changes for human well-being?

Four more specific questions were also considered:

- What are the consequences for ecosystem services and human well-being of strategies that emphasize economic policy reform (reducing subsidies and internalizing externalities) as the primary means of management?
- What are the consequences for ecosystem services and human well-being of strategies that emphasize local and regional safety and protection and that give far less emphasis to cross-border and global issues?

- What are the consequences for ecosystem services and human well-being of strategies that emphasize the development and use of technologies allowing greater eco-efficiency and adaptive control?
- What are the consequences for ecosystem services and human well-being of strategies that emphasize adaptive management and local learning about the consequences of management interventions for ecosystem services?

Additional questions for comparing the scenarios include:

- What are the most robust findings concerning changes in ecosystem services and human well-being across all four scenarios?
- What are critical uncertainties that we are confident will have a big impact on ecosystem services and human well-being?
- What are gaps in our understanding that we can identify right now that will affect our ability to model ecosystem services and human well-being?
- What opportunities exist for managing ecosystem services and human well-being?
- What is surprising in these results?

The four scenarios differed with respect to most of the direct and indirect drivers that are part of the Millennium Ecosystem Assessment framework. (See Chapter 5.) Two critical uncertainties emerged as primary issues in the discussions of the Scenarios Working Group. (See Figure 8.1 in Appendix A and Table 8.1.)

One of the working group's main foci was on the potential impact of ecological feedbacks on human well-being in the future. Key issues with respect to the emergence and management of these feedbacks include:

- whether governments and other decision-makers consider ecosystems to be fragile or robust to human impacts,
- whether they see ecosystems as primary underpinners of value to humans or of secondary importance after economic and social issues, and
- whether they therefore manage ecosystems proactively to avoid undesirable ecological feedbacks or reactively in the belief that problems can be fixed after they become apparent.

Thus, two of the scenarios were developed around proactive environmental management policies and two around reactive policies.

In TechnoGarden, proactive policies arise due to recognition of the economic value of ecosystem services. In Adapting Mosaic, they emerge from a strong recognition of the broader value of ecosystem services in underpinning human life and human well-being and the need to work with rather than against nature. In Global Orchestration, belief in the ability of humans to find technological approaches to repair or replace lost ecosystem functions is high, and ecosystems are considered to be robust to the impacts of humans. In Order from Strength, an inward focus on national security and economic growth by individual wealthy countries, together with a belief that ecosystems are robust and that reservation of representative ecosystems is enough to keep future options open, means that ecosystems are considered only after more pressing economic and social issues. In poorer countries, the struggle of people to survive economically and physically, combined with poor understanding of the relationships between human well-being and ecosystem health, makes conservation of ecosystems a low priority and exploitation an apparent necessity.

Our combined experience led us to identify the degree and scale of connectedness among and within institutions as the other major driver of how ecosystems will be managed in the future and what ecosystem services outcomes are possible. Two broad future trends seemed to be plausible from past and emerging present-day trends. A continuation and escalation of the present trend toward globalization and connectedness across country borders, with associated reductions in trade barriers and barriers to movement of people, were seen as plausible in the future. In Global Orchestration there is confidence that the right global policies will achieve economic equity among all countries and that environmental impacts will take care of themselves as prosperity grows. In TechnoGarden there is enthusiastic development of environmental technologies that are adopted

Table 8.1. Defining Characteristics of the Four Scenarios

Scenario Name	Dominant Approach for Sustainability	Economic Approach	Social Policy Foci	Dominant Social Organizations
Global Orchestration	sustainable development; economic growth; public goods	fair trade (reduction of tariff boundaries), with enhancement of global public goods	improve world; global public health; global education	transnational companies; global NGO and multilateral organizations
Order from Strength	reserves; parks; national-level policies; conservation	regional trade blocs; mercantilism	security and protection	multinational companies
Adapting Mosaic	local-regional co-management; common-property institutions	integration of local rules regulate trade; local nonmarket rights	local communities linked to global communities; local equity important	cooperatives, global organizations
TechnoGarden	green technology; eco-efficiency; tradable ecological property rights	global reduction of tariff boundaries; fairly free movement of goods, capital, and people; global markets in ecological property	technical expertise valued; follow opportunity; competition; openness	transnational professional associations; NGOs

by global companies and shared across international boundaries.

Alternatively, it was considered that a less connected, regional focus could emerge in two ways. One way could be by a continuation of the emerging trend toward decentralized decision-making, especially with respect to the environment. A failure or partial failure of global systems could see regional processes emerge as the major routes for environmental decision-making (Adapting Mosaic). The other way could be the escalation of concern about national security, filtering down to actions by wealthier parts of society within countries to protect their security and defend their access to scarce resources (Order from Strength).

Subsequently, similar uncertainties about global and local institutions emerged from some sub-global assessments. (See Box 8.1.)

8.2. Linkages with Chapter 9 on Quantitative Modeling

Readers may notice some inconsistencies between this chapter and Chapter 9. The quantitative models in the other chapter are based primarily on assumptions for which there is good published evidence. Three of the assumptions that have strong influence on both the models and our thinking in the storylines are about trends in population and income and the sizes of regional economies. Figures 8.2 and 8.3 illustrate just how large the changes from today are likely to be in all four scenarios, primarily due to the inevitable effects of population growth. Other important elements in the quantified scenarios include relationships between income growth and demand for goods and provisioning ecosystem services such as food, energy, and timber. The consequences of increases in the consumption of such goods and services in terms of global environmental change is relatively well explored in these models. In contrast, the models are less developed in dealing with ecological processes that occur at the local scale and in dealing with the impacts of ecological changes on human development and human behavior. Regulating services are generally less well covered by the global models, and supporting and cultural services are not able to be addressed at all in the models.

The storylines differ from the models in that the storylines can explore some plausible changes for which no models or little data currently exist. These largely have to do with people's attitudes and the ways in which they adapt to challenges. The biggest differences between the storylines and the models occur for Adapting Mosaic because the models inadequately address ecosystem feedbacks, which are a key factor in people's approach to management in this scenario. We think people in this scenario would be successful in developing cooperative approaches to overcome many of the challenges that the models suggest they would be faced with (such as declining production yields, falling food availability, and high food prices). Taking the models together with the storylines, we can see both the optimistic future in which humans adapt appropriately and the less

BOX 8.1

Issues Arising from the Southern African Millennium Ecosystem Assessment

In terms of standard indicators of human well-being, southern Africa has some of the poorest conditions to be found on the globe. Many of these conditions are related to the services provided by ecosystems. Life expectancy in sub-Saharan Africa has declined from 50 to 47 years of age since 1990, mainly due to the high infant mortality rate. HIV/AIDS is the leading cause of death; malaria and tuberculosis also present serious health problems. Lack of clean, affordable energy sources increases susceptibility to illness and malnutrition, and contributes to the poor domestic air quality experienced in many African cities. Cyclical droughts, political instability, and ongoing conflict in parts of the region disrupt food production systems and have displaced large numbers of people, increasing pressure on resources in asylum areas.

The Southern African Millennium Ecosystem Assessment consisted of five component studies at three nested spatial scales (a regional, two mega-basin, and two sets of local community assessments) in mainland Africa south of the equator. (See the MA *Multiscale Assessments* volume.) Each component of SAfMA, in consultation with its specific stakeholders, developed its own set of scenarios as a framework for considering the future of ecosystem services in the particular study area.

Governance emerged as a key uncertainty in scenarios developed at all scales of SAfMA. Uncertainties regarding economic growth, the type of policies pursued, and the effectiveness of policy implementation were all linked to governance. One important uncertainty of policy implementation was whether policies enhanced social equality and distribution of wealth, or whether wealth remained concentrated among the elite and powerful. Also related to this was the uncertainty regarding the degree of decentralization in governance and the strength of civil society.

Most scenarios indicate that the conditions in southern Africa remain stable or worsen over the next three decades; only under a limited set of circumstances is a significant improvement anticipated. It is expected that biodiversity, freshwater quality and quantity, biomass fuel, and air quality will decline under both scenarios of strong and poor central governance, although the degree of decline as well as the underlying processes will differ between the two. Food production is expected to remain stable or decline slightly under conditions of poor governance, whereas improved governance is anticipated to result in a strong improvement in food security. Mapped onto the MA global scenarios, most global-scale scenarios translate into similar outcomes for southern Africa, probably due to its marginal status and relative disconnect from many global socioeconomic processes.

The SAfMA local-scale scenarios highlight that general trends in ecosystem services at the regional and basin-scale may be reversed in particular local situations. The multiscale structure of the SAfMA also showed that certain responses or developments at larger scales are experienced as surprises or shocks at local scales—such as mega-parks and large irrigation schemes implemented without adequate local stakeholder participation and consideration of impacts. The Gorongosa-Marromeu scenarios, in particular, emphasized the need for good operational and transparent governance structures at all scales to ensure the equitable distribution of wealth and use of natural resources, and thus to also ensure longer-term sustainability.

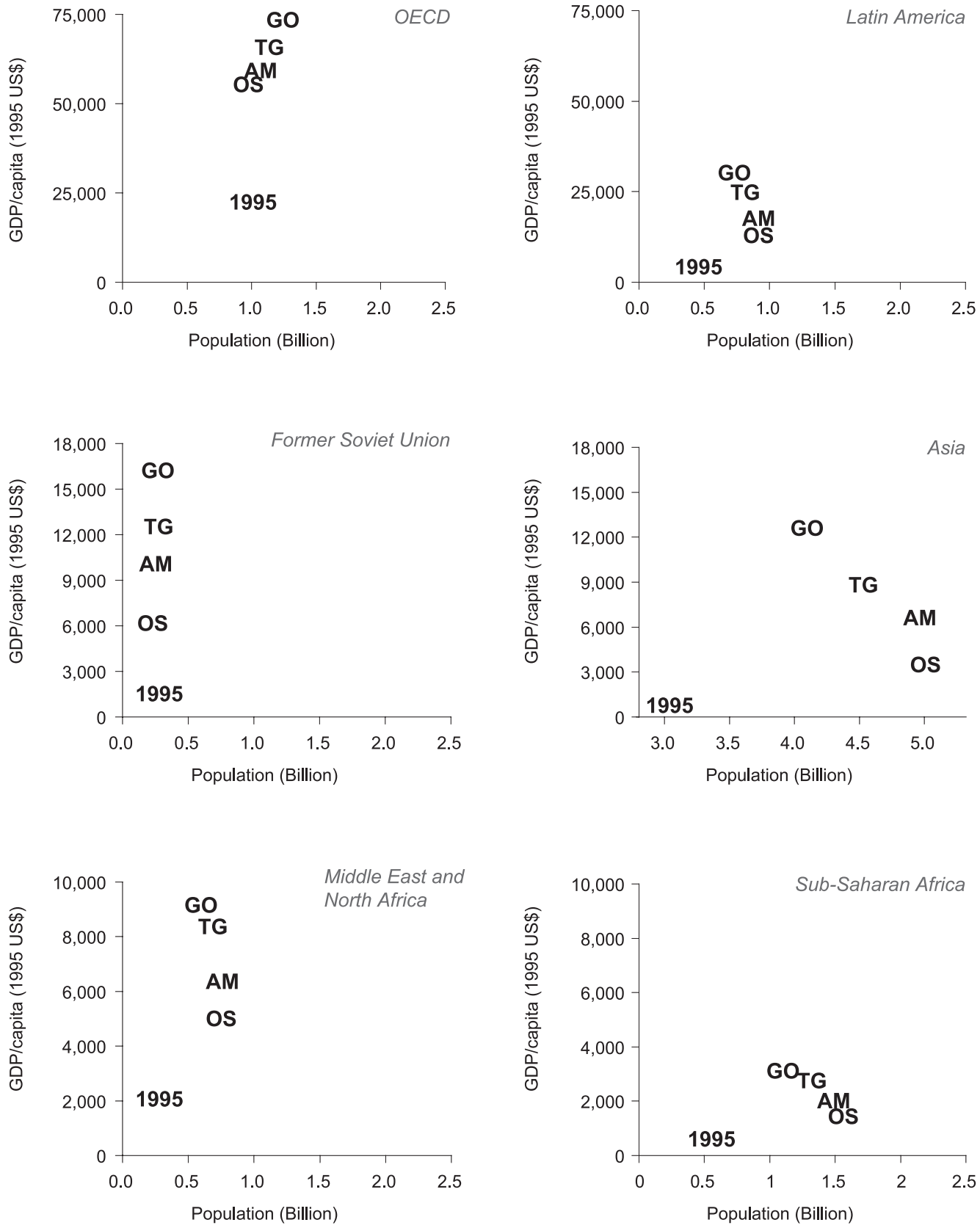

Figure 8.2. Projected Changes in Population and Income in MA Scenarios in 1995 and 2050. The number 1995 indicates the 1995 data while the projected data for 2050 are indicated by the code for each scenario. GO: Global Orchestration, TG: TechnoGarden, AM: Adapting Mosaic, and OS: Order from Strength. (Data from Chapter 7.)

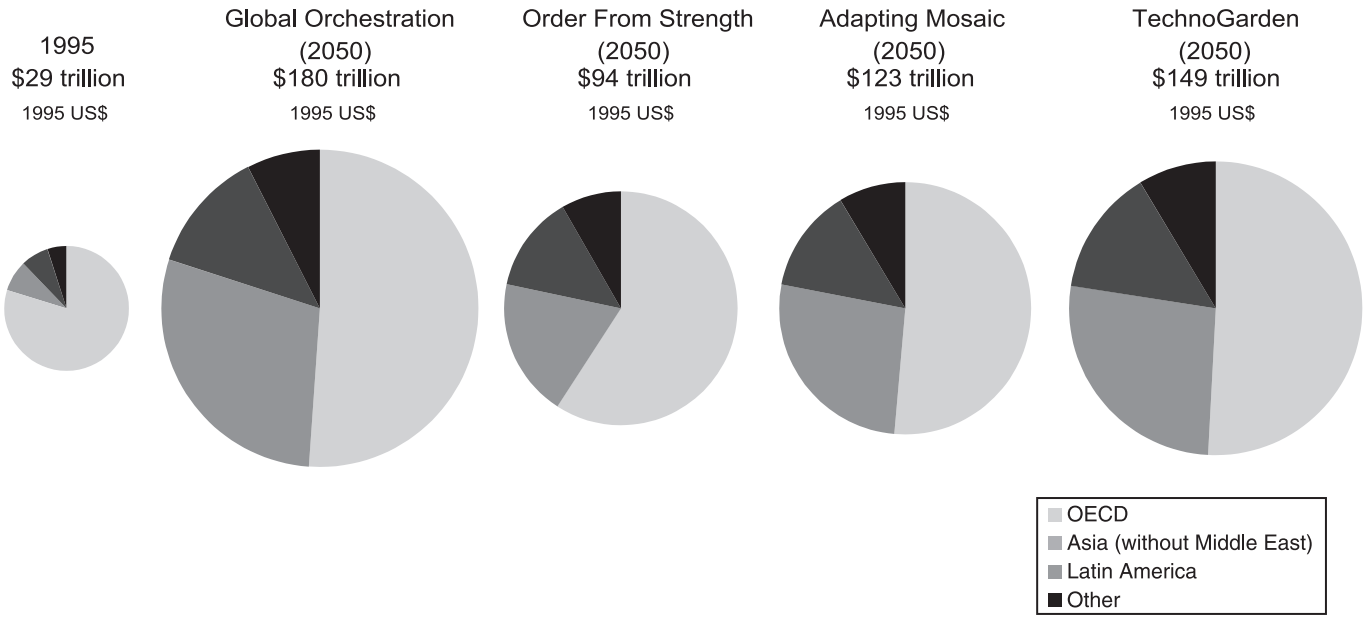

Figure 8.3. Projected Changes in Relative Size of Economies in MA Scenarios (Data from Chapter 7.)

optimistic view in which responses are less pronounced. The models do, however, contain some assumptions about human responses (see Chapter 5), some of which are optimistic and others not so optimistic. We have inserted footnotes in the relevant places in each scenario to highlight and explain the major differences between chapters.

8.3. Global Orchestration

This scenario is about global cooperation not only to improve the social and economic well-being of all people but also to protect and enhance global public goods and services (such as public education, health, and infrastructure). There is a focus on the individual rather than the state, inclusion of all impacts of development in markets (internalization of externalities), and use of regulation only where appropriate. Trade liberalization and free markets are key ingredients, but decision-makers in this scenario have gone beyond philosophies such as the Washington Consensus.[1]

People generally recognize that the environment provides a suite of global public goods and services, but the approach to environmental management is largely reactive. Environmental problems that threaten human well-being are dealt with after they become apparent. Those that have little apparent or direct impact on human-well being are given a low priority in favor of policies that directly improve well-being. People are generally confident that the necessary knowledge and technology to address environmental challenges will emerge or can be developed as needed, just as it always has in the past. The scenario highlights the risk that this lack of proactivity in addressing environmental concerns can lead to increased risks from ecological surprises, particularly emerging infectious diseases and other slowly emerging problems that are hard to control once they are established. Other benefits and risks (see Box 8.2) emerge from the inevitable and increasing connections among people and nations at social, economic, and environmental scales.

8.3.1 Global Orchestration 2000–15

8.3.1.1 The Legacy of the Twentieth Century: Tensions, Inequalities, and Concern for the Environment

At the beginning of the twenty-first century, poverty and inequality, together with environmental degradation, were being singled out by more and more concerned individuals

BOX 8.2
Potential Benefits and Risks of Global Orchestration

Potential benefits:

- Economic prosperity and increased equality due to more efficient global markets
- Wealth increases the demand for a better environment and the capacity to create such an environment
- Increased global coordination (such as markets, transport, fisheries, movement of pests and weeds, and health)

Risks:

- Progress on global environmental problems may be insufficient to sustain local and regional ecosystem services
- Breakdowns of ecosystem services create inequality (disproportionate impacts on the poor)
- Reactive management may be more costly than preventative or proactive management

and groups as some of the world's most pressing problems, although they were not always at the top of the agendas of global and national decision-makers. Social tensions were arising from inequalities in wealth, civil liberties, and access to food, water, other basic human needs, and global markets. Trust in vested interests was declining as governments and big business in all parts of the world were exposed for withholding and manipulating information about finances, people, and security issues.

These tensions were seen as the underlying causes of growing civil unrest, uncontrolled migration, and conflicts. Terrorism was on the minds of people in richer countries after an unprecedented attack on New York in 2001, although deaths of far more people from conflict, disease, poor nutrition, and inadequate sanitation were regular events in many poorer countries. While some saw terrorism as an evil that needed to be stamped out with force, others called for greater equality of access to the fundamentals of human well-being as the way to remove terrorism by removing the underlying causes.

There were increasingly vocal calls for the world's leaders to accept the responsibilities as well as the benefits of globalization.

8.3.1.2 Global Connectedness

Attempts by global aid and development agencies to reduce the number of people with low well-being led to a more connected world, as open markets joined countries and peoples together through trade. Borders—real and virtual—were under threat. Electronic communication allowed ideas, information, and misinformation to be rapidly propagated and shared. A global generation of teenagers shared thoughts and beliefs electronically. They had heightened concerns for the environment but also a yearning for the latest in consumer products and fashions. No force could hold back the movement of ideas and merchandise across borders. The power of global brands equaled that of governments when it came to manipulating the values and viewpoints of this generation. Music was bought and sold illegally with seeming impunity via worldwide computer networks, and independent television channels broadcast in competition with major international networks during conflicts.

While movies, music, tourism, and printed media promoted elements of the culture of the most industrialized countries globally, the influence of poorer countries was increasing through growing investments in technological innovation and their increasing impact on demand as consumers.

Airline travel was affordable to middle-income people in many parts of the world. People from all walks of life traveled frequently between east and west, north and south, around the globe. This not only made global business possible but also allowed regular face-to-face meetings between politicians and public servants of different countries. This high level of connectedness meant that, more than ever, most issues were global, as solutions applied to social, economic, or environmental problems in one country or region had major social and economic impacts on other countries and regions.

There were some counter-trends to this early globalization,[2] but some early successes in dealing reactively with these challenges through cooperation and the application of social or technological solutions increased the global majority's faith in globalization. These successes increased confidence, at least among the dominant countries, that money, technology, and human ingenuity could fix any problem that arose and that the benefits of a global community far outweighed the costs.

8.3.1.3 Focus on Social and Economic Policy

At the beginning of the twenty-first century, there was a wide variety of views about how to solve the world's problems. Since the mid-twentieth century there had been forecasts by some ecologists that natural resources were declining to critical limits.[3] The concept of resilience (see Box 8.3) had emerged to explain the way in which the complex interactions among species in ecological systems allow those systems to absorb perturbations and keep functioning. At the turn of the century, a major multi-partner multidisciplinary appraisal of the world's ecosystems, the Millennium Ecosystem Assessment, made use of the popular concept of ecosystem services as a focus for its assessments of how trends in ecosystem function might affect human welfare into the twenty-first century.

This assessment gave examples of emerging ecological disasters,[4] but many believed that smart policies and technological solutions could fix these problems as they arose, and pointed to examples of how this had been done in the past. This was a time of strong confidence in people's ability to take charge of their own destiny. The predominant attitude among wealthy and powerful countries, the development community, and international organizations was that a rational application of knowledge about economic and social

BOX 8.3

Ideas about the Resilience of Ecosystems and Society
(Adapted from the Resilience Alliance at www.resalliance.org)

- The systems that include people interacting with the environment rarely remain in a single, unchanging state. Shifting among alternative, distinctly different states (over various time periods, depending on the system) is the norm, not the exception.
- Surprises in these systems are created in cycles of long phases of increasing growth, efficiency, and predictability followed suddenly by brief phases of reorganization.
- Resilience is the capacity of a system to absorb disturbance, undergo change, and still retain essentially the same function and structure.
- Variability and flexibility are needed to maintain the resilience of nature and people. Attempting to stabilize such systems in some perceived optimal state (the command-and-control approach to management), whether for conservation or production, reduces resilience and often achieves the opposite result of driving a system toward rapid change.

processes would not only achieve economic growth but would also make sure the benefits flowed throughout societies. The emphasis of these reforms was on creating markets that would allow equitable participation and provide open access to goods and services. Transparent governance systems, like participatory democracies, were seen as the necessary foundations to economic growth.[5]

Occasional failures, though, brought up questions about how resilient ecosystems really are and how to balance this uncertainty with the lost economic and employment opportunities that could arise if the environment were protected more than it needed to be. At the time, these questions could not be resolved because the information was not available for most ecosystems. As time went on, investment in obtaining this sort of information waned because no major ecological disasters were apparent and it appeared that ecosystems could withstand anything that people did to them (subsequently it was found that this was often due more to luck than good management).[6]

It was becoming clear that the dream of a better world built on a foundation of reformed social and economic policy would live or die depending on how several major challenges were addressed. (See Box 8.4.) Wealthy countries, and especially the large corporations based in them, were optimistic that improving the flow of financial capital to poorer countries would lead to beneficial social reform and would encourage both demand for sustainable management of the environment and the development of appropriate institutions to achieve sustainable economic growth. But many people in poorer countries were concerned about an overly rapid inflow of financial capital before formal and informal institutions were ready to cope. This, they feared, would undermine maintenance or enforcement of environmental protection, encourage inflow of materials and practices harmful to the environment and people, and lead to overexploitation of natural resources to capitalize on new opportunities and to pay for debts incurred when foreign investments go wrong.

The hopes for resolving these issues rested on various multinational negotiations to seek agreement on rules of trade and environmental management. A measure of global agreement about the need to work together to address issues of environmental and human welfare had emerged from the Rio and Johannesburg Summits in 1992 and 2002.

8.3.1.4 Promising Developments

A number of small but hopeful examples of successful international cooperation in Asia, Africa, Europe, and the Middle East in the years either side of 2010 built confidence in the connected-cooperative model. This confidence tipped the balance of world opinion toward global cooperation. The United Nations, with renewed confidence, reinvented itself as an organization primarily focused on promoting social and economic equity and relinquished its role as an international peacemaker and policing body.

Quietly, China addressed its long-standing environmental problems, including dismantling of unsustainable and polluting industries.[7] It took the first major steps to address desertification and began to develop agricultural and other industries in its western provinces based on ecological principles. Its economy continued to grow, accompanied by social reforms that developed a peculiarly Chinese form of participatory democracy,[8] which took until late into the 2020s to really become entrenched.

India continued its economic growth, which started toward the end of the previous century and would not plateau until the 2020s. This growth was largely due to innovation in communication and information technologies and services.

In Africa, the widespread unrest and instability of the early 2000s continued until around 2010. By this time, the growing prosperity of a few nations allowed them to make virtuous investments to assist their neighbors. These initiatives spread slowly through Africa, as national leaders united to develop cooperative policies for dealing with disease and poverty and to strengthen the continent's trading position globally. Despotic leaders were encouraged to stand down, and participatory democracy began to develop in many countries throughout the 2010s. Some African cities became centers for innovation in digital technologies.

Changes in these three places encouraged governments and private investors in rich countries to increase their investments in improving the wealth and well-being of poorer countries.

In Europe, Russia became more accepted as part of the European community, and the threat of conflict in the Balkans decreased as all nations worked hard at maintaining cooperative and friendly relations.

BOX 8.4

Branch Points for a Globally Orchestrated World

This scenario is moderately optimistic about a globally orchestrated world. This reflects the belief of several members of the Working Group in what reform to global social and economic policy can achieve. Others find it easier to imagine disastrous outcomes from this scenario. The nature and quality of outcomes depends on a number of critical challenges being overcome. These can be likened to the world taking the right paths or branches in a journey by road or river.

Critical branch points include:

- Whether globalization and trade liberalization are accompanied by strategies for developing appropriate institutional arrangements in poorer countries and for avoiding undesirable activities by richer countries and corporations
- Whether global cooperation, including globally consistent standards for health, business, and intergovernmental relations, is developed without losing or threatening cultural diversity, including culturally appropriate approaches to democracy
- Whether ecosystems reach critical thresholds resulting in adverse changes that happen too fast or too extensively for reactive remediation to be effective
- Whether dominance of intellectual property by a few countries is substantially reduced—if not, global cooperation is much less likely to be achieved or maintained
- Whether ways are found to reduce the heavy debts carried by poorer countries

8.3.1.5 Environmental Issues Overlooked

With the strong focus on economic, social, and political issues throughout the 2000s and 2010s, thinking and research into the dynamics of socioecological systems proceeded only slowly. Things were going well for many people. Ecologists and environmental activists were still saying that society existed at a dangerous edge, but they had been saying this for a long time and, so far, most things had gotten better. It gradually became easier and easier to ignore their calls for stricter controls and more caution with respect to the environment.

Although the mantra of the 2000s was ''triple bottom line,'' the environment was considered to be secondary to, and reliant on, economic and social issues. By 2015 it was becoming clear that information on the meaning and state of sustainable development was lacking and that public understanding of the underlying issues had been allowed to remain at a very low level. It had been assumed that increased income and access to the consumer goods of the day would improve the confidence and happiness of the public, but people were beginning to suspect that this was only true up to a point. As people's material well-being improved, cultural issues like identity, spiritual connection with the land, and harmony with other life-forms began to dwell more and more on their minds. Additionally, while people were able to reverse some environmental problems when they became wealthier—like local air pollution caused by factories[9]—there were other environmental problems, such as toxic waste, that did not appear to be easily fixable. The best they could hope for was to become wealthy enough to move away from the waste.

Thus the decade 2010–20 saw renewed efforts to address the environment directly, but progress was slow because information about how ecosystems worked was scarce.

8.3.2 Global Orchestration 2015–30

8.3.2.1 Improving Globalization by Including More Cultures

Starting in the late 2010s and continuing into the 2020s, a slow but vital process of change in world thinking happened. Up until then, increasing connectedness of the world had seen western culture, language, and thinking permeating other cultures, with little return of information in the other direction. The belief that western values and styles of governance were universally appropriate and beneficial had grown stronger.

There were, however, growing numbers of people voicing concern about global homogenization of culture and values. The improving economies of Asian, African, and Central European countries brought increased confidence in questioning the desirability of universal styles of governance and beliefs.

By 2012, these trends and concerns led to a flurry of international meetings to contemplate better ways of global governance. Models were sought from times in the past when economic prosperity was achieved while diverse cultures coexisted.[10] Using these, people recognized that everyone requires cultural identity and security as well as wealth and that cultural identity can be supplied in diverse ways throughout a country's development.

This was no sudden change in world values. The lessons were learned slowly and sometimes painfully. It was eventually realized, however, that global markets and the continued economic growth of both rich and poor nations could only be achieved by allowing the return to diverse regimes and values but within globally agreed rules of engagement between countries.

From then into the 2020s, there were changes in many cultures. For example, the western business community adopted a more Asian approach to business, with relationships, respect, cooperation, and trust becoming more prominent than they were in the highly competitive first decade of the century. Countries with large proportions of populations living in high-density urban or rural settings saw big changes too, as global institutions demanded uniformity of community health standards, business practices, and governance for reasons of health, security, and distribution and management of foods, building materials, and fuels.

A major unstoppable force that encouraged nations to work together was technology. Since the first transatlantic telegraphic cables were laid in the second half of the nineteenth century, nations had seen the benefits of sharing technologies. One country doing something in a unique way could find itself isolated from the rest of the world and might lose out on trade or other benefits of globalization. Technological developments, especially with respect to agriculture,[11] food production, and energy generation, became more and more rapid as the twenty-first century unfolded.[12] Many of these arose from Asian, South American, and African countries, which had been investing in innovation for two decades or more and were less constrained by existing technologies than countries that had been developed for longer. As these technologies became used widely, it was critical for countries to work together to form accepted ways of using them. No one wanted to be left behind.

8.3.2.2 Global Health Concerns

Increases in wealth, and in the availability of technology, had led to improvement in the health of people in many poorer countries. However, many problems still remained. Obesity-related diseases remained a threat, particularly in rapidly developing areas as new food choices became available and societies shifted their eating habits to less healthy styles. Emerging infectious diseases were also a risk. Several times, new pathogens arose in parts of the world where ecosystems were suddenly exposed to massive human impacts. Decline in the natural processes for regulating animal populations, together with greater visitation and exploitation of wildlands by humans, caused humans to be a frequent host for these new pathogens. In some cases, deaths from these new diseases were limited to a few hundred people, and the spread was contained around the source by international cooperative action. The mechanisms for this action were progressively refined from the impressive responses to SARS in 2003. But in each case, industries related to international tourism suffered economic downturns

as the scare of spread via travelers and transportation systems swept the world. Increasingly, there were concerns that social progress was being delayed by environmental decline feeding back on human well-being.

The international health community was concerned about the emergence of new pathogens due to close human contact with animals, as occurred with SARS in China in 2003. Impressive international procedures were put in place to prevent, detect, and cope with outbreaks of this sort, led by the United Nations in its redefined role as a human welfare agency. Risk of such outbreaks remained high due to high global mobility of people and goods and varying standards of health monitoring and sanitation. Some attempts to promote (or impose) uniform approaches and standards met with resistance and resentment when they threatened the rural-, village-, and family-focused cultures in poorer countries, especially Asia and Africa. Countries had long been exposed to progressive acceptance of trade and migration policies emphasizing global cooperation, however, and they often agreed to these procedures to minimize disease risks, especially after seeing the problems caused by outbreaks of disease.

High global mobility was also a concern because it threatened to move exotic species around the world. The possibility of spreading crop and livestock pathogens was of major concern because enthusiasm for opening borders and removing trade barriers outstripped research and monitoring.[13] Increasingly, the role of maintaining functional ecosystems that regulate pest populations was being recognized, but the costs of returning ecosystems to functionality were now very high.

8.3.2.3 Removal of Some Lingering Barriers to Global Equity

Several other barriers to increased equity among nations were addressed around this time. There had been hope that high debt loads carried by developing countries in the 2000s would be reduced by 2015 with the new trade policies and loan restructuring. But setbacks due to the costs of implementing new health security policies gave impetus to calls for writing off a proportion of these debts. These calls had previously remained subdued due to the hope that improved access to international markets would help poor countries pay off their debts. The ever more apparent impacts of global climate change increased pressure on countries as well as corporations to take remedial action. Between 2015 and 2020, around 50% of the debts of the developing world were written off in exchange for carbon credits.

8.3.2.4 Pluses and Minuses of the New Trade Order

The benefits of open trade became apparent early, as countries providing temperate-zone agricultural products, such as certain cereals, meat, and milk, realized the economic benefit of better market access and less distorted market prices. As new market opportunities emerged, economic growth improved in some countries of the Americas and in a number of Southern and East African countries. Agriculture in these countries became increasingly intensified and simplified. The economies of scale were initially very beneficial to economic growth in these countries. With a mixture of international competitiveness and cooperation, the areas under agriculture expanded in some countries and receded in others.

Developments with respect to trade were not all rosy, however. Countries that relied mainly on export of tropical crops such as coffee and cocoa did not necessarily get any benefit from improved trade opportunities. Economic growth in this group of countries depended on additional opportunities for diversification of the economic base. In many cases, these opportunities were held back by slow development of policies aimed at improving human capital and infrastructure.

8.3.2.5 A Moderate Greening of Attitudes

As prosperity among the global middle class increased, so did demand for cleaner cities, less pollution, and a more beautiful urban environment. In most countries, this led to efforts to maintain green spaces and protect representative areas of natural environment for people to visit. Pollution in and around cities was addressed with vigor. Before the need for communication towers disappeared, it became global best practice to disguise these towers as artificial trees. Some children grew up to think pine trees really are 200 meters tall. Amusing as it sounds, this was symptomatic of a general lack of appreciation of the need to understand the processes that maintain natural systems. We now realize, however, that longer-term ecological challenges that were harder to address were more or less ignored by the general population because so many other things were going well. Examples included the slow rundown in fertility of agricultural soils, decline in natural controls on pests and diseases, and the slow loss of wildlands and their biodiversity.

The nongovernmental organizations that played such a strong role in raising human consciousness about the environment during last century had waned in their influence by this time, as public confidence in the ability of governments to solve the world's problems increased. The groups still existed, but they focused more on human well-being issues and addressing immediately obvious environmental challenges.

8.3.2.6 Agriculture: Expanded Area But Narrower Diversity and Ecological Basis

Driven by policies aimed at increasing GDP and human well-being in poorer countries, human impacts on terrestrial ecosystems increased as the total area under agriculture expanded.[14] The world was focused on generating employment and feeding a growing population. Since the turn of the century, many had argued that hunger was a problem related to equitable distribution rather than an absolute shortage of food. Distribution and equity issues were steadily addressed, but increasing the area under agriculture was the faster, and therefore the preferred, option among most communities in the meantime.

Since late in the twentieth century, large transnational companies had been steadily increasing their control over agricultural crops and livestock through the development of new genetic strains with improved performance. Economies of scale caused fewer and fewer varieties to be distributed over larger and larger areas, leading to agricultural specialization and simplification. In both the richer and the poorer worlds, very little of the agricultural land was not consolidated into large, highly mechanized industrial farms. There were still people practicing low-intensity farming, either as a lifestyle choice or in areas of marginal land quality and economic hardship, but they contributed little to food production or the countries' economies.

While these trends initially brought economic efficiency and growth to many countries, others suffered because their local conditions did not suit the mass-distributed varieties and their market was not large enough to encourage the industries to develop locally appropriate varieties. Many commentators at the time were concerned about loss of local ecological knowledge. The prevailing policies for dealing with natural genetic diversity and other natural assets like vegetation and soil systems and their associated fauna was to preserve or reserve representative examples in parks and museums. A positive legacy of these policies was the establishment of major gene banks containing the vast majority of wild varieties of crops previously used by humans.

8.3.3 Global Orchestration 2030–50

8.3.3.1 Broken Stranglehold on Intellectual Property

By 2025, a major international tension that had been growing since the early 2000s came to a head. Had this not been resolved, the world could not have continued down a path of increasing cooperation.

In the last decades of the twentieth century and into the 2000s, a complex web of laws and regulations relating to intellectual property had developed worldwide. This had many impacts on attitudes toward and management of the environment. For example, it led to the dominance of the market for seeds and stock varieties by large multinational companies that could impose rules and regulations that often discouraged the use of locally sustainable varieties and practices. Genetic diversity declined, and wild varieties largely existed in museums. Dominance of intellectual property was maintained by formidable networks for commercial intelligence, and wealthy nations were more able to attract the best minds from poorer countries. Furthermore, the culturally diverse nations of Asia, Africa, the Middle East, and even, to a degree, Europe could not speak at this time with a strong and uniform voice.

Things were changing, however. The growing unity within Europe, Asia, South America, and Africa by the mid-2020s, together with the increasing impacts of developing nations as innovators and participants as consumers in global markets, forced a review of patent and intellectual property institutions.[15] (See Box 8.5.) While the changes were not wholesale, they were enough to allow local pharmaceutical, genetic, and nanotechnological industries to establish with a focus on regionally differentiated markets. In small but significant ways, the brain drain started to reverse. These trends were gradual but consistent starting in the second quarter of the twenty-first century.

8.3.3.2 Benefits and Risks of Global Orchestration

By 2030, most elements of the strategies for global economic and social reform were in place. Many countries and individuals had realized enormous benefits from globalization. Impacts on ecosystem services were variable but mostly either neutral or improved in poorer countries.

But big challenges have also emerged by 2050. During the last two decades the balance of benefits and costs of the globally orchestrated policies of this half-century has become clearer. Most countries have prospered under the economic and policy plans put in place in the mid- to late-2000s. Overall, advocates of the principle that economic growth produces improvement in human well-being feel themselves vindicated by the state of the world in 2050. Their opponents suggest that economic growth was only achieved without major collapses in Earth's life-support systems because massive efforts were put into reducing environmental impacts as problems arose. The costs have been major in all nations.

The unprecedented enthusiasm for global cooperation among governments, NGOs, and companies was spurred on by early successes in dealing with conflicts, diseases, and global equity issues in the early part of the century. This helped the world cope with a number of important social and environmental issues that economic growth alone could not have dealt with. Limiting population growth to a maximum of 8 billion by 2050, which was largely a consequence of economic development in the previously poor world, also helped to limit environmental impacts.

In our globally orchestrated world, we have seen great technological progress within the energy sector, which has provided low-cost energy for all people with a high level of reliability. But early global complacency about climate policy forced us to adapt to many problems caused by climate change, even though the institutions for global cooperative action could have addressed the problem earlier.[16] In hindsight, we realize that the slow response to climate change was a major missed opportunity.

Increasing prosperity brought increased demand for meat in people's diets, which in turn led to growing demand for food and feed and a rapid expansion of crop area in all regions. Particularly hard hit was sub-Saharan Africa (see Box 8.6), which saw 50% of its forests disappear between 2000 and 2050. In the early 2000s doctors in the industrial world were concerned about an obesity epidemic. Steps were taken to encourage greater levels of activity and low levels of fat consumption. This was outweighed glob-

BOX 8.5

A Story of India (Global Orchestration)

As I wait for the Australian to arrive, my thoughts turn to the changes I have seen in my lifetime. India is one of the leading economies in the world of 2050. Americans, Brits, Germans, Russians, South Americans, Africans, and more are looking to build partnerships with us and learn from our successes.

In my mother's youth, the world's teenagers yearned for American clothes, music, appliances, movies, and the like. India, of course, always resisted the global culture. Our attitudes to life and death, wealth and poverty, were never well understood by westerners. Whereas we look at those worse off and feel thankful, Westerners look at those better off and feel envious. True, we have been touched a little by the global culture of envy—at least according to my aunt. The huge popularity of Indian literature and movies early this century was just one sign of our ascendancy. We invested in business and technological innovation, starting with call centers last century, which gave us the confidence to innovate in many other fields. Now India, China, Brazil, and a handful of other growing economies are influencing global consumerism and global culture. In Paris, every second young girl I saw was wearing *salwar kamis* (Indian clothing).

As a woman, I am privileged to have received a good education. When I was born in 2010 the girls in poor rural towns like ours didn't go to school—it was too expensive and they had women's work to do. But by the time I was old enough to attend there were places in schools for girls whose families wanted them to go. Education of girls was starting to be seen as an investment in a "more prosperous future"—the slogan of the government change-programs when I was growing up. In many places the new philosophy has worked. Of course the young people, like me, usually had to move to the cities to get jobs, but at least the jobs were there.

"Rural life" has changed so much. When I go home to visit my brother, all I see is field after field of rice, sometimes a bit of maize, but that is all. Boring. The harvests are bigger and better some years, but they still fail regularly. The changing weather has brought bigger extremes of hot and cold, wet and dry, and storms that wash away our topsoil. Locally, pests and diseases break out from time to time, and no one seems to be expecting them. Our government played a major role in international efforts to address existing global issues like climate change and international fisheries. But at home it expected economic prosperity and good education to be enough to fix environmental problems. The government was right sometimes, but when it was wrong it hurt many people. My cousin drowned in the big floods of 2015, along with 200 others from our district.

The company I work for now was started in 2012 by two young Indians who trained in the United States and returned home as new opportunities arose here. Southern India was booming, and at one time it even seemed like it might break away from the north. But the two Indias stayed together, in the spirit of cooperation that was spreading the world. The company survived that first decade as trade arrangements and intellectual property regulations were sorted out in sometimes strained negotiations between established and emerging powers. I joined them first as a trainee in 2028 and then as a graduate after 2032. I didn't stay long, changing jobs 10 times and retraining with new skills four times before returning as a senior manager in 2043.

So what do I tell the Australian about Indian attitudes and tastes today? In the cities we want cleaner streets and more green areas, but the environmental researchers tell us we still don't understand the essential role of nature in our lives and economy. My company is seen as a leader in socially responsible production. We've minimized our environmental damage, too. But now the government is looking for industry leaders to help develop an environmental repair program as the costs of complacency over the past decades are biting back. The Australian's company is in the same situation in his country. Environmental repair looks like it will be the next big growth area.

It is good to be on a new wave again. Still, I can't help wondering why we didn't see this one coming sooner.

ally by the spread of obesity-related illness through the now rapidly developing countries of Asia and Africa.

Increased irrigation and intensive inputs of fertilizers and chemicals for control of agricultural pests, combined with low levels of environmental protection, led to compounding cross-scale interactions among outbreaks of resistant pests, groundwater contamination, soil degradation, and accumulation of nutrients to toxic levels for crops and water sources for humans.[17]

Between 2030 and 2050, many of the world's fisheries collapsed. While there was at least superficial global cooperation in managing species, open borders and reduced trade barriers led to insurmountable obstacles to effective monitoring of stocks. In turn, there was uncontrollable exploitation and overfishing of many stocks. Because the dynamics of fisheries are complex, problems were often not noticed until after they were so severe that they could not be fixed.

The reactive nature of environmental management resulted in a number of cases of regional ecological degradation that were difficult, costly, or even impossible to recover from. Marine ecosystems and coastal wetlands were affected most strongly, as urban growth in virtually all countries with coastlines and moderate climates was concentrated around river mouths and along a 100-kilometer band off the coastline. Tourism and fishing in the Caribbean, for example, both declined after the loss of many coral reefs. In Australia and Africa, the tourism industry took heavy hits due to almost complete loss of coral reef ecosystems. During the 2010s, aquaculture industries worldwide were threatened by pollution and sediment run-off from increasingly urbanized coastlines in virtually all countries. Technological solutions were developed and implemented in the 2020s, but the industries did not recover until the early 2030s. And the global impacts of invasive species increased the costs of timber and agriculture and decreased people's well-being.

8.3.4 Challenges for 2050–2100

In reviewing the years 2000–50, we are struck by how far the world has come, how much has changed, and yet how much stays the same. In 2000, debate was intense around the relative merits of economic growth, global open trade, and social equity policies versus the alternatives. Today, the debate goes on, although many believe we did the right thing entering a path of increased globalization. We have seen many benefits of these policies but have also felt the distress of lost opportunities. We must ask whether similar

BOX 8.6

Sub-Saharan Africa under Global Orchestration

As the world moved into the twenty-first century, the growing focus of decision-makers on poverty and inequality as sources of conflict and civil unrest drove greater attention and openness toward the economies of sub-Saharan Africa. Countries like Ghana, with a growing pool of educated labor, became prized sites for the outsourcing of data entry jobs, such as the cataloguing of parking tickets from New York City. Yet Ghana, along with Botswana and a handful of others, was attractive not only for its educated population, but for its successful transition to democracy after an extended postcolonial history of coups and dictators. The success of participatory democratic institutions in places like Ghana reassured businesses seeking to invest, and therefore worked in concert with initiatives sponsored by governments of the industrial world, such as the U.S. African Growth and Opportunity Act, to drive investment in these economies.

Such investment spurred economic growth in several sub-Saharan African nations and, with it, the development of a middle and an upper class with sufficient education and financial resources to spend time worrying about the degradation of their national environments. These countries funded environmental assessments and studies, gave priority to issues like deforestation, and promoted the sustainable use of their natural resources. At the national scale, these efforts gained momentum as several countries funded environmental preservation and management programs with the money saved when at least half of their external debt burden was forgiven in debt-for-carbon-credits trades.

The remarkable progress of these nations, however, must be considered in light of the important divisions that arose across the period 2000–50, both within countries and between them. Within the most successful countries in sub-Saharan Africa, the rural-urban divide was heightened by the increased educational and economic opportunities afforded to those living in the cities and by the concentration of decision-makers in urban areas. In many cases, environmental management projects were designed at the national scale by urban residents, with little or no consideration of the local, rural livelihoods likely to be affected by such projects.

Thus, the establishment of forest reserves in Ghana's Upper Guinea Forest effectively displaced tens of thousands of Akan farmers reliant on swidden agriculture for their subsistence from "preserved areas" into unprotected parts of the forest. This displacement had two important results. Environmentally, the result was a patchwork effect, where protected parts of the forest flourished and unprotected parts were heavily degraded by increased agricultural pressure. Socially, the rural poor felt less and less connected to their national decision-makers, and therefore less and less a part of the national project. In countries like Ghana and Botswana, the development of a national identity was a key part of their political and economic success at the turn of the twenty-first century. The internal divisions driven by this success, though, threatened this identity, and therefore the very foundation of that success.

If intranational tensions are important to discuss, so too is it critical to note that economies and political systems such as that of Ghana and Botswana were not the norm in sub-Saharan Africa. The incentives of the U.S. legislation were not extended to many nations that failed to develop political transparency and pluralism, in effect reinforcing the concerns of business seeking to invest in this region. Thus while some countries saw unprecedented growth and opportunity in the period 2000–50, others were caught in a cycle of decline and closure in which authoritarian governments were shut off from the globalized world, and the people under them were closed off as well. This process then created a patchwork effect at the regional scale, where successful countries often directly abutted one or more "rogues" or "failed states." The improved conditions in the stable states encouraged immigration, which no sub-Saharan African state had the resources to control.

These surges of migration, driven by conflict and by dramatic environmental shifts in Southern Africa, heavily stressed successful countries, causing some to experience political failures as migrants swelled the ranks of the disaffected rural people, sparking intranational conflicts. Even in the best cases, such migration stressed the capacity of successful states to manage their economies and environments, limiting their success and suggesting trouble on the horizon for even the most stable and successful nations.

benefits could have been achieved with fewer losses of life, property, and human well-being if greater attention had been paid to the ecological underpinnings of our economic and social systems. There are those who argue that we have been too ready to accept economic signals as signs of progress and too quick to assume that success in tackling fast-moving ecological variables is evidence that we are making the right choices.

8.3.5 Insights into Global Orchestration from a Southern African Perspective

In the Southern Africa Focal Region Assessment, several scenarios were developed that dealt with aspects of Global Orchestration. African Partnership is an economic development scenario and Policy Reform explores policies for intensification of agriculture. Global Orchestration includes, but is more than, these scenarios. Its drivers are not just economic development and agricultural reform but also broader social reform, including protection of global public goods like education, health care, and safety. Nevertheless, the issues explored in the Southern Africa scenarios are relevant to Global Orchestration and give insights into how such a scenario could play out at a sub-global scale. (See Box 8.7.)

8.4 Order from Strength

In this scenario, the world becomes progressively compartmentalized as governments and then businesses and citizens turn their focus inward in response to threats from global terrorism and the breakdown of several processes involving global cooperation. People see looking after their own interests as the best defense against economic insecurity. Citizens reluctantly accept the argument that a militarily and economically strong liberal democratic nation can maintain global order and protect the lifestyles of the wealthy world and provide some benefits for any poorer countries that elect to become allies.

In a fundamental departure from the early twenty-first century, even rhetoric about the importance of trade liber-

BOX 8.7

Insights in Elements of Global Orchestration from a Southern African Perspective

Under the African Partnership scenario in the SAfMA regional assessment (see MA, *Multiscale Assessments*), high economic growth is underpinned by the intensification of agriculture, using highly selected seeds (including genetically modified organisms), irrigation, pesticides, and fertilizers. This boosts productivity, relieving pressure to cultivate new lands. Regional-scale food security is greatly improved, but water pollution and pressure on water supplies increases.

A dominant focus on commercially grown cash crops and a strong linkage to the global economy marginalizes small growers and impoverishes agricultural diversity. Consequently, vulnerability to pest outbreaks grows, and together with an increased frequency of droughts and floods resulting from climate change leads to large swings in cereal production and intermittent food shortages. Rising wealth accelerates a higher dietary demand for meat products, largely satisfied by expanded cattle ranching north of the Zambezi. Reduced pressure for land facilitates the development of an extensive system of state, private, and community-protected areas, which forms the cornerstone of a growing tourism sector, serving both foreign visitors and a growing urban middle class. Good land management practices outside of protected areas contribute to the maintenance of biodiversity in the region.

Under the Policy Reform scenario in the Gariep basin, consequences of the recent policies on agricultural intensification (GMOs, irrigation, pesticides, and fertilizers) for ecosystem services in the basin are mixed. This intensification is met with some resistance from health and environmental advocates and from small farmers unable to invest in these inputs, yet organic farming practices are also on the rise. Overall, productivity is boosted, and the expansion of agriculture onto marginal land is prevented. Food security across the basin improves. Pressures on water supplies increase, but an effective system of water tariffs, together with the establishment of catchment management agencies, now ensures that irrigators are accountable for their abstractions.

Cash crops are widely produced by commercial farmers who trade in a global economy but, due to past biodiversity losses, these are based on an impoverished genetic stock. This marginalizes small growers except for those who are linked to designer markets, such as organic farmers. This makes the crops more vulnerable to pests and diseases and the more frequent occurrence of droughts and floods precipitated by climate change. Intermittent food shortages occur but do not threaten food security in the basin. Intensive livestock production—batteries and feedlots, for example—becomes more common across the Gariep. A drive toward more-intensive meat production leads to an expansion of game farming operations in the basin, thereby creating a link between protected areas. Reduced pressure for land means a more positive outlook for conservation in general.

alization disappears in a backlash against globalization, which is seen as a source of instability and threats. (See Box 8.8.)

Just as the focus of nations turns to protecting their borders and their people, so too their environmental policies focus on securing natural resources seen as critical for human well-being. But they see the environment as secondary to their other challenges. They believe in the ability of humans to bring technological innovations to bear as solutions to environmental challenges after they emerge.

8.4.1 Order from Strength 2000–15

8.4.1.1 Teetering between Fragmentation and Connection

The beginning of the twenty-first century saw the world teetering between getting more connected and becoming fragmented and compartmentalized. There was cause to be optimistic about world peace and prosperity, but leaders were unsure whether a focus on open interactions with other countries or an inward focus on national security would achieve the best outcome for their people.

With the collapse of the Soviet Union and destruction of the Iron Curtain, a major source of potential global conflict was removed.[18] Globalization of technology, travel, and economic markets, which had been progressing apace in the second half of the twentieth century, was reaching its peak. There were high expectations from multi-nation negotiations of the early 2000s that progressive liberalization of trade and the movement of people would decrease the gap between rich and poor countries and universally improve human well-being.

The world was getting superficially more and more connected. Electronic communications were spreading to more and more homes. Air travel was becoming faster and more affordable.

But conflict and terrorism, together with stagnant economies, were pressing problems on the agendas of global and national decision-makers. Many believed that social tensions arising from inequalities in wealth, civil liberties, and access to food, water, and other basic human needs were the root cause of these problems.

Nations were also wrestling with issues of equity internally. Everyone agreed in principle that all citizens should have access to the fundamentals of a healthy and fulfilling life, but there were many difficulties with achieving this. It was so easy to just leave a few people behind and so difficult to bring everyone up to the same economic standards. Would political will be strong enough to overcome vested interests and public indifference? Furthermore, would the emerging trend toward globalization of markets work for or against equity for the poor and disempowered within and between countries? Would the removal of barriers to trade and the international operations of business allow developing nations to improve their economies and social processes? Or would it allow domestic processes to be dictated by corporations who wanted low inflation and high returns on investment?

8.4.1.2 Fear of a Fragmented World

Around the turn of the century, futurists wrote scenarios that imagined a world in which inequity is unchecked, where the rich get richer and protect themselves and their assets with walls and razor wire while the poor get poorer and seek to break down the walls.[19] The stories portrayed a scary world in which civil society eventually breaks down and conflict is widespread.

BOX 8.8

Potential Benefits and Risks of Order from Strength

Potential benefits:

- Increased security for nations and individuals from investment in separation from potential aggressors
- Increased world peace if a benevolent regime has power to act as global police
- Less expansion of invasive pests, weeds, and diseases as borders and trade are controlled
- In wealthy countries, ecosystems can be protected while degrading impacts are exported to other regions or countries
- Ability to apply locally appropriate limits to trade and land management practice, as trade is not driven by open and liberal global policies
- Protection of local industries from competition

Risks:

- High inequality/social tension, both within blocs and within countries, leading to malnutrition, loss of liberty, and other declines in human well-being
- Risk of security breaches (from poor to well-off countries and sectors of society)
- Global environmental degradation as poorer countries are forced to overexploit natural resources and wealthier countries eventually face global off-site impacts like climate change, marine pollution, air pollution, and the spread of diseases that become too difficult to quarantine
- Lower economic growth for all countries as poor countries face resource limitations and rich countries have smaller markets for their products
- Malnutrition

Nobody wanted such a world. In fact, many refused to believe it was even possible. Yet many of the ruling elite in governments and businesses of the time practiced a form of controlled inequity, believing it to be both inevitable and desirable for economic growth. They had faith that they could control inequity within limits that would encourage the poor to consume in an effort to improve their economic position and would prevent widespread disruptive action.

And yet, as the century turned, the wealthy of most major cities around the world had bars on their windows and were protected by fences topped with razor or electrified wire.

8.4.1.3 The Fragmentation Escalates

The optimism of growing economies in the industrial world at the beginning of the century was deflated by a series of international events, including the attacks on the World Trade Center in 2001 and continued conflicts in the Middle East, Africa, and South Asia. These conflicts drove headlines and contributed to pessimism about future international relationships. Trust in other governments declined universally, as countries turned their focus inward to maintain their national security, access to resources, and the well-being of their own people.

Despite reforms in Russia and other former Soviet countries, there was ongoing friction with the United States and a number of European countries. The Balkans remained unsettled, and the role of Turkey in Europe was not getting any clearer.

At the same time, governments of the industrial world reluctantly accepted the argument that a militarily and economically strong liberal democratic nation could maintain global order and protect the lifestyles of the wealthy world and provide some benefits for any poorer countries that elected to become allies.

This mix of distrust in outsiders but belief in order from strength became clear in the debates in the global forum for addressing international issues of the time, the United Nations. Former allies undermined one another, and it was clear that domestic issues rather than international ones drove the agendas of the participating countries. Despite the efforts of many who believed that the world needed global cooperation more than ever, the trend toward inward focus on national security issues continued and intensified throughout the first decade of the twenty-first century.

Economic issues contributed to the fragmentation that had been started by national security issues. After the financial excesses of investing in Internet startup companies at the end of the previous century, and a mini global recession stretching into the first decade of the twenty-first century, the industrial-nation economies did not rebound. Many East Asian economies continued to suffer from the after effects of the Asian financial crisis of the 1990s.

But with the growth of digital technologies a new source of fragmentation emerged—the so-called digital divide. Some Asian, South American, and African nations took a lead and established digital networks across their whole countries. This did not guarantee economic success, but it did give them an edge in many aspects of business. Increasingly, countries that had dropped behind in this digital revolution found it hard to maintain cohesive and adaptive networks among industry groups, resulting in lack of competitiveness in markets.

The digital divide not only applied to the gap between poorer countries. Even some wealthy countries failed to get connected fast enough and found themselves on the wrong side of the divide. Within countries, too, people varied greatly in their access to computers and networks and this affected their life choices, financial prospects, and even their freedom and ability to make informed decisions. In poorer countries, some elites managed to get connected to the wealthy in the rich world through technology.

A key turning point was the trade negotiations set up by the meetings of trade ministers from around the world in various cities between 1986 and 2001 leading to the creation of a World Trade Organization. These negotiations addressed a wide range of issues, including setting up a fair and market-oriented global trading system for agricultural goods, market access to nonagricultural goods and services, and fair dealing with respect to intellectual property, especially with respect to indigenous knowledge and implications of intellectual property for public health. During 2003–10, these negotiations ran into deadlock as a number of rich countries could not find a mutually satisfactory mechanism to reduce trade barriers and domestic subsidies,

and several poorer countries began to stand their ground on these issues. In 2010, the World Trade Organization collapsed because the most influential nations no longer believed in trade liberalization.

The collapse of the negotiations soured political relationships among OECD nations and between those nations and the developing world. Further negotiations on access to markets, intellectual property, and the responsibilities of poorer and richer countries did not materialize. Rules and standards for intellectual property and digital communications, which could have been used as a tool for maintaining international equity and peace, rapidly became tools for drawing the best minds into the richest countries and for restricting access to markets. Large and innovative poorer countries flouted the rules and established their own standards. Corporations based in rich and powerful countries minimized investment in those nations, except where they could export profits to the country where they were headquartered.

The tensions already apparent among members and prospective members of the European Union early in the century were exacerbated during 2010–15 by the increasingly inward focus of nations. Negotiations about enlargement of the EU took longer than planned and took most of the attention of senior EU politicians, especially since global negotiations seemed to be going nowhere. The economies of the EU countries suffered from a prolonged downturn that further reduced the flexibility of its leadership in global negotiations in a variety of forums.

8.4.1.4 A Fragmented Approach to the Environment

Just as the focus of nations turned to protecting their borders and their people, their environmental policies also focused on securing natural resources seen as critical for their people. Among rich nations there remained belief in the ability of humans to bring technological innovations to bear as solutions to environmental challenges as well as confidence that a strong economy could afford the costs of that innovation. Natural environments were seen as providers of some critical services, like regulation of climate and the oxygen level in the air, but most other benefits from ecosystem services were believed to be either substitutable or repairable by technology. For example, everyone knew that water ultimately came from nature; during this time, however, the widespread belief was that water cleansing could be done better by human-powered technology than by use of preserved ecosystems.

In affluent nations, maintenance of biodiversity for its recreational and existence values was seen as an affordable luxury, one that people believed could be maintained by reservation of comprehensive, adequate, and representative samples of remaining ecological systems—so long as those reservations did not impinge on economic development. While governments claimed that these were proactive environmental policies, they were in reality reactive ad hoc solutions to growing public concern about declining species numbers. As the first decade of the century rolled on, the ad hoc measures merely slowed the decline in biodiversity and ecosystem function and delayed the inevitable environmental pathologies until the next decade.[20]

8.4.2 Order from Strength 2015–30

8.4.2.1 Economic Fragmentation Escalates

Lack of trust between countries, together with the impossibility of totally controlling movements of people, goods, and ideas across borders, caused increasing nervousness about industrial espionage and the spread of agricultural pests and diseases. Competition was uneven due to wealth and availability of resources between nations, so attention turned to the use of subsidies and tariffs, ecolabeling, and quotas as weapons for protecting countries' interests. Sanctions were also imposed by dominant countries and alliances on those countries that were thought to be threats to world political and economic order.

Only the wealthy nations could afford to use subsidies and indirect forms of support for within-country agricultural production. Though local residents in poorer countries got access to cheap products, their own production was put at risk by these practices. In some places, this caused a temporary environmental benefit, as exploitation of natural resources was reduced by low production.

The high level of concern about protecting farmers in wealthy countries with export subsidies had widespread negative impacts on the world's ecosystems in rich and poor countries. In poorer countries, economic activity was maintained through the export of alternative commodities not produced by wealthier nations. Typically these included nonagricultural products such as forest products, minerals, fish, wildlife, and the like. This introduced exploitation and degradation of ecosystems that affected human well-being by lowering the supply of raw materials, polluting air and water,[21] degrading soils, and eroding biodiversity and its associated services and roles. In rich countries, subsidized cropping systems expanded into former grasslands. This changed the habitat and carbon sequestering capacity and increased soil erosion and nutrient pollution.

Import tariffs and taxes were used in rich countries to raise money for government and to limit the amount of imports entering the country. These policies encouraged local industries and other economic activities. In poorer countries these same policies had the counterproductive effect of making agricultural technologies expensive so that farmers in poorer areas could not afford best-practice in relation to maintaining soil fertility and other ecosystem functions. As a result, food production there lagged behind other areas, and risks from pests and diseases were increased by continued use of old technologies. In response, people expanded agriculture over greater areas to maintain earnings, leading to increasing clearing of native ecosystems and reductions in their biodiversity.[22]

Many poorer countries used export bans and quotas on natural resources such as timber, minerals, and fish in order to foster domestic processing industries. While there were

positive economic outcomes for the countries that employed quotas, such policies made it increasingly difficult to address global environmental issues, such as deforestation and exploitation of endangered species, because they made market pressures ineffective.

8.4.2.2 Health and Safety

As countries became more and more isolationist and as global environmental problems worsened, nations turned their attention to the use of health and safety regulations to reduce the chance that diseases and pests would be introduced to their countries through trade. Wealthier countries increasingly used ecolabeling and certification schemes to guide consumer behavior toward preferred producers.

These and other safety measures were effective in reducing the spread of pests and diseases. Regulations in many cases reduced pollution by discouraging use of fertilizers and chemicals and encouraging better soil management. However, they also frequently had a negative impact on the livelihoods of local people, especially in poor places, who depended on exporting environmental products. Increasingly, these people turned to alternative uses of the land and to illegal activities that sometimes increased ecosystem degradation.

Throughout the early part of the century, new diseases broke out in Africa and Asia, many arising from greater contact between humans and either wild or domestic animals. Although thousands of people died, many of these diseases stayed confined to local areas because the people had limited mobility. The rest of the world was generally concerned only to the extent that it was not under threat. While global cooperation was possible when diseases threatened wealthy nations and the freedom of movement of their people, diseases like AIDS that primarily affected poorer people and nations were not effectively addressed. (See Box 8.9.) Wealthy nations did not care, and poor nations could not afford to do much without the help of rich countries.

In general, foreign aid was provided on an ad-hoc basis, to tackle particular problems or crises and emergency situations, not to deal with longer-term development needs unless there was some obvious benefit to the wealthier country. Where development aid was offered, it was on terms that suited the donor country. Many people in poor countries argued against taking this aid on grounds that the terms often made things worse rather than better.

8.4.2.3 Environmental Impacts of Sanctions on Poor Countries

In this world, sanctions were an easier way than international cooperation to deal with failure to comply with trade or political measures. During 2010–20, such sanctions severely limited the amount of trade between poorer and richer countries, and many of the former were forced to rely on what their own ecosystems could offer for survival. Reduced imports of basic products, such as food, medicines, and industrial raw materials, caused local environmental strain as ecosystems were pushed to produce beyond capacity to provide these necessities.

Forests, grasslands, fisheries, farmlands, and even resources normally under state intervention were opened to continuous and heavy exploitation, particularly in areas of high population.[23] Many ecosystems showed dramatic decline in function and were not able to keep up with demand for goods. Sometimes, these resources deteriorated to the point of affecting human well-being through disease, malnutrition, and other impacts from flooding, drought, erosion, and loss of cultural identity.

8.4.2.4 Impact of Security Measures on Tourism

As human well-being was reduced in poor countries, rich countries began to increase security measures against immigration and terrorism. Nations often barred or tightly restricted certain classes of people or particular nationalities from visiting. This was very hard on the tourism industry, which not only affected livelihoods of many people, especially in poorer countries, but reduced funds that previously had been used to maintain natural places that attracted tourists. With tourism and the income it used to bring to poor places reduced, exploitation of natural ecosystems for survival increased even more.

In poor countries, the need to strive for economic growth in competition with rich countries drove resource depletion. Forests were cleared, and agriculture expanded and intensified in and around the places where people lived. Soil erosion increased, and the incidence of loss of property and deaths from land slippage and flooding also increased steadily.

8.4.2.5 Development of New Trading Blocs

Of course, a total inward focus would have been suicidal for poorer nations, and the breakdown of the previous global negotiations opened the door for new trade alliances. The new trading blocs were somewhat different from those that sprung up in the previous century. These started to form in the middle of the first decade and by 2015 were the new world order.

After a series of rapprochements with India, an Asian economic union was formed. The remainder of the Southeast Asian countries formed various arrangements with this new union. Other tentative blocs formed, such as a bloc of European and African nations and a bloc of countries in the Americas. Each bloc was generally made up of a dominant economic and military power that was joined by several wealthy economies and many countries with low per capita incomes.

The westernmost members of the former Soviet Union continued and accelerated the economic growth begun in the late 1990s. After years of debate, discussion, and deliberation, these countries signed preferential trade agreements with the EU similar in many ways to the arrangements of EU-affiliated nations in the late 1990s. African and Middle Eastern countries pushed hard for membership in the EU.

BOX 8.9

A Story of India (Order from Strength)

The harvest was poor again, despite the headman's prayers and the revival of some of the old rituals. Babies died of vomiting, and the nurse hadn't come for months. Some children still went to school, but rarely after the age of seven—they were of more use in the fields. The people from the development NGO also had stopped coming, even though a couple of the older people had listened to them and learned the alphabet, developed way back in the 1800s by Welsh missionaries.

In the city a new health minister had been appointed. At least she knew how to read and write, and she sometimes came to work, but otherwise there wasn't much to say. No one dared criticize the politicians, and the vote banks meant they answered only to the illiterates, who were easy to fool by promises of food and a fresh shirt. The AIDS awareness workers had at first hoped that the health minister might take more interest in their subject than her predecessor, who had continued to deny that the disease had reached their area, even when her own son became infected. It had been brought here quietly, spread by drivers trucking coal to the border and by infected girls too frightened to either complain or to ask their clients to use a condom—that could only mean one thing. At least dying quietly seemed better than being beaten to death, as some of the drug addicts had been.

The old custom of caring for and preserving the sacred groves was almost forgotten, just as was the reason for and the importance of a fallow period. Well, perhaps it wasn't entirely forgotten—the reality was that in order to feed a family, even for a few months a year, not only did all the fields need to be used, but day laboring jobs were needed, too. That's why extra children were handy—with big brother shoveling coal, little sister could at least herd goats and scare the few birds away.

Following the collapse of the reformed United Nations, after the default of the New Alliance, foreign officials had stopped lecturing the central government about the new disease. The law preventing people from selling their blood more than once a month still existed, but a small "commission" cleared that obstacle. It seemed an easy way to earn some extra cash. For a few extra pennies the certificate of hygiene could be forged as well—anyway, the officials knew that was irrelevant since the new Health Minister had declared the area to be infection free.

But something else seemed wrong this year. True, even the police had become accustomed to paying "safety" money—once 11%, but now 23%—to the insurgents who had crossed the border, but there was something strange about my new job offer. Five months pay for one month's work—even if it was far away; it just seemed odd. But how could one have the power to ask? And how could one resist?

When I started at the camp it was, I have to admit, rather exciting. For the first time in two years I could eat twice a day. The sore on my knee even started to fill in. The instructors were different from anyone I had ever met, and that was exciting, too. They taught me how to light fuses, and how to use a gun. By the time the armed motorcade came to cross the bridge, I was ready.

Regional trade agreements between the EU and African countries that had been in existence for many years were eventually merged into an umbrella agreement due to pressure from activists and those who thought that some terrorism could be avoided by improving the well-being of the poorest people. After years of negotiation, African countries were granted affiliate status that provided lower trade barriers for some important commodities. In the Americas, regional trade agreements further increased the integration of the North and South American economies and reduced trade and investments to the rest of the world.

The United Nations, never very efficient in its deliberations, became essentially irrelevant in a world where regional arrangements predominated and change happened quickly. The planned World Summit on Sustainable Development meeting of 2012 was called off after it became obvious that participation from the major blocs would be low. Regions viewed the Millennium Development Goals as a list to choose from selectively, with an emphasis on issues important to the dominant members of the blocs. OECD meetings become more acrimonious, and consensus was even more difficult to reach. As a result, there were fewer attempts to reach agreements, even within the wealthy countries.

8.4.2.6 Considerable Environmental Decline

As the attention of governments turned toward maintaining economic and military security, attention to the environment was highly variable between countries and depended mostly on the type of environmental issue at hand. Global issues like climate change, air pollution,[24] marine fisheries, and the emergence of new strains of infectious diseases from wild or domestic animals were almost impossible to address —there was always at least one key nation unwilling to cooperate due to national interests, and the international institutions that might have been able to address international issues were unstable if they existed at all. Global climate change increased less than had been expected at the turn of the century due to a larger than expected proportion of the world's population being forced to live a simpler and less materialistic existence, but few among those people took consolation from the figures.

Local environmental issues were dealt with very differently from country to country. Increasingly, local governments felt powerless to solve environmental problems and were overwhelmed by global issues no one seemed able to fix.

In wealthier countries, the obvious problems arising from degrading ecosystems, such as soil erosion, nutrient pollution of water, dust pollution of air, and damage from floods and other extreme weather, were minimized by using state-of-the-art technologies or by siting ecosystem-degrading industries in other countries. Cultural values from ecosystems were treated as luxuries and maintained in a similar way. Early in the century, various research and assessments, including the Millennium Ecosystem Assessment of 2005, alerted the world to the potentially serious impacts of declining soil fertility, loss of pollinators, loss of genetic diversity, and loss of water filtration capacity in watersheds if steps were not taken to better understand the processes providing these services from ecosystems. The rich nations generally allowed agriculture and urbanization to proceed as before, but at increasing intensities and over greater areas as population increased, assuming that ecosys-

tems could absorb the impacts or if problems arose they could be addressed with technology and human ingenuity. As a consequence, urban sprawl continued to compete with agriculture for prime farmland. Agricultural land use was intensified where it could be and was extensified elsewhere. Problems were solved only when they could be easily solved with technology. When problems could not be solved or when areas became highly polluted, they were left for the poorest of the poor to inhabit.

In poorer countries, the situation was different. As aid from wealthier countries was progressively reduced and populations grew, communities were forced to extend the area under agriculture simply for survival. Where export markets were accessible, demands on the environment were increased to take advantage of opportunities. Where access to markets was lost or could not be maintained, the consequence was usually exploitation of natural resources. Two thirds of the central African forest present in 1995 disappeared by 2050, while about 40% of Asia's forests and 25% of Latin America's forests were depleted. By 2020, loss of soil, declining air quality, damage from flooding, and decline in coastal fisheries were severe in many poor countries. (See Box 8.10.)

These types of linked environment-economic problems in poorer countries caused increasing movement of people to wealthier countries searching for new opportunities. Most rich countries developed ever more sophisticated ways to keep unwanted refugees out but as the trickle became a flood, maintenance of border security was less and less possible. The problem became acute around 2020, and many of the wealthier countries sent funds and personnel into the main centers of unrest. For a while, this slowed down the pressure for immigration to wealthy countries, but the problems inevitably returned. Meanwhile, massive accumulations of people along borders started to generate their own ecological problems such as vegetation clearing, erosion, water pollution, and disease outbreaks that threatened adjacent wealthier countries. Wealthier countries also were threatened with particulate air pollution as forests burned in poorer countries and as soil mobilized from vegetation clearing was blown across continents.

8.4.3 Order from Strength 2030–50

8.4.3.1 Variable Economic Performances

By the mid 2020s, the differences between prospering and other regions were stark. The philosophy of protecting a personal patch permeated all aspects of life. The general sense of insecurity and the need to protect national interests and assets made the trading blocs tentative and always vulnerable to threats that countries would retreat if they were not getting enough benefits. Income disparities within blocs, both across the countries of the bloc and within individual countries, grew larger as rich nations were more easily able to take advantage of the opportunities of the bloc. There was great tension between the rich and poor countries within the blocs as they tried to maintain the delicate new balance among nations.

8.4.3.2 Declining Ecosystem Services

Until late in the first half of the twenty-first century, most residents of affluent nations were only partially aware of the decline in global ecosystems because the pollution, soil degradation, and habitat destruction associated with their consumption occurred primarily in other parts of the world. Reduced international travel only heightened the general lack of awareness among the public.

Demand for water increased beyond the realistic capacity to divert and collect rainfall for human use. Since countries were unable to develop cross-border agreements about water sharing, countries that happened to have enough water were extremely lucky and those that did not have enough were very unlucky. Availability of water had many follow-on effects in terms of the location of businesses that required water and other economic development factors. This often had the effect of keeping wealthy nations, which were also often rich in natural resources, rich and keeping poor nations poor. It also led to increased conflict over water, especially in water-scarce regions.

As investments in environmental protection and attention to ecological feedbacks diminished, marginal environments became increasingly vulnerable to extreme and surprising events. Since these environments were generally home to populations with low income and little economic resilience, there was pressure for migration both within poor countries and from poor countries to the more wealthy economies of a country's bloc.

8.4.3.3 Downward Cycles

Cycles of escalating poverty, environmental pressures, and potential conflict in less industrialized countries were interspersed with periods of ameliorative policies and investments by richer nations. This investment eased short-term problems like starvation and some illnesses. Longer-term problems, however, were made progressively worse because the underlying problems were not addressed. These included desertification from land clearing and overgrazing, the buildup of nutrients through excessive intensification of inputs to agriculture and poor infrastructure for dealing with urban wastes, chronic diseases caused through depleted ecosystem services for controlling disease-carrying species, and damage to crops and the environment from invasive species.

The lack of strategic and continuous investments by affluent nations in poorer ones led to increasing resentment by the less affluent countries and to conflict as they took violent action. Attempts to control terrorism after the high-profile outbreaks of the first decade of the new century kept a lid on this form of protest, but as time wore on resentment grew and it became harder and harder for governments to appeal to the morality of underprivileged, starving, and unwell populations.

Increasing expenditures on security, both by well-off nations and by well-off segments of populations within na-

BOX 8.10

What Happens to Marine and Coastal Fisheries in Order from Strength?

In this scenario, coastal habitats as well as some significant upwelling systems are significantly more susceptible to climate change, which ultimately has an impact on fisheries globally, with local and regional declines. Major events such as El Niño, extreme storm events, severe flooding, and significant changes in oceanographic process (such as in the Gulf Stream) have increasingly severe consequences, especially in the poor countries of each bloc and the poor within each country. Efforts to establish global fishing and environmental management agreements break down, but regional agreements expand to include some of the deep-water fisheries. With some exceptions that are important to selected species (such as squid harvested off the east coast of Argentina and sold to Europe), fleets from outside a bloc are discouraged from fishing in coastal waters, and some efforts to partition the deep sea take place. For some stocks, the regional regulation provides a degree of actual sustainability, but it is unclear whether this can last through 2050.

A focus on sustainable fisheries does not necessarily improve the ecosystem structure. Some nations focus on export-driven high-value fisheries that are often short-lived invertebrate species (shrimp, for instance). This results in larger, long-lived species that rely on the short-lived species as food being eliminated from the systems. These changed systems are vulnerable to severe events, and therefore food and fishmeal supplies are highly variable, which results in fluctuating profits. In areas without enforcement, destructive fishing practices continue, overexploitation is not reigned in, and stocks eventually decline along with inshore ecosystems. This has a cascading effect on coastal communities, which lose their source of food and income.

The wealthier nations of each bloc reduce their net outflows of fish products in order to secure food supplies and social benefits. There is a significant reduction in effort, starting with distant water fleets that are seen as threats to national food security. Fisheries that supply significant amounts of palatable fish biomass or contribute to the production of animal protein are well managed, along with their associated habitats. Areas are closed to fishing, where appropriate fisheries with low biomass production and destructive impacts (such as long-lining) are phased out. Marine protected areas, trade restrictions, and habitat restoration policies to sustain stocks and charismatic marine fauna are strengthened where selected fisheries are not threatened. In some areas, conflicts emerge between aquaculture and capture fisheries for space and marine water quality.

Exports of small pelagic species are eliminated in economically secure countries, as these fish are diverted to secure fishmeal and livestock feed. Aquaculture of low- to medium-valued species with high turnover rates expands, again to secure food supplies. Coastal environments are converted to accommodate the increase in aquaculture, but the profitability of the operations becomes questionable in areas where ecosystems have been degraded or areas are subject to increased major storm events.

Although some efforts are made to capture control of the deep oceans by the blocs, it proves impossible. Oceanic fishing continues to expand, with fleets exploiting stock farther offshore and in deeper waters. Soon long-lived stocks collapse, and fishing down the food web increases to the point where small planktonic invertebrates such as krill or species technically impossible to exploit in abysses are all that is left in the ocean.

tions, left little room for needed investments in human capital and local natural capital. In many ways, the moral character of many wealthy nations deteriorated, as altruism and ethical behavior were seen as inconsistent with the dominant paradigm of looking after personal interests.

8.4.4 Order from Strength beyond 2050

As we look back from 2050, we despair at the short-sightedness of our leaders over the past 50 years. Over short decision-making time frames, protection of borders and resources made sense to both politicians and their constituents. As the world became more compartmentalized, it became even harder for anyone to see clearly what was happening. Somehow we avoided the bleak forecasts of the early part of the century, but the seeds of those disasters are still with us. (See Box 8.11.)

The world's environmental condition has deteriorated substantially since 2000. In the first decade there was debate about when the consumption of the world's people would exceed the capacity of its ecosystems to maintain a sustainable supply of goods and services. (Some argued that this capacity had been exceeded at least two decades earlier.) It is now clear that in 2050 we are well and truly past the sustainable limit and the debate is around how far we can repair the damage done. Virtually all governments recognize they have major environmental problems, and they blame everyone except themselves.

Clearly, the lack of global cooperation played a major role in making environmental problems worse and allowing them to spread much farther than they might have with more cooperation in addressing them or a greater ability to address them earlier. Unless some form of global cooperation emerges in the next decade, associated with concerted efforts to improve equity among and within nations, the world seems destined to slip into deepening conflict and cultural decline. While the political will to make these changes is emerging, many of us fear that the resource base is too depleted to allow measurable progress within three decades. Our best hope is to minimize suffering during that time and aim for a stabilized world by the turn of the next century.

8.5 Adapting Mosaic

Underlying this scenario is society's strong emphasis on learning about socioecological systems through adaptive management. This focus on learning is linked with some local emphasis on balancing human, manufactured, and natural capital. There is optimism that we can learn about ecosystem management, but humility about our ability to prepare for surprises and know all there is to know about managing socioecological systems.

Initially, trade barriers for goods and products are increased, but barriers for information nearly disappear due to improving communication technologies and rapidly decreasing costs of access to information.

BOX 8.11

Sub-Saharan Africa under Order from Strength

As increasing fragmentation marked the world economy across the first decades of the twenty-first century, different areas in sub-Saharan Africa saw different results. West Africa remained in a state of uneasy stability after the removal of Liberia's Charles Taylor. This uneasy stability hinged on Nigeria, itself unsteady but propped up by increasing European and American interest in the oil reserves partially located beneath Nigeria's territorial waters and lands.

Southern Africa initially saw an overall decline in its economic fortunes, as it was forced to turn to its poorer African neighbors to replace industrial-country trading partners hiding behind ever-higher tariffs and other barriers. As the environmental impacts of intensive industrial farming began to make agriculture untenable in the industrialized world (for example, with the depletion of the Ogallala aquifer under the Midwestern United States), southern Africa saw something of an economic renaissance as it regained its role as the breadbasket of Africa, supplying both neighboring African regions as well as wealthier industrial markets.

For sub-Saharan Africa, the real problems began between 2020 and 2030, as changes in the global climate resulted in greatly decreased rainfall in southern Africa. The environmental impact of this change could not be offset by irrigation or GM technology, and farm output in this region went into sharp decline. As much of the income from this output was coming from international as opposed to domestic markets, the food that was produced continued to be exported, much as happened during the Ethiopian famine of the 1980s. Millions of people living in southern Africa found themselves without adequate food and without local resources with which to make up for this deficit. Unable to migrate to richer countries, the result of this widespread food insecurity was massive migration within sub-Saharan Africa, as millions moved from southern Africa north into East and West Africa.

The arrival of hundreds of thousands of hungry, unemployed poor in countries like Nigeria overtaxed the already limited social, political, and economic resources that held society together. In Nigeria, the results were catastrophic as large portions of the southern half of the country, overwhelmed by migrants seeking work and food in its cities, attempted to secede from the north in an effort to concentrate the petroleum resources found in this part of the country. This triggered internal fighting that was less coherent even than the Biafra conflict of the 1960s.

The Nigerian civil war was exacerbated by Cameroon's efforts to take advantage of this confusion to extend its own claims to the oilfields in the Gulf of Guinea, which spread the fighting to this nation as well. Migrants from these countries fled the conflict, joining those displaced from southern Africa, further swelling the ranks of the displaced in nearby countries. Opportunists throughout the region used this instability to lay claim to local territory, to stage coups (successful and unsuccessful), and to mobilize ethnic groups against one another for political gain. The wealthy countries did little to intervene, save for the dispatch of an American carrier group to the Gulf of Guinea to protect ongoing petroleum exploitation, especially by securing the oilfields of southern Nigeria.

By 2050, most of sub-Saharan Africa found itself in far worse shape than in 2000. Civil society and nation-building had failed in many places, and the redistribution of population throughout this region was wreaking untold havoc on local ecosystems as new migrants contributed to agricultural extensification at the costs of forests and other ecosystems. The industrial markets that once served as a key hope for sub-Saharan Africa's future turned their backs on this region as a "lost cause," ignoring the role that the industrial world itself had played in the sad state of this region, both in economic terms and in terms of its global environmental impact.

Power devolves to regions partly due to national government–led decentralization and partly because of disillusionment in the abilities of national governments to govern. There is a great regional variation in management techniques. Some local areas explore adaptive management, trying alternatives through experimentation, while others manage with command and control or focus on economic measures. The key idea behind the local management, though, is learning while managing.

Eventually, the focus on local governance leads to failures in managing the global commons. Problems like climate change, marine fisheries, and pollution grow worse, and global environmental surprises become common. Communities slowly realize that they cannot manage their local areas because global problems are infringing, and they begin to develop networks among communities, regions, and even nations to better manage the global commons. The rebuilding is more focused on ecological units, as opposed to the earlier type of management based on political borders that did not necessarily align with ecosystem boundaries.

People in this scenario have beliefs about the way the world works that drive ecosystem management. They believe that ecosystem services are important and that functioning ecosystems are an important part of providing ecosystem services; that cross-scale feedbacks happen, are important, and can be strong enough to change management policy and governance; and that focus on natural capital is enough to maintain adequate provision of ecosystem services. This changes later in the scenario, when there is increased focus on human and social capital. (See Box 8.12.)

8.5.1 Adapting Mosaic 2000–15

At the beginning of the century, several global trends were unfolding that were seen as a major threat to human well-

BOX 8.12

Potential Benefits and Risks of Adapting Mosaic

Potential benefits:

- High coping capacity with local changes (proactive)
- Win-win management of ecosystem services
- Strong national and international cooperative networks eventually built from necessity and bottom-up processes

Risks:

- Neglect of global commons
- Inattention to inequality
- Less economic growth than maximum because of less trading
- Less economic growth than the maximum possible because of diversion of resources to management

being on the global scale. Global trade expanded rapidly, institutionally regulated by the World Trade Organization rules of free trade. Conflicts in many regions were still present and often led to violent confrontations, both between as well as within countries. At the time, multinational companies played an important role in the process of globalization. Still, there were some major attempts to cope with arising environmental and social problems through international efforts, starting with the World Conference on Environment and Development in Rio de Janeiro in 1992 and the World Summit on Sustainable Development in Johannesburg in 2002. Global conventions, including ones on biodiversity or desertification, were signed to achieve better management of global environmental problems.

8.5.1.1 Growth of Civil Society: Investments in Social Capital

Though global efforts were still dominated by national governments, they were only part of the broader, self-organized system of global governance. In most of these efforts, civil society started to play a major role by the involvement of NGOs, the predecessors of the modern global civil society networks of 2050. The strengthening of local government and nongovernmental organizations was in large part due to an increasing perception that globalization was having negative impacts on the environment and social structures. Though this perception was only partly supported by scientific evidence, it was fostered by broad media coverage of examples like increasing unemployment rates in many rich countries or some major environmental disasters due to neglecting environmental standards in the developing world. Science played an increasingly important role, such as in support of the international conventions, and business was beginning to realize that some of these issues would endanger its long-term prospects.

At the same time, new partnerships emerged, both within and outside the global conventions and agreements. Systems for certification of renewable resources were developed or extended to new products, such as from forest goods to agricultural products.[25] These systems consisted of diverse groups of representatives from environmental and social groups, the trade and managing professions, indigenous people's organizations, community groups, and certification organizations from around the world. Although at the turn of the century only about 2 million hectares of the world's terrestrial ecosystems were certified under these systems, there was a growing demand for certified products due to increasing environmental concern among consumers in the rich world. As a result, the total portion of certified products rose to 18% of the global trade volume by 2010. The increased demand for environmentally sound products led to some of the first success stories of new, locally bounded partnerships for ecosystem management.

Though these initiatives brought some success to certain regions, they also exhibited some of the key problems of the century. On a local scale, many attempts to get a certificate brought about significant conflicts with powerful actors. In many instances, national decision-makers gained personal benefit from the traditional ways of ecosystem management. Corruption was abundant in many regions, and the people benefiting from it were afraid that the new system would put an end to their personal advantage. In other regions, professional lobbies strongly opposed the new systems, as they were reluctant to give control to local communities and actors. In some regions these conflicts were resolved by the proliferation of community-based land management authorities, and many people suspected that these opposition groups prevented an early boom of falsely certified forest sites.

The rise of new cooperation between NGOs and businesses was not the only sign of the emergence of new types of governance. The ''organizational explosion'' of civil society was evident in the first decade of the century. In the Philippines, for example, the number of nonprofit organizations grew from 18,000 in 1989 to 58,000 in 1996 and 134,000 in 2008. Many of these locally initiated groups became part of transnational advocacy coalitions on a broad range of issues, like human rights or the environment. Though access to the Internet still was limited in the developing world, the possibility of quickly exchanging information was an important condition for the proliferation of globally linked groups. The increasing number of broadband cell phones further helped to improve quick and fast information exchange. The number of mobile phones in China, India, and Brazil by far outnumbered those in North America and Europe already in the early years of the century.

These changes of civil society structures also had a qualitative dimension. An increasing number of organizations aimed at a nonprofit transfer of knowledge and skills throughout the world. Prototypical examples of this were Médicins sans Frontières (Doctors Without Borders) and the Academic Training Association. The first started off by bringing fast and nonbureaucratic medical help to civilians in areas of violent conflict or natural catastrophes. During the first decade of the century, it extended its aims by training and capacity-building activities. Similarly, the second group aimed to help restore academic training capacities in these areas, such as the region of the former Yugoslavia, in the early years of the century. These kinds of NGOs not only relied on the participation of politically interested people but were expert networks. Later in the decade, similar organizations developed for water management,[26] fisheries, labor safety, and pharmacy. These organizations turned out to be highly flexible and were thus able to incorporate the local contexts and peculiarities much better than the bureaucratic international or governmental aid organizations.

8.5.1.2 Education: Investments in Human Capital

The years of the first decade were also characterized by a strong increase in public and private education expenditures throughout the world. Whereas in the 1990s only a few low- or middle-income countries increased their spending for education, this was the standard trend in the first years of this century. Particularly in Latin America, but also in many other parts of the world, most countries spent more than 13% of their GDP on education in 2010. These countries reduced military expenditures significantly after democracies had stabilized. Also, in some pioneering countries

the success of educational intensification in terms of poverty reduction was significant. The examples of those countries strengthened the view that highly skilled and professional workers had a significant positive impact on human well-being. In addition, when it came to development aid or financial credits, some international organizations and industrial nations favored countries that had increased public spending for education.

But it was not only public spending that helped to improve educational standards. Educational initiatives by private companies were starting to play a major role, and though often used for reasons of improving their images, these initiatives were soon producing benefits as graduating students sought jobs within the philanthropic companies. These highly educated and culturally aware employees thus helped with the ''glocalization'' that began to take place—the development and marketing of products adapted to and produced in a region and its specific cultural background.

8.5.1.3 Managing Ecosystems: Successes and Failures

The increase in investment in social and human capital can be seen as an important first step toward the world as we see it now. Many of these changes were directly related to changes in the ecosystems in the regions. In general, the trends of degradation and loss of ecosystems that were visible at the end of the last century were continuing, and in many regions the livelihood of an increasing number of persons became endangered.

There were, however, some isolated successes in better management of marginalized socioecological systems due to strengthened local institutions for learning. The Alternatives to Slash-and-Burn initiative, for example, a science-based organization with a network of some 50 sites with this traditional form of cultivation, was able to improve the livelihoods of most people within its network. As progress was not widespread, however, the effect at the time was more symbolic. It revealed that alternatives are possible when knowledge is locally relevant and appropriate institutional settings are met. (See Box 8.13.)

The significance of global conventions on environmental issues, though officially still valid, started to decline. In 2008, the starting year of the commitment period of the Kyoto protocol, it became obvious that its goal to reduce carbon emissions by a total of 5.2% in the signing countries would not be reached. This was to a large extent due to the limited cooperation to effectively implement the mechanisms designed in the protocol to better achieve the targets, such as joint implementation, green development projects, or emission trading schemes. In the years before 2008, the negotiations on agreements for the period beyond 2012 made only slow progress, as some countries still were reluctant to discuss any binding reduction targets. Though discussions had continued, it was clear by 2010 that there would not be any binding reduction targets within the next decade. In parallel, initiatives were intensified to agree on an ''adaptation protocol,'' finally endorsed in 2019. These efforts were supported by the insight that climate change by this time had already brought about some major disruptions of ecosystems.

Nevertheless, there was some success with regard to climate protection. Western Europe continued its own efforts to reduce emission. It was still convinced that at longer terms the technological advantage gained by early implementation of new technologies would offer high economic benefits. In North America, the state initiatives for mitigation showed some success, though estimates of the overall reduction ranged from 1% to 3% below the baseline only. Though scientists continued to claim that climate change might have major impacts, especially in the developing world, mitigation of climate change as a global effort began to disappear from the global agenda.

8.5.1.4 Economic Struggling

In the beginning of the century, economic development was mainly seen as quantitative growth, and global cooperation and open multilateral trading were seen as the basic vehicles for growth. In view of a general slowdown of the global economy, the so-called Doha round of negotiations for better cooperation was started to maintain the process of reform and liberalization of trade policies. The negotiations were also intended to improve the effective participation of developing countries in the world trading system. It turned out, however, that the targets set were far too ambitious, and in 2005 negotiations finally failed. The primary consequence was a continuation of low growth rates on a global scale, although in some countries in transition, high growth rates prevailed throughout 2015.

Second, due to the failure of the negotiations, existing trade barriers and market distortions for agricultural products continued. These were seen as a major obstacle to agricultural development in poorer countries, as numerous subsidies in wealthy countries brought a substantial price advantage to their farmers.

Third, the growing limitations of free trade had some impact on the business strategies of multinational companies. Due to the raising of trade barriers, the multinationals started to look for new strategies to extend their business activities. At the beginning of the 2010s, it turned out that they could find these strategies by strengthening their local profiles in many regions of the world.

Due to the failure of the Doha talks, but also due to a trend of increased demand for environmentally sound products in richer countries, the process of globalization acquired a strong local component. People sought out local peculiarities and properties in order to maintain their cultural identity. This trend now increased, and global trade got a stronger local component. That is why we call the years between 2015 and 2030 the Era of Glocalization—a time when there was both a high degree of integration in the world economy and devolution to local and regional institutions in most countries.

8.5.2 Adapting Mosaic 2015–30

The Era of Glocalization started with a highly integrated world economy. Though the Doha round of negotiations for further liberalization of trade had failed, global trade was

BOX 8.13

A Story of India (Adapting Mosaic)

I was waiting for the Malaysian delegation when my thoughts started to wander back through time. It all started 10 years ago. No Indian will ever forget that summer, as it was like nature had become unnatural. Scientists told us that it was manmade, but how could it have been? How could man ever change the laws of nature? Even our grandfathers couldn't remember any stories of the past like this. Stories of a summer without any monsoon!

I can well remember the trouble we had in our village. We had been able to produce our own rice for centuries, but not that summer. Thanks to help from the government and from abroad we had only three casualties, but everyone was starving. And worst of all, one of our holy cows died because of the water shortage. It was simply too late when the water cars arrived.

There was intense debate on what we should do. The elders trusted nature and were convinced something like this would never happen again. Others said we should call for help from the government. Finally, four of us, who appealed to our own strength, were asked to create a better plan. My friend Yogesh had heard of an international water management organization that might help us. In the end, this help came in the form of Internet access for our village.

During the following years we collected information on integrated water management from all over the world. More important, however, we asked our elders about their knowledge of our local ecosystems. They, as well as many others in the village, remained highly skeptical and cautious. The challenge was to bring a range of knowledge—western and eastern, traditional science and local experience—together. Three years later we got permission to install three experimental fields to tests our ideas about ways to deal with water stress. Well, two years later the story repeated—no monsoon.

Two of the experimental fields completely failed and one of them was performing even worse than the traditional ones. Yet the third field actually was a big success, and its rice yield and water storage were better than five years before. The skeptics started to become curious about our system, and in the following months there was a lot of debate about how to further improve the approach. Many people from the neighboring villages also participated, and we were amazed about what they contributed. We experimented a lot and finally we got a system that not only helped us cope when the monsoon failed to appear, but also worked better in regular years. We now even sell water from this scheme—something that has become possible due to the new law on water trade. Thanks to this income, everyone is online in our village, the system is less labor-intensive, and more and more kids can now go to school.

Finally, the flight gate opened and Balan, the head of the delegation from Malaysia, was approaching me. I had had a regular e-mail exchange with him over the last weeks, and we were both looking forward to finally meet in person. In his first message he had told me a story—a story about a year without any monsoon.

still higher than in the early 1990s and than it is today in 2050.

8.5.2.1 The Rise of Regions

In 2015 the World Trade Organization had recovered from its struggle for a new strategy after the failure of the Doha talks. Within a new round of international trade negotiations, instruments to promote global economic growth were discussed. Perhaps the most important, in particular with regard to its long-term effect, was the Initiative for Regionalizing Global Trade. In this initiative, it was realized and acknowledged that, despite the prevailing barriers in the trade of goods, information could flow freely around the world. It was also conceived that the networks of civil society organizations might serve as a powerful vehicle for promoting the exchange of information and skills, and governments and others recognized that there was a still-growing demand for products that reflected the local roots of peoples' culture, attitudes, and lifestyles.

Within the Initiative for Regionalizing Global Trade, these trends were reflected by a system that gave leeway for transnational cooperation between business companies if these ''cooperations'' were based on local production of goods and the value-adding was documented so it was apparent for all participating partners. Though many NGOs criticized the agreement because it lacked human rights considerations, many large companies started to participate in these networks. Today there is no doubt that this initiative, though of limited success through 2020, brought remarkably positive stimuli to the world economy in the 2020s and 2030s, particularly after the initiative was extended to include civil society organizations in 2032.

The United Nations underwent a significant metamorphosis toward a stronger recognition of the emerging civil societies at smaller scales than the nation-state. In 2015, the United Nations Regional Organization (UNRO) was founded to seek to promote the ''exchange, proliferation, and sustainability of regional development.'' UNRO got wide-ranging responsibilities, including educational, environmental, and human rights issues.

At the same time, the decade saw a further increase in the number and, more important, the effectiveness of civil society organizations. The success of the certification systems of the 2010s was still most impressive, though in the face of increasing trade barriers, global trade in ecosystem products was declining. Nevertheless, according to some estimates by the World Resources Institute in 2020, 34% of global ecosystem production came from certified sites. Due to these increases, the peak certification bodies were no longer able to ensure the quality of all certified operations. To improve coordination and quality control, they reorganized themselves in 2022 to become the Global Sustainable Ecosystem Business Organization.

8.5.2.2 Ecosystem Services

The most visible change in the Era of Glocalization was taking place in the agricultural sector, particularly with respect to property rights. At the beginning of the period, agriculture in the wealthy world was still highly intensified, and fertilizers and herbicides were widely used. Though the share of environmentally friendly and healthy production had risen to 12% in Europe and 7% in North America, the ecological problems induced by traditional means of cultivation prevailed. The 2020s, however, saw a rapid increase

in the demand for high-quality, healthy food—a demand that could no longer be met. Major struggles between the various interest groups set in, which in some cases had to be resolved in courts. It turned out that most national legal systems were not capable of settling the disputes. As a consequence, major reforms were put in place, and in many countries the right for healthy food was included in the constitution. Many of the poorer countries followed suit, and by the end of the decade organic and naturally produced food had a market share of 34% in Europe and 21% in North America.

At the same time, the economic refocus on local and regional cultural values strengthened people's pride in their regions, and they started to consider "their" ecosystems as an integral part of their culture and local identity. This was also the reason why people in many dryland regions started to improve their well-being by adapting new agricultural techniques, which though based on traditional knowledge also incorporated innovations and experiences from other regions. In many of these regions, people were able to cope rather well with increased water shortages due to climate change.

In 2019 an adaptation protocol was signed within the Framework Convention on Climate Change. The pressure to agree on such a protocol was partly due to an increasing visibility of climate change effects. A significant increase in the frequency of extreme events, such as droughts in Europe or hurricanes in Central America and Southeast Asia, highlighted the need for adaptation. Hong Kong Metropolitan Area, at the time with a total of 25 million inhabitants and one of the largest metropolitan areas in the region, lost about 25% of its manufactured capital due to a single cyclone event in 2017. The Miami Protocol for adaptation to climate change established the Global Adaptation Facility, a fund that was set up to finance adaptation measures throughout the world. It was remarkable that this fund was administered by a partnership of the World Bank, the World Wide Fund for Nature, and the World Business Council for Sustainable Development.

A major challenge was the increased withdrawals of water as population increased in many parts of the world.[27] One of the most impressive success stories of this decade was the Euphrates-Tigris water scheme (see Box 8.14), which not only had massive impact with respect to water availability but also increased human well-being in the region. There were many more projects of this type, including experiments to combine local and network knowledge with regional specifics to gain better access to ecosystem services. Unfortunately, between 2015 and 2030 many of these experiments failed. There was, for example, the Midwest Organic Agriculture Project in the United States (see Box 8.15), which sought to meet the increasing demand for organic food in that country. Two of the main faults of the project were disregard of local traditions and an insufficient participation of local farmers in the design of the project.

BOX 8.14

The Euphrates–Tigris Integrated Watershed Management Project

One of the most impressive success stories of the 2010s was the Euphrates–Tigris water scheme, which not only had massive impact with respect to water availability but which also brought a new level of human well-being to the region. The project came from local initiatives, supported by the UNRO.

At the turn of the century, Turkey was trying to bring prosperity to its southeast region Anatolia through a large-scale water regulation scheme and the cultivation of irrigated cotton fields in the Anatolian highlands. Soon after, however, it turned out that many marginal groups in the region were excluded from the benefits of the project. Also, people working in the fields had major health problems, and salinization of soils progressed more rapidly than projected. Since Turkey finally had become a member of the European Union in 2012, there was moderate progress in the power these people actually had, and in 2015 the problems were so abundant that Turkey no longer could ignore the failure of the project. In its initialization phase, the project was heavily debated also because of its downstream effects—potential water shortages in Syria and Iraq. After the Iraq war in 2003, these conflicts were sharpened as the United Nations urged Turkey to release more water from the dams than it intended.

Altogether, in 2015 national and international pressure to revise and rebuild the project was immense. At the time, the international network of Water Engineers International, a nonprofit transnational organization similar to the Médicins sans Frontières initiative of the early years of the century, had ready-made plans for an alternative scheme, which would make use of the dams but which also sought to include ecosystem management in all three countries. When the project finally was realized with the help of UNRO, there were many win-win situations where the goal of "water by ecosystem management" was not only bringing a high degree of water safety to the region, but also increasing human well-being with respect to food security, health, and poverty alleviation. The trick was an adaptive mosaic of conserved areas, similar to the traditional three-field crop rotation system of central Europe in the fourteenth and fifteenth centuries.

At the time the world saw a rich portfolio of governance schemes for ecosystems and ecosystem services. In some regions, centralized management strategies were still prevailing by and large under national control. Other regions saw a profound switch to much more localized governance structures, often embedded into transnational networks of civil society organizations providing fruitful platforms for skill and knowledge exchange. The conditions and trends of ecosystems also showed a rich pattern of improvements and restoration, but also degradation.

The rate of biodiversity loss, though still a subject of global political and scientific debate, had been stabilized at low levels compared with 2000 in the regions where local management had been successfully implemented. In other areas, the trends of loss prevailing since the middle of the last century continued to threaten ecosystem functioning and human well-being. Yet attitudes toward biodiversity had changed quite substantially. Whereas at the beginning of the century people responded most to the loss of single, highly symbolic species, awareness now had switched to

BOX 8.15
The Midwest Organic Agriculture Project

In October 2014, the Midwest Organic Agriculture Project was launched in the United States with the goal of meeting the increasing domestic demand for organic food. The project was initiated by a national network of scientists and food co-ops that were actually able to gain support from major corporations in the food sector.

Based on the prevailing knowledge paradigm, the project developed a detailed strategy of land use throughout many areas in the region. They also designed training courses for the farmers and gave marketing guarantees for a range of products, including grain, maize, and beef. Unfortunately, the traditional networks of farming and marketing were overlooked, and the farmer's traditional decision-making with respect to what to cultivate and where to sell turned out to be much stronger than anticipated. Though 46% of the farmers in Nebraska participated, most of them applied the new techniques only for a limited time or on a small portion of their land.

The project was ended in 2018, and its impact on the national food market was negligible. There was, however, a thorough analysis of the project and its failures—an experience that helped make the next 15 years a period of rapid diffusion of success. One of the key faults of the project was the disregard of local traditions and an insufficient participation of local farmers in the design of the project.

BOX 8.16
Managing Malaria in Africa

In the 2010s, malaria was a highly limiting factor for economic development in Eastern Africa. In its 2020 Global Sustainability Outlook, the United Nations Regional Organization assessed that about 55 million people had died of malaria in the 2010s and that the overall costs of malaria in the region amounted to about 20% of its GDP and thus limited growth rates by another 50%. This was due in part to the fact that malaria took hold in new regions due to a significant warming of the region in the first decade of the century.

Facing these facts, UNRO decided to set up a competition in local ecosystem management for better prevention for malaria. Instead of earlier attempts of transferring knowledge into a region, the initiative sought to foster local initiatives and to build on existing networks of transnational NGOs. Within the first five years, most of the initiatives failed, but in 2028 a network of communities in Kenya and Tanzania came up with an idea of cooperative management of their local ecosystems, including far-reaching drainage into underground basins so that the breeding grounds of the vectors would be destroyed without the loss of water for agriculture and households. These small-scale constructions were accompanied by a medical treatment program with the aid of Médicins sans Frontières, which helped reduce the number of newly infected people significantly. After great success in the first five years, this combination of local aquatic ecosystem management and cross-scale knowledge transfer quickly spread to other localities. By 2035, the number of newly infected people per year in the region at large was down to 50,000 people, compared with 900,000 some 10 years earlier.

perceiving biodiversity not only as an essential supporting ecosystem service, but as a goal in and of itself. This understanding, though part of the scientific discussions for a long time, now took hold in the public debate in many regions. Demand for a cooperative management of provisioning and supporting ecosystem services grew steadily within the mosaic of success. The successful experiments of local and networked management made the message ''we, the people, can do something about it'' rather popular throughout the world. This attitude was largely responsible for the success of the initiative for malaria control in East Africa in the late 2020s. (See Box 8.16.)

The same holds true for other provisioning ecosystem services. The example of the Alternatives to Slash-and-Burn program and its achievements for improving human well-being was spreading further, and by the early 2020s it had reached 50 million people throughout the poorer world. Ecosystems in many of these regions had started to show signs of recovery, and people's livelihoods were safe and balanced. Nevertheless, due to a still-growing population and a general increase in the demand for ecosystem services, global trends showed a significant deterioration of the global environment. Global climate was changing rapidly and had been finally proved to be related to anthropogenic burning of fossil fuels and land use change.

Due to these global trends and the visible success of local strategies, the 2032 Global Conference on Sustainable Development, Rio + 40, further strengthened the proliferation of local and cross-scale learning initiatives. At the same time, the benefits of the educational imperatives of the first and early second decade showed up in many countries. This not only strengthened the efforts to manage ecosystems in a locally adapted manner, it also helped to broaden the expertise, skills, and knowledge base of the transnational civil society organizations. NGOs had gradually changed into highly professional companies, which in many instances served as lobby groups at international conferences and the UNRO meetings and also on the national level.

8.5.3 Adapting Mosaic 2030–50

This era was characterized by a rapid diffusion of civil societal management throughout the world. Based on the example of the Euphrates-Tigris integrated basin management scheme, there was increasing demand for new, small-scale, ecologically sound water basin management programs. Supported by UNRO or with participation of business coalitions within the World Trade Organization's Global Business Network Initiative, these schemes were put in place in as many as 23% of the main global basins. Though these programs were successful in many regions, there were quite a number of failures where the goals to integrate ecological and socioeconomic interests were not met. Some companies used these attempts as vehicles for their own interests. In other cases, local decision-makers used the schemes for their own enrichment. In many other cases, knowledge simply was not sufficient to realize ambitious targets.

8.5.3.1 A New Attempt at Free Global Trade

Though the signs of civil society were abundant at this time, economic development was still lacking in many regions.

The hope that glocalization would bring prosperity and wealth was fading, and the attempts to stimulate economic growth by a new round of negotiations showed only partial success. It was realized that the limits to growth induced by the prevailing high trade barriers could not be compensated for by the free flow of information and skills. The Global Business Network Initiative, though showing some success, was perceived as being too strict and not flexible enough to react to the rapid diffusion of the civil society and the increasing needs of a still-growing population.

Nevertheless, it was not possible to turn the clock back to the kind of world economy that was envisioned before the failure of the Doha talks at the beginning of the century. Though local and regional trade brought about some progress, the chances to invest in other countries were still not satisfying. As a consequence, in 2034 a World Conference on Economic Development took place at which new elements of a glocalized economy were discussed and put in place. The vision was to stimulate growth by bringing business interests together with the interests and needs of the emerging global civil society. (See Box 8.17.)

8.5.3.2 Tragedy of the Global Commons

Despite the widespread progress in managing local ecosystems, the inability to take care of the global commons—places and resources owned by all of the world's people and not just by one nation—brought forth major drawbacks for development. In 2022, world fish catch had declined to only 30 million tons, about 70 million tons below the peak catch at the turn of the century. This brought about a significant decline in protein supply for the world, in particular for those people heavily dependent on marine resources, such as those in the coastal zones of southern Africa, Latin America, and Southeast Asia. Consequently, the demand for meat increased significantly, which put additional pressure on land resources. Thus the hope to reduce land use change in the near future was fading.

Climate change also entered a new phase, bringing about major water crises in some regions of the world, including Togo, Mexico, and Turkey,[28] putting pressure on land resources in other areas, and finally having direct impacts on human well-being. Though the Miami Protocol for adaptation did show some success and probably helped many regions to cope with a changing climate, the funds in the Global Adaptation Facility were by no means sufficient. Also, the institution itself was heavily criticized for its ineffectiveness due to the major coordination problems of its leading organizations. It was not until 2038 that the fund was reorganized to address climate change directly by adding value to local programs.

Experts agreed that the danger of major disruptions of the climate system was still growing. Besides "traditional" disruptions, such as a significant weakening of the North Atlantic thermohaline circulation, new discontinuities were discussed, including a runaway climate change due to large-scale deforestation of the Congo basin.

As already described, the late 2030s and early 2040s were molded by a period of further promotion of civil society. Although there were still failing experiments, including the Mweru National Park tragedy (see Box 8.18), these efforts finally showed up in global trends by the early 2040s. The civil society–business partnership endorsed in the New Agenda for Development brought major progress with respect to economic development, and growth rates slowly but steadily increased in the 2040s. The broadening of skills and expertise continued due to an increased involvement of people from poorer nations, and thus the rates of technological progress in terms of sensible effectiveness of resource use and environmental pollution increased. Nevertheless, population was still growing quickly, and the need for ecosystem services was increasing in most regions and globally still outpacing any major progress.

8.5.3.3 Civil Societies Breakthrough

With respect to civil society–business partnerships, the example of the Vivanto-INESI partnership is most impressive. In 2038 many NGOs, including professional networks, formed the International Network of Sustainability Initiatives (INESI) in order to better coordinate their activities. Attempts made by UNRO to make INESI part of its own structure were rejected as the networks wanted to remain independent. INESI was a global player that not only brought together knowledge and skills of unprecedented depth and broadness, but also had economic power. By 2043, many of its professional network members were collectively self-organized and economically self-sufficient.

One of the major achievements of INESI was the founding of the Cooperative University for Sustainable Development in 2046. This completely new university system

BOX 8.17

The New Agenda for Development

In 2034, the World Conference on Economic Development took place in the Middle East. The conference agreed on a new framework for free trade. The most central tenets were:

- Free trade of end products certified to comply with the ecological and social standards of the region of origin.
- Free investments in regions under the condition of a sufficient and wide-ranging participation of local people and civil society organizations as well as professional networks (like Water Engineers International).
- Free flow of labor migration as long as both the country of origin as well as the country of destination complied with the minimal social standards set by UNRO.

The decisive point of the agreement was that the conditions were no longer bound to the nation-state, but much more to the regions. Nation-states agreed to these directives with the hope that within their countries those regions benefiting from the agreements would serve as a locomotive of growth for the whole country. Yet history has shown that although growth was stimulated in many regions, there were rising conflicts within states where not everyone had equal opportunities to take part in free trade. The late 2030s were therefore molded by the attempts of the nation-states to further extend the civil society within their countries.

BOX 8.18

The Mweru National Park Tragedy

After the success story of the tourism industry in the Okavango Delta late last century and in the first years of the twenty-first century, other places in sub-Saharan Africa sought to follow the same track and benefit from the growing revenues of tourism. The Okavango story also demonstrated that ecotourism can be designed in a fruitful and appropriate manner to sustain incomes, ecosystem integrity, and ecosystem services, in particular the aesthetic values of the deltas. Though the first national park in the Lake Mweru region in the border region between Congo and Zambia was established in the 1990s, initial efforts to increase the incomes by tourism were made in the 2010s. Based on the experiences in the Okavango, an ecotourism concept was developed by local authorities within a participatory process involving local stakeholders and indigenous people. This process guaranteed a high degree of ownership by the local people, both in terms of "mental" as well as legal ownership. Within its first five years, tourism brought a significant increase of income into the regions and people's well-being increased, in particular in its material dimension.

The high degree of partnerships and cooperation on the local level as it was established, however, was not sufficiently supported by regional measures. Thus a strong income gradient developed, in particular on the Congo side of the lake region. This induced a strong domestic migration, and in 2025 a total of 1.2 million people migrated to the Lake Mweru region. Though some of them were able to participate in the revenues by taking on minor jobs within the tourism facilities, many of the new settlers weren't successful. The informal settlements developing within the region undermined the positive image of the region, and the number of tourists started to decline—but not the number of migrants.

The new settlers also caused significant deforestation in the upstream region of Lake Mweru. By 2028, already 37% of the upstream area was deforested, and in 2029 a heavy rainfall event induced major landslides in the region, finally leading to a flash flood event in December. The flood not only destroyed almost all the tourism infrastructure, including the regional airport, but also directly caused a total of 1.2 million deaths in the region. The region did not recover well, as only 20% of the value of property was insured by international companies, and the local networks designed for taking over possible losses from small events as envisaged in the original concept were not able to cover the damage costs of the flash flood. This example again showed that the concentration on a single scale might induce major backlashes if cross-scale interactions are neglected.

was meant to promote mutual learning from local experiments, including learning from failures.

Finally, the decades between 2030 and 2050 witnessed the emergence of new types of global business players. Though many companies could still be considered global players, their internal structures had changed due to the need to adapt to the variety of local and regional standards and regulations. The most successful companies developed as a network of loosely linked subdivisions that have far-reaching competencies. They have internal trade systems that have taken up ideas developed for emission trading systems during the climate change debate at the turn of the century (such as ecosystem disturbance rights and proactive ecosystem management skills).

The most successful example in this regard is Vivanto, which makes 85% of its total revenues by ecosystem service trade. It had made its way through the turbulent decades of the 2010s through the 2030s by innovatively seeking new partnerships and reorganizing itself into a loosely coupled multinational company with rather independent subdivisions. After the New Agenda for Development was in place, Vivanto was able to increase its business with ecosystem service trading, and in 2045 the time was ripe for a closer cooperation with the civil-society sector—with INESI.

The 2040s also saw an increase in the efforts to extend the principles of civil society to the global scale and to seek new ways to cope with the problem of the global commons. In 2046 a partnership of the United Nations, INESI, and the World Business Council initiated a new round of negotiations for a globally orchestrated reduction of carbon emissions. Negotiations are still going on, though in 2048 an agreement was reached to extend the criteria of compliance of the Baghdad Treaty to the issue of carbon emissions. It is unclear what the effect of this agreement will be.

8.5.4 Adapting Mosaic: Where We Are in 2050

Over the last 50 years, a rich mosaic of local strategies to manage ecosystems and ecosystem services has emerged. There have been many successes in how individuals and communities have learned to manage the ecosystems they live in more proactively. They have achieved a high level of resilience of the coupled human-ecological system they are part of. This is, for example, reflected in the quick recovery of large areas in Central America after the most intensive hurricane ever, which scientists say was caused by climate change, which over the last 60 years has increased the global mean temperature by almost 2 K.

Though the direct damage was enormous, people's capacity to restore ecosystem services has been sufficient to recover from the impacts within two or three years in most cases. For the restoration of freshwater supply, for example, people used strategies based on the experiences gained in Viet Nam and Southern China after a typhoon hit that area in 2013. As key upstream ecosystems were identified and conserved, and as their water retention capacity and storm vulnerability were well managed, these ecosystems were hardly damaged by the hurricane.

The world has also seen the emergence of new networks and cooperations both across regions, like the one between Central America and Southeast Asia, and across various actors.[29] The Vivanto-INESI example described above is an example of cross-actor cooperation. The extent and content of such cooperation was barely conceivable at the turn of the last century. At the time, only a very few selective and small-scale cooperations of this kind were present. INESI itself constitutes a network that in its connectivity is by no means comparable to the so-called nongovernmental organizations of the turn of the century.[30] The effectiveness of the information exchange across the network is unprece-

dented and its Cooperative University for Sustainable Development, founded in 2046, is a success story in itself. The university has a strong focus on transferring and generalizing knowledge on ecosystem functioning and managing and does not, for example, have an engineering department, as a focus on one discipline is seen as being not helpful for its overall objective.

On the other hand, there are a large number of substantial failures where attempts did not bring about the necessary improvements of ecosystem functioning and human well-being. These failures led to unexpected breakdowns of ecosystems, either on local scales due to failed experiments or on global scales, as for fisheries, due to the general neglect of common property problems, especially during the first two decades of the century. Many ecosystems in sub-Saharan Africa, for example, are still under high pressure. (See Box 8.19.) The trends of losing ecosystem services are still increasing because in these places local knowledge for better management has been lost a long time ago or because insufficient institutional changes hindered the proliferation and implementation of local knowledge and learning. The strategies to manage the few successful areas in a much better way are specific to these regions, and their transfer to other regions were more or less a complete washout.

More recently, progress in understanding the conditions for success and failure helped to promote a better diffusion of good and effective management strategies. Accordingly, global trends of deterioration of ecosystems and human well-being have slowed down, in some instances even turned around. Nevertheless, in many areas major challenges remain in order to improve management strategies. In most of these cases, institutional settings are not in a shape that favors the development or adoption of new strategies. It is therefore highly important to reflect on the economic, political, and institutional changes of the last 50 years that enabled the changes we are witnessing. There are, however, some major indicators that give significant hope that ''dooming'' effects of large-scale disruptions of Earth's system can indeed be avoided. Most prominently, the improvement of local knowledge led to a decline in fertilizer input, and consequently nitrogen and phosphorus inputs in freshwater ecosystems have been reduced. This is seen as a good sign of hope for avoiding large-scale eutrophication.

The geography of success with respect to proactive ecosystem management based on local learning varied widely over the last 50 years. Some larger regions did quite well as a whole, whereas other regions with some very small exceptions by and large failed. In most regions of the world,

BOX 8.19

Sub-Saharan Africa under Adapting Mosaic

Sub-Saharan Africa emerged into the twenty-first century as a region under great stress from environmental degradation, poverty, and conflict. While the industrial world recognized the potential problems that might spring from such stresses, such as terrorism and global economic slowdowns, the efforts made by the wealthier countries to improve these conditions without sacrificing their economic superiority were largely ineffective. For example, in many countries the efforts to foster education as a means to manage population growth—a common effort in sub-Saharan Africa—found little governmental support, as these countries focused their financial resources on issues of debt and the costs of war (both financial and in terms of human capital). Further, these efforts tended to be focused in urban areas, bringing benefits to those already privileged by contact with money and education. Thus the NGO-organized education efforts that did not peter out after an initial push due to lack of funds or interest served to improve the situation of many urban dwellers, but in the process they heightened the urban-rural divide seen in most sub-Saharan African countries.

As governance devolved to regions, and as international accords on subjects ranging from economics to human rights fell by the wayside, the barriers to trade experienced here drove an increasing focus on regionally focused economic development. This created a situation in which the urban-rural divide was perpetuated. The urbanizing populations of this region needed food, which was available through the farms of rural dwellers. The continuing urbanization of the population became a threat to the social order in many states, as the migration drained the agricultural sector of their labor pool and threatened the urban food supply. Highly self-interested efforts to promote intensification in rural sites by urban elites were aimed at improving food supplies in the cities without concern for rural conditions. The result was, for example, the reintroduction of DDT into farming systems in several countries that, while improving crop yields and felicitously reducing mosquito populations and malaria rates, also induced enormous water resource degradation. Transnational organizations and groups that tried to connect with sub-national civil society groups often found themselves drawn into the growing tension between urban and rural, a tension expressed more often than not through violence.

While their economies were growing, many countries in sub-Saharan Africa were dealing with heavy debt loads that did not permit extensive expenditure on the adaptation measures called for in the 2019 adaptation protocol. Efforts on the part of organizations from wealthy countries to work with local civil society in various parts of the region succeeded in identifying key local knowledge resources that proved effective in managing local ecosystem change, but in the face of broad global shifts in precipitation and climate, as well as national pressures to increase agricultural production, much of this local knowledge was quickly obsolete. In southern Africa, there was simply no means for local farming systems to adapt to the ongoing loss of precipitation seen from 2000 to 2050, and no resources through which to construct the extensive irrigation systems necessary to preserve the agricultural systems of this subregion. Adaptive management, while productive in many other parts of the world, could not keep up with the changes in this region.

It was not until the period 2040–50 that the breakthrough of international civil society created an environment in which adaptive management could take effect in sub-Saharan Africa. The resources marshaled by these broad coalitions, both intellectual and financial, have served to supplement local knowledge and supplant local funding for such management. Struggles over the direction of such management continues, however, as international networks attempt to negotiate the regional and national politics of the urban-rural divide in order to ensure an adaptive management that is both sustainable and just. Whether such efforts will succeed in managing the urban-rural split or in overcoming the tremendous environmental problems experienced in sub-Saharan Africa over the previous 50 years remains to be seen.

however, a mixture of successes and failures can be observed. In a recent study by UNRO, major trends over the last 50 years were analyzed. The study revealed that the world divides into four major types of regions.

Some countries at the turn of the century started with a high potential for local, proactive ecosystem management but over time lost this capability by missing major opportunities for sustaining and further improving their social and human capital. Prominent examples are parts of southern North America, some countries within the European Union, and the former Pacific OECD. This group is sometimes called the *Northern Sleepers*.

Some countries managed to sustain the high level of social and human capital that they had at the turn of the century by strong investments in education and in improving networking capabilities, both in terms of infrastructure as well as institutions. The UNRO study called these countries *Sustainers*. Some countries within the European Union, major parts of North America, Australia, and some regions of what was known as the developing world at the turn of the century, such as India or South Africa, belong to this group.

Another group of countries that started off with a rather low potential for proactive, local ecosystem management was able to improve local institutions significantly to increase these capacities over the last 50 years. Educational programs further helped build human and social capital, and these countries have now experienced a significant improvement of human well-being. In analogy to the booming economies of the late twentieth century in South and Southeast Asia, the UNRO study refers to these countries as the *Pumas*. This includes some countries in Latin America, particularly Central America, plus a few large countries in Africa, like Nigeria or Mozambique, and some countries in Asia like Mongolia or the Philippines.

Finally, a last group of countries, in the UNRO study referred to as the *Trapped,* did not manage to sufficiently raise their human and social capital. This includes major regions in sub-Saharan Africa and a few countries in Latin America and Central Asia. These countries need further support to improve their social capital in order to catch up.

Due to the dynamics of investment in social capital in the different country groups, some previously developing countries have caught up with wealthier countries that were inattentive in taking care of the capabilities for learning and in facilitating networks for ecosystem management. (See Figure 8.4.)

Because of differences in social capital over time and because of natural conditions for resilience, ecosystem services developed rather differently in the different regions. Whereas the *Northern Sleepers* for some time profited from existing knowledge for proactive management, ecosystem services in these countries started to level off and even declined later in the century. In contrast, the further rise of services in the *Sustainer* countries, and later in the *Pumas,* was largely due to the increased capabilities for learning about ecosystem functioning. The end of the spectrum is constituted by the *Trapped* countries, where a significant decline in ecosystem services was observed, in particular after a number of failed experiments in the 2030s.

The trends in human well-being resulted from the interplay between economic, social, and political development with the trends and levels of ecosystem services. Note that the increase in richer countries, even for the *Sustainers,* was not as strong as for the previously poorer countries. This shows the important role of growth in social capital as a prerequisite for human development. This is also consistent with the decline in human well-being for the *Northern Sleepers*.

8.5.5 Insights into Adapting Mosaic from a Southern African Perspective

In the Southern Africa Focal Region Assessment, the Adapting Mosaic scenario was interpreted at regional (African Patchwork), basin (Local Learning), and local (Stagnation) scales. These scenarios are summarized in Box 8.20.

8.6 TechnoGarden

In the TechnoGarden scenario, technology and market-oriented institutional reform are used to improve the reliability and supply of ecosystem services. In this scenario, society's focus is on investing in human, manufactured, and natural capital. (See Box 8.21.) In this case, however, biotechnology and ecological engineering blur the distinction between natural and manufactured capital.

There is a strong belief that "natural capitalism," which focuses on looking for profits in working with nature, is advantageous for both individuals and society (Hawken et al. 1999). Technological improvements that reduce the amount of material and energy required to produce goods and services are combined with improvements in ecological engineering. Ecological understanding and technology allow people to alter ecological functioning to reduce trade-offs and increase synergies among ecological services. These technical advances are stimulated by, and in turn encourage, the development and expansion of markets in ecosystem services, such as requiring payment for carbon emissions and paying for ecological management that improves water quality.

Generally, ecological markets are established and property rights are assigned to ecosystem services following the identification of ecological problems. Because of investment in ecological understanding and natural capital, problems often are identified before they become severe. Ecological markets are established at local, national, regional, and global scales. Depending on the social and ecological context, property rights are granted to different actors.

This scenario explores the belief that ecological engineering will be fairly successful[31] and produce tolerably few major unexpected breakdowns of ecosystem services. Many

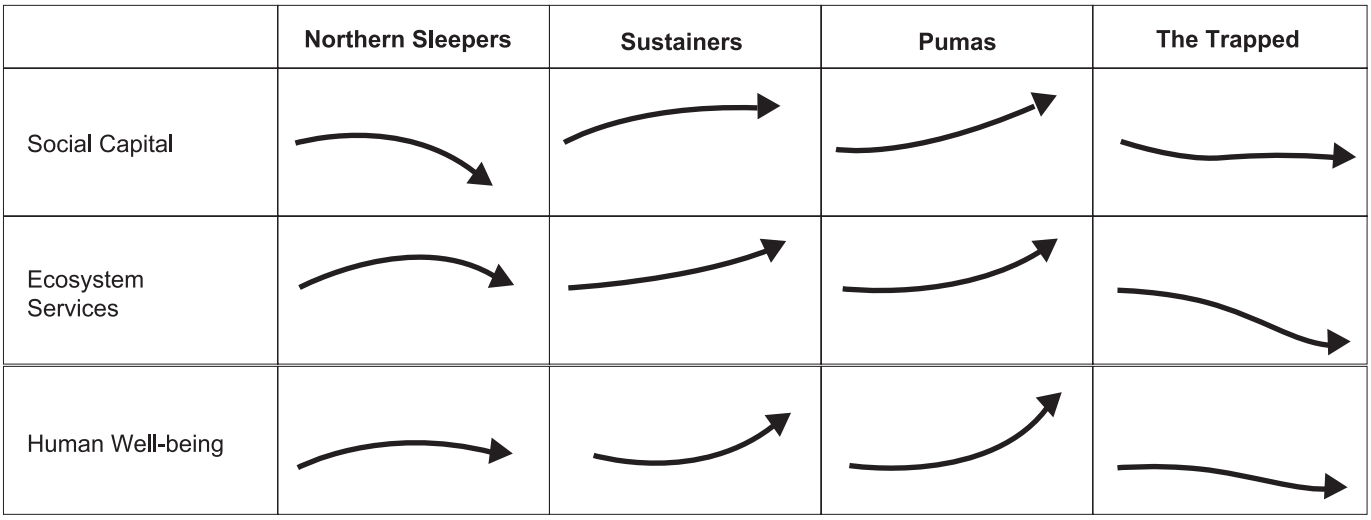

Figure 8.4. Trends in Social Capital, Ecosystem Services, and Human Well-being for Different Country Groups in Adapting Mosaic Scenario as Assessed by UNRO Study. For more details on country groups and the UNRO study, see Section 8.5.4. Note that the comparisons have been standardized for all countries for the year 2000.

ecologists agree that this assumption is plausible, but suspect that it is overly optimistic.

8.6.1 TechnoGarden 2000–15

At the beginning of the twenty-first century, poverty, inequality, and unfair global markets, together with environmental degradation, were pressing problems on the agendas of global and national decision-makers.

8.6.1.1 A Doubly Green Revolution

A key activity in which these issues intersected was agriculture. Agriculture was, and remains, the most extensive human modification of Earth's surface. At the start of the twenty-first century, world markets for agriculture were unequal. Trade barriers and perverse subsidies encouraged pollution in the rich world, impoverished rural communities, and undercut development in poor countries. A broad coalition of neo-liberals, development advocates, and environmentalists organized against agribusiness to stimulate a global transformation of agriculture in the early twenty-first century.[32]

These changes began to take hold in the 1990s, when, following a series of agricultural disease and food safety crises in Europe, governments in several European countries began to remove perverse subsidies from agriculture.[33] New EU policies encouraged farmers to manage their land to produce a bundle of ecosystem services rather than focusing on crop production alone. These policies required the development of property rights for ecosystem services. That is, people were paid for improving water quality by preserving key watersheds, while others had to pay to release pollution.[34] Soon farmers began providing additional ecosystem services, such as breeding habitat for birds, trout fishing, carbon sequestration, and improved water quality. These policies were reinforced during a decade of floods and droughts that raised the political importance of water and water quality across Europe. The initial success of policies to reduce agricultural runoff, which was lowering water quality and contributing to toxic algal blooms, combined with the realization that farmers could increase their income by receiving money to provide additional services, stimulated the expansion of multifunctional landscapes.[35]

Agriculture changed rapidly.[36] By 2015, roughly 50% of European agriculture, and roughly 10% of North American agriculture, was aimed at balancing the production of food with production of other ecosystem services. In other words, the land was dedicated to the goal of providing multiple services at once—food and some other service, such as recreational opportunities or biodiversity. This resulted in the diversification of agricultural production and lower yields, but increased profits for local farmers.

Buoyed by the success of these changes, the agricultural reform coalition convinced governments to remove export subsidies and trade barriers from global agricultural trade. Agricultural producers in poorer countries used the World Trade Organization and other international organizations to remove subsidies and other agricultural trade barriers. The liberalization of agricultural markets lead to a huge growth in food imports into richer countries, and further stimulated alternative forms of production of agricultural land. Increased imports attracted investment from agribusiness and supermarket chains in agriculture in Eastern Europe, Latin America, and Africa, which resulted in agricultural intensification in these regions. However, this intensification did not follow the same path as in Europe or North America. Agricultural entrepreneurs in these regions bred new varieties of existing crops and created locally adapted genetically modified crops and farming systems. Despite initial opposition in the EU, quick response to several minor ecological problems led to the increasing use, spread, and development of genetically modified crops, especially after the success of locally engineered varieties increased farm production and profitability in Asia, Africa, and Latin America. (See Boxes 8.22, 8.23, and 8.24.)

BOX 8.20

Adapting Mosaic in the Southern Africa Focal Region Assessment

The Adapting Mosaic scenario was interpreted in Southern Africa Focal Region Assessment at the regional (African Patchwork), basin (Local Learning), and local (Stagnation) scales. These storylines are based on an extrapolation of current trends in the region (see the MA *Multiscale Assessments* volume). While democracy and good governance take hold in some countries in southern Africa, severely limited state effectiveness, economic mismanagement, and conflict in other countries prevent the region from improving the well-being of its citizens.

Under the regional African Patchwork scenario, development trends apparent in the South African Development Community region over the past few decades generally persist until 2030. Low economic growth rates and declining foreign investment lead to the increased economic marginalization of Africa. Localized military conflicts continue to drain resources, damage infrastructure, and impede the provision of services.

Improvements in agricultural productivity per hectare are not sufficient to meet the needs of the growing population, resulting in large-scale conversion of woodlands to crops and the expansion of agriculture into marginal lands. While the maintenance of agricultural diversity affords some protection against pest outbreaks, climate change brings more frequent droughts and consequently crop failures, especially in marginal areas. The rural population relies heavily on a declining natural resource base for their subsistence, and many people migrate to cities, where they remain impoverished. Large quantities of food aid are needed to support the urban poor in particular; delivery of food aid in rural areas is impeded by poor infrastructure and conflict. Those rural people with access to land and resources are highly self-reliant, and locally organized. Protected areas are encroached, and wildlife and high-value plants virtually disappear from many areas.

Most governments are unable to ensure the provision of reliable, safe water or modern energy sources, resulting in continued high mortality from waterborne diseases and indoor air pollution, and large-scale deforestation for charcoal production. Poor enforcement of environmental standards, where they exist, make the region a dumping ground for dirty industries and waste from wealthier regions, resulting in deteriorating water and air quality. Water quality is further degraded by increased soil erosion and untreated sewage. A water supply crisis in the shared river basins in the southern part of the region is a major source of regional tension.

In the Gariep basin, the Local Learning scenario illustrates that most local authorities, facing severe budget constraints, are unable to make good on the promises of the free basic water and electricity programs. Lack of access to water, land, and mining rights increasingly causes local tensions and conflict across the basin. The remnants of commercial agricultural are sufficient to feed the urban markets until 2030 but are expanded onto more marginal lands with devastating environmental consequences. The conditions for the urban poor deteriorate rapidly due to the absence of a resource base and a lack of service delivery. The rural poor are isolated by a declining and impoverished infrastructure.

In the absence of effective central governance and market mechanisms, strong civil society networks encourage local infrastructure development, with service provision dependent on community initiative. The rural population, growing steadily and faced with a declining resource base for subsistence farming, becomes increasingly locally organized. Local tourism initiatives that emphasize conservation do spring up in places, and catch the eye of international NGOs, which lend them support.

Throughout the basin, regions are increasingly self-sufficient in obtaining the services they need. Their well-being varies: while there is less ambitious development of resources, there are also lower levels of pollution, producing only moderate declines in water quantity and quality region-wide. The sparsely populated arid west manages to maintain its energy, food, and biodiversity at constant levels. Small declines in energy occur in all other regions. Food production drops drastically in the Great Fish River, where the effects of climate change, land degradation, and a reduced labor force as a result of HIV/AIDS curb the capacity of the remaining arable land to feed its growing population. In the urban centers, reduced economic activity means a slight, though not severe, deterioration in water, energy, food, biodiversity, and air quality, while the minerals industry's output slowly increases, still fueled by foreign investment. For its affluent inhabitants, life is slightly worse; it is much worse for the poor. The arid west elites maintain their well-being at constant rates, while the poor in this region are slightly worse off. In the regional "grain basket," many who rely on a now-reduced agricultural income are slightly worse off regardless of affluence. Lesotho, recognizing the need for economic independence from South Africa, embarks on a program to reform its agricultural productivity, but needs international assistance. Foreign interest in Lesotho is piqued when a local discovery is made that a plant endemic to the Lesotho grasslands has high pharmaceutical value, calling attention to the need for formal conservation of this biome, as well as stronger legislation to protect intellectual property rights.

In the local communities of the Gariep basin, a Stagnation scenario takes hold. With the contraction of the macroeconomy, policies are weakly implemented, and projects are put in place in a heavy-handed way. There are no prospects of employment; human lives and values in the cities are cheap, and people migrate back to rural areas. People wait in vain for relief projects. Pensions and state grants stagnate and are delivered intermittently. The youth remain in rural areas. Basic services and infrastructure are not supplied, and health services are limited to mobile clinics and schools. Schools deteriorate. There are too many children, and classes are held outdoors. People realize that their survival and future is in their own hands, and human capital becomes the main asset. Community identity and bonds are strong. However, the few projects that are implemented from outside create a few jobs, and this tends to undermine community structures. Cohesion suffers because of strong competition for meager resources, and corruption increases.

Land use becomes destructive and land is limited. Grazing lands are taken over by protected areas, and village committees allocate the rest. Less water is available for drinking, irrigation, mining, and livestock. Fuelwood becomes scarcer. Most agricultural production is for home consumption. There are land invasions and uncontrolled extraction, with people making extensive illegal use of plant and animal resources on state land.

The combination of market-based environmental regulation of agriculture with the creation of air pollution emissions trading schemes stimulated a broader set of ecological property rights regimes that encouraged businesses, states, and individuals to adjust their practices and consumption. Decreasing costs and increasing quality operated in tandem with environmental concern to catalyze a broad set of technological changes.

8.6.1.2 Transportation Innovation from Latin America

Small and large high-technology companies in some poorer countries experienced rapid growth during the first decade

BOX 8.21

Potential Benefits and Risks of TechnoGarden

Potential benefits:

- Win-win solutions to conflicts between economy and environment
- Optimization of ecosystem services
- Societies that work with rather than against nature

Risks:

- Technological failures have far-reaching effects with big impacts
- Wilderness eliminated as "gardening" of nature increases
- People have little experience of non-human nature; leads to simple views of nature

BOX 8.22

Genetically Modified Organisms in TechnoGarden

Genetic modification serves as an evolving source of conflict in TechnoGarden. A succession of conflicts arises from continual advances in molecular biology that encourage the expansion, diversification, and regulation of genetic manipulation and modification.

Well-designed agricultural biotechnology, encouraged by multiphase physiological, medical, and ecological regulation, lead to great expansion of the use of GM crops in the early part of the twenty-first century. This expansion leads to conflicts between farmers growing GM crops and those growing organic and other non-GM crops. Farmers not using GM had their crops contaminated by plants and genes from GM crops, preventing the sale of their produce. While these cases lead to the additional expansion of ecological property rights and further encouraged the expansion of multifunctional agriculture, these changes are cold comfort to the small organic farmers who had their livelihoods eliminated.

Conflict over GM crops paled in comparison to the use of GM to produce crops to create pharmaceuticals. "Pharming," while lowering the cost of many drugs, rather predictably lead to cases where drugs contaminated the food supply, causing a range of serious and subtle health problems. The food scares and lawsuits lead to massive losses for farmers and some biopharmaceutical firms, as well as the reorganization, formulation, and regulation of the public use of GM. Pharmers abandoned the use of agricultural crops as producers of drugs and concentrated their farming in areas that contained few relatives of the pharming hosts. This gave a huge boost to the nascent biotech industries in isolated species-poor areas. Iceland, New Zealand, Japan, and Canada all used their industrial infrastructure and remoteness to a huge advantage.

Despite these problems, GM biofuels, such as rapeseed, and fast-growing trees were planted and developed with little opposition. Concern over the use of GM was limited because it did not involve the food supply, and the demand for renewable energy fuels was stimulated by carbon taxes. For decades biofuel plantations were successes for GM technology; however, in the late 2020s a previously unknown fungal disease caused catastrophic forest fires in a large number of biofuel plantations. These agro-industrial accidents led to a further refinement in biosafety protocols and stimulated the growth of multifunctional agriculture, based on the general principle that more diverse biofuel plantations would be less vulnerable to catastrophic surprises.

Many specialized uses of GMs, such as detecting mines, were quite successful. However, the spread of GM technology resulted in the casual use of GM technology that produced substantial environmental damage. For example, the accidental release of GM organisms produced by artists resulted in a series of catastrophic incidents. A GM algae escaped from an art installation at the Bio-(Diverse) City Art Bienalle in Tokyo, for instance. The algal infestation of Tokyo's water system resulted in over 189 deaths, $18 billion in renovation and decontamination costs, 49 criminal convictions, and the bankruptcy of the University of Melbourne (which was operating the exhibit).

Despite these setbacks, the continual development of professional, legal, and technological control methods allowed GM technology to be continually improved and used. GM organisms have produced decreases in soil erosion, salinization, biodiversity loss, and global carbon emissions, but these benefits must be evaluated against the death, disease, genetic contamination, and ecological disruption that GM organisms have also produced. In 2050, many molecular biologists compare GM to other technologies and assert its incredible environmental scorecard, while other scientists object to the loss of non-GM nature.

of the twenty-first century. Advances in computation and communication enabled substantial improvements in logistics, which lowered both the price and environmental impact of a wide variety of businesses and helped ensure that development in poorer countries during the twenty-first century did not replicate that of the countries that became rich during the twentieth. This new kind of development, driven in part by the costs of ecological services, took advantage of profitable opportunities for growth that did not impose huge environmental costs. These differences were perhaps best exemplified by the development of flexible low-cost transportation systems in rapidly growing cities.

Beginning at the end of the twentieth century, the combination of the economic costs of congestion, social concerns over fair access to transportation, and the impact of air pollution on urban health stimulated the development of advanced bus systems in South American cities such as Curitiba and Bogota. These systems used scheduling software, clean-fuel buses, and safe, enclosed subway-style stations. They demonstrated that even in poor, rapidly growing urban centers, mass transit could provide a faster commute, in a fraction of the implementation time of subways or light rail, with a lower economic and social cost. In the early twenty-first century, the replication of these advanced bus systems in other developing cities was aided by improvements in rapid construction techniques and logistics and by the availability of low-pollution vehicles. (See Box 8.25.) These systems required minimal new infrastructure and so were set up rapidly by removing a few highway lanes from the use of the minority of the population who owned automobiles.

The establishment of a variety of national, regional, and global tradable emission permits helped stimulate the spread of these transit systems from Latin America to other rapidly urbanizing cities such as Mumbai, Dhaka, and Lagos. This spread was facilitated by Latin American transit and logistics companies, as well as rival Indian and Chinese transnational bus corporations. By the second decade of the twenty-first century, intense competition between these transit compa-

BOX 8.23
A Story of India (TechnoGarden)

The market was crowded as always. While the bus filled, Raja looked out over the crowd of people. He was tired. Last night he had returned late from his weekend pilgrimage. The travel and excitement had left him exhausted. It had been great to see his cousins again. It had been years since they had been together. His father always talked about the old days, about all the time his brothers and cousins spent together. But now that all his uncles had moved to the city, he and his father were the only ones left, and they didn't farm anymore. Because Raja had never been interested in farming, they had sold most of the land to one of the local farm companies.

His father sold the farm after his mother died from a deadly bacterial infection. She had been healthy, but a week later she was dead. His dad changed after his mother died, he just played on his computer all day. Raja didn't know what to do for his father—other than to play video games with him. It was too bad that his father hadn't come on the pilgrimage. Raja knew that he would have loved to have seen the family, but he was old and weak. The doctors didn't know exactly what the problem was, but he had an unidentified immunological condition that left him exhausted.

After seeing his cousins, and hearing their tales of Bombay, Toronto, and Bangkok, the market seemed dull and provincial to him. His uncles had tried to convince him to use his genomics database administration skills to get a contract overseas, but that would mean leaving his father, who was sick, and he still hadn't been able to get his second-class genomics license.

As the bus pulled away from the market station onto the highway, it accelerated through the large irrigated fields of GM cotton that surrounded the town. The bus briefly stopped at the big temple complex outside of town, where a few French-speaking European monks got off. They were all part of the international project to rebuild a "famous" twelfth century temple garden that Raja, at least, had never even heard of before the monks had arrived. But they were fairly friendly, polite, and good gardeners.

After 10 minutes speeding through multihued agricultural fields they finally stopped at the grove of trees that held the offices of Raja's employer, Naidu Biosystems. Raja left the bus and saw his colleagues Sam, Kiran, and the new engineering intern from Bangalore, but he was too tired to chat right now. He shuffled along the gravel path, through the trees, and into his group's air-conditioned office. He was the last of his team to arrive and his coordinator, Ms. Patel, wished him good morning while she looked at the clock. She then asked him to check the field's aphid distribution data and compute the intervention options. It was a long, dull job. He slumped into his chair and then began poking and tapping his way though the data that streamed from the surrounding fields into the building—he sighed and got down to work.

nies and car manufacturers led to substantial improvements in vehicle technology, systems management, and emission reduction technology. New urban centers operated transit systems that provided better service at less cost and had fewer health and environmental impacts than their equivalents in wealthier countries.[37]

Some cities in the rich nations also adopted these systems, but not all. In most cities in these countries, transit services were increasingly diversified and flexible. Especially in dense cities, the costs of car ownership, particularly parking fees and congestion, stimulated the rapid growth of car-sharing companies. Urban residents increasingly avoided the costs associated with car ownership and chose instead to use a combination of taxis, mass transit, local car-sharing networks, and longer-term car rental agencies, which provided them with a range of affordable, flexible transportation services.[38]

8.6.1.3 Islands in the Net

In the early years of the twenty-first century, national governments became more deeply enmeshed within some global institutions while withdrawing from others. The success of EU federalism served as a model for the creation of regional partnerships among nations. The lessons of the EU were used to argue for its expansion and to design regional confederations, such as those that loosely joined more prosperous countries in South America, southern Africa, Southeast Asia, the Caribbean, and Polynesia. As a result, economic integration within Asia and Latin America increased.

Due to security concerns and other stresses of globalization, rich countries attempted to increase restrictions on trade and immigration, but this was prevented by pressure from a coalition of transnational companies, retailers, and cosmopolitan communities, particularly the Chinese and Indian diasporas. This cosmopolitan alliance pushed for globalization, the relaxation of trade barriers, and efficient systems of immigration (especially for the well educated and the rich). The alliance was able to overcome isolationist interest in a number of rich countries in Asia, Europe, and North America, which led to an even stronger set of global organizations and treaties.

Within this dense global net, some islands remained isolated from the expansion of global civic society and benefited little from increases in wealth and health in the world at large. Regions in conflict failed to attract international investment or much help from global civil society. In particular, drylands in Central Asia and the Sahel regions in Africa were subject to droughts and suffered from food shortages and chronic malnutrition. Weak or failed states remained havens for criminal networks, drug manufacturing, financial fraud networks, pirates, and guerillas. (See Box 8.26.) These groups benefited from lack of control in these areas, and often maintained conflict. Along with these local troubles, these areas often exported violence, disease, and pollution. While some war zones became involuntary parks—areas in which political and technological collapse allowed natural processes to reassert themselves (see Box 8.27)—the majority of the war zones suffered ecological degradation from unsustainable hunting and fishing, water pollution, mining, and deforestation.[39]

8.6.2 TechnoGarden 2015–30

8.6.2.1 Consolidation of Globalization

Transnational corporations, international NGOs, action groups, and global associations continued to flourish and

BOX 8.24

Sub-Saharan Africa under TechnoGarden

While sub-Saharan Africa entered the twenty-first century facing the challenges of poverty, disease, environmental degradation, and conflict, the increasing ecological awareness of the global population had rapid and beneficial effects on these challenges. The gradual elimination of agricultural subsidies in richer countries, especially in Europe, opened these markets to agricultural products from sub-Saharan Africa. Tens of billions of dollars flowed into African economies, allowing for the management of debt and the development of key infrastructure in transportation, communications, health, and education. Many major cities in this region became cleaner and more livable from these developments, and urban life expectancies rose in response.

Though market forces were keys to the success of agriculture in sub-Saharan Africa between 2000 and 2015, the introduction of GM crops to this region was also a critical development. Sub-Saharan Africa became something of a testing ground for these and other environmental technologies, with the result that many early feedbacks and problems were concentrated in this region. While these issues were eventually managed, the ecological damage they caused is still visible in many parts of this region through biodiversity loss and landscape change. Further, the widespread focus on agriculture in this world region has also contributed to massive intentional landscape transformations, such that today entire ecosystems, such as the Upper Guinea Forest, no longer exist in any functional manner. Instead, small remnants remain as protected areas—tourist attractions for those who seek to visit "the forests of Africa."

While much of sub-Saharan Africa saw its economic fortunes improve across this early period, several states lacked either the political will or ability to muster the resources necessary to take advantage of these changes. Further, true-cost pricing of fossil fuels struck a major blow to the economies of several nations around the Gulf of Guinea, as oil became a far less lucrative export. Smaller petrostates experienced coups and political instability, while larger states with more diversified economies were able to weather these economic changes through agricultural transformation. Thus sub-Saharan Africa found itself dealing with nations of strong growth next to nations of little or no growth and great conflict.

The nations experiencing strong growth recognized the threat that regional conflict presented to their long-term stability and growth, especially in the form of cross-border migration and international image. Rather than allow their neighbors to continue unchecked, as they had in the days of the Organization for African Unity, under the African Union stronger nations like South Africa, Ghana, and Nigeria began to exert political, economic, and, where necessary, military influence on their neighbors to ensure regional stability. The long-term result of these early efforts was the development of two strong regional organizations, one growing out of the Southern Africa development community and the other from the Economic Community of West African States. These organizations created shared currencies, promoted economic integration, and greatly enhanced the stability of their regions.

The increasing political stability and economic growth in sub-Saharan Africa enabled the use of highly developed technologies for ecological management. Further, the development of pop-up infrastructure allowed for the provisioning of economic, social, and ecological services to a wider constituency than ever before. In 2050, sub-Saharan Africa is hard to recognize from the perspective of the late twentieth century. Much of the ecology that shaped the industrial world's imagination about this region no longer exists or does so only in small reserves. The violence that so characterized this region in the late twentieth century has largely abated thanks to regional and subregional organizations. In the place of this mysterious, violent territory stands one of the globe's "breadbaskets," with some of the cleanest cities and most rational land use in the world.

BOX 8.25

Bogota's Success Story: The Bus Rapid Transit—A Solution for Megacities in Developing Countries

By 2030, 3 billion more people will be on Earth. Developing-country governments have noted with alarm that most of this growth will be in their already congested and polluted megacities and could be crippling. Novel transportation systems will be essential. One such system, Bus Rapid Transit, or BRT, is a high-speed, low-cost public transportation innovation first developed in Curitiba, Brazil, in the early 1980s.

The BRT model has helped to transform developing-country cities like Bogota and could help to avert severe crises in the transportation, environment, and health sectors (Ardila and Menckhoff 2002; Fouracre et al. 2003). Major cities in China and Mexico are looking to follow suit. Bogota's Transmilenio, as its BRT system is called, transports subway-level capacities of 1 million people a day at high speeds, but has two critical advantages over a subway system. It costs only 5% of what a subway with similar reach would, and it can be built in just three years—a fraction of the time needed for a subway.

What distinguishes BRT from conventional bus systems so that even the middle-class residents with cars prefer to use Transmilenio in Bogota? A successful Bus Rapid Transit system like Transmilenio is an integrated one where buses move at very high speeds, since they are physically separated from car lanes and can signal traffic lights to turn green; where people can get on and off in seconds, since riders prepay before boarding and buses have wide, low-level doors like a subway; where there are several express busses that do not stop at every station, but connect to local buses, similar to a subway model; and where stations are well maintained and have parking lots and taxi access plus excellent bicycle, pedestrian, and disabled facilities.

In 2004, the success of BRT systems led the Chinese government to begin developing policies to bring Bus Rapid Transit to its major cities. BRT in Bogota not only averted a crisis, it transformed the public space by lowering air pollution (since significantly fewer cars come into the city) and improving the quality of life in the urban core. Well executed, it promises to do the same for more of the developing world's overcrowded and polluted cities.

BOX 8.26

Failed States, Pirate Zones, and Ecological Disruption across the Scenarios

Many areas with the lowest state of human well-being and the greatest poverty are areas in which states have failed to maintain order. Most of these areas are within the remnants of failed authoritarian states or in the interior of states whose internal control has failed.[a] Following the end of the cold war, powerful countries stopped investing in some of the governments they had been supporting because the governments had become expensive and unimportant. In these areas, government sometimes collapsed, leaving a void where central government has not been able to enforce its rule. Frequently, militias supported by smuggling or extraction are based in regions like this that are not governed by states, where the central government has failed to provide any type of security, prosperity, or freedom to its inhabitants.

In these areas, various armed groups engage in violence to disrupt state intervention and to promote their own power and profits. These groups engage in resource extraction and smuggling—growing, processing, and distribution of narcotics. Often, groups in these areas have links with international criminal organizations, armed militias, and guerillas. For example, in many parts of the world drug production and smuggling is used to fund militias, while in other places militias are paid a tax to protect drug production from state intervention. Often the presence of valuable resources in a region can sustain conflict among various armed groups, because the presence of valuable, easily transportable commodities such as gems, gold, or narcotics provides funds to attract and arm militias. During the early twenty-first century, there were a number of such areas in which conflict combined with resource extraction in areas as diverse as the Congo River basin, the Thai/Burma border, and Colombia.

Improved transportation, communications, and logistics facilitate the activities of these groups by providing better opportunities for the movement of illicit drugs, weapons, and money and illegal immigrants. These groups innovatively fuse cutting-edge technology, local knowledge, and family ties to coordinate their networks, broadcast propaganda, and move people, guns, drugs, gemstones, and other valuable commodities across national borders.

These areas are often bad places for people to live. In particular, in areas where contesting militias exist, local people are often the targets of theft and violence. Disease is common due to a lack of public health infrastructure. These conflict zones have mixed ecological consequences. Small areas of heavy exploitation are used for mining or drug production, while bushmeat hunting and timber cutting occur over more substantial areas. Drug manufacturing can result in forest clearing and chemical pollution of streams and groundwater, while attempts at narcotic control by the larger world can also pollute local ecosystems. For example, anti-narcotic programs have resulted in the haphazard use of pesticides; stimulated land clearing, deforestation, and erosion; and increased the mortality of wildlife.

Impoverished, unsafe people are unlikely to be able to organize themselves to steward local resources effectively; indeed, there is every incentive for them to extract resources as quickly as possible. On the other hand, if conflicts prevent the clearing of large areas of land for agriculture, they may inadvertently conserve some aspects of local fauna. In other cases, however, there are more negative consequences for ecosystem services.

The world outside these areas both takes advantage of their chaos and suffers from it. The lack of any government to protect the public interest allows foreign companies to dump toxic waste and extract unprotected natural resources. For example, fishers from all over the world have been fishing off the unregulated coast of Somalia, while other boats have been dumping toxic waste there. At the same time, international shipping is affected by the disorder there by frequent pirate attacks (Christian Science Monitor 1997; The International Chamber of Commerce Commercial Crime Service).

While the piracy, trafficking, and conflict in these areas often spills out into the outside world, these spillover effects are frequently tolerated due to their relatively minor impact and the difficulty of intervening in the lawless areas. The persistence of these areas depends on the inability of local governments to control the area, the disinterest of global institutions or neighboring countries to intervene, and the continued profitability of conflict, smuggling, or piracy. For marginal places, with minimal resources of interest to the outside world, it takes extreme events, such as the September 11, 2001, attacks, to stimulate world forces to intervene in these areas.

The likelihood of lawless regions is higher in some scenarios than others. Pirate zones arise due to local issues. But the response to local problems depends on the role of the region within the world and the attitude of the larger world toward such regions. The likelihood of such regions both arising and persisting varies across the scenarios.

These sites are mostly likely to arise in a more fragmented, less globalized world like that of Order from Strength. The presence of extensive global trade, multilateral treaties, and international NGOs is likely to result in intervention from outside a region, either humanitarian or military, to reincorporate such regions within the global system. These regions are also more likely to arise when conflict and injustice are allowed to thrive within countries, and there is little effective regulation of global trade.

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[a] As part of the MA, the Colombia Sub-global Assessment focuses on Colombia's main coffee region, which is located in the central part of the country and includes the mountainous regions of Antioquia, Caldas, Risaralda, Quindio, and Valle. In this region, traditional agriculture has transformed mountain ecosystems into rural landscapes. The assessment attempts to understand the factors that cause changes in ecosystems and how those drivers generate serious impacts that can in the long term cause environmental, economic, and social imbalances.

thrive. Easy travel, cheap communication, social software, and ''intelligent'' databases aided the management of these groups.[40] International migration increased, producing increasingly intertwined diasporas and an increasingly interconnected, powerful, and diverse global civil society. The impact of new civil organizations was diverse and multifaceted. Decreased costs of communication and travel stimulated the formation of many NGOs, but the main beneficiaries of these advances were the many technical and professional associations, who globalized and intensified their activities. International technical standards groups, formed by technical associations and endorsed by transnational corporations and national governments, developed increasing numbers of global technical standards for telecommunications, transport, manufacturing, and environmental management. One of the major symbolic steps in the process was the adoption of the metric system by the United States in 2029.

The proliferation of international standards in turn increased the power of professional associations; facilitated

BOX 8.27

Involuntary Parks across the Scenarios

Buffer regions between conflicted states as well as contaminated areas can become perverse nature preserves. The health and security risks of people entering these regions are so great that human activity is excluded. People are unable to use these areas to produce local ecological services, but they can benefit from the refuge that the areas provide to wildlife. The migration of people out of these regions, the presence of minefields, and continuation of conflict can in some ways act as a perverse form of conservation by creating involuntary parks.

The Demilitarized Zone between North and South Korea provides an example produced by conflicts between states. The Korean DMZ, which is roughly 250 kilometers across and 4 kilometers wide, contains the largest area of forest in the Korean peninsula and has been only minimally affected by human activity since the end of the Korean War in 1954. It contains a variety of species, including white-naped crane and the red-crowned crane as well as the Asiatic black bear, that are rare or endangered in the rest of the Korean peninsula (Government of Korea (website); Kim 1997).

The Chernobyl accident in the 1980s produced a large radioactively contaminated area in the Ukraine. While the radiation in this area increases mortality of people and wildlife, the absence of people has resulted in forest growth and a great increase in wildlife population. The slow decline in radioactivity has led to an increase in disaster tourism. The soil remains contaminated with radioactive fallout, however, preventing human use.

These circumstances could arise in all four scenarios, but the likelihood is greater in some than others. Conflicts and industrial disasters are both more frequent in Order from Strength, and there is less interest in and capacity for restoring such areas. In Global Orchestration there may be industrial disasters, but there are fewer unresolved conflicts, and there is global interest in repairing contaminated areas, leading to fewer involuntary parks. In TechnoGarden there are more involuntary parks, since more ecological engineering provides more potential for disaster, and pursuit of profit rather than equity leads to less repair of involuntary parks. However, increasing capacities in ecological engineering and potential profits available from repairing such areas leads to a gradual increase in their repair. Adapting Mosaic results in fewer large involuntary parks, as local organizations frequently occupy and attempt to make the best of small contaminated or conflicted areas.

more transnational collaborations of engineering, medical, and legal associations; and increasingly influenced government and corporate policies. While these groups encouraged the free flow of information within their professional organizations, they raised barriers to entry into these professions.

The process of globalization also focused on regulating many global and regional ecological commons. The success of a revised Kyoto treaty, and the new commitments taken up for the post-Kyoto period, combined with the growth of global institutions, resulted in a number of frameworks to govern the high seas, the atmosphere, and transboundary seas, rivers, and wildlife. One high-profile case was the increased regulation of high seas fishing in an attempt to deal with declines in catch from pelagic fisheries. Tuna, and later other large fish, were ''ranched'' using implanted transponder chips, radiotelemetry, and satellite monitoring. While these global regulations were often successful, formalized use tended to displace many local resource users, such as small-scale fishers.

8.6.2.2 Urban Eco-Development

The rapid urbanization of Asia and Africa during the twenty-first century resulted in both health disasters and unexpected successes. Asian cities experienced dynamic periods of urban reinvention. The regional dialogue between cities about their approaches to urban reinvention stimulated a new Asian urbanism and an approach to urban living that was emulated and adapted worldwide through its promotion and implementation by a competitive group of Asian-based transnational construction and maintenance corporations.

New-Asian urbanism combined existing technologies in novel ways and stimulated new ways of thinking about city planning. People found new uses for composite materials, and produced flexible, green building materials, which lowered building energy and water use while improving quality.

Asian urban areas, with their new construction, transportation, and manufacturing, produced rapidly increasing air pollution and carbon emissions. Global mean temperature had increased by over 1 degree Celsius, leading to further restrictions in emission permits. Increasing emission costs and the demand for healthier, cleaner cities enabled the rapid growth of innovative Indonesian design and architecture companies. The successful franchising of bus systems by Latin American transit corporations in combination with locally developed ''green'' housing techniques helped achieve this goal and produced surprisingly attractive cities that increasingly became tourist centers.

Unfortunately, much of the innovation of New-Asian urbanism was driven by the need to help people cope with environmental problems caused by rapid urbanization. Many urban ecological engineering efforts were the result of catastrophic disease outbreaks, with especially severe problems in rapidly growing tropical cities, such as Dhaka, Bangkok, and Manila. Poor water quality was a major chronic cause of disease in many rapidly urbanizing cities. Poverty and poor sewage spread cholera and typhoid. Irrigation projects spread schistosomiasis. Poor drainage in slums allowed populations of disease-spreading mosquitoes to thrive.

However, the emergence of several families of new respiratory diseases with high social and economic costs resulted in a global movement to enact health-oriented reforms that used ecological engineering to improve water quality in many cities (World Resources Institute 1998). In many regions, people began to modify and convert existing irrigation systems, often using multiple-use, managed canals to better connect cities and countryside. These urban technologies were quickly transplanted and adapted by the cities of Asia, especially new cities in China, and then gradually spread to some parts of Africa and Europe.

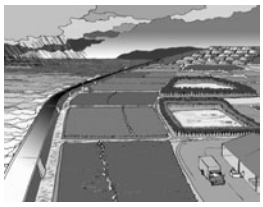
In richer countries, there was a different set of urban issues: cities were aging and shrinking. ''New-Asian'' ur-

banism emerged in countries like Japan as a way to make cities more beautiful, livable, and healthy. The Japanese approaches sought to combine Asian traditions with large-scale ecological restoration, which resulted in a substantial return of species formerly displaced from urban areas. New-Asian urbanism became a model for revitalizing the stagnating major cities in all richer countries.

Urban restoration, using techniques from agriculture, ecological engineering, and simple nano-machines, led to some enormously beautiful and popular restoration projects on Japan's inland sea. But it also produced some of the first biomechanical disasters, such as vast algal blooms due to unexpected interactions between water purification nano-machines and invasive waterborne bacteria. Fortunately, these blooms were quickly controlled and eliminated, but not before the catastrophic loss of most large marine life off the coast of Japan.

8.6.2.3 Green Design and Ecological Agriculture

The gradual removal of subsidies for fossil fuels, nuclear energy, and large hydro projects was motivated by the combination of global trade liberalization, local health concerns, and the rising costs of oil and natural gas as a result of the development of a variety of smaller-scale energy projects in the developing world. Large energy companies funded some projects, but there were many successful start-up energy companies founded by Chinese and Indian entrepreneurs. These developments were stimulated by the Global Environmental Facility's New Energy Fund, which was set up to mitigate climate change by stimulating the development of low-carbon emission energy systems. These efforts led to substantial decreases in the cost of power produced by wind, solar, and biofuels, as well as great increases in effectiveness of fuel cells and low-pollution fossil fuel power plants.



Following successes in cities and agriculture, people increasingly began to apply ecological engineering to optimize the supply of desired ecosystem services. Consequently, ecosystems were increasingly shaped to provide different bundles of ecosystem services. Ecological engineering was done privately at local, small, or regional scales by a variety of private, public, and community and individual actors.

Over time, the economic benefits of ecological engineering increased due to advances in technology and the decreasing costs of engineering techniques. Additionally, the costs of not engineering skyrocketed due to increasing local ecological problems that were most easily and quickly solved through ecological engineering techniques. Ecological engineers used advances in computer, communication, and materials science to build ecological infrastructure that was increasingly flexible, dynamic, and adaptive. Distributed monitoring networks operated in conjunction with advances in precision agriculture, allowing ecological dynamics to be cheaply steered. Innovations such as pop-up infrastructure, which only existed when needed, allowed people to intervene in ecological dynamics with far fewer direct, inadvertent side effects. One persistent issue, however, was the discovery that desired populations of wildlife depended on some previously unknown aspect of local ecosystems that was eliminated once ecological engineering improved the system.[41] It frequently turned out that ecological engineering solved the problem it was aimed at, but created some decline or problem in provision of another ecosystem service.

Unintended consequences of the increasing use of genetically modified crops, including wildlife die-offs and allergic reactions, eventually led to strict programs of testing and certification of genetically modified organisms. These regulations stimulated the further development of large-scale agriculture that used micro-doses of pesticides and introduced insect predators to control insect damage to crops. The fusion of some of these techniques with contemporary low-input farming methods produced large-scale ecological precision agriculture that included mapping, tracking, and biomonitoring of trace elements and disease.

8.6.3 TechnoGarden 2030–50

8.6.3.1 Technocrats Ascendant

The complex interlocking nature of the global economy and increased use of technology made it difficult for companies to adopt anything other than global standards. These technical standards, which played such a powerful role in determining policy and action, were set by scientific societies, professional groups, and their affiliated corporations and NGOs. The unelected technocrats in these organizations became increasingly important legislators of the world. The increased enforcement of global environmental and civil regulations by technocrats lead to an intense series of ''police and nation building'' wars in the 2030s as regions once controlled by militias, guerillas, or local groups were forcibly incorporated into the global economy. Ecological restoration projects, backed by military force, were implemented in conjunction with large-scale health and education networks.

Continued gradual improvements in energy efficiency, alternative energy, and biofuels left the Middle East with much lower than expected oil wealth. Social problems were further complicated by migrants from degraded dryland areas in the Sahel and Central Asia. Social tension led a globally connected diaspora of young people to violently contest the future of countries within this region until, aided by their foreign allies, a technocratic civil society of economists and engineers prevailed over religious leaders and nationalists and began to open and reform the economy. Innovative experiments, which adapted and combined technology and institutions from Asia, Africa, North America, and Europe, allowed the region to develop solar-driven technology that transformed its coasts and river valleys.

The openness of science and the technocrats' great faith in scientific and technological progress to stimulate economic and social growth moved intellectual property away from closed proprietary systems and toward more-open systems.[42] One side effect of this was the general availability of sophisticated open source educational resources, which greatly improved the educational opportunities available to most of the world's population. While information was freely available, however, access to professions was strongly regulated. Universities increasingly served as places for social networking and were differentiated by the opportunities for practice, experimentation, and research.

8.6.3.2 Eco-technology

By the 2040s, cheap, reliable eco-technologies were available worldwide. While a few of these were developed in richer countries, a major growth of eco-technology occurred across the poorer section of the world. Small companies and cooperatives developed eco-technologies to address local needs and local markets. These technologies gave many local communities the power to improve their situation by providing valuable ecosystem services, such as fresh water to nearby cities and exotic organic produce to the rich world. In the poor nations, these technologies substantially controlled AIDS, malaria, and many other diseases. The reliable provision of ecosystem services, along with economic growth, lifted many of the world's poor into a global middle class.

The continued development of new energy technologies resulted in substantial increases in the cost-effectiveness of some alternative energy sources, such as wind and solar, and great increases in effectiveness of fuel cells and low-pollution fossil fuel power plants. In many poorer countries, local companies developed efficient biofuels to replace inefficient charcoal and wood-burning stoves, providing people with more time, more forests, and better health. In conjunction with the decline in coal use, Asian engineers developed low-pollution methods of using coal to produce natural gas and hydrogen. Thus conditions for an effective response to climate change were very good under TechnoGarden. Due to the combination of greener energy production and more-efficient energy use, global greenhouse gas emissions peaked in the 2020s and declined to levels below those of the start of the twenty-first century well before 2050. However, because declines in emissions of particulates from fossil fuel burning temporally offset decreases in carbon emissions, there was still a 1.5-degrees Celsius increase in global average temperature by 2050.

8.6.3.3 Eco-urbanism

By 2035, most of the world's large cities had become polyglot, cosmopolitan places due to global connections and migration. Though some aspects of local culture were eliminated, cheap global communications created a huge diversity of global subcultures. While many of these subcultures were technical and global, intersecting groups were often locally based. Most of the world's urban population lived in new cities that were strikingly different from cites 50 years earlier. Ecotechnology and ecological markets allowed cities to vary their zoning, development, and architecture to local climate and ecology, even as global technology and culture drove city policies to be more similar. Unique aspects of locality led to new cultural traditions, such as the salmon festivals of the American Pacific Northwest and the Gojiro festival that symbolically destroyed large areas of Tokyo every five years.

Many people owned cars, but rates of car ownership converged worldwide such that the countries that were industrialized at the beginning of the twentieth century had fewer cars per capita than they did at the turn of this century, and many other countries had more. Urbanization and the creation of diverse, flexible, and adaptive transit systems reduced the relative value of car ownership in big cities. Most city dwellers chose to rent cars when they needed one. As air pollution and other car-related pollution problems got worse in high-density cities, consumers demanded cars that produced less pollution. Chinese and South Asian automobile manufactures led the way in providing affordable, fuel-efficient, low-pollution vehicles. New urban transportation systems substantially reduced emissions, increasing urban air quality and decreasing health costs of transport and greenhouse gas emissions.

Ecological restoration adopted and adapted many technologies from green precision agriculture that allowed a more fine-tuned approach toward steering an ecosystem through succession and response to external shocks, such as flooding and drought. These technologies were used for ecological restoration, gardening, and occasionally the creation of entirely novel designer ecosystems. These led to fierce conflicts between restorationists, who wanted to ''rewild'' landscapes and bring back the Pleistocene era, and those who wanted to create ecosystems that functioned in completely novel ways.

8.6.4 The TechnoGarden World in 2050

The world in 2050 is cosmopolitan and wealthy, but unequal. Nine billion people occupy the planet, half of whom live in Asia. Poorer countries have almost the same share of the world economy as richer ones, but a much lower per capita income. Migration, urbanization, and global interconnectedness have transformed or eliminated a huge number of local, rural, and indigenous cultures. While the number of people living in absolute poverty has declined, huge differences in income exist between richer and poorer countries as well as within nations. This inequality is blamed for social tension, crime, and sometimes terrorism.

There has been considerable progress in addressing environmental problems related to pollution[43] and human health. Global agreements led to new management approaches to global and regional commons, such as the atmosphere, the oceans, and large rivers. The global energy

system remains dominated by fossil fuels, but the dominance is gradually declining. Emissions of greenhouse gases are lower now than they were at the start of the century, despite a much larger global population and economy. The establishment of property rights has provided further incentive to the production of clean energy sources, efficient transit options, multifunctional agriculture, and various forms of eco-technology.

Societies have engaged in many ecological engineering activities to provide desired ecological services. Increasing wealth, expansion of education, and growth of the middle class led to demand for cleaner cities, less pollution, and a more beautiful environment. For example, in many rich countries new housing developments include rain gardens and wetlands to clarify runoff and provide wildlife habitat. People engage in different activities depending on the ecosystem services they desire and the difficulty of providing those services. For instance, planting trees for local climate moderation is much easier than designing an ecosystem to sustain a tiger population. These differences in abilities and potential produce regional differences in types of ecological modification. In general, richer countries focus on providing water regulation services, amenity services, and cultural services while poorer countries focus more on the production and regulation of water and the production of ecological goods and services. Within the rich and the poor worlds there are regional differences due to culture and the way that property rights are organized and the density, wealth, and activities of people within a region.

Ecosystem services have changed since 2000. In some areas they have improved beyond what experts expected at the end of the twentieth century. Despite successes of ecological restoration, in some cases ecological simplification has been irreversible. For example, despite substantial efforts at restoration, coral reefs have not improved greatly. In general, provisioning services have increased, but biodiversity has declined.

Many regulating ecosystem services have become less resilient and dependent on continual human management. Access to basic ecosystem services has improved for most of the world's poor, but at the cost of wilderness and the loss of populations of large mammals.

8.6.5 Challenges for TechnoGarden 2050–2100

Earth's ecosystems have been transformed by human intervention. While management has often been successful, it has become increasingly intense. Despite significant advances in rates of recycling and reuse in all sectors, increases in the consumption and use of materials and increases in human population mean that humanity's impact on global and local ecologies continues to intensify. Due to ecological engineering, however, some of these changes produce positive impacts for nature and humanity.

While the provision of basic ecosystem services has improved the well-being of the world's poor, the reliability of the services, especially in urban areas, is increasingly critical. While management has been able to cope with this complexity in the past, today people question whether depending on so much management is wise.

The privatization, professionalization, and ubiquity of ecosystem management have led to increasing risks of management failure. Ecosystem management tends to simplify ecosystems, particularly as the intensity of management increases, because the more obscure, apparently unimportant, or simply unknown processes are not supported or maintained.

The highly engineered ecosystems and ecosystem services that are now found in the world make these systems vulnerable to disruptions. Even subtle, successful ecosystem management poses a number of risks that arise from the loss of process diversity, loss of local knowledge, and increasing reliance on ever-decreasing variance in the supply of ecosystem services.

Increasing social reliance on the reliability of the provision of ecosystem services has led to a gradual decline in the maintenance of alternative mechanisms of supplying these services within regions, leaving the systems and people who depend on them increasingly vulnerable to fluctuations in supply. In cases where the increased risk of variability has led to more interventions and attempts at greater control, the need for extremely reliable provision of services has created a spiral of increasing vulnerability.

Furthermore, ecological engineering tends to focus on particular processes and services, which leads to problems at the boundaries between ecosystems and emergent problems where subtle local effects of engineered ecosystems interact at large scales to produce surprising fluctuations in the functioning of ecosystems. For example, agricultural areas rely on the existence of pollinators, which depend for their survival on surrounding ecosystems. Changes in these surrounding ecosystems that reduce the population of pollinators can increase the vulnerability of the agricultural areas. Sometimes these conflicts can be solved with changes that are mutually beneficial, but in other locations conflicting goals result in ecological instability. Difficulty in managing the flow of material and species among ecosystems and difficulties in managing subtle, slow changes have caused society to overlook a set of emerging cross-scale feedbacks that threaten to bite back beyond 2050. These problems are exacerbated by confident application of technological fixes without understanding various cross-scale system dynamics.

Although there is a belief that nature is important and should be monitored, increasing confidence in technology has allowed the monitoring effort to wane somewhat. Furthermore, a disproportionate amount of effort is put into technology for landscape manipulation rather than monitoring technology, with the result that by 2050 there is a dangerous imbalance between our ability to create unintended ecological feedbacks and our ability to detect them in time to deal with them and then respond to them effectively.

While the world has grown wealthier overall, persistent hunger remains in many regions due to poverty and conflict. Coping with ecological variation and environmental surprises are the main challenges facing the world at the start of the second half of the twenty-first century.

8.7 Cross-cutting Comparisons

The scenario storylines have not attempted to include discussion of all ecosystem services. This would have made the stories too cumbersome. Detailed quantitative consideration of impacts on some ecosystem services across scenarios is given in Chapter 9.

The reader might be surprised that all scenarios have both positive and negative aspects with respect to ecosystem services and human well-being. This was intentional. Some of the extreme risks in each scenario are explored in Boxes in each section.

The scenarios were developed around a set of logics (assumptions), and we tried to keep those assumptions constant throughout the stories. This enabled us to explore the implications of those assumptions. As our storylines developed we realized that no world based on fixed assumptions can hope to achieve sustainability of ecosystem services and human well-being.

This might seem self-evident, but commentators often give ''recipes'' for the perfect world that are essentially lists of fixed strategies assumptions. One of the strongest lessons for us from this project has been that success in achieving a sustainable world will require the strategic application of the full range of approaches to social, economic, and environmental management—including at times, perhaps, strategies that tend toward compartmentalization (for example, policies aimed at limiting the spread of invasive species). Our intent in developing four extreme stories was to draw out the situations in which any of the strategies could have unintended negative impacts.

Later chapters will draw out comparisons across scenarios in more detail. This section draws comparisons across scenarios with respect to issues of importance to:

- the major Conventions supporting the Millennium Ecosystem Assessment (Convention on Biological Diversity, U.N. Convention on Combating Desertification, the Convention on Wetlands, and the Convention on Migratory Species);
- a set of five key issues of concern identified by the MA (emerging diseases, decline of fisheries, climate change, eutrophication, and desertification); and
- a few other issues that have arisen as important in the development of the storylines (including invasive species, urbanization, and an example of how a present-day ecological challenge in the United States might be addressed in the future under the four scenarios).

8.7.1 Biodiversity, Wetlands, and Drylands

Figure 8.5 depicts a scorecard for the four scenarios with respect to biodiversity, wetlands, and drylands—indicators important to the conventions on biological diversity, wetlands, and desertification. For each variable, the two arrows indicate how we expect the indicator to develop within this scenario over the next 50 years. The full lines indicate the ''best'' possible case, whereas the dashed lines show the ''worst'' case. Note that these results have been derived by combining quantitative results from modeling (see Chapter 9) with qualitative considerations based on the individual storylines. In order to depict differences between scenarios more clearly, we have included statements on the major drivers of changes in the respective indicator.

8.7.1.1 Biodiversity

In Chapter 10 the outlook for biodiversity in the four scenarios is considered with respect to published trends and predictions from quantitative models. Here we explore ecological feedbacks that cannot presently be included in models, due to insufficient data, so the curves described are sometimes more complex than those in Chapter 10.

Chapter 10 argues that over the near future, TechnoGarden and Adapting Mosaic are likely to see a decrease in the rate of biodiversity loss. In TechnoGarden, this is due to a significant reduction in land use change. In Adapting Mosaic, it is due to a reduction in invasions of non-native species. Movements of invasive species between countries also are reduced in Order from Strength, but the number of outbreaks within poorer countries is higher and the overall chance of invasives reaching richer countries is still high. Also, land use changes, particularly in poorer countries, put high pressure on habitats. Land conversion pressures are much more significant for Global Orchestration due to the scale of conversion.

In the longer term, two different types of risk might counteract the positive developments within TechnoGarden and Adapting Mosaic. TechnoGarden bears the risk of significant, major technological failures that can lead, for example, to outbreaks of new pests and diseases threatening biodiversity. Thus, the worst-case curve for biodiversity in Figure 8.5 shows a rather abrupt increase in biodiversity loss midway through the period, which flattens out after appropriate countermeasures are developed. Toward the end of the scenario period, the rate of loss starts to decline as new knowledge is developed and brought to bear.

In Adapting Mosaic, failed experiments and climate change might also increase the rate of biodiversity loss in the longer term, but this is not seen as happening as abruptly as for TechnoGarden. The other two scenarios see some chances for reducing the rate of loss on longer terms, though this is more pronounced in Global Orchestration than in Order from Strength (and mainly in richer countries, where economic prosperity is higher). Within Global Orchestration, a decrease in the rate of biodiversity loss would occur if increased economic prosperity brings reduced pressure on the environment (a central assumption of this scenario). However, climate change might counteract the optimistic outlook for both Order from Strength and Global Orchestration.

8.7.1.2 Wetlands

Although population pressures assumed in the quantitative modeling are high for both Order from Strength and Adapting Mosaic, we could see a relatively slow loss of wetlands in the short term in these two scenarios, for different reasons. The ''disconnected'' character of these scenarios and the reduction in international trade and direct investments, particularly in poorer countries, could curtail the construction of new large-scale water schemes within the

Key:
++ strongly increasing pressure by this driver
\+ increasing pressure
0 no change when compared with today
– decreasing pressure
– – strongly decreasing pressure
→ a change in the pressure of the driver during the scenario

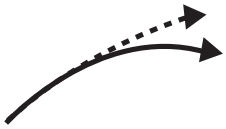
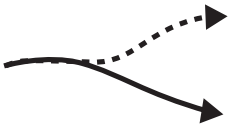
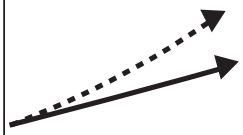
	Global Orchestration	Order from Strength	Adapting Mosaic	TechnoGarden
Biodiversity (rate of loss)				
Direct Drivers				
N-S Deposition[a]	++ → +	++	++	+ → 0
Climate Change[b]	++	++	++	+
Invasive Species[c]	++	0	0	++
Land-Use Change[d]	+	++	+ → 0	0
Wetlands (area degraded)				
Direct Drivers				
Land-Use Change	+	++	+ → 0	0
Invasive Species	++	0	0	++
Climate Change	+	+	+	+
Water Schemes	++	0	0 → –	+ → 0
Water Withdrawals	+	++	+ → 0	0
Drylands (area degraded)				
Major Drivers				
Poverty[e]	–	++	+ → 0	+
Climate Change[f]	++	++	+	0
Irrigation	–	+	0	+

Figure 8.5. The Convention Scorecard. Arrows indicate the development over time of the issues named in the left-most column, which are important to the Convention on Biological Diversity, the Convention on Combating Desertification, and the Wetlands Convention. Solid lines indicate the best case, dashed lines indicate the worst case envisioned for each scenario. The row below the arrows for each issue contains a qualitative indication of changes in the relevant drivers.

[a] These two categories are merged into a single one, though one might observe rather different trends in the future. General trends throughout all scenarios suggest a reduction of sulfur emissions over the next 10–20 years more or less equally across all four scenarios, maybe to a lesser extent in Order from Strength. (See also Chapter 9) In contrast, emissions of NO_x will differ across scenarios according to technological progress which is most pronounced in TechnoGarden (See, for example, Box 8.23 on new transportation systems). Technological innovations do not play an important role in Order from Strength and Adapting Mosaic.

[b] Here, climate change is not restricted to particular regions or ecosystems. (See Chapter 9 for an extensive discussion)

[c] See Section 8.7.7

[d] See Chapter 9

[e] See Section 8.7.2 and Chapter 10

[f] See Table 14.7 this volume and its discussion

very near future. Within Adapting Mosaic, small-scale and integrated water management projects are developed. This releases some pressure on wetlands, which is not the case in Global Orchestration and is true only to a much lesser extent in TechnoGarden. In the latter scenario we can expect some improvements by technical solutions, although some wetlands are allowed to decline as their ecosystem services are provided elsewhere by technological alternatives.

In the most optimistic version of Order from Strength and Adapting Mosaic, there would be relatively low risks of invasive species due to the low levels of global trade and movements of people. In the worst-case versions of these scenarios (the dotted lines in Figure 8.5), population and invasive species have larger impacts. In addition, Order from Strength bears the risk that conversion of wetlands to other uses, particularly for inefficient production of food and to fuel economic growth, counteracts the positive effects mentioned and further exacerbates loss and degradation of inland wetlands.[44] A more detailed consideration of implications for coastal wetlands is given in Appendix 8.1.

On longer time scales, however, two other major drivers lead to further bifurcations in the trends of wetland loss. In both Order from Strength and Global Orchestration, there is a long-term increase of conversion to agricultural land use. For TechnoGarden and Adapting Mosaic, however, the technologies or skills for ecosystem management in place for the second half of the period until 2050 can even induce a restoration of wetlands, in the optimistic case. In addition, climate change, which only becomes significant in the second half of the period, might put further pressure on wetlands. Though various scenarios of climate change, including those presented in Chapter 9, do not show a significant change in effective precipitation (the difference between precipitation and evapotranspiration), we expect that sea level rise leads to loss of coastal wetlands like estuaries or tidal flats and deltas. This effect is most pronounced in Global Orchestration, Order from Strength, and Adapting Mosaic, where it might even overcompensate for the effects of learning. The effect is not so strong in TechnoGarden, thus further allowing for the leveling or turnaround of the trends of loss of the first 20 years of the century.

8.7.1.3 Drylands

Drivers for dryland degradation can be considered in two groups: the ''disposition'' of a region—that is, its climate and water availability—and the pressure that is put on the environment by land managers. Chapter 14 indicates that, globally, changes in arid areas as a result of climate change are relatively small up to 2020. Thus, in the short term it is the pressures of land management that play a more significant role. This leads to different risks within the four scenarios.

If the assumptions of Global Orchestration are borne out, the scenario sees a significant decrease in material poverty, which could induce a decrease in dryland degradation. If the poverty reduction is not sufficient enough, however, degradation can be expected to occur at a similar pace to today. In the short term, the other three scenarios do not see this kind of relieved pressure, and degradation can be expected to carry on.

In the longer term, the chances for reduced degradation appear in TechnoGarden and Adapting Mosaic. The reduction in TechnoGarden comes from technological progress bringing about new methods for production in dryland areas. It is not certain, however, that these methods will be available for the marginalized people who actually need them. Boundaries for technological diffusion will still exist, and if these persist no positive effect on drylands in marginalized regions may be possible. Adapting Mosaic sees improvement of local knowledge and property rights for better managing agriculture and ecosystem services. Yet some risk exists, either due to failed experiments or to major changes in climate, which makes the present skills inappropriate.

Global Orchestration might at the end of the scenario period see a halt of degradation due to the further reduction of poverty. Yet the risk remains that this reduction is not significant enough. Order from Strength sees the strongest degradation throughout the whole period, and the present trends might even increase due to climate change and further institutional failures.

8.7.2 Human Well-being

Human well-being is considered to have five main components: the basic materials needed for a good life, health, good social relations, security, and freedom and choice. (See Chapter 11.) As such, well-being differs across the scenarios, not only in its overall level but also in its composition. Furthermore, the scenarios differ with respect to the underlying direct causes of changes in human well-being—for example, different trends in development of human, social, manufactured, or natural capital. Figure 8.6 depicts the scorecards of the different scenarios for all five dimensions of human well-being.

8.7.2.1 Basic Material Needs

The four scenarios differ with respect to the form of capital that is the focus of development. Global Orchestration has a strong emphasis on manufactured capital (technological innovation for production and for ecosystem repair) on a global scale and a weaker focus on human capital (education about most things is a high priority, but learning about the environment is not) and natural capital (it is assumed that the environment will take care of itself if human capital is high). In contrast, Order from Strength focuses almost entirely on manufactured capital (industry) on a local to regional scale. TechnoGarden concentrates on manufactured capital in a way that is built on accumulated human capital (learning, tightly targeted as ecosystem management) and on building natural capital to provide financial and other benefits to humans. Finally, Adapting Mosaic puts major emphasis on the development of social and human capital through learning and development of cooperative networks.

Due to these considerations, the scenarios differ in terms of the dynamics of material income and its composition.

Key:
++ strongly increasing pressure by this driver
+ increasing pressure
0 no change when compared with today
– decreasing pressure
– – strongly decreasing pressure
→ a change in the pressure of the driver during the scenario

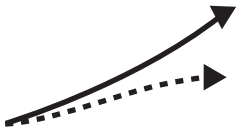
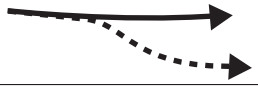
Component of Human Well-being	Global Orchestration	Order from Strength	Adapting Mosaic	TechnoGarden
Material Basic Needs				
Sources Human Capital Social Capital Manufactured Cap. Natural Capital	 + 0 ++ 0	 0 – + –	 + ++ 0 +	 ++ 0 + +
Health				
Background Food Security Water Availability New diseases	 ++ + 0	 – 0 –	 0 → + 0 → + 0	 ++ ++ –
Security and Social Relations				
Elements Equity Civil Society New Weapons	 + 0 0	 – – – 0	 + ++ 0	 0 0 –
Freedom and Choice				
Regions Richer Countries Poorer Countries	 0 +	 – –	 0 +	 + +

Figure 8.6. Human Well-being Scorecard. Arrows indicate the development over time of the component of human well-being named in the left-most column. Solid lines indicate the best case, dashed lines indicate the worst case envisioned for each scenario. The row below the arrows for each issue contains a qualitative indication of changes in the relevant drivers.

Assessing the overall tendencies of material income for the different scenarios is complicated by uncertainty about if and how substitution among the different forms of capital will happen. It appears, however, that Global Orchestration and TechnoGarden offer the best opportunities for ensuring basic material needs. Nevertheless, the success of the development paradigms behind the policy reform scenarios in Global Orchestration is still debatable. On the other hand, TechnoGarden bears major risks of technological failures and ecological feedbacks, which would directly bring about major disruptions for material income. Order from Strength can be expected to show the weakest income growth, though some leeway does exist depending on the resilience of ecosystems. Finally, Adapting Mosaic offers opportunity for growth later in the century, depending on the degree of learning and success.

8.7.2.2 Health

The scenarios differ with respect to the general development of human health due to income change, changes in food consumption, or changes in the health system, and also with regard to the risk of new diseases. Emergence of new diseases is a direct outcome of ecological changes, whereas the other factors are only indirectly affected. Due to high income growth and increased equity in Global Orchestration and TechnoGarden, we expect improvements in human health globally. The introduction of new biotechnologies in TechnoGarden, however, introduces a high risk for new diseases. The high degree of global interconnectedness in both of these scenarios creates increased chances for the spread of diseases, but also the opportunity for global cooperation in fighting them.

The introduction of new diseases also constitutes a major risk within Order from Strength. The impact, however, is restricted to the poor regions of the world. In these regions, this risk comes from a general decline in human health due to low overall socioeconomic development, which also prevents effective measures to counteract diseases like malaria or AIDS. In Adapting Mosaic, we can expect an initial decline in health due to the limited growth and international cooperation. In the course of time, as new networks and skills develop, we expect improved health.

8.7.2.3 Social Relations and Security

Investment in social capital and the strengthening of civil societies constitute the core of Adapting Mosaic, thus the scenario sees the strongest improvement of social relations. Some risk exists if the conflicts that accompany the redistribution of political power persist over time and hinder the development of social networks. In Global Orchestration, economic equity improves over the short term, which makes the world a safer place. This also contributes to improved social relations in poorer countries, though economic competition might intensify over time and might even counteract the benefits of improved equity. Also, ecological feedbacks can introduce new sources of inequality.

TechnoGarden sees a world in which the new means and methods for managing ecosystems and ecosystem services are owned by an elite group of scientists, engineers, and business people. This leads to an increase in inequality and a general decline of social relations. If, however, the options for open-source ownership start to play a stronger role, relations might improve again, also within the emerging groups of professionals. The scenario also bears the danger of developing new biological weapons, which can make use of the technological skills and knowledge gained. Finally, Order from Strength sees a decline in both social relations and (ironically) security, especially in the poorer countries. Although the scenario is about nations protecting their own interests, leading, especially in richer countries, to stronger physical, economic, and political barriers at borders, this is likely to cause people to feel less secure personally. It might also induce some internal conflicts that further reduce people's feelings of security.

8.7.2.4 Freedom and Choice

The development of freedom and choice within the scenarios strongly depends on the regions. As we expect that the policy reforms in Global Orchestration come with an increase in strong and stable governance in many poorer countries, this scenario sees an increase in freedom and choice in the developing world. This outcome is also expected for Adapting Mosaic but for other reasons—the growth of the civil society and the devolution of power to lower scales also increases freedom and choice in poorer countries but might also change the character of participatory forms of governance in richer nations. In contrast, Order from Strength by its very character restricts the rights of people to choose and move and thus sees a strong decrease of freedom and choice in all parts of the world. Finally, technological development in TechnoGarden is connected with new forms of property rights and new ways to enter careers that increase freedom and choice in all regions.

8.7.3 Emerging Diseases

The complex issues surrounding emerging diseases are discussed in more detail in Chapter 11.

8.7.3.1 Global Orchestration

In Global Orchestration, the lowest population growth of the four scenarios is itself likely to minimize the outbreak and spread of infectious diseases. (See Table 8.2.) For example, diseases such as SARS and new forms of influenza arising from cohabitation of humans and domestic animals might be expected to be less likely with lower population growth. On the other hand, current population densities are sufficient for these diseases to arise, so the risk may remain high. Similarly, increasing wealth in developing nations and international cooperation to address global health threats should allow more effective control of disease outbreaks both locally and globally.

While the chance of new chronic diseases crossing from a nondomesticated animal species into humans, as HIV is thought to have done, is small, the environmental stresses encouraging such an occurrence may not be detected early in a Global Orchestration scenario. Furthermore, if the flow of wealth to poorer countries is slower than contemplated

Table 8.2. Emerging Diseases across the Scenarios

Factors	Global Orchestration	Order from Strength	Adapting Mosaic	TechnoGarden
Population growth	low	high	moderate	low
Nutrition	good	low in poorer countries	moderate	good
Sanitation	good	low in poorer countries	moderate	good
Exposure to non-developed ecosystems	low	high	moderate (but with strong learning)	low (but new ecosystems are created)
Management of known environmental risks	high	high in richer countries; low in poorer countries	high	high
Monitoring for unexpected environmental risks	low	low	high	high
Ability to detect and control outbreaks locally	high for expected outbreaks; low for unexpected	low	high	high
Global cooperation to control outbreaks	high	very low	low	high
Overall assessment	good outlook if optimistic assumptions are met—high risks if assumptions not met	poor outlook for poor countries; substantial risks to wealthy countries if inequalities are not kept within manageable bounds	good outlook for dealing with local problems; substantial risks from broad-scale outbreaks until cooperation among local entities is established	good outlook if technology is successful; low risks of manufactured diseases but the consequences could be devastating

in the scenario, if states fail through escalating corruption, if the expected decrease in pressure on the environment does not occur, or if other assumptions of the currently optimistic scenario fail, then diseases associated with poor sanitation or the emergence and spread of infectious diseases could become a major concern.

Even in the optimistic version of Global Orchestration, diseases of affluence (such as diabetes and kidney and heart diseases) and environmental contamination with heavy metals and other persistent pollutants (such as intellectual impairment and cancers) will be significant risks that could become a more expensive burden on health services than predicted.

8.7.3.2 Order from Strength

The hope for Order from Strength is that one or a few powerful nations can act in the interests of all nations to maintain global peace and economic stability. Even the most optimistic expectations, however, would see technology, knowledge, and wealth gaps among countries either maintained or worsening, due to the strong focus on national economic, social, and physical security. We expect to see high population growth in the less wealthy countries; low investment in human capital, including basic literacy and numeracy; increasing degradation of ecosystems; poor governance; and high corruption brought on by adversity. People in poorer countries will be driven to greater exploitation of undeveloped ecosystems, thus increasing exposure to known and unknown diseases (current examples include hemorrhagic fever and sleeping sickness).

Whereas health probably would increase in richer countries, due to their wealth and strong protection of borders, epidemic diseases are likely to be encouraged in poorer countries by these conditions. Known diseases like AIDS and TB would be hard to control, and those affected would include many knowledge-rich young and middle-aged adults. Declining nutrition would likely exacerbate poor health, fueling additional epidemics. The global impact of emerging disease would depend on how effectively wealthy countries could control emerging diseases that threaten their people. With poor international cooperation, this is likely to be a major challenge that from time to time will be impossible to meet, resulting in diseases affecting wealthy populations. What seems inevitable, however, is that local disease outbreaks in poorer countries would be frequent and would kill many people.

Although there is only a low probability of emergence of totally new, chronic diseases that cross from a non-domesticated animal species into humans, as HIV is thought to have done , this scenario provides the highest likelihood of such an event.

8.7.3.3 Adapting Mosaic

Adapting Mosaic brings the hope of better functioning social institutions leading to improved mental health and lowered incidences of alcoholism, domestic violence, diabetes, and depression in all cultures. There might be greater reliance on traditional health systems, and closer attention to managing environmental factors that could encourage the emergence and spread of human, animal, and plant diseases.

The risks in this scenario relate to how well ideas, technology, and capital circulate internationally. This could be a problem for development and distribution of vaccines, for example. The local focus of environmental management

could improve detection of outbreaks, but coordinated management across regions and nationally could be a challenge at times. It is unclear how disease outbreaks like SARS or the periodic epidemics of meningitis that sweep the Sahel would be managed—probably poorly in the early stages of the scenario.

There are major ironies in this scenario with respect to health and emergent diseases. The strong focus on the environment and local learning come about because national and global governance structures have become ineffective and have lost credibility. So we see the second highest population growth among the scenarios, slower rates of technological and agricultural breakthroughs, and probably high impacts of climate change. This could put strains on ecosystems services, sanitation, and food supplies, producing the ingredients for outbreaks of old diseases and emergence of new ones in some places. Capacity to deal with broad-scale outbreaks would be relatively low.

In summary, this scenario brings both hope of effective control of disease emergence locally, but fears that management of outbreaks across broad scales will be hard to deal with effectively.

8.7.3.4 TechnoGarden

The focus on environmental and other technologies in TechnoGarden could see improved human, animal, and plant health through greater disease resistance in crops, improvements in human nutrition, extended life, reduced need for surgery, cheaper and more effective vaccines that confer lifetime immunity to multiple diseases, and reduced pollution of water and air. These factors, together with the second-lowest population increase among the four scenarios and a proactive approach to environmental monitoring and management, could cause this scenario to see low levels of heart and kidney disease, cancers, and mental impairment from heavy metal pollution. The conditions for emergence and spread of new diseases should be minimized, and global action to deal with emergence should be coordinated and effective.

Health issues relating to new pressures on a highly technological society are potential problems, and the easy and increased availability of calorie-dense food could exacerbate the nascent global epidemic of obesity and diabetes.

With respect to emerging diseases, there is also the (small) risk of the escape or deliberate release of devastating diseases engineered in environmental, health, or military laboratories. The genetic homogenization of food and other crops, for example by genetic engineering, also creates vulnerability to new agricultural diseases, which could have flow-on effects to human health.

8.7.4 Fisheries

The consequences of all four scenarios for fisheries are quite different in richer and poorer countries. (See Table 8.3.)

8.7.4.1 Global Orchestration

Although Global Orchestration is about cooperation among nations, we expect to see this cooperation emerge more slowly for marine resources than for other aspects of global governance. This is because of the already established power imbalances and the promise of rapid economic returns from exploiting these resources.

In some areas of richer countries, sustained catches are achieved (especially for high-value fisheries like tuna) through economic incentives, regulation, and creation of marine protected areas to eliminate destructive fishing practices. The need to deal with global climate change is a driver, as is economic gain from biodiversity and tourism. In other areas it is too late. Fisheries are abandoned, resulting in localized social impacts. The richer countries that continue to focus on optimizing profits from fishing continue to experience ecosystem degradation and eventual reduction in fisheries and, ultimately, jobs and other social conditions.

In poorer countries with stable governance, removal of trade barriers and support for institutional reform allows economic benefits to be gained from fisheries while ecosystem management is reformed, based on lessons and experience passed on by other countries. There is a race against climate change, as coral reefs are lost, coastlines are degraded, and river flows change in the tropics.

Poorer countries with poor governance experience short-term economic returns but see overexploitation of marine ecosystems through illegal activities, corruption, and lack of enforcement. Those with cheaper labor become fish-processing centers. Countries with few environmental controls have a significantly higher concentration of facilities but they also have to deal with degraded coastal waters.

Coastal aquaculture continues to expand in wealthy countries, although limited by the rate of development of technologies for feeding the fish. Often, economically depressed coastal communities are targeted. Conflict between the industry and conservation advocates continues, as biodiversity decline is noted in some areas and as social impacts become apparent. Offshore aquaculture expansion is slow at first but accelerates, especially for high-value species like tuna, once technology is developed to reduce the costs of operating far from land in heavy seas.

Coastal aquaculture (land- and water-based) expands even more rapidly in poorer countries, especially where environmental controls are minimal, as richer countries begin to be constrained by environmental and social policies as well as by rising labor costs. Coastal environments are severely affected, coastal fisheries degrade, small-scale fishers are displaced, and food security becomes an issue for many areas. Poorer countries with good governance and appropriate environmental controls use some of the economic benefits gained from improved fisheries management to develop appropriate aquaculture programs that provide cheap sources of protein for the domestic market with minimal environmental impacts but with significant social and economic benefits.

Wealthy countries continue to expand fisheries into the high seas. There is increasing exploitation of pelagic resources, but deep-sea fisheries such as those on seamounts and deep-sea corals cease. A system of high-seas marine protected areas is initiated after much negotiation between fishing nations. Some stocks become threatened but are re-

Table 8.3. Fisheries across the Scenarios. The final row indicates relative impacts on ecosystems and ecosystem services, from 4 being best and 1 being worst.

Factors	Global Orchestration	Order from Strength	Adapting Mosaic	TechnoGarden
Fishing practices	Decline in fisheries and ecosystems addressed once their economic importance becomes apparent.	Decline in fisheries and ecosystems addressed by rich nations expelling foreign fleets from exclusive economic zones, expanding EEZs, and pressuring poorer countries for access to additional fish resources.	Fisheries policy focuses on maintaining and repairing marine ecosystems.	Decline in fisheries and ecosystems addressed through repair using environmental technologies.
	In rich countries: • Ongoing ecosystem decline in many places due to optimization of fisheries for economic return. • Protection for valued species.	In rich countries: • Policies focus on maintaining production. • Protected areas supported only where not in conflict with fisheries or where there is tourism potential.	In rich countries: • Various interventions tried, with considerable regional variation in success and learning. • Protection and adaptive management given high priority.	In rich countries: • Engineering and simplification of many fisheries for economic return. • Attention to a broader range of ecosystem services in some systems.
	In poorer countries: • Fisheries in tropical countries at risk from climate change as coral reefs are lost, coast lines are degraded, and river flows change. • Free trade improves economic returns from fisheries. • Benefits from access fees and processing industries that are established, but coastal environments are severely affected.	In poorer countries: • Already exploited systems bear many of the impacts of climate change. • Some countries exploit high-value fisheries and minimize ecosystem impacts, while others maximize biomass through short-lived species and have high ecosystem impacts. • Rebuilding stocks depends on investment from richer countries wanting to further secure food supplies.	In poorer countries: • Over time, lessons are shared and many ecosystems are stabilized (temperate areas taking longer than tropical). • Developing nations struggle to find the right balance between maintaining ecosystems and economic development.	In poorer countries: • Technologies made available by investment from big corporations based in industrial countries. • Free trade improves economic returns from fisheries. • Benefits from recreational values of technologically enhanced coastal ecosystems, but danger that the value will flow out of the country.
Technology	Technology is developed to replace wild-caught fish meal for aquaculture.	Technology is slow to develop in rich countries because they are able to appropriate additional resources and in poor countries as they cannot afford it.	Low investment and uncoordinated effort in technology to replace fish meal slows the expansion of aquaculture, especially in poorer countries, where the high cost of environmentally appropriate technologies is another issue.	Rapid development of artificial food to replace wild-caught fish meal for aquaculture. New, simplified ecosystems engineered for one or a few valuable species.
Institutions	Effective development of, and compliance with, international conventions and treaties to reduce and ultimately eliminate illegal fishing. Developing countries with stable governance achieve economic returns and more sustainable fisheries, while those with weak governance get short-term economic gain but eventual collapse of fisheries.	International conventions ignored and power used to appropriate marine resources. Developing countries with sufficient marine resources to host distant water fleets negotiate as a regional block so that financial returns improve, and enforcement and management are more effective and efficient.	As inshore coastal areas and stocks are stabilized, fishers look outward to larger areas and regional fishing bodies become more relevant. Developing countries with strong governance attract financial aid to implement interventions, but those with weak governance and corruption struggle to implement appropriate interventions.	Global institutions strong—allows development and enforcement of international conventions.

High seas	Elimination of deep-sea fisheries for environmental reasons but increased pressure on pelagic resources on the high seas. The developing world benefits less than rich nations from the high seas. Benefits that do accrue are from processing facilities that are established by big corporations based in industrial countries.	Distant water fleets expand, international agreements are ignored, and a "slash and burn" attitude prevails with high seas resources. Countries with significant aquaculture industries heavily exploit small pelagic fisheries. Many long-lived species collapse. Some countries defend their high-seas aquaculture sites with force.	Initially, distant water fleets continue to expand into the high seas with few restrictions, and illegal, unregulated, and unreported fishing in these areas is ignored as countries struggle to find the right management intervention and as regional fish bodies are ignored.	Technology supports high-seas aquaculture and a grab for ocean estates in which poorer countries are left out.
Aquaculture	Coastal aquaculture expands, especially in economically depressed coastal communities. High-seas aquaculture develops slowly due to the economics of the technology and the cost of operation in the high seas. Richer countries try to secure disproportionate access rights to the high seas for aquaculture, bioprospecting, and carbon sequestration—open international dialogue required to ensure equity.	Inshore aquaculture expands rapidly for food security in poorer countries. Significant areas are converted, losing a number of ecosystem services. Pelagic stocks are overexploited to supply fishmeal. Climate change worsens the problem. Offshore aquaculture expands slowly as the technology is slow to develop and the costs of protection are high.	In wealthy countries, the expansion of aquaculture is based on current technologies, which have widespread and expensive impacts on coastal ecosystems. Aquaculture practices are reexamined and new practices are tested. Further offshore, aquaculture is only experimental due to the limited understanding of its impacts. Water-based coastal aquaculture is limited in poorer countries due to the cost of using environmentally appropriate technologies as well as the high price of fish food.	Technology-driven rapid increase in aquaculture in rich countries. Slower growth in poorer countries until technology is made available through investment by large corporations. Poorer countries focus on high-turnover, herbivorous species to meet food demands, but this has high environmental impact.
Overall outcome	Balance between unintentional overexploitation, due to a primary focus on food and dollars, and reinvestment of some profits in ecosystem repair. Both risks of ecosystem collapse and the costs of preventing it increase due to lack of a proactive approach. Strength is high degree of international cooperation. (3)	Risks of fisheries collapse are high worldwide due to unchecked exploitation at all scales and lack of international cooperation to address global processes. (1)	Increasingly informed local management achieves alot, but global processes are not dealt with well until late in the scenario. This is the classic problem of institutional responses being at the wrong scale for many of the ecological processes. (2)	High economic and social returns due to investment in technologies for environmental repair and enhancement. But technologies are initially expensive and some engineered ecosystems are vulnerable to unexpected perturbations. (4)

built through various economic instruments and trade negotiations.

Poorer countries do not benefit as much from the high seas as richer nations; benefits that do accrue are from processing facilities that are established in poor countries.

High-seas aquaculture is at first limited by excessive operating and technology costs and risks. It takes three to four decades to overcome these problems. Richer countries try to secure access rights to the high seas for aquaculture, bioprospecting, and carbon sequestration, but poorer countries are reluctant to agree. Ultimately, a global oceans commission is formed to manage the use of the oceans.

8.7.4.2 Order from Strength

Rich nations expel foreign fleets to ensure their food and economic security. They also try to extend their exclusion zones and to pressure poorer countries for access to fish resources. Fisheries policies of wealthy countries are focused on production and not necessarily ecosystem maintenance. In some ecosystems, fish or landing biomass is maintained or enhanced, but biodiversity or ecosystem services are not necessarily. These systems are vulnerable to disturbances such as disease and climate change. In countries where there is a significant aquaculture sector, small pelagic stocks are heavily exploited for fish feed. The highly variable nature of these stocks makes them difficult to manage, and some stocks that are affected by climate change collapse while others are sustained. Marine protected areas are supported only in areas not in conflict with fisheries or where there is considerable tourism potential. Protected areas, along with trade restrictions and habitat restoration, are used also to sustain stocks or protect economically important fauna such as whales and dolphins.

This scenario has the most significant negative impact on poorer countries since they bear many of the impacts of climate change—El Niño, storm events, flooding, and erosion. For many, the marine ecosystems are heavily exploited, and as the scenario progresses, exploitation increases further as wealthy nations try to secure food supplies. Some countries maximize high-value fisheries and thus are able to minimize ecosystem impacts. Others are forced to maximize biomass through short-lived low-trophic species so that food security improves but ecosystem impacts are major. Countries with effective enforcement eventually bring fisheries management under control and some stocks are sustained; however, some stocks collapse because intervention is too late. Efforts to rebuild stocks depend on financial and technical assistance from richer countries wanting to secure more food supplies. Countries with poor enforcement continue to have their stocks heavily exploited except where richer countries see this lack of management as a threat to their food security. Eventually, enforcement improves and the remaining stocks are sustained. Poorer countries with sufficient marine resources to host distant water fleets also begin to negotiate as a regional block so that financial returns improve, and enforcement and management is more effective and efficient.

Aquaculture expands rapidly inshore and offshore in richer countries for food security reasons—but at a high cost to the environment. Significant areas are converted, losing a number of ecosystem services. Primarily low-value, short-lived species are farmed, since they are economically efficient at producing protein, although some high-valued species are also farmed. Offshore aquaculture expands slowly as the technology is slow to develop and most fishmeal is used for either the aquaculture sector or the livestock sector. Also, the cost to protect offshore farms is expensive compared with inshore systems.

Poorer countries develop water- and land-based aquaculture to provide food security and to generate foreign exchange. Consequently there is a mix of high-value and low-value species farmed. The expansion of aquaculture is based on current technologies, which result in widespread impacts on coastal ecosystems. Some of these impacts are long-term, and rehabilitation is prohibitively expensive.

On the high seas, distant water fleets from wealthy nations continue to expand. International agreements are ignored and a ''slash-and-burn'' attitude prevails with high seas resources. Countries with significant aquaculture industries heavily exploit small pelagic fisheries. Many of the long-lived species in pelagic as well as in the deep-sea systems collapse, and soon the system is fished down to the point where small invertebrates dominate the landings. Initially, high-seas aquaculture develops slowly due to the high costs of technology and of operating in the high seas.

Some poorer countries attempt to address food security by securing sites for aquaculture through extending their exclusive economic zones. This creates significant problems between countries that have distant water fleets and those that do not. The latter countries see expansion of exclusive economic zones as a ''sea grab.'' They are also concerned about the potential impacts from high-seas aquaculture (such as disease and genetic dilution). Conflicts arise, with some countries defending their high-seas aquaculture sites with force. There are also localized problems as disease and genetic dilution arise in countries that ignore international standards (such as the FAO Code of Conduct).

8.7.4.3 Adapting Mosaic

Fisheries policy in many richer countries focuses on maintaining marine ecosystems and, where it is economically feasible, rebuilding them as adaptive experiments. Destructive fishing practices are phased out. Initially, various interventions are tried, including modified individual transferable quotas, community quotas, marine protected areas, and construction of artificial reefs. There is considerable regional variation in the measures that are tested. Most international and regional fishing agreements are ignored, however, as are regional fishing bodies. Over time, as lessons are learned and shared, many ecosystems are stabilized, enabling them to buffer extreme events and climate change. Temperate areas take considerable time, compared with sub-tropical and tropical zones, to show the benefits of the interventions. Consequently there is considerable variation in areas and fisheries that recover or stabilize. As inshore coastal areas and stocks are stabilized, fishers look outward to larger areas, and regional fish bodies become more relevant. The interventions that succeeded previously are re-examined and modified for larger-scale management.

Poorer nations struggle to find the right balance between rebuilding ecosystems and economic development, since they lack the technical expertise and financial resources to reduce domestic and foreign fishing effort. Regional fishing bodies are important sources of technical assistance. Countries with strong and stable governance attract financial aid to implement interventions, especially once the lessons learned in richer countries are evaluated. Some ecosystems, especially in the tropics, respond quickly to reduced effort and the elimination of destructive fishing practices. Countries where governance is weak or corruption prevalent continue to struggle to implement appropriate interventions and stocks collapse.

In richer countries, aquaculture practices are re-examined and new practices are tested. Expansion of aquaculture is slowed due to reliance on wild-caught fishmeal. Alternative feed technologies take 20–30 years to develop. Further offshore, aquaculture is only experimental due to the limited understanding of its impacts.

Water-based coastal aquaculture is limited in poorer countries due to the cost of using environmentally appropriate technologies as well as the high price of fish feed. Countries with strong and stable governance are provided with technical and financial assistance to develop coastal low-tech aquaculture for both high-value species (to generate foreign exchange) and low-value species (to contribute to food security in the area). Countries with weak governance continue to expand and establish aquaculture that affects the coastal ecosystems and wild stocks. Such developments are economically viable for approximately 10 years, and then they are abandoned with irreversible loss of a range of ecosystem services.

Initially, distant water fleets continue to expand into the high seas with few restrictions, and illegal, unregulated, and unreported fishing is ignored as countries struggle to find the right management intervention after regional fish bodies are ignored. Only a few countries develop high-seas aquaculture, and much of it is experimental due to the ecological risks and high technology and operating costs. The rebuilding of inshore ecosystems and the development of appropriate technologies for coastal or inshore and freshwater aquaculture eliminates the need to expand aquaculture into the high seas.

8.7.4.4 TechnoGarden

In richer countries, destructive fishing practices are eventually eliminated, and some ecosystems are reconstructed (such as artificial reefs), although the costs are high and sometimes prohibitive. Many countries engineer marine ecosystems to provide high-value food—large shrimp, salmon, or cod systems, for example. But these systems suffer, due to their simplification, from surprises such as pests and diseases. Wild species are maintained for genetic purposes (similar to breeding zoos). As new technologies remove the need for wild-caught fish as food for aquaculture, some wild capture fisheries in wealthy countries service the gourmet and luxury food market, while aquaculture feeds the masses.

Economic imperatives drive most poorer countries to convert their waters to high-value fisheries, mostly financed by large corporations based in the wealthy world. Much of the production is exported with few economic and even fewer social benefits to the host countries. Initially, the low-value fisheries in these countries are used to service the fishmeal market, due to the rising price of fishmeal, but eventually new technology for producing artificial food for farmed fish puts these fisheries out of business, requiring international aid for industry and social restructuring.

New technologies reduce the environmental impacts of aquaculture and remove the need for wild-caught fishmeal in richer countries. Aquaculture expands rapidly in coastal areas to ensure a consistent source of fish for domestic consumption and trade. Much of the production is of high-value fish. The big risk here is maintenance of good water quality and prevention of surprises from disease. The highly managed, but simplified, ecosystems in shallow coastal areas are found to be unstable and vulnerable to even small perturbations. Offshore, deeper aquaculture is developed within national boundaries for high-value fisheries. These operations are technologically advanced with a high initial capital cost, but have low running costs since much of it is automated. Only high-value species such as tuna are farmed this way.

The cost of water-based aquaculture technology slows the growth of aquaculture in poorer countries. There is some investment by large corporations, since labor and other operating costs are cheaper. However, environmental quality is not as secure as in richer countries and therefore the coastal aquaculture sector in many poorer nations focuses on lower-value, high-turnover herbivorous species. These species become important for food security in many poorer countries, but the intensified aquaculture also results in conversion of large areas of coastal land and loss of ecosystem services, such as erosion control and maintenance of habitat for fish breeding.

Fleets (primarily from wealthy countries) continue to expand into the high seas, and landings of deep-water species maintain catch levels early in the century. However, soon these long-lived stocks are depleted, and catches decline to pre-1990 levels as large pelagic species such as tunas and sharks are all that remain. Pressure on pelagic fisheries as well as the krill fisheries in the Southern Oceans decreases as new technology produces artificial food for aquaculture. The richer countries, which have the technology for high-seas aquaculture, negotiate regional agreements to provide some form of security for aquaculture operations (fixed and floating) to develop outside of national exclusive economic zones. These operations are highly risky economically since large marine mammals as well as collisions with other vessels can destroy the crop. Poorer countries are left behind in this race for ocean real estate since, compared with richer countries, they lack the technology to stake a claim.

8.7.5 Climate Change

The complex issues surrounding climate change are discussed in more detail in Chapter 9. In the storylines in this chapter, climate change is discussed in different contexts in different scenarios. This is because the drivers of climate change, especially the amount and type of technology used, differ considerably between scenarios, as do the approaches to addressing impacts versus causes. As indicated in Chapter 9, the biggest differences between the scenarios with respect to the rate of climate change are seen in the rate of temperature change. (See Table 8.4.)

8.7.5.1 Global Orchestration

In this scenario, the mechanisms for global cooperative action to address climate change are in place, but the importance of the problem and its ecological causes are not recognized, and action is not taken until things get really bad. The crucial question under Global Orchestration is when interest will grow strong enough among all major partners to start cooperating on building an effective response to climate change.

The fact that causes and impacts of climate change are decoupled both in time and place complicates an effective response. It complicates the evidence that will be required to make climate change a priority under Global Orchestration, but it also makes it more difficult to negotiate a treaty among parties that can be both losers and winners from global climate change. In the quantification (see Chapter 9), no explicit climate policy is assumed under this scenario. Based on the storyline, however, we find it just as likely that after some time a final agreement can be made on a delayed response. Such a response would need to include major adaptation action and also mitigation action based on market-based incentives. The financial flows that are connected to trade in carbon credits could in fact be a great stimulus for poorer economies.

Table 8.4. Climate Change across the Scenarios

Factors	Global Orchestration	Order from Strength	Adapting Mosaic	TechnoGarden
Temperature change—degrees Celsius per decade (see Chapter 9) Current rate assumed to be 0.20° Celsius per decade	gradual rise to around 0.35° Celsius by 2050 (declining to 0.20° by 2100)	fluctuating but reaching around 0.26° Celsius by 2050 (increase to 0.30° by 2100)	gradual increase to around 0.28° Celsius by 2050 (declining to 0.16° by 2100)	initial rise to around 0.23° Celsius by 2020, then decline to 0.15° by 2050 (and to 0.06° by 2100)
Drivers	strong emphasis on economic growth; slow emergence of low-impact technologies	depressed industry and slow technological development in developing world keeps global emissions lower than other scenarios	initially poor international cooperation allows climate change to continue unchecked; eventually, focus on ecologically friendly industries lowers emissions and also economic growth	focus on economic growth but rapid emergence of low-impact technologies
Mechanisms	Market-based (e.g., carbon credits); international trade in carbon	displacement of impacts by wealthy countries; global cooperation almost impossible	local adaptation to impacts by better ecosystem management at first; later, global environmental management through cooperating networks	Market-based incentives; environmental technologies to reduce consumption and repair and enhance ecosystem services like carbon sequestration
Geographic differences	Impacts greater in developing countries until late in the period	Much greater impacts in poorer countries but feedback impacts on wealthy ones	Local adaptation to impacts of climate change until later in the scenario where global networks develop to address causes	Different environmental technologies in different regions depending on culture, opportunities, and resources

Despite policies and commitment to reducing inequity, the impacts of climate change are greater in poorer than in richer countries.

8.7.5.2 Order from Strength

Natural environments are seen as providers of some critical services, like regulation of climate and the oxygen level in the air, but most other benefits from ecosystem services are seen as either substitutable or repairable by technology.

Global issues like climate change are almost impossible to address, because there is always at least one key nation unwilling to cooperate due to national interests and because the international institutions that might have been able to address international issues are unstable (if they exist at all). Consequently, formulation of an effective response to climate change will be very complex in this world. The best hope might be partial deals among like-minded nations.

Ironically, up to 2050 global climate change increases less in this scenario than in the other three because a large proportion of the world's population is forced to live a simpler and less materialistic existence. (But climate change is still increasing at 2050 and is likely to be worse than in all the other scenarios by 2100; see Chapter 9.)

8.7.5.3 Adapting Mosaic

Problems like climate change grow worse because of disenchantment with global and national governments and an increasing focus on local issues. This leads to a focus on adapting to climate change for much of the period between 2000 and 2050, using sophisticated learning and intervention in ecosystem management. Eventually, however, it is recognized that problems like climate change require global action, so networks of cooperating local groups and businesses develop and take action toward the end of the period. The rate of climate change is relatively slow because the focus on environmental rather than technological solutions leads to lower environmental impacts and slower economic growth.

8.7.5.4 TechnoGarden

Among the four scenarios, TechnoGarden is clearly best equipped to deal with the issue of climate change, based on its international cooperation and proactive attitude toward solving ecological problems. Removal of subsidies for fossil fuels, nuclear energy, and large hydro projects stimulates the development of a variety of alternative energy sources. Large energy companies and entrepreneurs from a range of countries, especially poorer ones, support these developments. Big business invests in environmental technologies to ameliorate and address the causes of climate change, and global agencies are established to implement strategies.

The type of environmental technology and action employed within the richer and poorer worlds varies due to culture, the way that property rights are organized, and the density, wealth, and activities of people within a region. As under Global Orchestration, international trade in carbon credits could become a major financial flow under TechnoGarden.

8.7.6 Eutrophication

Nutrient pollution (eutrophication) of fresh and coastal waters expanded greatly over the second half of the twentieth

century. These nutrients came mainly from three major sources: agricultural runoff, sewage, and the burning of fossil fuels. Nutrient pollution stimulates the growth of algae that consume oxygen and produces areas of low oxygen in waterways. These low-oxygen areas decrease the ability of fish, shellfish, and other organisms to persist. Furthermore, algal blooms can make fresh water toxic to people. These consequences of nutrient pollution decrease fishing, the supply of clean water, the aesthetic value of waterways, and habitat available for many species.

The extent and impact of eutrophication in the future will be determined by a number of factors:

- Algal blooms are worse when populations of top predators are reduced or when wetlands, which can remove excess nutrients before they reach waterways, are absent.
- Agriculture's impacts will be determined by the area under agriculture and the amount of nutrient runoff from land (nutrient runoff in turn will be affected by the type of agricultural practice, rainfall intensity, slope of the land, fertilizer application, and the amount of nutrients accumulated in the soil).
- The impacts of fossil fuels (which release NO_x) will depend on the total amount used and the technology that is used to burn them.
- The impacts of sewage will be determined by the volume produced and the ability to treat it for nutrient removal.

The technologies developed in TechnoGarden should reduce the risks of eutrophication, despite a rise in area under agriculture, by reducing the impacts of agriculture, sewage, and energy use.

In Adapting Mosaic, better local management of agricultural runoff, fossil fuel burning, and sewage will reduce the chances of eutrophication. But these could be offset by increasing use of fossil fuels and expansion in area under agricultural areas. Consequently, water quality in inland waterways should improve, but coastal eutrophication—especially where populations are dense, such as in the tropics—will increase.

Global Orchestration can expect increases in eutrophication. Minimal population growth combined with technological advances will increase energy efficiency and result in more-efficient agriculture. However, these moderate improvements will not purposefully address the nutrient runoff from agriculture and fossil fuel burning, resulting in an increase in nutrient pollution, especially in poorer countries. In addition, the reactive management style favored in this scenario is likely to be too slow to address changes in soil and sediment phosphorus, which may set the course for eutrophication that is very problematic to reverse if it is addressed after it is a problem.

Order from Strength is very vulnerable to increases in nutrient pollution, and areas of eutrophication should greatly expand. In this scenario, there is little investment in environmental technology or management to offset substantial increases in agricultural area and fossil fuel use.

In all scenarios, people will have to cope with eutrophication caused by storage of phosphorus in soils and recycling of phosphorus from lake sediments—two factors that make eutrophication extremely difficult to reverse once it is a problem.

8.7.7 Invasive Species

A recent meeting of experts on invasive species (Various Authors 2003) identified several major issues:

- *Species spread:* Species invasions are not natural and have been greatly accelerated by people. The world's biota are being homogenized by moving species accidentally and purposefully. Species are being mixed between places that have not been in contact for millions of years.
- *Regulating valuable invasive species:* It is difficult to get rid of invasive species that have high economic value to some people.
- *Anticipating invasions:* Only a small proportion of introduced species become invasive, but it is very hard to predict which ones will.
- *Invasion control:* Control of species invasions is complicated and difficult. Chemical and biological control frequently backfire. Physical removal is very expensive.
- *Monitoring and detection:* Due to the difficulty of control, the best approach to invasives is to reduce the rate of arrivals and to monitor for introductions. The best approach from a conservation point of view is a combination of no tolerance and immediate eradication.

This section looks at how people might deal with these challenges in the four scenarios. (See Table 8.5.)

8.7.7.1 Global Orchestration

The openness of borders, growth in economies of countries all around the world, and the strong emphasis on trade creates increasing opportunities for intended and unintended movement of species across borders. The confidence in technology to solve environmental problems as they arise is likely to discourage research to anticipate invasions or the scaling back of species that have economic value unless they became serious threats to economic growth in other sectors. Response to invasions should be facilitated by well developed global cooperation, but with invasives such approaches are likely to be too late to be cost-effective.

8.7.7.2 Order from Strength

This scenario has the highest risks with respect to invasive species. Global trade is expected to be lower than in other scenarios but still high enough to transmit invasive species. Global cooperation for controlling the spread of invasive species is likely to be poor. Outbreaks of invasive species, especially in poorer countries, are much more likely than in other scenarios due to poverty and poorly resourced management. Research into understanding, detecting, and controlling invasive species is likely to be low, consistent with the low priority given to proactive environmental management. Thus the only defense against invasions is tight border controls, which are unlikely to be effective since only small numbers of individuals need to get through to start an invasion. Control is likely to be unaffordable in poorer countries, and richer countries are likely to have many other demands on their treasuries, such as maintaining national security in the face of terrorism and other conflicts.

Table 8.5. Invasive Species across the Scenarios (Various authors 2003). Within each issue, the scenarios are ranked from best (4) to worst (1). See text for further explanation.

Factors	Global Orchestration	Order from Strength	Adapting Mosaic	TechnoGarden
Species spread	The large scale of global trade combined with the fivefold expansion of the global economy will increase the risks of biological invasions. (1)	Global trade will roughly double under this scenario. Strong border control is unlikely to be effective. The lack of international guidelines and attention to environmental processes means that invasions are likely to increase. (2)	Reduced long-distance transport of materials should reduce pressure on ecosystems, and a focus on local management should help respond to local invasions. Overall, risk is likely to decline. (4)	The large scale of global trade combined with the fourfold expansion of the global economy will increase risks; however, ecological technology should help mitigate this. Overall, the risk of species spread is likely to increase. (3)
Regulating introduced species that are valuable	The focus on economic growth in this scenario is unlikely to reduce this problem. (2)	There will be little attempt to control such species until after they have spread and have negative impacts. Ecological management is not a priority in rich countries, and poor countries cannot afford it. (1)	Effective local action but lack of national or global cooperation means that local groups will have to deal with frequent re-invasions. (3)	Use of tracking technologies (e.g., bio, nano, IT) will allow for the partial control of the spread of valuable potentially invasive species while allowing their continued economic exploitation. (4)
Anticipating invasions	Global cooperation helps but is usually too late, due to reactive environmental policies. (2)	All countries caught off guard. (1)	Early detection and action locally, and sharing of information globally, but lack of coordinated action to reduce risks. (3)	Attempts at early detection and effective control using environmental and other technologies partially effective. (4)
Invasion control	Use of combination of processes, but not in any organized or integrated way. Frequent mistakes result in species spread and negative ecological consequences. (2)	Little control. When applied, done haphazardly with little consideration of risks. Failures discourage further control. (1)	Probably beyond local management to develop. Focus would be more on managing landscapes to prevent invasion or to increase competitiveness of desirable species. (4)	Sophisticated regimes of biotechnologies, possibly including biological control. Danger that confidence in ability to manage nature leads to rediscovering the mistakes of previous generations. (3)
Monitoring and detection	Detection would not be early, but national and international action could be rapid once the problem is evident. (3)	Late detection and poorly coordinated response. (1)	Early detection with rapid response locally. However, lack of coordinated regulations on global trade leads to frequent surprises. (2)	Detection early, rapid, and effective due to extensive and internationally coordinated ecological monitoring by public, private, and citizen groups. (4)
Overall damage from invasive species	Major expansion in global trade combined with lackluster monitoring and control increase spread of invasive species. Monitoring and control are partially effective and mitigating damage. (2)	Despite lower species spread, the failures in monitoring, control, and management produce the largest risks. (1)	Local regulation prevents arrival of invasive species, and local monitoring, management, and control are effective at reducing species damage. However, a lack of coordination at national and global scales results in increased invasions. (3)	Despite an expansion of global trade, the effective international regulation, monitoring, control, and management work to reduce damage produced by invasive species. (4)

8.7.7.3 Adapting Mosaic

The local focus in this scenario will reduce long distance transport of materials. This should reduce the chances of species introductions, and close monitoring and learning by local managers should effectively deal with most invasions before they get established.

However, poorly developed national or global cooperation means that local groups could have to deal with frequent reinvasions. Similarly, until mechanisms develop for sharing the results and lessons from local monitoring and for developing coordinated response strategies, broad-scale outbreaks could be difficult to control.

8.7.7.4 TechnoGarden

This scenario also sees open and increasing trade, but with a proactive attitude toward environmental management supported by investment in environmental technologies. Depending on whether detection and control technologies improve fast enough to counteract the increasing opportunities for species movements, this scenario could see an in-

crease or decrease in species introductions. On balance, the opportunities for species movement should grow faster than control technologies and the risk of species spread will increase.

Technologies (such as tracking technologies using biotechnology or nanotechnology) could help follow and control the spread of invasive species and could be used to keep the economically valuable ones contained. Investment in research for understanding, detecting, and controlling invasions—combined with international cooperation in amelioration—would give this scenario a distinct edge over the others. There is the danger that overconfidence and complacency could lead to surprises, however, and that technology could create new pests that are hard to control.

8.7.8 Urbanization

Table 8.6 summarizes some of the roles of ecosystem services in supporting the major urban center of São Paulo, Brazil. Table 8.7 summarizes the different challenges for urban areas in the four scenarios, which are discussed in more detail in the storylines.

8.7.9 Example: Agriculture and Hypoxia in the Gulf of Mexico

The Mississippi River drainage basin extends over roughly 3.2 million square kilometers, covering almost half of the continental United States. This basin is the third largest in the world and is home to about 70 million people. The Mississippi River basin's agricultural economy is worth $100 billion per year and produces about 40% of the world's corn and 40% of the world's soybeans (Donner et al. 2002).

However, the focus of the regional economy on increasing agricultural production has reduced the ability of the region's ecosystems to provide other ecosystem services, such as clean drinking water, fisheries, and wildlife. One of the major impacts of agriculture has been the decline in

Table 8.6. Ecosystems Services Supporting Urban Areas. The São Paulo Green Belt Sub-global Assessment explores the importance of ecosystem services to the 17.8 million inhabitants of the Metropolitan Region of São Paulo, Brazil, which is the world's fourth largest city. The Table summarizes some of the interactions between urban processes and the surrounding Green Belt.

Ecosystem Service	Environmental Good/Service	Description/Importance of Environmental Good / Service
Supporting service	ecological processes and biodiversity	The Atlantic Forest is one of the planet's richest biomes in terms of biodiversity; maintaining its integrity is crucial to the population of Brazil and important to the global population in general (for potential new medicines and other products). Locally, the Green Belt woods are important ecological corridors, acting as links connecting different forested regions of Brazil.
Provisioning services	underground and surface water supply	Water resources within the GB supply water to over 20 million people. Their endangerment can lead to a collapse in public water supply: water shortage is already common during the dry season. There is also a strong correlation between forest intactness and water quality; the trade-offs between these two services (or synergies) have serious economic implications.
	food safety	Today, 15% of the world's food is produced in backyards and small land tracts (Ian Douglas, Univ. of Manchester, 2002, personal communication). The GB has this tradition and today is one of Brazil's top organic produce regions (sustainability). Besides, the choice for agriculture in areas surrounding cities is regarded as an alternative to the outspread of big cities.
	forest resources	The forest products originating in the Green Belt are the mainstay of São Paulo State's economy, mainly coming from reforestation. The natural forests also provide important resources to several communities, including fuelwood and building material.
Regulating services	climatic regulation	The SPGB acts to counter the urban cask that causes temperature to rise (heat islands). This phenomenon has been linked to thermal imbalances that influence rainfall patterns and can lead to heavy floods in urban areas.
	soil protection and run-off regulation	The forests in the GB prevent soil erosion and minimize floods.
	carbon sequestration and pollutant reduction	Carbon sequestration: The GB has 311,407 hectares of undergrowth and 84,620 hectares of reforestation, which add up to help to balance a large fraction of the CO_2 generated by the urban population.
		Pollutant reduction: Forests act as a physical barrier against the movement of pollutants from metropolises. This has both global and local health implications.
Cultural services	social use	Metropolises like São Paulo and Santos lack green areas. The GB is often the only alternative for the population to be in contact with the natural environment. This is crucial for humanizing as well as for the physical and psychological health of the population.
	sustainable tourism	Brazil's forests generate income for urban-based tourism operators and other supporting businesses.

Table 8.7. Urbanization and Its Issues across the Scenarios

Factor	Global Orchestration	Order from Strength	Adapting Mosaic	TechnoGarden
Rates of urbanization	high as wealth and technological lifestyles grow in all countries	high in rich countries as wealth and technological lifestyles grow high in poorer countries due to poverty and rural decline	moderate as people reconnect with nature and many decide to live in rural areas	high as ecosystems are managed remotely
Infrastructure	global uniformity of community health standards, business practices, and governance for reasons of health, security, and distribution and management of foods, building materials, and fuels	urban sprawl competes with agriculture for the best land water pollution, poor infrastructure for dealing with urban wastes, chronic diseases caused through depleted ecosystem services for controlling disease-carrying species, and damage to crops and the environment from invasive species, are all made progressively worse because underlying problems were not addressed	damage to urban centers due to climate change is sometimes large, but people's capacity to restore ecosystem services has been sufficient to recover from the impacts within two to three years in most cases using strategies based on lessons learned elsewhere	improved transport and pollution management systems arising from innovation in developing countries increased use of public transport cities become multicultural and designed around local climate and ecology
Challenges	major impacts on coastal systems as coastal cities grow poorer cities face challenges as money is injected into their economies and urban populations grow rapidly due to rural people moving to cities and people moving from other countries	cities in wealthy countries face challenges managing their poor and preventing terrorism inflamed by poor living conditions in less wealthy countries cities in less wealthy countries face challenges building and maintaining basic infrastructure due to poverty and resource degradation that affects water quality, food production, waster disposal, and amenities	there is growing interest in life outside cities, increasing the challenge for urban planners to keep cities interesting for the residents city planners struggle to get high-quality scientific input to establish ecologically sustainable systems, and lessons learned by other cities are not freely shared	rapid urbanization, especially in Asia and Africa, creates pollution and disease challenges in richer countries, environmental technologies improve the livability of cities but create some new environmental challenges tensions exist between landscape designers and restorationists some cultures, especially indigenous, threatened by global homogenization
Demand for greener cities	high demand in all parts of the world as prosperity grows	low as ecosystems not seen as fundamentally important in richer countries and survival takes precedence in poorer countries	very high as the connection of humans with nature is seen as fundamentally important	high demand due to appreciation of ecosystem services rapid growth of Asian cities leads to innovation and periods of dynamic urban reinvention
Technology	technology to make life in cities more comfortable and rewarding is a high priority increased sharing of technologies across the world as global markets continue to grow environmental impacts are dealt with as modifications to technology once they are detected	moderate development of technologies to improve urban infrastructure in richer countries poorer cities struggle with outdated technologies	a strong emphasis on using ecosystem services instead of technology wherever possible, but this requires cooperation among several watersheds for big cities, and this is initially a challenge in this fragmented world	new-Asian urbanism combines existing technologies in novel ways and stimulates new ways of thinking about city planning
Sharing of solutions for livable cities	high	very low	low initially, then higher through networks of individuals	high

Gulf fisheries caused by increased flow nutrients from agricultural fertilizer into the region's surface waters. These nutrients flow through the Mississippi basin into the Gulf of Mexico, where they are the cause of seasonal low oxygen levels and hypoxia, which many aquatic species cannot survive. In 2002, the area of hypoxia extended over 20,000 square kilometers (Rabalais et al. 2002a). This region of hypoxia, know as the ''dead zone,'' forms in the center of the most important commercial and recreational fishery in the continental United States (Goolsby et al. 1999).

During the second half of the twentieth century, land use and land management practices changed greatly in the Mississippi river basin. Following the invention of cheap industrial fertilizers in the middle of the twentieth century, the use of fertilizer has increased massively, from almost non-existent levels to yearly applications of 150 kilograms of nitrogen per hectare (Foley et al. in review). The expansion of industrial agriculture has increased nutrient runoff. In the second half of the twentieth century, the amount of nitrate entering the Gulf of Mexico tripled, due to increased runoff and a sixfold increase in fertilizer use (Donner et al. 2002).

The increase of nutrients in the Gulf increases aquatic net primary production, which consumes oxygen. In the warm summer, the water in the Gulf of Mexico is stratified into layers that do not mix much. The diffusion of oxygen into the water from the air is also reduced. This stratification is controlled by river outflow, wind mixing, the circulation of the Gulf, and summer temperatures. The combination of stratification and fertilization produces the area of low oxygen called the hypoxic zone. This area began to appear around the start of the twentieth century and became more severe after the 1950s. The nitrate flux leaving the Mississippi increased by a factor of three between the middle and the end of the twentieth century (Rabalais et al. 2002b).

Hypoxia simplifies the ocean bottom communities, reducing populations of shrimp and other commercially valuable species. Important fisheries are variably affected by increased or decreased food supplies, mortality, forced migration, reduction in suitable habitat, increased susceptibility to predation, and disruption of life cycles (Rabalais et al. 2002b). Since the 1960s, many other regions of coastal anoxia have emerged worldwide. Between 1990 and 2000 the area affected by anoxia has doubled (UNEP 2003).

8.7.9.1 How Will Hypoxia in the Gulf of Mexico Change across the Scenarios?

At the start of the twenty-first century, U.S. federal and state officials have developed a set of plans to reduce nitrogen export from the Mississippi. Will these programs be successful? Will they be sufficient to reduce the dead zone? We compared the four global scenarios using the issue of hypoxia in the Gulf of Mexico. First, we identify the factors that influence the dead zone (see Figure 8.7) and then we assess how these factors will vary across the scenarios.

8.7.9.2 Factors Influencing the Dead Zone

We identified five factors influencing the dead zone: climate, agricultural practices in the Midwest, the management of the main stem of the Mississippi, the management of the delta and New Orleans, and fishing.

Climate will influence hypoxia in the Gulf by influencing runoff from the Midwest, stratification of the water, and the agricultural practices of farmers in the Midwest. The timing and amount of rainfall influences how much fertilizer runs off from agricultural fields. Intense rainfall on frozen ground will transport larger amounts of nutrients into the Mississippi, while the same amount of precipitation spread out over a longer period will produce less erosion. It is uncertain whether climate change will or will not increase the flow of the Mississippi River (Justic et al. 2003). The temperature of the Gulf of Mexico is also expected to increase. This would increase productivity and increase stratification, both of which would increase the vulnerability of the Gulf to hypoxia (Justic et al. 2003). While past climate changes appear to be indirectly linked to increases in yield, it appears that these increases have approached a ceiling and that further improvements in climate will not substantially increase yields or area planted (Foley et al. in review).

The extent and type of agriculture practiced will influence the vulnerability of fields to runoff. The use of artificial drainage over the past 200 years in the Mississippi has eliminated once-common wetlands and riparian zones, decreasing the ability of the landscape to retain and recycle nutrients. Intensive agriculture, which uses large amounts of fertilizer in large fields, will produce more runoff than would agriculture that is adapted to local topography, disturbs the soil less, and uses less fertilizer. Nutrient runoff can be decreased by lowering the amount of fertilizer applied and reducing the amount that runs off the landscape. Less fertilizer can be used on the land by changing from row crops, such as corn and soybeans, to perennial crops such as alfalfa. Another approach is to apply nitrogen in the spring rather than in the fall, when there is more runoff. A third approach is to fertilize crops only when needed. This means using it only in areas of a field where it is required, and not adding nitrogen that is already being supplied through nitrogen fixation by soybeans, manure application, and atmospheric deposition. Runoff can be reduced on the farm by lowering runoff from livestock farming operations and by the construction, maintenance, and restoration of wetlands and riparian buffers (Mitsch et al. 2001).

The management of the river and its floodplain alters the transport of nitrogen to the Gulf. Wetlands have been destroyed and the Mississippi River's main channel has been shortened, dredged, and bordered by flood protection levees. These changes reduce the amount of nitrogen that is taken up by plants and animals living in the river, increasing the amount that flows into the Gulf (Turner and Rabalais 2003). Levees prevent seasonal flooding, protecting buildings near the river and preventing the movement of sediments and nutrients into nearby wetlands. Riparian buffers and floodplain wetlands can prevent nutrient-rich runoff from reaching the river. However, care has to be taken that water does not spread over the buffer, because if runoff cuts channels through a buffer it is not useful (Mitsch et al. 2001).

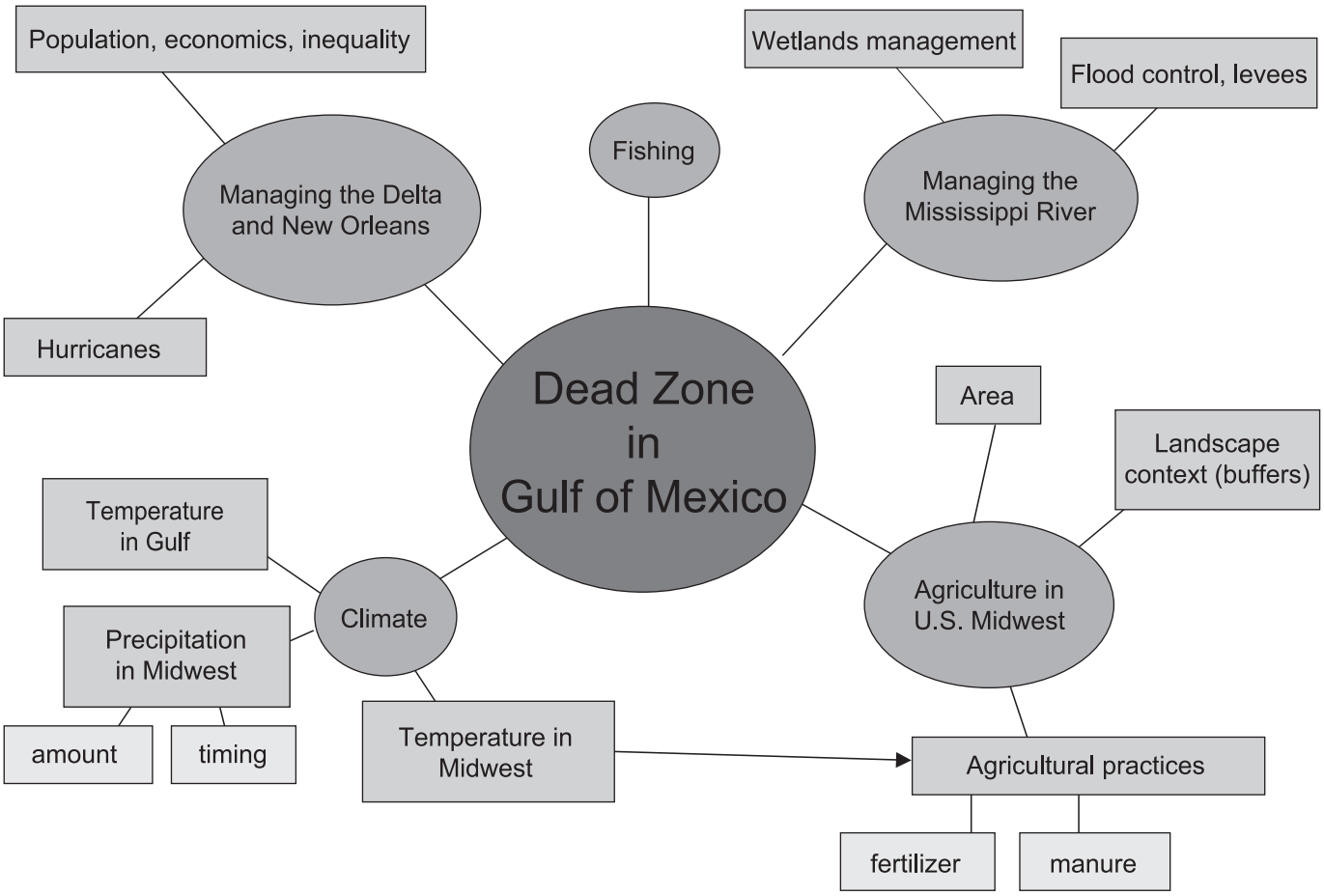


Figure 8.7. Conceptual Map of Direct and Indirect Drivers of the Dead Zone in the Gulf of Mexico

Hypoxia in the Gulf of Mexico is influenced by the separation of the Mississippi River from its delta. The channelization of the river prevents it from spreading over the floodplain. This prevents nitrogen from being removed in delta wetlands and is contributing to land erosion in the delta. Attempts to restore the delta could also decrease the movement of nutrients into the Gulf. Efforts to protect New Orleans from flooding and hurricanes could make the export of nutrients either worse or better, depending on how they modify the river and the delta (Mitsch et al. 2001).

Fishing is influenced by hypoxia, but the presence of substantial populations of algae-eating fish would likely decrease the vulnerability of the Gulf to hypoxia by reducing the production of phytoplankton. There has been increasing evidence that overfishing can increase the vulnerability of coastal areas to eutrophication, which contributes to hypoxia (Jackson et al. 2001).

8.7.9.3 Comparison of Factors across the Scenarios

The global scenarios differ in changes to global trade, investments in ecological technology, and approaches to regional ecological management. These differences shape how these scenarios could influence the five key factors that influence the extent of hypoxia. Climate change will not be significantly different across the scenarios—warming in the Gulf of Mexico and increased rainfall in the Midwest will increase the vulnerability of the Gulf to hypoxia in all scenarios. Differences among the factors influencing vulnerability are summarized in Table 8.8.

Overall, we expect that the dead zone should be reduced the most in the TechnoGarden scenario due to changes in agricultural practices, more sophisticated management of the delta and main stem, and better management coordination among upstream and downstream parts of the river. The coordination and ecological engineering across large scales required by this problem are well addressed by the society and technologies developed in TechnoGarden. Furthermore, ecological engineering of water and biogeochemical cycles are more predictable and better understood aspects of ecosystem dynamics.

Adapting Mosaic would decrease the area of hypoxia due to the cumulative effects of many local attempts to solve local ecological problems in the Mississippi basin. However, the decrease in global trade could lead to a higher amount of agriculture to meet local needs. Furthermore, problems of coordination among the Midwest and the Mississippi delta limit the effectiveness of local action. In this scenario, the dead zone would initially increase in area due to the existing nitrogen in the system, but this worsening will gradually slow and then be reversed.

Global Orchestration sets up a number of forces that decrease and increase nitrogen movement into the Gulf of

Table 8.8. Consequences of Each Scenario for the Factors Affecting Hypoxia in the Gulf of Mexico

Factor	Global Orchestration	Order from Strength	Adapting Mosaic	TechnoGarden
Farming	decrease in area; no change in nutrients; some improvement in land management; constant or minor decrease in nutrient runoff	increase in area; increase in fertilizer use; limited improvement in land management; increased nutrient runoff	increase in area; less fertilizer use; better land management practices; less nutrient runoff	decrease in area; less fertilizer use; better land management practices; less nutrient runoff
Managing the river	management of river for barges eliminates wetlands and increased channelization; some increase in wetlands and buffers; no change in proportion of nutrients entering the Mississippi	some local addition of riparian buffers and wetlands combined with decrease in wetlands and building levees; increased proportion of nutrients entering the Mississippi	some levee removal driven by farming and flood protection; restored wetlands and riparian buffers; decreased proportion of nutrients entering the Mississippi	levee removal and reengineering of floodplains with ecologically sophisticated levees and engineered wetlands; decreased proportion of nutrients entering the Mississippi
Managing the river delta	investment in human well-being in delta results in many local improvements; however, river channelization leads to only small increases in flow through delta	some area abandoned; regulation of river; further decrease in delta despite some local increases in wetland	local projects, but disagreements about what to do about the river; slightly increased flow through the delta	federal ecological reengineering of the delta leads to greatly increased area of wetlands
Changes in hypoxia	slow growth in area	substantial growth in area	initial increase in area, then gradual decline	reduction in area
Changes in fishery	sport fishery persists, commercial fishery closed due to low profitability	fishery eliminated	local management and improvement of fishery	fishery increased and combined with delta aquaculture maintained

Mexico. On the decreasing side, a rise in global agricultural trade and the cutbacks of agricultural subsidies reduce the extent of agriculture in the Mississippi basin. Furthermore, the decrease in the importance of agriculture in the economy leads to greater demand for clean water. These concerns lead to local mitigation measures. However, the management of the river for trade, including keeping it deep enough for boats, and the lack of basinwide integrated nutrient management work against the decrease in nutrient movement into the river. Local development in New Orleans and education and social development programs ease some of the problems of the delta and reduce its vulnerability to hurricanes. These positive and negative effects roughly cancel one another out, and ongoing transport of nutrients at present levels leads to an increase in the dead zone.

Order from Strength has largely negative consequences for hypoxia in the Gulf of Mexico. The decrease in global trade leads to continued high levels of agriculture in the United States. The non-local impacts of nutrient runoff are not addressed, and there is substantial conflict among upstream and downstream states over river management. Lack of integrated policy and political struggles among various jurisdictions over who is responsible for the nutrient pollution, together with social inequality and a lack of effective responses to rising sea level in the delta, combine to ensure that higher levels of nutrients enter the river and are transported into an increasingly vulnerable Gulf of Mexico. There would be substantial increases in the size and severity of area of hypoxia in the Gulf in this scenario.

8.7.9.4 Discussion

The comparison of Gulf of Mexico hypoxia across the scenarios provides lessons on the legacies of past decisions, the relationship between society and nature, and the scale of ecological management. Land use decisions over past centuries, in particular the use of large amounts of fertilizer following World War II, have put huge amounts of nutrients into the Mississippi River. Even with radical changes in land use and river management, these nutrients will remain at high levels within the Mississippi for decades.

Poor and rural people are most vulnerable to the loss of ecosystem services. Social policies, such as providing alternative livelihoods for fishers and investing in human capital in Mississippi delta communities, can mitigate the impact of the dead zone on human well-being.

The dead zone in the Gulf of Mexico has been produced by land use decisions decades ago and hundreds of kilometers away. The impact of these decisions on the Gulf depends on river management, delta management, and fishing, however. In such a situation, local ecological management can help address local problems but is insufficient to deal with the broader problem. Management responses that are integrated at a variety of scales are required to deal with large-scale emergent ecological problems, such as coastal eutrophication.

8.8. Insights into the Key Questions Posed in the Scenario Project

The following section draws insights from the scenario storylines with respect to the key questions posed in the sce-

nario project, which are outlined in Chapter 6. Further insights are drawn in later chapters and brought together in Chapter 14.

The key questions are:

- What are the consequences of plausible changes in development paths for ecosystems and their services over the next 50 years, and what will be the consequences of those changes for human well-being?
- What are the most robust findings concerning changes in ecosystem services and human well-being across all four scenarios? What are critical uncertainties that we are confident will have a big impact on ecosystem services and human well-being?
- What are gaps in our understanding that we can identify right now that will affect our ability to model ecosystem services and human well-being?
- What opportunities exist for managing ecosystem services and human well-being?
- What is surprising in these results?

8.8.1 Consequences of Plausible Changes in Development Paths

Strategies for human development that emphasize economic policy reform (that is, reducing subsides and internalizing externalities) as the primary means of management potentially improve human well-being most rapidly of all, but they also carry risks of major social collapses and adverse environmental backlashes due to unforeseen feedbacks. Such strategies (our Global Orchestration scenario, for example) are likely to be based on the assumptions that increasing economic well-being decreases environment impact (Kuznets greening) and that ecosystems are sufficiently robust and human (technological) ingenuity is sufficiently great that environmental problems can be dealt with once they become apparent.

Because they address economic inequality directly, such strategies promise the most rapid improvements in human well-being. However, they carry several risks. If they are wrong about the robustness of ecosystems, then ecological crises could accelerate inequality because they disproportionately affect the poor. Although humans have a long history of technological solutions to environmental problems, post hoc technological solutions usually are much more costly than early detection and action. Such strategies are most likely to succeed in a world of centralized decision-making and global cooperation. If this is accompanied by a de-emphasis on local responsibility and authority for environmental management, then there is a risk that potentially unmanageable national and global issues could arise from aggregations of local problems that are not detected and addressed early enough. Global climate change, the salinization of landscapes, and overexploitation of fisheries are examples.

Strategies that emphasize local and regional safety and protection and that give far less emphasis to cross-border and global issues offer security in a world threatened by acts of aggression and the spread of environmental pests and diseases, but they lead to heightened risks of longer-term internal and between-country conflict, ecosystem degradation, and declining human well-being. In the Order from Strength scenario, countries turn inwards in response to terrorism, war, and loss of faith in global institutions. Trade and movement of people are restricted, leading to temporary security from human aggressors and some environmental benefits from control of the movements of exotic plants and animals.

Such a world encourages boundaries at all scales, and inevitably the gap between rich and poor grows within and between countries and the need for multiscale proactive management of ecosystems is neglected. Inequity leads to increasing demands on the environment for survival by the poor, and the threat of both aggression and environmental degradation increase. The only benefits for ecosystem services imaginable relate to protection of key natural resources in rich countries, although if (as is likely) this is combined with reactive rather than proactive environmental policies, then ecological problems are likely to emerge at both local scales and across scales from local to global.

Virtually all environmental problems currently imaginable, including outbreaks of pests and diseases, famine, erosion and flood damage, soil and water degradation, air pollution, and decline in fisheries, are likely under extremes of this type of strategy. In moderate forms, however, we could see periods of increasing inequity and environmental degradation interspersed with periods of alleviation of the problems by strategic intervention by the wealthy to keep cross-scale problems in check. Such cycles might continue for some decades but are unlikely to be sustainable in the long term.

Strategies that emphasize the development and use of technologies allowing greater eco-efficiency and optimal control offer hope for a sustainable future but still carry risks that need to be addressed. In our TechnoGarden scenario, such a strategy develops due to recognition of the importance of ecosystem services for human well-being and the emergence of markets that encourage trade in these services. Managing ecosystem services becomes a focus for business, and rights of ownership and access to ecosystems become more formal. As population continues to grow and demand for resources intensifies, people increasingly push ecosystems to their limits of producing the maximum amount of ecosystem services.

The risk under this strategy is destruction of local, rural, and indigenous cultures. The increasing confidence in human ability to manage, or even improve on, nature leads to overlooking slowly changing variables that are not easily reversible, like the loss of local knowledge about ecosystem services and eutrophication of fresh waters and coastal oceans. The new technologies themselves can even engender their own ecological surprises. But in general, people around the world have better access to resources, and managers think more about multifunctionality and systems approaches rather than single goals.

Strategies emphasizing adaptive management and local learning about the consequences of management interventions for ecosystem services are the hope of many ecologists and environmental groups, but creating a world like this might bring some challenges that cannot be overlooked. Our Adapting Mosaic scenario arises from some of the same

inward-looking tendencies that produced Order from Strength. In this case, there is dissatisfaction with the results of global environmental summits and other global approaches, and trust in centralized approaches to environmental management declines. The focus is on learning about socioecological systems from multiple sources of knowledge, experimentation, and monitoring. The compartmentalization implied by these trends fosters competition and limits the sharing of learning for a time.

In Adapting Mosaic, there are failures as well as successes and there is the risk that inequality can increase rather than decrease, both within and between countries. Economic growth is likely to be less than in Global Orchestration or TechnoGarden, and this could threaten the establishment and persistence of this strategy unless gains in other aspects of human well-being are obvious in a majority of communities. While local problems become more tractable and are addressed by citizens, global problems like climate change and marine fisheries sometimes grow worse, and global environmental surprises become more common. The hope of this scenario is that there is scope for communities to reconnect at larger scales and to turn their attention back to addressing environmental challenges at multiple scales from local to global.

8.8.2 Robust Findings across the Scenarios

Adverse and unforeseen ecological feedbacks are risks in all trajectories of human development. In all four scenarios there was significant potential for adverse cross-scale ecological interactions. The key message is that whatever trajectory of human development is taken, we need to be alert to the nature of the cross-scale feedbacks that could be overlooked due to the characteristics of the trajectory.

In a globally connected but environmentally reactive world (Global Orchestration), global environmental issues like global climate change or large-scale national issues like salinization of landscapes could be dealt with at national and global scales because institutions at these scales would be well developed and strong. However, such problems often could be well advanced and difficult to reverse in time to avert disaster for two reasons: First, institutions involving local communities who are in touch in real time with ecosystem change could be relatively poorly developed. Second, the assumption that economic prosperity will equip society to deal with environmental challenges could entail lower investment in understanding and monitoring the ways in which small-scale processes aggregate to become larger-scale problems.

In a globally connected but environmentally proactive world (TechnoGarden), we imagine the risk of overconfidence in environmental technologies to the point where humans manipulate landscapes to get more and better ecosystem services. Presumably in this world, fast (short-term) processes will be well understood, but the risk is that slower (longer-term) processes that determine the long-term persistence of ecosystems could be overlooked and that ecological collapses could sneak up on future TechnoGardeners.

In a globally compartmentalized but environmentally proactive world (Adapting Mosaic), there is strong focus on and a dedication to learning about local-scale processes. But we explore how the social forces that allow local institutions to gather such strength and authority could also cause barriers to communication between localities that are competing with one another for better environmental outcomes (such as entry to green markets) and how the ability to spot the aggregation of processes across landscapes and regions might be diminished. Thus, new challenges akin to salinization or global climate change might grow to dangerous proportions before they are identified and action is taken. We see dangers in this scenario for world fisheries, for example.

And in a globally compartmentalized, environmentally reactive world (Order from Strength), we see potential for undesirable environmental impacts at all scales. For poorer individuals, regions, or nations, environmental management becomes a luxury that ranks after the essentials of economic and physical survival. The wealthy not only face the risks of a reactive strategy with respect to their own ecosystems, they also face risks from problems arising in poorer regions and nations that can have an impact across scales. An example is increased risks from major flooding, land movements, dust and other forms of air pollution, and the spread of pests and diseases, including human pathogens.

All trajectories of human development have potential benefits for ecosystem services and human well-being, although these benefits are distributed differently and are rarely uniform. Each of the scenarios lists both benefits and risks. (See Table 8.9 and Figure 8.8.)

8.8.3 Critical Uncertainties

Two fundamental ecological uncertainties underpin the ecosystem services outcomes from future human development. Two of the main ways in which our scenarios differ are around whether the world is more or less connected and whether policy-makers and decision-makers are more or less proactive about environmental management. This differentiation was chosen because we wanted to explore the implications of at least two critical uncertainties about ecosystems that arise from lack of information on ecosystem function and from the uncertainty associated with predicting outcomes from the interactions between human social systems and ecosystems.

The first uncertainty is about the ways and circumstances in which impacts on the environment at different scales interact, sometimes just among themselves but often with human interventions, to produce unexpected and undesirable outcomes.

The second uncertainty is about when and where different ecosystems are robust (able to withstand impacts without fundamentally changing in terms of the services they provide) versus fragile (likely to change rapidly and dramatically in terms of the services they provide).

Because of the tight linkages between ecosystem services and human well-being, virtually all policies for human development involve assumptions about these two uncertainties. Usually these assumptions are implicit rather than explicit. Policies that are reactive to environmental issues assume robustness, while proactive policies at least anticipate the possibility of fragility in some places and at some times. Policies seeking more or less connectedness do not

Table 8.9. Comparison of Potential Benefits and Risks across the Scenarios

Scenario	Potential Benefits	Potential Risks
Global Orchestration	economic prosperity and increased equality due to more-efficient global markets	progress on global environmental problems may be insufficient to sustain local and regional ecosystem services
	wealth increases demand for a better environment and the capacity to create a better environment	breakdowns of ecosystem services create inequality (disproportionate impacts on the poor)
	increased global coordination (e.g., markets, transport, fisheries, movement of pests and weeds, and health)	reactive management may be more costly than preventative or proactive management
Order from Strength	increased security for nations and individuals from investment in separation from potential aggressors	high inequality/social tension, both within blocs and within countries, leading to malnutrition, loss of liberty, and other declines in human well-being
	increased world peace if a benevolent regime has power to act as global police	risk of security breaches (from poor to middle well-off countries and sectors of society)
	less expansion of invasive pests, weeds, and diseases as borders and trade are controlled	global environmental degradation as poorer countries are forced to overexploit natural resources and wealthier countries eventually face global off-site impacts like climate change, marine pollution, air pollution, and spread of diseases that become too difficult to quarantine
	in wealthy countries, ecosystems can be protected while degrading impacts are exported to other regions or countries	
	ability to apply locally appropriate limits to trade and land management practice as trade is not driven by open and liberal global policies	lower economic growth for all countries as poor countries face resource limitations and rich countries have smaller markets for their products
	protection of local industries from competition	
		malnutrition
Adapting Mosaic	high coping capacity with local changes (proactive)	neglect of global commons
	"win-win" management of ecosystem services	inattention to inequality
	strong national and international cooperative networks eventually built from necessity and bottom-up processes	less economic growth than maximum because of less trading
		less economic growth than the maximum possible because of diversion of resources to management
TechnoGarden	creating "win-win" solutions to conflicts between economy and environment	technological failures have far-reaching effects with big impacts
	optimization of ecosystem services	wilderness eliminated as "gardening" of nature increases
	developing societies that work with rather than against nature	people have little experience of non-human nature; leads to simple views of nature

usually arise from environmental concerns, but they often involve assumptions about how environmental issues will be dealt with. These assumptions can make different ecological surprises more or less likely. Our scenarios draw out the assumptions and their potential consequences.

8.8.4 Gaps in Our Understanding

Critical gaps exist in our understanding of the robustness and resilience of ecosystems generally, the qualitative and quantitative nature of their response to human impacts and repair efforts, and the ways in which ecological processes can interact across scales of space and time. Our scenarios suggest that these are critical elements in determining when and where reactive environmental policies will be adequate and whether scales of institutional arrangements are appropriate for detecting and dealing with threats to ecosystem services and human well-being.

8.8.5 Opportunities for Managing Ecosystem Services and Human Well-being

Three of the four trajectories for human development explored in the scenarios offer both benefits and drawbacks with respect to ecosystem services and human well-being. A globally compartmentalized, environmentally reactive world offers few benefits and many drawbacks.

The major likely sources of adverse impacts on ecosystem services and human well-being are failure to address inequity within and between countries, failure to monitor and learn adaptively from changes in ecosystems across scales of time and space, failure to establish and maintain cross-border cooperation in monitoring and addressing cross-scale ecological processes, and failure to ensure that institutional capacity is appropriate before applying political and economic solutions to perceived social challenges. The diversity of viewpoints and expertise brought to the dialogue about the scenarios consistently found this set of issues arising as problems as the storylines were developed and tested for plausibility.

8.8.6 Surprises

A globally compartmentalized, environmentally reactive world could mask developing ecological and social disasters for several decades. Several other global scenario analyses include a fortress world scenario leading to breakdown of

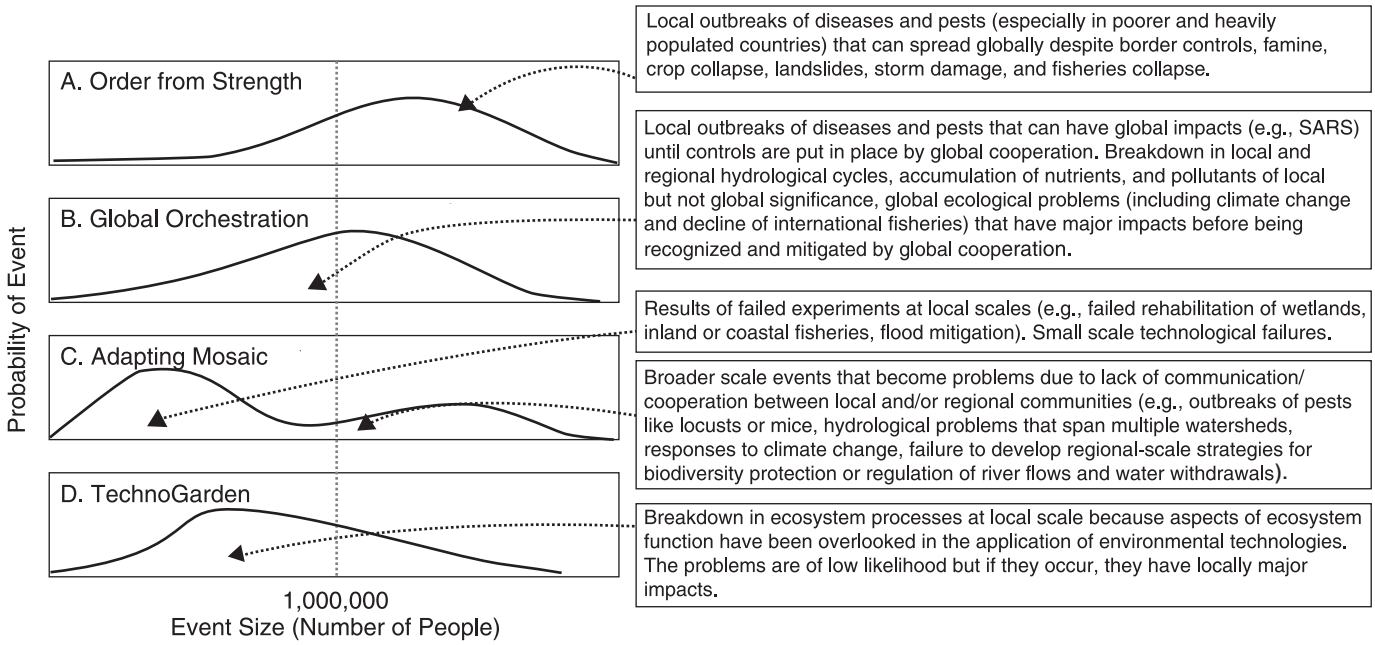


Figure 8.8. Types of Plausible Extreme Events across Scenarios. The distribution curves come from Figure 5.3, this volume. The x-axis is the magnitude of the disturbance of ecosystem services, measure by the number of people affected. The y-axis is the likelihood of an extreme ecosystem event of a given magnitude.

society. The Scenarios Working Group was unanimous that the Order from Strength scenario is unsustainable and ultimately disastrous in terms of ecosystems and the societies they support. But we were surprised at the diversity of viewpoints on how such a scenario could unfold and over what time scale. Despite the heightened risk of massive disasters from conflict and ecosystem breakdown in this scenario, some of us could imagine an ongoing cycle of escalations of social and ecological problems among poorer countries and sectors of society interspersed with strategic mitigation efforts by the wealthy to limit problems before they become global. This raises the possibility that, if current trends toward increasing compartmentalization continue, the world could develop a false sense of security in coming decades unless efforts are made to understand and monitor ecosystems and their services.

Current understanding of ecological and social systems is inadequate to predict when and how ecological-social systems will produce adverse cross-scale ecological interactions. There is considerable evidence of adverse cross-scale interactions between ecological processes and human activities (including interventions intended to fix problems). There also is emerging understanding of how these adverse outcomes have been caused. This understanding allowed us to agree on the types and relative risks of adverse cross-scale interactions in the four scenarios. However, we found it surprisingly difficult to locate when within the next five decades the impacts would emerge or precisely what combinations of policies and interventions are most likely to produce them. This uncertainty and lack of control is precisely the reason for employing a scenario approach (see Chapter 6), but a very large number of scenarios would be necessary to address all possible combinations of drivers that could produce desirable or undesirable outcomes.

Appendix 8.1. Potential Impacts of the Four Scenarios on Major Coastal Wetlands

Land management and climate change effects throughout catchments combine to have an impact on coastal and near-coastal systems. Addressing these impacts requires coordinated actions nationally and internationally, which are big challenges in the compartmentalized scenarios. The time lags between taking action within catchments and seeing responses in coastal systems can be many decades, due to the slow change in ecological processes and the accumulation of nutrients and other chemicals in the catchment soils. Even proactive approaches will face these time lags, but the problem will be much greater for reactive approaches.

Appendix Table 8.1 gives one view of the impacts on various types of coastal wetlands under the four scenarios.

Appendix Table 8.1. A View on Impacts of the Four Scenarios on Major Coastal Wetlands. This view is based on an interpretation of the scenario storylines (this chapter) and the modeling (Chapter 9).

Area	Global Orchestration	Order from Strength	Adapting Mosaic	TechnoGarden
Coral reefs	Although there is considerable coordinated national and international effort to address combined catchment-management and climate change impacts, the late response and long lag time between action and impact means that reefs continue to decline throughout much of the world under this scenario. Areas where impacts are greatest (e.g., many areas of the Caribbean and Southeast Asia) do not recover to their original state. Coastal communities relying on reefs for food and shoreline protection are at the greatest risk, especially with increased storm frequencies. Tourism in many areas declines or is lost altogether. Costs of amelioration are high, but the ability to mount internationally cooperative strategies prevents out-of-control escalation of environmental problems in many areas.	Climate change causes major bleaching events to occur. There also are major outbreaks of diseases, and food chains become unstable so that predators have major impacts in many areas of the world. Developing countries suffer substantially as the loss of coral reefs affects the lives of poor coastal communities relying on reefs for tourism as well as for food. Developing countries attempt to maintain their reef systems and in some areas the decline slows. As sea temperatures rise, however, there is little that can be done. In these countries the major impact is on the tourism industry, which shifts its focus from reefs to island/sandy beach destinations. The lateness of responses combined with inability to mount internationally cooperative approaches causes many of these problems to spiral out of control.	Various initiatives are instituted locally to reduce the impact of climate change. Community-based management becomes widespread and there are local successes first at maintaining the coral reefs and later at addressing external issues such as predators and pollution. Initially, there is lack of clarity in some areas about who has responsibility for reefs, but as communities realize the benefits of cooperative networks, reefs get more attention. Ultimately the rate of loss is slowed down in much of the world, but many areas remain vulnerable to disease and require careful management by local users. Restoration of lost areas is usually not successful; there is net loss of coral reefs by 2050, and reefs are no longer a source of food for many communities in developing countries. Where reefs are still in good condition, tourism is a strong incentive for good local management.	Coral reefs continue to decline. Services such as shoreline protection are provided through engineering works in rich countries, while in poorer countries communities are vulnerable to increased storms and coastal erosion. Food security is addressed through aquaculture, and the greatest benefits to local communities come if they have property rights over the sites. Some communities lose their tourism industry, but others develop stronger industries based on selling tourism and other ecosystem services. Some coral reef areas that are not as affected by climate change are maintained as reference sites and to safeguard genetic resources for future uses. Often these areas are owned and managed by private interests or NGOs because of their recognized ecosystem services values.
Seagrasses	Areas outside major urban/industrial centers and agriculture catchments survive in the long term. Impacts on coastal systems decline later in the scenario period as action is taken to increase the efficiency of agriculture. Beds in proximity to large urban areas are lost and cannot be recovered due to permanent changes in coastal features (e.g., port developments, break walls, etc.). In areas where coastal modifications are absent, reactive policies and actions to reduce pollution, freshwater loading, sedimentation, and destructive fishing produce some recovery. For many coastal communities in developing countries, food security is threatened.	Climate change and invasive species reduce biodiversity in some areas, especially where pollution from urban or industrial centers and agricultural catchments is not controlled. In other areas the development of coastal aquaculture to ensure food security destroys vast areas of seagrass and contributes to coastal pollution. While some wealthy nations are able to institute development and pollution controls, and therefore buffer the impact of climate change and reduce habitat conversion, other countries cannot. Direct impacts on seagrasses and indirect impacts on fisheries threaten food security in many poor countries.	Local communities soon appreciate the importance of seagrass to maintaining fisheries and other ecosystem services and various approaches to managing these habitats are tried. Trade-offs between protection of seagrasses and other social and economic benefits of development are major challenges, especially for coastal communities experiencing rapid urban growth. These are addressed through integrated regional initiatives to address broader coastal issues, but these initiatives take two decades to develop. In some cases, seagrass beds are eventually restored, but in others continued pollution means that seagrasses do not recover. The greatest progress in protecting and managing seagrass is accomplished outside of urban/industrial	There is a general loss of seagrass beds because many of the ecosystem functions can be provided through aquaculture, pollution controls, and engineering works. The loss of seagrasses is more rapid in wealthy countries, where the technology is readily available and can be funded by private enterprise. In poorer countries the rate of loss is less since they cannot afford the technology and there are incentives to protect seagrass beds that can be sold to corporations as offset credits to allow development elsewhere.

			areas, where changes to coastlines are limited.	
Mangroves	Countries continue to lose areas where sea level rises too fast for mangroves to adapt. Losses are highest in poorer countries, where conversion to other uses, such as aquaculture, housing, and agriculture, continue to expand to accommodate economic and population growth. Communities relying on mangroves are at risk in terms of food security and shoreline protection early in the scenario, although social reforms may alleviate this situation later. Eventually the value of mangroves in providing ecosystem services is recognized and measures are initiated that focus on sustainable use (e.g., crab farming, sustainable harvesting regimes, etc.) Rich countries fair much better, but storm frequencies increase so that remaining stands are threatened in some areas. Fisheries decline until measures for protecting mangroves are instituted, but even then recovery is slow and often fails because it has been left too late. Where there is sea temperature rise, some mangrove beds expand but are susceptible to episodic events such as disease and predation from other organisms.	The increasing storm frequencies, rising sea levels, and high freshwater inundation resulting from climate change results in many mangrove areas being environmentally stressed. Pollution from upstream sources as well as in the coast adds further stress to the mangroves. This has impacts on local fisheries (food security) and other services, such as flood control and carbon sequestration. Some stands are lost, exposing coastal communities to the direct impacts of storms and flooding and threatening their food security. To ensure food security, some countries convert many areas of mangroves to aquaculture ponds. However, the increased areas of standing water result in a rise in mosquito-borne diseases.	In some areas the conversion of mangroves to other uses is halted through targeted community-based management projects, and there are attempts to restore some of the services of mangroves. A few work, and the lessons learned are shared with other communities and other management agencies. As examples emerge to show that the benefits of converting mangroves are short-term, many communities cease conversion and initiate restoration works as part of larger coastal management programs. Once the loss of mangrove is slowed down, and especially where there is rehabilitation, fish stocks improve along with other socioeconomic benefits (e.g., improved coastal protection) and appropriate fisheries management measures are implemented so that the benefits are distributed equitably throughout the community, furthering the incentive to protect and manage mangroves within a larger coastal system. Much of the protection and management of mangroves takes place outside of large urban/industrial areas since fewer people are displaced.	Although technological developments can provide many of the provisioning services of mangroves through aquaculture, substitutes for other important services such as nutrient cycling and bioregulation are not well developed by 2050, and therefore the conversion of mangroves to other uses is reduced significantly once the limitations of technology are realized. Technology, however, does enable local communities to use mangrove resources sustainably through environmentally appropriate aquaculture in constructed ponds/cages. This allows less industrialized countries to take advantage of expanding markets for a range of marine products while avoiding overfishing. However, the concentration of aquaculture developments results in systems being more vulnerable to disease and other surprises.
Kelp beds	Beds close to the coast are stressed by a loss of predator fish species when pollution, storms, sedimentation, and in many areas elevated sea temperature cause beds to shift to being dominated by sea urchins. This results in a further cascading effect as other species that rely on kelp are stressed. Once measures are in place to improve water quality and reduce sedimentation and to improve the management of fisheries, some areas recover, but the return of some marine mammal species takes a very long time and some never recover. Many inshore areas are highly susceptible to stresses, and therefore	In coastal areas, kelp beds in many areas are exposed to increased storm action, increased freshwater inputs, sedimentation, and overfishing, resulting in increased stress and susceptibility to disease, predation, and competition from urchins and other invasive species. In wealthier countries action is taken to manage pollution and coastal development, but the long lag times mean that benefits take decades to emerge. Poorer countries cannot afford the trade-offs with production and development, and ecosystems continue to decline due to overfishing, pollution, and coastal development.	Kelp beds decline for at least a decade as they are overlooked by the focus on local community action. However, as communities recognize the benefits of cooperating to manage common goods and services, a range of initiatives emerge that protect coastal kelp beds as part of integrated coastal and fisheries management initiatives. The loss of kelp beds is halted or reduced, and in rare cases recovery takes place depending on the levels of disturbance. In those kelp beds where overfishing of top predators is addressed, the state of kelp beds and the services they provide improves. This requires the	A focus on better fisheries management and recognition of the financial benefits of ecosystem services encourages the protection of kelp beds as fish spawning areas. But climate change and lack of management success limit major benefits to rich countries. In regions with a history of overfishing, kelp beds shift to urchin-dominated areas in which kelp infrequently recovers. In this scenario there is a risk of overlooking the slow processes that maintain kelp beds in the long term in favor of shorter-term processes that are amenable to ecological engineering.

(continues)

Appendix Table 8.1. Continued.

Area	Global Orchestration	Order from Strength	Adapting Mosaic	TechnoGarden
	restoration efforts wax and wane depending on how well climate change is brought under control. Farther offshore, beds are less stressed, and in some areas beds expand as temperatures rise.		development of international cooperation, which is a big challenge in this scenario. In those areas where there has been a long history of overfishing and beds have shifted to urchin-dominated areas, the recovery of kelp systems is sporadic, and some areas never recover.	
Estuaries and embayments	Estuaries undergo major structural changes as flow regimes change with increased storm events and flood events, resulting from land conversion and climate change in both wealthy and poorer countries. This results in major changes in species and productivity of estuaries. Estuaries close to urban/industrial areas lose many ecological functions as pollution levels, freshwater flows, and coastal infrastructure increase and as flooding becomes more common. Hypoxia continues to be problematic in more and more areas, especially in the developing world. In areas, especially in wealthier countries, where estuaries have undergone minimal modifications in the past (e.g., military installations) or where pollution levels have been managed through foresighted or fortuitous management of catchments and domestic and industrial discharges, hypoxic events are reduced. Non-urban areas are also stressed and susceptible to surprises but not to the same extent (relatively more resilience in these systems). A major challenge for this scenario is that although the declining quality of estuaries is recognized, the actions take decades to produce improvements, and remedial programs are difficult to maintain over several terms of government.	Estuaries and lagoon systems are exposed to increased flooding, increased freshwater inputs, and sedimentation due to climate change and land conversion. This results in changes in the diversity of flora and fauna in these areas and alters the scope and nature of ecosystem services as well as increasing the risk of episodic events such as hypoxia and disease (e.g., cholera). These problems are made worse in areas where nutrient pollution is not controlled. Similarly, where coastal developments including aquaculture (pond and net) increase to ensure food security and economic growth, then there is a further decline in ecosystem services such as erosion control. In regions where estuary quality is determined by the actions of several countries, cooperative action is needed but hard to achieve under this scenario.	Communities try various approaches to managing estuaries. A problem early in the scenario is that the quality of estuaries is determined by the decisions of many communities, and cooperation among them is difficult to achieve while they focus on their own constituencies. As cooperative thinking emerges and lessons are shared, it becomes clear that estuaries are best managed as part of an integrated system and that the loss of ecosystem services cannot necessarily be replaced by technology or other parts of the ecosystem. As further lessons are learned, these management programs are then placed in regional strategies and plans that address external issues (e.g., hypoxia) that local communities cannot address as well. The focus on the importance of maintaining and where possible restoring ecosystem services increases. This results in a slowing of the rate of loss of estuaries and corresponding lowering of the extent and size of hypoxic zones. An important element of this scenario is that local learning allows communities to appreciate the slow ecological processes that cause lags between action and results.	Some of the impacts of climate change (storms and flooding) on estuaries are managed through engineering works, and provisioning services such as food are provided through aquaculture. The issues of pollution and freshwater flows are also managed through appropriate upstream practices. Ecological simplification contributes to the loss of genetic diversity, which reduces the long-term sustainability of aquaculture. Communities that maintain estuaries prosper by benefiting from improved water quality, reduction of disease, and maintenance of fisheries.
Intertidal areas	Flooding and storm events degrade low-lying shallow intertidal areas. Coastal erosion continues to be a problem, while conservationists and engineers	In poorer countries erosion continues to be a problem since there is limited assistance from the rich countries to implement engineering solutions. In	Intertidal areas are often managed within a broader integrated coastal management program that considers intertidal areas as well as others. In areas where	Soft engineering solutions are the focus of managing erosion as part of integrated management of coasts in both rich and poorer countries. This becomes the business of a

	debate hard and soft engineering solutions to manage the coast. In the wealthier world, hard engineering is used as an interim measure to halt erosion. Poorer countries are helped with aid from wealthier countries but, even so, engineering approaches are too expensive economically and socially.	wealthy countries action is taken to address coastal environmental problems only when they outweigh or impinge on economic imperatives. In poorer countries, there are constant conflicts between the ecological and social values of areas and basic needs for food, shelter, and economic development. In both rich and poor countries, erosion becomes an increasing issue because of failure to address the role of well-maintained ecosystems in stabilizing landforms. Both public and private property are threatened, as well as recreation, tourism, and food provisioning.	shorelines have been severely altered through engineering works (channeling, break walls, etc.), many ecosystem functions have been lost, while in other areas further degradation or restoration is possible, especially in the rich countries, where such expensive works can be funded. In the developing world, once better environmental management programs are in place and corruption is managed, the loss rate for intertidal areas slows, but not as slow as in the wealthy world.	number of specialist environmental engineering companies, who make money by providing not just stabilization services but a range of other ecosystem services. Despite the many successes of these companies, there are several spectacular failures due to underestimation of surprises from coastal systems and the power generated by rare combinations of natural processes.
Coastal lagoons (open and closed)	Lagoons are highly disturbed due to increasing storm frequencies resulting from climate change. Poorer countries are hardest hit, since many coastal communities depend on lagoons for food and income. Rich countries cope better, especially where urban areas are sparse and protection works are funded for large urban areas. The hydrology for many lagoons changes, resulting in decreased fisheries production and increasing the threat of food security in coastal communities in developing countries. With decreasing water quality, the risk of diseases and invasive species increases. Overall, these lagoon systems are not lost, but there is significant degradation. However, where environmentally appropriate protection works (hard and soft engineering) as well as where integrated coastal management is implemented, fewer ecosystem functions are lost.	Climate change impacts are not addressed in many countries until late in the scenario, resulting in a decrease in the number of functioning lagoons and substantial degradation of coastal lagoons, especially in poorer countries. Lagoons with sufficient water quality are used for aquaculture production and therefore continue their food provisioning services, but other services such as flood control, biodiversity, and bioregulation are lost. These systems are more vulnerable to major disease outbreaks and invasive species. Lagoon systems that are exposed to pollutants or subjected to shoreline changes are less resilient than lagoons that have some of their structural integrity intact and are not threatened with pollution.	Sea level rise and storms affect coastal lagoons through changes in water quality and hydrological processes. Communities develop a range of management systems to adapt and buffer these impacts. Over time, communities develop integrated management systems that are more effective and easier to implement. Systems managed outside an integrated system are more vulnerable to eutrophication, lose ecosystem services, and are at risk of diseases and invasive species.	Technological solutions (soft engineering) are developed to reduce the impact of climate change; to reduce pollution, including nutrient inputs; and to increase food production in lagoons. Some of this technology, especially relating to intensive aquaculture, is transferred to poorer countries, increasing food production, food security, and economic development. However, ecosystem services such as biodiversity and bioregulation are reduced, and lagoon systems become less resilient to disease and invasive species (ecological surprises). Where lagoons are part of an integrated management system, many of the stresses are addressed, and the delivery of ecosystem services improves.

Notes

1. The phrase ''Washington Consensus'' was coined by John Williamson in 1990 (Williamson 2000) to ''refer to the lowest common denominator of policy advice being addressed by the Washington-based institutions to Latin American countries as of 1989.'' These policies were fiscal discipline; a redirection of public expenditure priorities toward fields offering both high economic returns and the potential to improve income distribution, such as primary health care, primary education, and infrastructure; tax reform (to lower marginal rates and broaden the tax base); interest rate liberalization; a competitive exchange rate; trade liberalization; liberalization of inflows of foreign direct investment; privatization; deregulation (to abolish barriers to entry and exit); and secure property rights. The term has been used since in a variety of ways. Williamson says: ''Audiences the world over seem to believe that this signifies a set of neo-liberal policies that have been imposed on hapless countries by the Washington-based international financial institutions and have led them to crisis and misery. There are people who cannot utter the term without foaming at the mouth'' (www.cid.harvard.edu/cidtrade/issues/washington.html).

2. For example, after the worldwide outbreak of SARS, some people were concerned that closer global linkages among nations could bring more problems than it was worth. Difficulty getting some major nations to ratify the Kyoto Protocol, along with a number of major flooding and fire events related to climate change, caused some people to think that achieving global cooperation was hopeless idealism. This feeling was reinforced by problems achieving consensus in free trade discussions and some major multinational conflicts that for awhile had nations talking more about national security than international cooperation. Many activists in rich countries worried about the potential for negative impacts on the poor if globalization was not carefully controlled and balanced to benefit the poor.

3. For example: Carson (1962), Ehrlich (1968, 1974), Hardin (1993), Meadows et al. (1972).

4. Including decline in many ocean fisheries, uncontrollable pollution impacts on rivers and estuaries arising from rapidly increasing industrial activity in both rich and poorer countries, massive damage from floods arising from clearing of vegetation on floodplains, and impacts from the movement of refugees due to civil and military conflicts.

5. The rise of the Brazilian Worker's Party to government in Brazil, for example, illustrates a strong desire of the electorate to have more say in government (see discussion at www.pt.org.br and www.npr.org/programs/npc/2002/021210.lula.html).

6. Nobel Prize winner Paul Crutzen (1995) claims that the decision to use chlorine in chlorinated hydrocarbons was a lucky chance based on the interests and expertise of the chemists involved. Chlorine reacts with ozone only under certain conditions. An alternative would have been bromine. Bromine is 100 times more reactive. If by chance bromine had been used, there could have been devastating effects on humans before the problem was detected and action could be taken.

7. It did this to minimize input costs (e.g., coal) to industry and it did it because the political system allowed strong central control and rapid decision-making.

8. ''Peculiarly'' alludes to the observation (Gray 2003) that there is more than one potential approach to democracy, depending on such variables as a country's culture, history, and economic circumstances, and that China, in particular, has resisted copying an American model.

9. The possible trends in air pollution are complex and are explored in more detail in Chapter 9. Under Global Orchestration we expect lower levels of sulfur-related air pollution in all regions except sub-Saharan Africa. For NO_x, however, the trends are favorable only for OECD and Latin America. Elsewhere (*with low to medium certainty*) NO_x-related pollution increases substantially (Asia and the former Soviet Union) or moderately (sub-Saharan Africa and Middle East/North Africa).

10. John Gray (2003) gives examples of Buddhist India (centuries ago), the Ottoman Empire, the Moorish Empire of Medieval Spain, and China up to the nineteenth century as societies in which cultural and political diversity were tolerated and even celebrated.

11. The quantitative models (see Chapter 9) illustrate the delicate balance of trends that are required for this scenario to succeed. The trends include:

- a rapid rate of technology development and investments in agricultural research that lead to substantial yield increases rendering large expansion in new crop areas unnecessary (only in sub-Saharan Africa is a large expansion of cropland projected);
- irrigation of much more agricultural land (the projected increase in area of irrigated land is the highest among the four scenarios spurred by high economic growth and large investments in irrigation systems—this will require appropriate increases in efficiency of water use to avoid demand exceeding supply);
- total agricultural land is projected to grow because of the demand for pasture land and biofuels;
- trade liberalization and economic opening will create new markets and more trade among increasingly prosperous poorer countries; and
- large investments in agricultural research and infrastructure, particularly in poorer countries, help bring down international food prices for livestock products and rice.

12. Various authors discuss the exponentially increasing rate of advancement of some technologies, leading to a potential singularity (rate of change beyond the ability of society to adapt without fundamental and unpredictable change). See, for example, Vinge (1993), Brand (1998), Moravec (1998), Kurzweil (1999), Calvin and Loftus (2000), Broderick (2001), and Whole Earth Magazine (2003).

13. Issues associated with invasive species are discussed later in this chapter and in Various Authors (2003).

14. In the quantitative models (Chapter 9), all four MA scenarios result in increased global food production, both total and per capita, by 2050 compared with the base year. Demand for and prices of food increase with population and for other reasons that differ between scenarios. As would be expected, variation between regions of the world is very different from scenario to scenario. Global Orchestration achieves the largest global production increases, fuelled by trade liberalization and economic opening. The richer countries help to meet demand from poorer countries, but as agriculture expands regions like sub-Saharan Africa and Latin America become net exporters of certain foods, while the OECD and Asia are projected to increase net imports. Large investments in agricultural research and infrastructure, particularly in poorer countries, help bring down international food prices for livestock products and rice.

15. For example, China recently stood its ground in standards for electronic communication and won a compromise from the United States (Anon 2004a; Markus 2004).

16. Climate change represents a typically difficult problem to deal with under the Global Orchestration storyline, as the impacts of climate change are disconnected from its causes in both time and place. This means that it is difficult to pass a test of ''sufficient evidence'' for people to decide to start mitigating this problem. It is for this reason that development of climate change policy is very slow under Global Orchestration, even though the international focus of the scenario could create the required condition for formulating climate responses.

17. The projections from the modeling in Chapter 9, which were unable to take future social and technological responses fully into account, indicated that unless there are large improvements in the efficiency of water use and treatment of return water, both water withdrawals and wastewater discharges will have increased by 40% worldwide by 2050. Return flows were predicted to decrease on average in OECD and former Soviet countries because of a levelling off of population, decreasing irrigated area, and improving efficiency of water use. Even though low priority is given to environmental protection in Global Orchestration, the richer societies maintain their current efforts at environmental management. Hence it is reasonable to assume that the level of wastewater treatment in OECD countries will remain at least at its current level. Because of the booming water withdrawals, however, return flows increase by a factor of 3.6 in sub-Saharan Africa, a factor of 2 in Latin America, and more moderately in the Middle East and North Africa (22%) and Asia (48%). Therefore, it is likely that wastewater will remain untreated in many areas and that the level of water contamination and degradation of freshwater ecosystems may increase (*low to medium certainty*). Chapter 9 estimates that nearly 60% of the world will live in these areas in 2050. Thus a major requirement for Global Orchestration to have an optimistic outcome is significant improvement in treatment of wastewater, which will be expensive and technically challenging if the roles of ecosystems in minimizing these challenges are addressed reactively rather then proactively.

18. We acknowledge than many commentators are currently arguing that a multipolar world is in fact more stable than a unipolar world

19. For example: ''Fortress World,'' ''Barbarization,'' ''Breakdown,'' and ''Mad Max'' (see Chapter 2 and Costanza 2000).

20. Lack of international cooperation is also likely to have direct consequences for the type of response options that are available to humanity under this scenario. It seems very unlikely that people could negotiate global solutions and treaties to address problems of global environmental change under the disaggregated Order from Strength. Moreover, the reduction of international trade also meant that countries tended to focus on using resources within their own regions. This can imply significant ecological consequences for regions like Asia that are likely to rely on using domestic coal resources (with relatively large environmental impact), or land-scarce regions that will need to consider using even more marginal land resources for food supply.

21. In the quantitative modeling (Chapter 9) this scenario has the largest withdrawals of water because of its slower improvement of the efficiency of water use and faster population growth. Accordingly, it also has the largest return flows, with a doubling of worldwide total flows by 2050. The smallest increase is in the former Soviet Union (9%), followed by OECD (nearly 40%). All other regions experience much larger increases—Asia and the Middle East/North African countries with approximately a doubling, Latin America more than a factor of three, and sub-Saharan Africa a factor of 4.7. The combination of exploding wastewater discharges and negligence of the environment could lead to large risks to freshwater ecosystems and water contamination. An additional dimension of this scenario is that return flows continue to increase rapidly after 2050.

22. In the quantitative models (Chapter 9), all four MA scenarios result in increased global food production, both total and per capita, by 2050 compared with the base year. Demand for and prices of food increase with population and for other reasons that differ between scenarios. As would be expected, variation between regions of the world is very different from scenario to scenario. Under Order from Strength, food production in poorer countries stalls because of low investments in technology and infrastructure, and this puts pressure on many to import food. This is only partly offset by low income growth, which dampens food demand in poorer countries. As a result, prices for most foods are projected to increase over the coming decades, and food shortages are a major risk in this scenario.

23. The quantitative models in Chapter 9 project that in Order from Strength there is the fastest depletion of forest area worldwide among the scenarios (at a rate near the historic average, only to slow down after 2050 because of slowing population growth). The loss of forest cover is in particular large in sub-Saharan Africa.

24. The possible trends in air pollution are complex and are explored in more detail in Chapter 9. The level of sulfur-related air pollution declines only slightly worldwide in Order from Strength, because of declines in OECD, the former Soviet Union, and Latin America. Asia and Middle East/North Africa have the largest emission increases of all scenarios. There is a significant decline in NO_x-related pollution in OECD countries, and a major increase elsewhere.

25. For present examples of certification, see the Forest Stewardship Council (www.fscoax.org) or the Marine Stewardship Council (www.msc.org).

26. In the quantitative modeling (Chapter 9), large water withdrawals and large returns of wastewater are projected. This could cause major health challenges, especially in regions where the largest increases might occur (sub-Saharan Africa, Latin America, Asia, and the Middle East/North African countries). However, these projections are based on the larger populations and lower investments in technology projected in this scenario. The models could not take account of adaptations in land management and possible application of inexpensive approaches to waste generation and management that would take advantage of ecosystem services like waste assimilation services. In our storylines, we are optimistic about the emergence of new approaches like these supported by local learning and the sharing of lessons learned between regions. Nevertheless, the emergence of these approaches is vital for the success of this scenario.

27. Chapter 9 projects large increases in water withdrawals in this scenario, probably beyond what would be available, which could dramatically affect food production. However, the modeling could not take account of people's reaction to increasing water withdrawal. In this scenario, we expect that people will recognize this problem early and learn to deal with it through more efficient use of water, including reduction of water losses in irrigation, greater return of water to the environment, and better choice of crops and cropping areas. The contrast between the storylines and the modeling illustrates that dealing with water withdrawals by increasing human populations will be one of the major challenges of the future, even for a scenario based on adaptive learning at regional scales.

28. These examples are based on projections by McCarthy et al. (2001), Chapter 4.5.2.

29. The reader might notice some apparent inconsistencies between these storylines and the quantitative models for this scenario in Chapter 9, especially with respect to expansion of agriculture and production and availability of food. The differences are because the storylines have been more optimistic about the development of better environmental management and the ability to minimize losses in productivity through local learning and the emergence of cooperation among local groups at regional to global scales. When the models were developed, we expected this scenario to feature a disconnected world throughout. However, when developing the storylines we realized that despite disaggregated global institutions, people would still take advantage of the increasing opportunities for electronic communication and that "bottom-up" connections would inevitably develop. The models could not take account of these developments, but they provide a stark statement of the increasing challenges that a world based on local learning would have to address to avoid failure. The quantitative models assumed low investments in food production technologies and no breakthroughs in yield-enhancing technologies. Globally, irrigated area is expected to grow very slowly up to 2050, but to increase particularly in sub-Saharan Africa and Latin America. Crop harvested area is projected to increase, particularly in sub-Saharan Africa, Latin America, and the Middle East/North Africa. Food prices are projected to rise, and increases in calorie availability are very small. The number of malnourished children is projected to increase initially but then decline globally by 2050, but there could be major increases in some poorer countries. (See Chapter 9 for details.)

30. See also Jaeger (1994), in particular Section 5.4.

31. Some people are skeptical that large improvements in technological efficiency are possible in only a few decades (Jacobs 1991). Many other authors, exemplified by the Rocky Mountain Institute and Wuppertal Institute, have made convincing cases that massive improvements in efficiency are possible even with current technology. As TechnoGarden is based upon technological improvement, we have maintained this assumption.

32. The recent collapse of the WTO talks in Cancun provides an example of the coalitions and issues.

33. For example, England Rural Development Programme (www.defra.gov.uk/erdp/default.htm) and FOE's campaign (www.choosefoodchoosefarming.org/).

34. The quantitative modeling (Chapter 9) projects lower water withdrawals and returns of wastewater than in other scenarios due to a stronger emphasis on improving water efficiency and the development of environmental technologies to minimize pollution and maximize ecosystem services for maintaining water quality. The development of these technologies during the first decade of this scenario is vital for its success. Otherwise, it could become more like Global Orchestration, with reactive approaches to emerging environmental problems, except that it could also create new problems through ill-equipped attempts at manipulating ecosystems.

35. See Web sites and reports on multifunctional landscapes in the Netherlands and the EU, www.urban.nl/index.htm, and in Denmark, www.naturraadet.dk/start.htm#english/default.htm.

36. In the quantitative models (Chapter 9), all four MA scenarios result in increased global food production, both total and per capita, by 2050 compared with the base year. Demand for and prices of food increase with population and for other reasons that differ between scenarios. As would be expected, variation between regions of the world is very different from scenario to scenario. The TechnoGarden scenario operates somewhat similarly to the Global Orchestration scenario, with substantial improvements in crop yields combined with a lower preference for meaty diets reducing pressure on crop area expansion. Increased food demand is also met through exchange of goods and technologies. Both calorie consumption levels and the reduction in the number of malnourished children are similar, albeit somewhat lower than, the Global Orchestration scenario.

37. Some of these possibilities are discussed by United Nations Population Division (2001). China's energy changes are discussed by China Energy Group at Berkley Labs, at eetd.lbl.gov/EA/partnership/China.

38. Car-sharing is discussed at www.carsharing.net.

39. The Korean Demilitarized Zone provides an example of an involuntary park. Hunting of bushmeat, mining, and logging during the war in the Congo is an example of ecological degradation. (See Price 2002.)

40. Cheap communication and organization is allowing vast online groups to organize and function. Linux provides an example, but so does the anti-globalization movement (Arquilla and Ronfeldt 2001; Ronfeldt et al. 1998).

41. The UK's Royal Society's report on recent large-scale field trials discusses the impacts of GM agriculture on wildlife populations. This is available at www.defra.gov.uk/environment/gm/fse/index.htm.

42. See Creative Commons at creativecommons.org for a current nongovernmental organization advocating more open copyright laws. They have recently moved to create international licensing agreements.

43. The possible trends in air pollution are complex and are explored in more detail in Chapter 9. Under TechnoGarden, major reductions in sulfur-related pollution are achieved globally (except for sub-Saharan Africa). Meanwhile, NO_x pollution declines substantially only in OECD and Latin America, while elsewhere it continues to increase about the same as in Global Orchestration.

44. Note that the quantitative models (Chapter 9) were unable to take social factors like these into account, and their outputs more strongly resemble the worst than the best case in Figure 8.5.

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