Chapter 11

Human Well-being across Scenarios

Coordinating Lead Authors: Colin Butler, Willis Oluoch-Kosura
Lead Authors: Carlos Corvalan, Julius Fobil, Hillel Koren, Prabhu Pingali, Elda Tancredi, Monika Zurek
Contributing Author: Simon Hales
Review Editors: Faye Duchin,* Richard Norgaard, David Rapport

---

*Member of Board for first round of review only.

BOXES

FIGURES

TABLES

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

Main Messages

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 of choice and action. Human well-being is a context-dependent, multidimensional continuum—from extreme deprivation, or poverty, to a high attainment or experience of well-being. Ecosystems underpin human well-being through supporting, provisioning, regulating, and cultural services. Well-being also depends on the supply and quality of human services, technology, and institutions. Technological and social changes cannot fully substitute for ecosystem services.

Adverse effects to human well-being occur when ecosystem service loss exceeds certain thresholds. The scenarios have different implications for ecosystem services, institutional evolution, and other determinants of human well-being. Together, the storylines and the model results provide a foundation for estimating future human well-being. However, models cannot yet predict critical turning points in the relationship between supply and human demand for ecosystem services. Beyond such points, the scenarios themselves may transform in ways that are difficult to predict.

Social and ecological systems are characterized by threshold points and alternative states, which are qualitatively and quantitatively different from their pre-threshold condition, often in unpredictable ways. Such systems produce surprises when system states change in ways that are counterintuitive, unexpected, difficult to reverse, or disproportionate to the magnitude of external forcing. Surprises may be beneficial or adverse. The magnitude, sign, and significance of future surprises for the socioecological system are intensely contested.

A bi-directional causal relationship exists between some adverse ecological and social surprises. Such interactions may occur, for example, between runaway climate change, desertification, fisheries collapse, eutrophication, new diseases, major violent conflict, governance failure, and increased fundamentalism and nationalism. Feedbacks between ecological and social surprise may generate new, comparatively durable social conditions that are harmful to human well-being.

The vulnerability of human well-being to adverse ecological and social surprises varies among the scenarios. High levels of human and other forms of capital do not always guarantee preparedness for adverse surprise and in some cases may even generate complacency. The vulnerability of human well-being to adverse surprise in each scenario is determined by interactions among the likelihood of, social preparedness for, resilience to, and magnitude of adverse surprise. These qualities vary among the scenarios.

Scenarios vary in their assumed rate and direction of economic, social, and institutional change. Scenarios characterized by socially beneficial institutional change may inadvertently undermine human well-being by increasing the vulnerability to adverse ecological feedbacks. However, scenarios that stress high ecological protection may prove unexpectedly vulnerable to adverse social change. The degree of improvement for human well-being, though uncertain, is probably positive in three of the scenarios but negative in Order from Strength, which has the highest vulnerability to social and ecological change.

Scenarios exchange impenetrable complexity for simpler but less realistic conceptualizations. The future is likely to include elements from all four scenarios, as well as others both undescribed and unimagined. Given sufficient cooperation, information flow, preparedness, and adaptiveness, the human future may respond to a dynamic interchange between various scenarios, at varying temporal and geographic scales, in ways that lead toward sustainability.

11.1 Introduction

This chapter describes the implications for human well-being across the four Millennium Ecosystem Assessment scenarios. These implications are derived from a qualitative analysis of the storylines, quantitative model results, and an assessment of the assumptions that underpin the scenarios. Case studies and examples are used to illustrate principles, but the chapter does not attempt to be exhaustive. The primary focus is through 2050, though some categories of major adverse surprise are more likely to occur in the following 50 years.

11.1.1 Ecosystems and Human Well-being

Human well-being lies along a multidimensional continuum—from extreme deprivation, or poverty, to a high attainment or experience of well-being. Human well-being is complex and value-laden; context- and situation-dependent; and reflects social and personal factors such as geography, ecology, age, gender, and culture. Well-being is experiential—that which people value being and doing. Despite this diversity and subjectivity, there is wide agreement that human well-being has five key, reinforcing components: the basic material needs for a good life, health, good social relations, security, and freedom and choice (MA 2003). It follows that poverty is more than material lack and that material sufficiency alone does not guarantee human well-being.

Ecosystems underpin human well-being through their supporting, provisioning, regulating, and culturally enriching services. Shortages of food, fiber, and other material goods adversely affect human well-being via direct and indirect pathways, as does scarcity and failure of ecosystem-regulating services. Ecosystems also affect well-being through many cultural services, which influence the aesthetic, recreational, cultural, and spiritual aspects of human experience. Many causal routes link ecosystems and ecosystem service change and human well-being, forming a complex weave with social, economic, and political threads. Often, though by no means always, the quality, frequency, and availability of ecosystem services is a present or historical contributor to these social, cultural, and economic factors. That is, these factors are not always independent of ecosystem services. Turning points, or thresholds, further obscure the causal connections between ecosystem services, the social milieu, and human well-being. Sometimes, a minor increment of change in ecosystem services can trigger a substantial change to human well-being, operating through causal routes that are often obscure or in some cases widely denied.

Human well-being is also intimately related to the supply and quality of human-generated services, institutions, and technology. Institutions—formal and informal—are the body of laws, customs, economic relationships, property rights, norms, and traditions that operate within society (Dietz et al. 2003; Arrow et al. 2004). Among other func-

tions, institutions regulate many of the links between ecosystem services and the constituents and determinants of human well-being. Inequitable access to ecosystem services is also influenced by institutions, which in turn are vulnerable to the influence of powerful individuals or groups.

There is growing concern over the degree to which the necessary suite of ecosystem services can be maintained at both geographical and temporal scales. Global population and average living standards continue to increase, but at the expense of many ecosystem services, particularly those that are non-provisioning. While ingenuity, technology, and human services have partially substituted for many ecosystem services, other services have been damaged, lost, or appropriated, often for the benefit of some human populations at the expense of others.

Future human well-being is a function not only of what happens to its five constituents, but also of their interactions. In turn, these constituents and interactions depend on economic circumstances, ecosystem services, global and local institutions, and feedbacks and interactions between these determinants. Over the long run, many decisions that have an impact on ecosystem services also affect human well-being.

11.1.2 Ecological and Social Surprises

Social and ecological systems are characterized by alternative states and thresholds (Kay et al 1999; Scheffer et al. 2001), which we call "surprises." Surprises occur when system states change in ways that are disproportionate to the magnitude of external forcing. These changes are often counterintuitive, unexpected by most people, and difficult to reverse. Human well-being, in aggregate, is vulnerable to many adverse ecological surprises, and to most if not all adverse social surprises (Levin 1999; Folke et al. 2005). The distribution of adverse changes to human well-being as a result of adverse surprise is rarely uniform, however, so that subgroups of humans can often increase their well-being even when aggregate well-being declines. The potential magnitude, sign, and significance of future surprise for the socioecological system are intensely contested, not least because of this unevenness of distribution (Arrow et al. 2004; Johnson 2001; Lomborg 2001).

The trends described by the MA scenarios reflect this wider debate. While the model results described in Chapter 9 suggest a general improvement in most aspects of human well-being in most scenarios, this should not be interpreted as meaning that the risk of a major decline in human well-being on a regional or even global scale is trivial. The results may more accurately reflect the inability of scientific knowledge to as yet adequately conceptualize, quantify, and model surprise. While the comparatively modern science of computer model-based prediction is likely to be improved by better theory, more accurate monitoring and data, and more powerful computers, uncertainty and debate will be perennial (Gunderson and Holling 2002). Nevertheless, it may be possible to model, at least approximately, how critical scarcities of human, social, natural, physical, and financial capital and flows could interact to cause a major discontinuity at a local, regional, or even global scale (Butler et al. 2005).

Surprise, by its nature, cannot be precisely forecast by time, place, nature, or scale. Even so, at any time the likelihood of some form of surprise at some place and scale is high. In the next century, a non-trivial possibility exists in all scenarios that one or several adverse surprises will occur that are of sufficient magnitude to substantially reduce human well-being in ways that are not captured by the model results described in Chapter 9.

We distinguish between ecological and social surprises. While some positive surprises are likely, we judge that the frequency and magnitude of positive surprise is unlikely to fully balance that of adverse social and ecological surprise. Plausible adverse ecological surprises include runaway climate change, major emerging diseases (including to plants, crops, and animals as well as humans), wide-scale eutrophication, desertification, and multiple fisheries collapse. Plausible adverse social surprises include the collapse or erosion of beneficial institutions, a global stock market collapse, a major energy shock, and many types of violent conflict. A combination of these surprises is also plausible.

Surprises of one category often have an impact on other systems. For example, a major adverse social surprise is likely to have ecological effects, and vice versa. Causality between ecological and social surprises is frequently bidirectional and sometimes operates through incompletely understood, often controversial, psychosocial factors. In some important cases, major adverse social surprises are likely to be precipitated by reductions in ecosystem services. Beyond certain thresholds, feedbacks can generate downward spirals, establishing new forms of social conditions harmful to aggregate well-being. Examples of such social phenomena include major violent conflict and may also include intensified fundamentalism, nationalism, or a failure of markets and governance. Other forms of major adverse surprise include an increased frequency of earthquakes or volcanic eruptions. Such events would interact with ecological and social systems, as well as have many direct effects upon human well-being.

Decisions taken to enhance human well-being over short time scales can sometimes impair well-being over a longer period, such as the prolonged collapse of the North Atlantic cod fishery that was precipitated by years of overfishing, once sanctioned in the pursuit of shorter-term well-being. In the future, several trajectories approaching thresholds could interact, forcing at least one trajectory to exceed a threshold.

Understanding the linkages between the components of human well-being and future changes to ecosystem services, though important, is insufficient to describe future well-being. As mentioned, well-being also depends on human-generated services, institutions, technology, and energy.

11.1.3 Risk, Vulnerability, and Social Coping Ability

The vulnerability of human well-being to adverse ecological and social surprises varies among the scenarios. Vulnera-

bility is conceptualized as an interaction between the likelihood of an adverse surprise, social alertness to such a possibility, and the social coping ability to deal with an adverse surprise. Opportunity costs restrict levels of alertness to only those events perceived by society as both likely and partly remediable. Although high levels of human, social, physical, and other forms of capital are correlated with social resilience and alertness to some risks, this does not guarantee adequate preparation to adverse ecological and social surprise. High levels of capital induce complacency and thus may perversely reduce alertness and preparedness to some forms of adverse surprise.

Complacency concerning the possibility of adverse ecological surprises is likely to be higher in societies where the connection between ecosystem services and human well-being is poorly recognized, seen as highly indirect, or both. Societies may also be vulnerable to adverse ecological surprises if their quality of preparation is low, even if they are acutely aware of its possibility. However, even where there is inadequate preparation for adverse surprise, the quality and richness of human and other forms of capital can still provide a kind of safety net. In summary, vulnerability is a function of the likelihood of adverse surprise, the adequacy of alertness and other forms of preparation, and the presence or absence of concurrent stresses, whether ecological, social, or another form.

11.2 Material Needs

11.2.1 Indicators and Determinants

Basic needs include access to a secure and adequate livelihood, income, and assets. Livelihood implies the activities, claims, and access that help individuals meet material needs (food, water, shelter, fiber, clothing, medicinal, and other materials) from ecosystems in a sustainable way.

An indication of the ability of populations to meet basic material needs in the scenarios is provided by the average consumption of materials, by purchasing power, and by nutritional indicators such as the number of malnourished children. Averages ignore the equity aspects of material access, however. In some cases, parts of the population may consume an excessive quantity of a material such as food, while another group may be undersupplied with food. Data concerning the distribution and the trend of distribution of basic needs are desirable to make inferences about human well-being, including for many nonmaterial aspects of well-being. At the same time, quality differences of some material needs are difficult to disentangle.

11.2.2 Global Orchestration

Global Orchestration is broadly characterized by increased income for rich and poor, by many forms of social and economic convergence between wealthy and poorer countries, and by investments in human capital, especially education. Institutions that promote fairness, equity, and property rights are strengthened, both globally and locally. Technology registers advances, and even though ecosystem services are stressed in many regions, important indicators of basic needs—including average income and average per capita food production—improve substantially during the period under examination. Many inequalities within and between nations decline. Food insecurity in poorer countries is greatly alleviated.

While policies that favor market forces are encouraged, it is recognized that these policies must be harnessed with strategies geared at improving the quality and structure of economic growth, including generating better governance mechanisms and reducing inequality. However, there is little explicit focus in this scenario on the connection between natural systems and human well-being. Instead, it is argued that a materially wealthier society will in the long run demand and be able to afford improved ecological conditions (UNEP 1999). Losses in ecosystem services are thus viewed as a temporary and correctable trade-off for greater material wealth. Improved technologies are used to increase the effectiveness of restoration and to substitute for lost or damaged ecosystems and their services. People also assume that other components of well-being, such as freedom and choice, will be enhanced as long as material levels of consumption increase, no matter what happens to ecosystems and ecosystem services.

In this scenario, globalization processes continue through the dynamic and intensive interaction of economic, social, political, communicative, ethical, humanistic, and environmental spheres (UNEP 1999). Specific reform policies adopted by governments, corporations, and others include trade and other forms of deregulation, reduced public expenditure for social services, and privatization of state enterprises, goods, and services (Kydd et al. 2000).

The cross-border flow of ideas, capital, people, goods, and services, including of transformed and disguised ecosystem services, expands. Migration is uncontrolled. Most agricultural subsidies and other barriers to trade are removed in order to allow more equal participation and access to global markets for all trade partners. The opposition of trade unions, farmers, and others who predicted a ''race to the bottom'' as a result of free trade gradually fades as it becomes clear that these fears were exaggerated. New technologies and economic niches increase employment in both rich and poorer countries, especially in the service industries that tend to the increasingly aged populations in Europe and parts of Asia. The strong focus on education and effective governance systems in poorer countries aims to enhance the ability of these populations to take advantage of the new opportunities.

Most ecosystem services in wealthy countries continue to improve because of both protection and deliberate restoration. In poorer countries, increased demand for eco-tourism slows tropical deforestation and strengthens protection for endangered ecosystems such as coral reefs and trophy species such as the white rhinoceros. Higher levels of education, urbanization, information access, and press freedom increase the demand for family planning services in poorer countries. Freer migration compensates for the low fertility rate in many rich countries, including in European nations and Japan (Vallin 2002; Demeny 2003). Declines in fertility

rates further contribute to increased economic takeoff (Coale and Hoover 1958; Kelley 2001). In turn, positive feedbacks develop that build on deliberate policies to improve transparency and governance.

In this scenario, growing incomes due to economic and policy reforms, urbanization, and increased global trade lead to a rapid growth in effective food demand (Sen 1981). Populations that are mostly vegetarian shift their food consumption patterns to higher-protein diets, increasing the demand for fish and meat, as described in Chapter 9.

Among all four scenarios, the increase in food supply is predicted to be the greatest in Global Orchestration. (See Chapter 9.) This is achieved mainly by raising yields on land currently in production through techniques such as genetically modified crops, more-intensive cropping practices, and increased use of fertilizers. Aquaculture continues to expand, and although this contributes to the depletion of oceanic fish stocks (Pauly et al. 2003; Powell 2003), both fish and other food prices remain affordable. Therefore, the basic supply of food, a foundation for alleviating poverty, improves, including in poorer countries.

The risk of adverse ecological surprise in Global Orchestration is high. If these adverse changes are of sufficient magnitude and effectively irreversible, then people in this scenario are likely to find that their efforts to reduce poverty and increase wealth will be undermined (McMichael and Butler 2004). Coastal dead zones may increase in size, reducing the provisioning and cultural services of coastal services, such as fishing, swimming, and water sports. Global temperature increase and sea level rise are highest in this scenario until 2050, hence there is a risk of declining regional or even global agricultural productivity that is not fully captured by the model results. Beyond 2050, however, the effects of climate change in several other scenarios approach that of this one, as described later. This scenario also projects large increases in water withdrawal and water pollution, particularly in poorer countries.

In summary, the basic material needs component of human well-being is predicted to improve in Global Orchestration. (See Figure 11.1 in Appendix A.) But this result is predicated on the proper functioning of local and global institutions; the ability of markets, governments, and technological systems to respond rapidly and appropriately to price signals; and the absence of major adverse ecological or social surprises of sufficient power to radically alter the social and institutional trends described.

11.2.3 Order from Strength

Order from Strength is characterized by increased emphasis on security and national protection, at the expense of global issues. International and domestic inequality are largely ignored while people become more concerned with securing boundaries between rich and poor. As with Global Orchestration, there is a widespread assumption that ecosystems are either robust or unimportant, and this is used to justify the weak protection of a few representative ecosystems within richer countries. In poorer countries, the fate of ecosystems is left largely to unrestrained market forces, magnified by the growing population.

In both rich and poorer countries, priority is given to short-term interest, disregarding the effects of policies on ecosystem services and on less powerful peoples. This has far-reaching implications for the material supply of goods, especially to the poor. Although some wealthy populations are able to increase consumption of material goods, for most people material well-being decreases. (See Figure 11.1b.) Market forces, unencumbered by mechanisms designed to protect the interests of the poor, exacerbate many kinds of inequality, both within and between nations. Declining international cooperation and trust (Wright 2000) causes the collapse of global negotiations, including for climate protection and trade. Reduced trade reinforces poverty traps in wealthy and poorer countries. Expensive, inefficient industries and farming practices are sheltered in this scenario, which is also marked by increased smuggling, including of drugs, weapons, and scarce and valuable ecosystem goods, such as endangered fish stocks and charismatic species.

Restricted human movement limits trade and employment as well as the flow of ideas, information, trust, and understanding between the poor and rich world. This worsens poverty wherever it exists. The demographic transition in poorer countries falters, as the spread of education slows, leading to larger populations that damage local ecosystems because of their need to obtain an increased proportion of their material goods locally.

Decreased international cooperation harms many global environmental public goods. In wealthy countries, reliance is placed on adaptation rather than mitigation to deal with climate change. The low rate of technology transfer to poorer countries increases the rate of greenhouse gas accumulation, however, as those economies remain fossil-fuel dependent for longer, especially by burning poor-quality coal. Toxic wastes are produced in large quantities in those countries, with much of it dumped and burned locally. Some pollutants, including persistent organic compounds and mercury, are disseminated widely in the atmosphere and food chain.

11.2.4 Adapting Mosaic

In Adapting Mosaic, decision-making is decentralized to local authorities and communities. As well, there is a shift in thinking toward policies that proactively try to manage ecosystems. Civil society is strengthened, including among indigenous populations. The proximity of communities and their ecosystems, combined with devolved political power, facilitates intense engagement between local actors and local ecosystems. Rather than helplessly witnessing the erosion of valued ecosystems by distant, often unknown actors, local populations are better able to protect (or, in some cases, elect to transform) their local ecosystem. This facilitates the sustainable use of many of these local ecosystems for material provision (Ros-Tonen 2003).

The connectedness between resource users and ecosystems implies the existence of strong, locally powerful institutions, able to protect and regulate common resources. (See Box 11.1.) Alliances may also be forged on a wider

BOX 11.1

Management of Common Forest Resources in Tanzania (Kayambazinthu et al. 2003)

In the pre-colonial period, the common forest and pasture resources of the Miombo woodlands in Tanzania were managed through institutions that ranged from local to national and formal to informal. These operated independently and sometimes in combination. While some still function, many have been weakened.

Traditionally, chiefs were the holders of powerful, stable, and valued user-group rules, which encapsulated spiritual, cultural, economical, and ecological beliefs and practices that in turn facilitated the durable use of valued natural forest resources. These included rules and taboos to manage and protect sacred woodlands, specific tree species, and sometimes even individual trees. Cutting of living trees was prohibited.

These institutions operated at complementary temporal and hierarchical levels. They included *Dgasinga,* instrumental in the communication and articulation of indigenous knowledge, attitudes, and practices in regulating access to natural resources. The bylaws of *Ngitili* arose from the need to reduce overgrazing at a regional scale. At the local scale, *Lyabujije* provided clear rules to regulate pasture and woodland resources within and between villages.

The strength of these institutions rested with the village elders, who acted as custodians and enforcers of the forest-preserving bylaws. Their authority was reinforced by their subjects' acceptance and faith in their political, religious, and spiritual power. This resulted in a stable and durable social and resource cohesion for extended periods. Yet elders were not beyond the law; those who committed misconduct could be dismissed.

Following colonization, however, these traditional institutions were weakened. Colonial powers tended to view the traditional institutions with disdain, and they also promoted new religious beliefs that undermined traditional authority, including taboos. Though intended to facilitate development, many new institutions had little local legitimacy, and undermined previously successful resource management mechanisms. The establishment of forest reserves, which restricted access to local communities (except for some sacred groves and graveyards), was often unsuccessful, in part because of reduced local autonomy. Centralized management raised tension between newly established committees and traditional leaders.

This situation was exacerbated by many enforced institutional changes from structural adjustment programs during the 1980s and 1990s, characterized by commercialization of forest products and reduced subsidies. Declining productivity and increased poverty, in part because of increased input prices, also forced many farmers to sell forest products and to neglect the traditional values of the woodlands. In summary, exploitation of Miombo woodlands increased.

Belatedly, government institutions are rediscovering the value and relevance of reviving and harnessing local institutions for effective management. There is a growing realization that ancient institutions that devolve power and that use traditional belief are not only more enduring and culturally resilient, they are better suited to resource management than fiats from centralized governments and committees.

scale. In some cases these alliances provide complementary knowledge and goods, building a beneficial, large-scale symbiosis. Less nationalism leads to reduced military spending and the freeing of resources for the improvement of human and social capital. Greater autonomy reduces local and regional disputes and, consequently, civil war and terrorism.

Material well-being in this scenario stays, on average, at about the same levels as in 2000 (see Figure 11.1c), but inequality is reduced, increasing material goods available to poor people while decreasing material consumption of the wealthy. While economic growth, as conventionally measured, is slower in wealthy countries in Adapting Mosaic than in Global Orchestration and TechnoGarden, this is due to more saturated demand for material goods, with more people voluntarily reducing consumption (Hamilton 2003). There is also slower growth in the demand for meat, as people adapt to the health and ecological concerns arising from high meat consumption. This reduces the pressure to convert forests to pasture for export purposes. There is less global trade and most food is produced locally. This improves food security, including through greater self-sufficiency.

However, protection of the global commons—including the climate, deep sea fisheries, Antarctica, and some aspects of biodiversity—is impaired in this scenario due to the shift of focus from global and regional to local (Buck 1998; Kaisiti 2003; McMichael et al. 2003). A trade-off occurs between improved local conditions and the continuous strain on and poor management of the global commons, which suffers in the absence of effective global protective strategies.

11.2.5 TechnoGarden

TechnoGarden shows an increase of material human well-being. (See Figure 11.1d.) This is achieved by spectacular improvements in many kinds of technologies that are geared at improving access to goods and services and at the same time protecting ecosystems for the long term. Environmental engineering advances include improving ecosystems such as wetlands and polluted rivers, lakes, and coastal zones (Odum and Odum 2003; Palmer et al. 2004). Agricultural landscapes become more diverse and less dependent on fertilizers and pesticides as farmers increasingly focus on producing multiple ecosystem services in addition to food. Farmers in both rich and poorer countries are paid for providing non-provisioning ecosystem services, such as reducing erosion, sequestering carbon, increasing pollination, and providing recreation.

Nutrients and water are better metered and used more efficiently, reducing waterlogging and salinization, eutrophication, and coastal dead zones. Crop yields increase because of many ingenious improvements in plants, such as modified flowering times to improve heat tolerance (Sheehy 2001). Other advances, including indoor cropping, hydroponics, and genetic engineering and conventional breeding, may improve photosynthesis and tolerance of current limits, such as drought, frost, heat, flooding, pests, diseases, and soil deficiencies (Johnson 1990; Botkin 2001; BIO 2003).

The development of synthetic timbers helps preserve native forests, sparing habitat for endangered species and simultaneously increasing ecotourism. Implanted computer chips, radio telemetry, and satellite surveillance are used to better regulate common resources, such as the open ocean and the Amazonian rain forest (Nepstad et al. 1999; Laurance et al. 2001). Technological improvements reduce wastage by facilitating ''just in time'' manufacturing and delivery systems. Improved recycling and design greatly reduce material and embedded energy wastage (Prabhakar 2001; WBCSD and UNDP 2003).

Increased trade and technological exchange between rich and poorer countries spurs agricultural and other forms of development. Cheap greenhouse gas–neutral techniques for large-scale desalinization of seawater are developed, facilitating the transformation of vast areas of coastal desert into productive farmland, fostering millions of new jobs and thousands of new industries. Improved energy efficiency along with renewable, decentralized energy technologies and a greater use of biofuels reduce the income and influence of Middle East oil exporters, accelerating their economic diversification.

The modeling results show a similar increase in global food production as in Global Orchestration, with substantial variation in demand between the regions of the world. The growth in demand for livestock products is slower than in Global Orchestration because of health and ecological concerns. Food prices decline, especially in poorer countries. Increased food supply is achieved mainly through agricultural intensification and more-intensive livestock production. There is also a substantial expansion of irrigated area until 2050, when there is a decline. The scenario results also assume an emphasis on technical water use efficiency for agricultural, domestic, and industrial use. Therefore, water stress is foreseen to grow only slowly on a global scale, though large regional differences are observed.

Reliance on technological approaches increases the risk of technology failure. More important, unless accompanied by a parallel development of institutions, this scenario is at a high risk of adverse social surprises. The analysis of the scenarios (see Chapters 8 and 9) identifies two possible problems in this regard. First, most innovations are likely to be aimed at improving provisioning ecosystem services, which have an immediate, direct impact on human well-being, without similar attention to supporting or regulating services. Second, increasingly complex technologies are vulnerable to breakdown. New technological solutions are likely to cause new problems, which in turn will require new fixes, in a cycle that may never end and that, in fact, may lead to solutions that are increasingly complex and therefore increasingly prone to breakdown.

The unfolding of this scenario depends not only on the successful development of new technologies but also on their worldwide dissemination and adoption by ecosystem users and managers. As is evident from the last 30 years, this process is slow and difficult, particularly in low-income and disadvantaged populations. Techniques for better natural resource management are not automatically adopted. Location-specific needs, poor education, and the cost and difficulty of finding appropriate local information complicate the process.

11.3 Health

11.3.1 Indicators and Determinants

The World Health Organization defines health as a state of ''complete physical, mental and social well-being and not merely the absence of disease or infirmity,'' a concept similar to that for well-being. But more commonly, health is viewed as a desirable physical and mental state, characterized by strength, stamina, equanimity, and a lack of pain.

Life expectancy, the best-known measure of health, is insensitive to quality of life issues. Instead, disability-adjusted life years are often used to establish priorities between different health problems (James and Foster 1999). However, DALY-based burdens of disease assessments do not fully account for complex causal pathways, long time scales, potential irreversibility, and individual versus community responsibility properties, which ideally would be included in assessing the health burden of ecological change.

Individual health depends on interacting genetic, environmental, social, and medical factors. Adverse change in any single factor is rarely, if ever fully, compensated for by increase in other factors. Civil society is an important determinant of health through means such as education, leadership, and the distribution of limited resources. Technologies also depend on social factors, especially cooperation in their design and implementation. Health is also related to perceptions of individual and collective freedom and hope. And it depends on community factors. For example, even the most prudent person living in an air-polluted city will sustain lung damage, while only the most informed fish-eater will know the likely mercury content of the next fish dish.

Human health depends on all four forms of ecosystem services. Most obviously, it depends on the provisioning services that generate food and fresh water. Regulating services enhance health through means such as reducing floods and drought. Psychological health is influenced by many culturally enriching ecosystem services (Frumkin 2002). Supporting ecosystem services, such as the recycling of nutrients underpin the other services and are thus indirectly essential to health. At the same time, the health of many people relies on income obtained from the extraction and transformation of ecosystems, often for consumption by wealthier populations.

Predicting global population health over the next decades is difficult (McMichael 2001; Butler et al. 2005). But future health is still likely to be mainly determined by these social, political, and environmental factors. The evolution of many health determinants is implicit in the storylines of the different scenarios, while others are explicit in the model results. These determinants include the degree and trend of regional and global inequality, the quality of institutions, the degree of technological innovation, population growth, and the productivity, distribution, and accessibility of ecosystem services. It is increasingly feasible to predict the future range and severity of several important infectious

and noninfectious diseases (Hales and Woodward 2003; Murray and Lopez 1997; Tanser et al. 2003; Webby and Webster 2003). Predicting the regional and global disease burden of emerging diseases is a bigger challenge, however.

11.3.2 Global Orchestration

Global Orchestration is characterized, broadly, by increased income in all countries, by strong institutions conducive to human development, and by investments in human capital, including education. Food production per person improves and the percentage of energy- or protein-undernourished children is reduced by 2050 to 20% from its current level of over 30%. The absolute number of undernourished children also declines. Total population growth is lowest in this scenario, minimizing the chance of regional population decline through catastrophic conflict, disease, or famine.

These projections suggest that health will improve substantially, particularly in poorer countries. (See Figure 11.1a.) The burden of epidemic diseases such as HIV/AIDS, malaria, and tuberculosis are reduced compared with today and also with the other scenarios. Mental depression, currently predicted to constitute an important burden of disease in 2020, is comparatively reduced in poorer countries in this scenario, as poor populations gradually improve their living standards, benefit from better, more inclusive governance, see that their children have greater opportunity, and yet retain significant social connectiveness, cultural pride, and a sense of meaning. In wealthy countries, depression may also be reduced if recent trends toward increased atomization and loss of meaning can be reversed (Eckersley 2004).

Improved vaccine development and distribution allow people in this scenario to cope comparatively well with the next influenza pandemic (Webby and Webster 2003). The impacts of other new diseases, such as SARS, are also limited by well coordinated public health measures, including vaccines (Gao et al. 2003). On the other hand, the lack of a precautionary approach to public health, combined with a shallow understanding of ecological risk, generates more zoonoses, such as through poorly regulated ''wet markets'' (Webster 2004). Global health organizations are better funded, as is regional health capacity, including for primary health care, laboratories, and hospitals. Regional shortfalls in food harvests are adequately managed by effective food relief programs.

There are, however, some important caveats. The most important is that the increased resources in this scenario are distributed in ways that benefit the public good. The scenario is highly vulnerable to adverse ecological shocks. Many environmental conditions needed for good public health could worsen. For example, microbiological water pollution in poorer countries could become an even more important source of ill health than it is now. Environmental contamination with persistent pollutants (Webster 2003), including heavy metals, could also become more pervasive, with many adverse health effects. These include a further reduction in cognitive potential for affected populations (Kaiser 2000; Tong et al. 2000), in addition to that from macro- and micronutrient deficiency (Couper and Simmer 2001; Berkman et al. 2002; Grantham-McGregor 2002) and increased endocrine diseases and cancer (Butler and McMichael in press). For wealthy populations in poorer countries, the complications of diabetes such as renal and cardiac disease could entail a large and expensive burden on health services (Zimmet 2000). Although total calories per capita increase in this scenario, dietary diversity may fall, narrowing micronutrient intake.

11.3.3 Order from Strength

Population growth is highest in this scenario, and there is the lowest investment in human capital, including basic literacy and numeracy. There is decreased commerce and scientific and cultural exchange between richer and poorer countries. Inequality increases between and within these nations. In both rich and poor countries, there are more enclosed, gated communities, whose inhabitants are tended for by less wealthy and generally less healthy service populations. This scenario has the least convergence between health and social conditions for rich and poorer countries, and it is likely that these will actually diverge, thus widening the existing ''health gap'' between these groups (WHO 2002). (See Figure 11.2 in Appendix A.)

In many regions of poorer countries, the supply of critical ecosystem services reaches critical levels of scarcity, leading to new forms of poverty traps, conflict, and impaired governance, such as was recently seen in Rwanda (André and Platteau 1998) and Haiti. Institutions conducive to development and good governance in poorer countries are weak, including those designed to improve global governance. They are overwhelmed by powerful lobby groups with narrow interests, including calls for greater security, and by schemes that promote corruption.

Stocks of human capital in many poor regions weaken because of the death and migration of knowledge-rich adults (Piot 2000; de Waal and Whiteside 2003). Infant and maternal mortality rates remain high in poorer countries, as do the health consequences of difficult births and obstructed labor, such as infections, epilepsy, and fistulas. Nutrition in these countries deteriorates further, exacerbating ill health, including by further reductions in cognitive development and immunity.

''Orphan'' diseases—poorly researched and little-understood conditions that primarily harm poor populations—remain neglected, as do orphan drugs and orphan crops. Efforts such as the Roll Back Malaria campaign (Teklehaimanot and Snow 2002) remain underfunded. The limited research into health problems of poorer countries focuses primarily on ways to reduce short-term rather than long-term risk, such as vaccines for tourists rather than insecticide impregnated bednets (Sachs and Malaney 2002). Increased population pressure in these countries forces more contact between humans and nonagricultural ecosystems, especially to obtain and trade bushmeat and other forest goods. This exposes non-immune populations to new viruses, leading to more outbreaks of hemorrhagic fever and zoonoses. Sleeping sickness increases as poverty forces humans to penetrate tsetse fly–infested regions.

In many parts of poorer countries populations decline, at least for short periods, because of epidemics such as AIDS and TB, as well as episodes of violent conflict. The modeling results predict substantial population increase in these countries in this scenario over the next 50 years, but this is questionable, perhaps best illustrating a case where the modeling constraints and assumptions lead to implausible results.

New and resurgent diseases increase in poorer countries, but few, if any, become major disease burdens in richer ones (Glass 2004). However, it is possible, though with low probability, that a more chronic disease could cross from a nondomesticated animal species into humans, slowly and then more rapidly colonizing human populations, as HIV is thought to have done (Wolfe et al. 2004).

Some aspects of health improve in wealthy countries, but at a lower rate of improvement than in Global Orchestration. In part this is because the higher emphasis on security causes an opportunity cost to health research. The higher risk of terrorism in this scenario causes increased anxiety for people in rich nations. The increased emphasis on competition and the free market also reduces aspects of population health in comparison to scenarios with more cooperation.

In summary, even if a modest improvement to health in rich countries occurs it is unlikely to compensate for the deterioration of health in poorer ones that is likely in this scenario. Also, an ever-growing fraction of the world's population live in these poorer nations and experience chronic ill health.

11.3.4 Adapting Mosaic

In Adapting Mosaic, local solutions are developed for ecosystem and political management. This scenario is characterized by greater regional pride and more cultural and social diversity. This improves mental health, including of minority populations, and leads to reduced alcoholism, domestic violence, depression, and intravenous drug use. Knowledge and practice of traditional health systems is better preserved, but this could also mean the persistence of practices that some find offensive, such as child marriage and female circumcision.

Population growth is second highest in this scenario, and technological and agricultural breakthroughs are less marked than in TechnoGarden. The number of energy-undernourished children in 2020 is predicted to increase by about 16% before declining. At the same time, however, the percentage of malnourished children in every region declines.

The greater emphasis on small-scale cooperation leads to a more even distribution of ecosystem services. Greater social connectivity improves some aspects of health. However, the global capacity to provide disaster relief weakens. A lack of global leadership also undermines effective global environmental treaties. Climate change and other large-scale environmental problems are thus comparatively severe in this scenario, exacerbating their long-term adverse health effects.

Without an explicit focus on promoting development, many regions are unable to develop a sufficient critical mass of expertise to foster the new technologies needed to maintain high living standards and at the same time cope with the adverse effects of climatic and other harmful environmental change. While a few communities voluntarily adapt an energy-sparing lifestyle, their impact on global greenhouse gas emission reduction is small. However, this scenario is not very different from the others with regard to climate change until the second half of this century because of the many forms of inertia involved.

Crucial to health improvement is the degree to which ideas, technology, and capital circulate internationally. In other words, health standards are likely to fall behind in communities disconnected from the broader research community. For example, while education is well recognized as integral to the improvement of health in the materially poor Indian state of Kerala, this improvement is also dependent on the existence and availability of modern health services and technologies; education in this case may be necessary, but it is not sufficient.

In summary, health does not improve as much in poorer countries in this scenario as it does in Global Orchestration. (See Figures 11.1c and 11.2c.) In wealthy countries, on the other hand, greater local cooperation and connectivity improve psychological and mental health. Communities in poorer countries become more culturally distinct and more resistant to the forces that operate through the mass media to promote phenomena such as ''coca-colonization'' and tobacco consumption. As a result, conditions such as obesity, diabetes, and cancer may not become as common in those countries as now seems likely. Still, the prevalence of these conditions increases in other communities that voluntarily adopt health-damaging behavior.

11.3.5 TechnoGarden

TechnoGarden sees spectacular improvements in many kinds of technology and agriculture, improving nutrition globally. Cheaper communications technology facilitates improved literacy and access to useful information. Medical breakthroughs extend life expectancy and improve the quality of life in old age. Heat-stable, single-dose oral vaccines that confer lifetime immunity to multiple diseases are developed. Water and indoor air pollution, currently responsible for the sixth and tenth highest component of the global health burden (Ezzati and Kammen 2002; Ezzati et al. 2002), are virtually eliminated.

Technological and scientific advances greatly increase the global human carrying capacity. For example, solar energy breakthroughs allied with desalinization enable the irrigated agricultural development of deserts, allowing the migration of millions of people from areas that are currently densely populated.

The rate of institutional evolution is particularly important in this scenario, since rapid technological development could undermine many institutions, either inadvertently or through its deliberate use by powerful actors. Optimisti-

cally, new health technologies and better nutrition could themselves trigger social and economic improvements, especially among poor tropical populations, by reducing the development-stalling impact of disease, undernutrition, and high birth rates (Birdsall et al 2001; Sachs and Malaney 2002; de Waal and Whiteside 2003).

Though cheap robots reduce danger, drudgery, and servitude, they are also used to increase unemployment and the exploitation of people. Virtual reality is misused to pacify and condition people in ways that reduce their freedom. Family and social ties loosen when children bond to ''virtual'' nurses rather than to flesh-and-blood playmates. Audiences desensitized by an excessive diet of virtual violence and pornography challenge civil society norms when whetted appetites demand ever-increasing doses. Alternatively, societies could use the new technologies for greater expression, strengthening social, family, and human capital, while unemployment could be reduced by managers insisting that overworkers take more leisure time, freeing job opportunities for others.

The easy and increased availability of calorie-dense food exacerbates the nascent global epidemic of obesity and diabetes, in both rich and poorer countries. Obesity also increases the rate of some forms of cancer. Lack of large muscle use in childhood and poor gross motor coordination fostered by sedentary lifestyles reduces mobility and bone density in later life, canceling surgical improvements. Designer drugs prove more dangerous and addictive than promised. Discrimination based on genetic profiles, for employment and insurance, for example, becomes commonplace.

On the positive side, the development of genetic engineering leads to cheap and widespread ''nutraceuticals,'' providing both micronutrients or individually tailored medications. New surgical techniques greatly extend life expectancy, for those with sufficient means.

TechnoGarden could also—though with low probability—see the development of truly devastating diseases. These could escape or be deliberately released from biowarfare laboratories (Anonymous 2001a). Diseases targeting specific genetic characteristics could be engineered for ''ethnic cleansing'' or other forms of genocide. New diseases could also arise or be more widely disseminated by new technologies, as occurred with several infectious diseases in the twentieth century. The genetic homogenization of food and other crops creates vulnerability to new agricultural diseases, with adverse knock-on effects to human health. Although the scenario assumes remarkable technological ingenuity, a struggle could develop between increasingly sophisticated technologies and increasingly complex problems. Some problems are likely to be deliberately caused by human techno- and eco-vandals. On balance, health improvements in all countries are not as marked as in Global Orchestration.

11.4 Social Relations and Security

11.4.1 Forms, Expressions, and Determinants

Social relations refer to the degree of influence, respect, cooperation, and conflict that exists between individuals and groups. These relations underlie security and, in some cases, violent conflict. Social relations, expressed through manners, customs, traditions, diplomacy, and other means, operate at many scales—including among and within families, neighborhoods, genders and within religious, cultural, economic, political, and ethnically linked communities. Social relations influence and are influenced by the distribution and management of limited resources, including of ecosystem and human services. Social relations are also influenced by current and previous institutions and by past and present social and economic relationships. Differing perceptions over complex issues are inevitable (Adams et al. 2003), but good social relations can reduce tension and, in many cases, prevent violent conflict.

Many societies and groups have developed institutions that have maintained a durable and adequate stock of common resources by mediating access and use of ecosystems (Ramakrishnan et al. 1998). Sometimes, these institutions have evolved to cope with periodic ecosystem service shortages, such as by reciprocal trade between climatically distinct regions (Cordell 1997). In recent centuries, many indigenous populations have experienced a profound loss of local ecosystem services, especially of their intertwined provisioning and culturally enriching aspects. In many cases, these ecosystems have been appropriated by more powerful populations, who have then transformed them. While this has often multiplied the provisioning aspect of the original ecosystem, there has been little regard for the culturally enriching aspect. In addition, the material benefits of such transformations have rarely been distributed equitably. In some cases, the effects of such loss have been transmitted through generations.

Position and rank, influenced by such factors as age, gender, birth order, family, wealth, income, class, caste, education, ethnic group, and ability, are universal within societies (Price and Feinman 1995). But changes in either the rank or entitlement of individuals and groups can both alter or reflect changed social relations.

Important shifts in social relations may occur if the supply of desired goods (including, in extreme cases, the loss of an entire ecosystem) reaches a critical threshold (sometimes far above zero) and may lead to intensified grievance and resentment. Losses that reflect and alter social relations often have a nonmaterial aspect, such as eroded rights and freedoms, including of cultural expressions and physical movement. While social relations can deteriorate at any scale, violent conflict is often most intense between cohesive groups, such as tribes, states, and multinational alliances. In some cases, grievance and deprivation (including perceived deprivation) can spawn rigid positions, based on core cultural beliefs that are often religious in character. Such positions, frequently characterized by opponents as ''fundamentalist'' or ''extremist,'' often provoke similarly strong responses.

Security includes the ability to gain access to natural and other resources and to safely retain personal safety and physical property. It also refers to a person's sense of the future, especially to periods characterized by increased vulnerability, such as old age, sickness, and economic downturn.

Causality between social relations, ecosystem services, and other valued ends is often multidirectional. While poor economic circumstances are usually associated with reduced physical and economic security, violent conflict can also often reduce the stock and flow of material goods, not only by destroying physical and ecological capital, but also by repelling the flow of financial and human capital, which can worsen poverty traps and insecurity (Bloom and Canning 2001).

11.4.2 Global Orchestration

On balance, social relations improve in Global Orchestration as wealth increases, democracy spreads, and inequality declines. (See Figure 11.1a.) Reduced international and domestic inequality is a major step toward solving hostilities and widening the scope of cooperative society. The power and authority of global organizations such as the United Nations increases, fostering improved international relations. In parallel, strengthened participatory democracy increases decentralized decision-making, especially within poorer countries. This motivates governments and other leaders to work genuinely to reduce disease and poverty, including in sub-Saharan Africa. However, the reduction of agricultural and other forms of subsidy is bitterly resisted by some farming and other groups, who resent the loss of income and privilege that this entails for them.

In combination, these factors that enhance cooperation strengthen institutions that potentially improve management and conservation of global commons. Because of the low value given to ecosystems, however, this scenario is likely to see the continued transformation—and in some cases the destruction—of ecosystems that are of high value to indigenous but relatively powerless populations. This may lead to a deepened sense of resentment, which cannot be completely assuaged, even by financial compensation.

While the aesthetic, material, and spiritual loss of a comparatively small number of such people may be viewed by the majority as acceptable, such loss and grievance could still fuel guerilla wars, insurgencies, protest movements, and legal action. Coalitions between concerned populations in wealthy countries and indigenous populations are likely in an attempt to protect particularly charismatic ecosystems, such as mountain gorilla habitat. But many less famous ecosystems are likely to be forcefully transformed in this scenario.

Beyond these foreseeable but small-scale conflicts, social relations and security could deteriorate if the scenario unravels because of institutional failure or unexpectedly severe ecological surprise or simply because the scale of problems in poorer countries proves intractable to the improvements that have been posited. For example, accelerated climate change could interact with tropical deforestation and poor coastal ecosystem service management to cause repeated and severe landslides, storm damage, and coastal flooding, eroding other forms of progress in populous poorer countries. This could damage social relations, both within the affected area and between affected populations and others who are less affected yet at least equally responsible. At the worst, such disaffected populations could contribute to locally and regionally active terrorist networks, for whom recruitment increases with infrastructural damage, material shortage, unemployment, and non-conciliatory governance. Deepening inequalities, if allowed to occur, could then weaken the capacity to solve social, economic, and cultural problems. At the worst, civil unrest, terrorism, and resource-based conflict could further undermine social cohesion, leading to emergence of an Order from Strength scenario. It is important to note that some forms of adverse ecological surprise, of which the most stark and foreseeable example is runaway climate change, could relentlessly erode good governance, year after year, because of their intractable, inexorable, and essentially irreversible nature.

11.4.3 Order from Strength

Out of the four scenarios, social relations are the most impaired in Order from Strength, especially in poor regions where investment in natural and human capital is particularly limited. (See Figure 11.1b.) This is likely even in the absence of severe adverse ecological surprise. The collapse of global trade talks and the abandonment of poorer countries lead to a compartmentalized world, where economically powerless populations are left to their fate, which can include local tyrants. There is very little interest in the public good. Consequently, social relations deteriorate on many scales, from local to international. Civil society deteriorates, especially in poorer countries. In the worst case, ''barbarization'' could develop, characterized by widespread lawlessness, corruption, prejudice, and terrorism (Raskin et al 2002).

Among countries and regions where order prevails, security is very strict, particularly along borders and at official entry points. Many borders are physically and electronically fortified, with constant surveillance. The high and increasing transaction costs of security reduce both trade and travel, lowering the material and social quality of life for many people. This is especially true when extended families straddle both sides of these barriers. Legal migration from poor to wealthy regions is strictly controlled, and the few migrants who are admitted face substantial discrimination, low wages, demeaning jobs, and limited opportunities. Racism and other forms of appearance-based and culturally derived prejudice increase, while direct experience of other regions and cultures falls, increasing the likelihood of stereotypical descriptions of alien peoples and cultures. Thus, social relations at the global scale deteriorate, locking in even more discrimination, apathy, and disrespect.

Inequality is increased within as well as between countries. Civil wars and rebellions become even more frequent within poorer countries. Domestic and other forms of hidden violence also rise in richer countries, including through the promotion of a culture that is more militarized, fearful, and discriminatory. Refugee numbers outside the fortified borders increase, and many refugees are confined indefinitely in large squalid camps. International organizations lose their autonomy, or even cease to exist. For a time, a few poorer countries struggle to maintain educational stan-

dards, but the repeated successful luring of their brightest and best graduates by wealthy countries gradually lowers the morale and expertise in poor areas. Consequent feedbacks in poorer nations reduce investment, increasing debt defaults, poverty, economic failure, mistrust, crime, corruption, epidemics, and violent conflict.

11.4.4 Adapting Mosaic

In Adapting Mosaic many locally cooperative networks and actors emerge. Civil society strengthens local government and organizations. Science and businesses play an increasing role in the support of conventions to address persisting environmental problems. Decentralized management helps conserve local ecosystems that are of importance for religious, spiritual, recreational, educational, and aesthetic reasons (Kaisiti 2003). New partnerships emerge, incorporating professionals, indigenous peoples' organizations, community groups, and product certification organizations, to bring change at the local level. While the devolution of power to the local level initially triggers conflicts with the former holders of power, the scenario envisages that these struggles are successfully resolved.

Military expenditure and conflict are reduced, freeing enormous resources to improve human well-being. For example, investment currently channeled to improve weapons is used to build roads and develop improved crops. On the other hand, the power of the United Nations and other global organizations to tackle any global crises, including disputes that might still arise over the management of common resources, is weaker in this decentralized scenario. New actors may have conflicting interests, objectives, and values not reflected in previous management regimes. Thus, tensions and conflicts may still arise, even within the new power structures. This is most likely where there are changes in customary rights and practices.

11.4.5 TechnoGarden

Several unique characteristics influence social relations in TechnoGarden. The most important is the extent to which technology changes human relationships, shaped by evolution over millions of pre-TechnoGarden years. Humans have always had some technologies, and for generations many humans have experienced an increasing rate of technological change. Humans remain social animals, however, requiring physical affection and contact for proper development. This scenario sees the development of technologies that lead to cheaper and easier forms of multilingual communication. This enhances social development, including between NGOs, social activists, and special interest groups. But new technologies also distort social development by, for example, creating people who feel more bonded with synthetic forms of reality and stimulation rather than other people and life-forms. In times of stress, such relationships are unlikely to be fulfilling. Such people, even if relatively few, not only feel alienated from society but also behave destructively.

Cloning, ''designer children,'' and other forms of social manipulation also affect social relations. Too late, people realize that genetic tinkering releases undesirable traits, including behavioral. On the positive side, violent conflicts lessen and social relations improve as new technologies facilitate the expansion of agriculture to areas that are currently sparsely inhabited. But without sufficient institutional evolution, new technologies—including of weapons—generate new arms races at regional, international, and even local scales. In summary, as previously indicated with regard to this scenario, the rate of institutional evolution is vital in steering and controlling humanity's growing technological prowess in ways that improve human well-being.

On the negative side, cheaper and better communication could also be used by groups such as drug smugglers and terrorists, whose aim or effect is to disrupt social relations. Disaffected individuals and groups could also make use of new weapons. The diffusion of eco-technology may reduce indigenous and other local knowledge of ecological processes and management, creating vulnerability and dependence.

11.5 Freedom and Choice

11.5.1 Determinants and Expressions

Freedom and choice includes the ability to acquire, to experience, and to select what someone likes, including from ecosystems. It also includes the capability of fulfilling personal choices. Freedom is much more than material. It relates also to the ability to participate in debate, to travel, and to hold, study, and express personal beliefs, including views that differ from the majority. There can be an asymmetric relationship between freedom and choice and the other components of well-being. For example, it is possible to have enough material goods to survive comfortably and yet to feel far from free. It is also possible to feel secure, to enjoy good social relations and health, and yet not be free (Sen 1999). And reduced freedom means reduced well-being.

Freedom implies the ability to pursue the other components of well-being, though without guaranteeing their attainment. Yet freedom must also be limited, both for individuals and groups, because an excess of freedom for one party results in the dearth of another's. The distribution of access to resources, ecosystems services, and the quality of institutions are vital determinants of the degree of freedom and choice. Excessive material inequality can not only create but also result from a sense of grievance. This can contribute to the generation of religious and other forms of fundamentalism, reducing freedom of expression. It is also possible to have societies where most people have fairly equal access to material goods yet there is a highly asymmetrical distribution of influence and a consequent lack of freedom.

11.5.2 Global Orchestration

In Global Orchestration, many forms of material freedom and choice increase because of the greater purchasing power predicted in this scenario, the greater supply of many goods and services, and the lessening of material and other

forms of inequality. (See Figure 11.1a.) Democracy increases greatly, causing a range of virtuous feedbacks, such as better education and a greater, less skewed flow of information. This liberation of human potential is particularly striking in societies that have previously been repressed. The convergence between wealthy and poorer countries leads to more freedom of movement both within and across borders. Reduced inequality sees less envy, crime, and discrimination, generating new freedoms of expression, especially for minorities.

Some freedoms are reduced, however. Although the total supply of many goods and services increases, many consumers have less choice. Goods, both manufactured and grown, are relatively homogenous culturally, technologically, and genetically. Many services are delivered anonymously, supplied by providers based in physically distant economies with cheaper price structures.

Scientists, ecotourists, and deep ecologists have less opportunity to visit, experience, study, and honor ecosystems destroyed or irrevocably altered to further material progress. Others who feel deeply connected to natural systems, such as many indigenous people, also experience a sense of loss, including lost freedom. It is also plausible that micromanagement, applied repeatedly with the best of intentions, could reduce freedom through a combination of market and benevolent government tyranny.

11.5.3 Order from Strength

Order from Strength clearly results in a marked restriction of freedom and choice in many regions. (See Figure 11.1b.) Goods, trade, and travel are tightly controlled, including by the manipulation of information, the suppression of protest, and the control of the mass media using public relations techniques, particularly to benefit and protect powerful individuals and groups (Stauber and Rampton 1995; Beder 1998). Communication technologies, including the Internet, are censored and manipulated by governments and powerful corporations, with limited freedom for NGOs and other groups attempting to provide countering views.

In this scenario, many individuals and groups receive arbitrary treatment according to qualities such as their name, nationality, dress, ethnicity, and appearance. Freedom of speech and self-expression suffer. Religious, ethnic, and other forms of fundamentalism strengthen, further reducing freedom of expression, including, paradoxically, of religion.

Global initiatives and conventions for ecosystem management decline, in part because of the opportunity cost of constantly responding to the numerous security problems likely to occur in this scenario. The freedom of individuals to share information, even to ameliorate environmental problems, is restricted. The access by many individuals to ecosystem services in this scenario is also likely to fall as regional inequalities increase. This reduces human freedom.

11.5.4 Adapting Mosaic

In Adapting Mosaic, freedom of choice and action are improved on average over conditions in 2000. (See Figure 11.1c.) Resource users acquire many local forms of freedom and choice. These include the ability to manage ecosystems through local institutions and the freedom to experiment with different forms of management and to modify and manipulate ecosystems to produce services consistent with their needs and wants. Poor people in poorer countries gain the freedom to restrict foreign investment by imposing taxes and tariffs, including those that could weaken environmental protection.

Yet the limited international reach of global society is likely to extend beyond that of an impaired capacity to form global environmental agreements to also include impaired international policing and a weakening of international cooperation in spheres such as global human rights protection. Although the scenario assumes a high degree of social harmony, it is in fact likely that some groups will try to take advantage of the comparative legal and peacekeeping vacuum likely to form. This could lead to gross human rights violations that go unnoticed by the wider community. Freedom and security will be reduced for vulnerable groups.

11.5.5 TechnoGarden

Freedom and choice are, on average, improved in TechnoGarden compared to 2000. (See Figure 11.1d.) The rate of increase of freedom in TechnoGarden depends crucially on the accompanying rate of institutional evolution. Technologies themselves are benign, having no capacity to either constrain or liberate freedom. If they can be used successfully to increase the per capita supply of well-managed ecosystems, however, and at the same time allow a greater preservation and restoration of wild ecosystems, then many forms of freedom and choice are likely to increase. For example, higher food production, cleaner water, and, possibly, expanded areas suitable for human habitat should increase freedom.

Consumers with sufficient means have new choices of foods, production systems, technologies, and entertainment. Nanotechnology, robotics, and other technologies enable niche markets to become economic. Books never go out of print, as microprinting technologies become inexpensive and widely available. Other technologies preserve languages and customs, broadening cultural and consumer choice.

Freedom and choice for some populations, such as those living in areas flooded by new dams or whose land has been appropriated for other uses, are reduced, however. The scenario could also unravel, with new technologies being adapted to reduce freedoms, including by new forms of surveillance, policing, and military techniques. Some of these technologies could also be used illicitly or accidentally in ways that reduce freedom.

11.6 Ecosystem Services and Human Well-being across the Scenarios

11.6.1 Provisioning Services

Without adequate provisioning services, human well-being will clearly decline. Material needs and health are obviously

vulnerable to reduced provisioning services (below a threshold), but such declines are likely to lead to reductions in the other aspects of human well-being as well. This relationship is not linear. Once adequate provisioning services are available to deprived populations, additional increases in provisioning ecosystem services are unlikely to lead to commensurate improvements in human well-being.

In all four scenarios and in all regions analyzed, the model results show that per capita cereal consumption (as food, rather than animal feed) remains little changed in 2050 compared with the present, although in Adapting Mosaic it falls slightly in sub-Saharan Africa, the region with the lowest current consumption. (See Chapter 9, Figure 9.23.) However, per capita meat consumption is found to increase by 2050 in sub-Saharan Africa in all four scenarios. In Adapting Mosaic and Order from Strength, the absolute number of energy-undernourished children in poorer countries is predicted to increase by 2020, but this improves by 2050, particularly in Adapting Mosaic. (See Chapter 9, Figure 9.31.)

These model results raise deep questions about the assumptions used to generate them. The finding of a reduced percentage and absolute number of energy-malnourished children in sub-Saharan Africa in 2050 in Order from Strength seems optimistic, particularly in the context of the tripling of population projected for this region in this scenario. Instead, several factors appear likely to reduce the capacity of sub-Saharan Africa to lower the number and percentage of energy-undernourished children. These plausible factors include a substantial increase in the price of energy, harmful effects to domestic agricultural productivity because of HIV/AIDS and probably other diseases, and, perhaps most important, the damage to infrastructure and human capital from repeated violent conflict. The models conclude that the demand for food increases strongly in all four scenarios, but this conclusion is in doubt with regard to a large increase in effective food demand in Order from Strength (Sen 1981).

Biofuel includes trees, agricultural wastes, and crops grown specifically as energy carriers, such as maize fermented to produce alcohol. Most biofuel is burned to produce electricity rather than used for heating and cooking, as traditional firewood would be. Biofuel production increases substantially in the Global Orchestration and TechnoGarden scenarios. (See Chapter 9, Table 9.33.) If there is a co-existent oil shortage, together with an immature or costly substitute fuel for transport, large areas of agriculturally productive land may be harnessed to produce biofuel, with adverse effects for total food production.

11.6.2 Regulating Services

Regulating services are also essential for human well-being. Most obviously, these include ecosystems sufficiently intact to reduce flooding, landslides, and storm surges and to maintain river flow in dry areas. Less obviously, there is a strong interaction between land cover and climate at the regional and global scales. Many ecosystems can be transformed to supply markets (such as forests to lumber, or mangroves to fish farms) but this is at the loss of regulating services, for which markets are weak. Beyond thresholds of loss, diminished regulating services lead to disproportionate harm to human well-being, especially for vulnerable communities.

Globally, regulating services are best preserved in TechnoGarden and Adapting Mosaic. For example, tropical deforestation is lowered in TechnoGarden by a combination of reduced tropical hardwood consumption by rich populations, technological developments leading to substitution, and slower population growth in poorer countries. In Adapting Mosaic there is in general greater protection of local ecosystems, including through greater resistance to the organized criminal systems that have contributed to much illegal logging in Southeast Asia (Dauvergne 1997; Jepson et al. 2001).

In contrast, in both Order from Strength and Global Orchestration, a combination of market forces, undervaluation, and feedbacks lead to substantial deforestation, not only in the mostly tropical poorer countries but also in large swathes of Siberia. In Central America and the Caribbean this leads to more local flooding (Hellin et al. 1999) and development reversals, as occurred following Hurricane Mitch in 1998. As the century passes, deforestation increasingly interacts with climate change and fires, reducing the terrestrial carbon sink and enhancing the chance of runaway climate change (Cox et al. 2000). This risk exists in all scenarios, but is highest in Order from Strength and Global Orchestration.

11.6.3 Cultural Services

Cultural ecosystem services are also essential for human well-being, particularly by supplying aesthetic, recreational, psychological, and spiritual benefits. In turn, the sense of loss from or connection with such services is a factor in broader issues of security, cultural relations, and freedom. The protection of sites, species, or ecosystems of special significance can improve the morale of large populations, just as the loss of such icons can exacerbate despair, violence, and loss.

The cultural services of ecosystems are best protected in Adapting Mosaic. In this scenario, the greater autonomy of local groups facilitates stronger protection of valued landscapes, streams, and species, though some species remain vulnerable to circumstances well beyond local control, such as the lack of protection of distant landing sites for migratory birds or the dissemination of persistent chemicals that may reduce fertility.

In Global Orchestration, the cultural services of many ecosystems are undervalued unless they already generate substantial income, such as through tourism. Economic growth is viewed primarily in monetary terms rather than as an incomplete indicator of what is really important (Arrow et al. 2004). Consequently, old-growth forests are converted to palm oil plantations and wetlands to fish farms.

In TechnoGarden, there is also an undervaluation of many cultural ecosystem services. There is a pronounced belief, merging with hubris, in the ability of technology to

provide adequate substitutes, such as through virtual life forms and ecological engineering. Ultimately, these are likely to prove less compelling to humans than living species and genuine ecosystems. However, the greater efficiency of transformed ecosystems, such as those used to grow food, also means that there is less demand to transform ecosystems that are currently little changed. This will result, de facto, in greater protection for some cultural services, especially in poorer countries.

In Order from Strength, many cultural services of ecosystems decline, especially in poorer countries. Numerous species, including birds, mammals, and fish, are forced into extinction, both directly by hunting and indirectly by habitat loss and pollution. The more privileged populations in the wealthy countries also lose access to many cultural services, not only through the probable extinction of charismatic species, such as some of the great apes, but also because firsthand experience of species that do survive in poorer countries is increasingly rare. The genetic health of species protected in richer countries in zoos and wildlife parks also suffers, as they become more inbred.

The decline of cultural ecosystem services in Global Orchestration, TechnoGarden, and Order from Strength is likely to have a generally negative impact on human well-being, especially for people with a high degree of biophilia (Wilson 1984; Frumkin 2002).

11.7 Vulnerability

11.7.1 Ecological Surprises

Major adverse ecological surprises are more likely to occur in Order from Strength and Global Orchestration than in TechnoGarden. Adapting Mosaic has the lowest rate of adverse ecological surprise. Social resilience to such surprises is seen to be strongest in Adapting Mosaic and TechnoGarden but is particularly low in Order from Strength.

The vulnerability of Global Orchestration to a major ecological surprise is an important weakness of this approach to development. The reduced emphasis on ecological issues in this scenario means that society and individuals will be poorly equipped to detect early indicators of major ecological change. Symptoms such as localized eutrophication, strange but limited animal and plant diseases, or fisheries collapse are likely to be dismissed rather than recognized as significant. This is likely to further delay and weaken action, risking ineffectiveness. By the time a major ecological change is occurring, such as runaway climate change, it may be impossible to stop. Order from Strength has a similarly reactive approach to ecosystem management, which, coupled with societal ignorance about ecology, gives this scenario a very high potential for adverse ecological surprise.

Any major ecological surprise is likely to have important social consequences, even in a society as well-educated, harmonious, and technologically advanced as postulated in Global Orchestration. Runaway climate change is a particularly serious threat in this scenario. Its likely manifestations would include increased extreme weather events such as droughts, floods, fires, and, perhaps, more violent storms and fires. It could also precipitate many adverse agricultural effects in tropical poorer countries, including in sub-Saharan Africa and South Asia, both of which could experience increased food shortages and famine. In the subcontinent, climate change could exacerbate pre-existing security tensions between nuclear-armed rivals.

Some technologies developed in TechnoGarden are likely to have unexpected effects. While some will be trivial, others could be serious. The twentieth century provides many examples of how technologies and new techniques conceived as benign or beneficial in fact had harmful consequences (European Environmental Agency 2001). Some—such as the spread of bovine spongiform encephalopathy (Butler 1998) and of HIV among Chinese blood donors (Anonymous 2001b)—have cost billions of dollars and affected thousands of lives. An apparently more benign case was the accidental exposure between 1955 and 1963 of over 100 million people to a polio vaccine potentially contaminated with a simian virus (McCarthy 2002). While this did not cause a major public health problem (although there are concerns that this virus may be associated with lymphoma) (Vilchez et al. 2002), it could have. The natural but unforeseen arsenic contamination of tubewells developed to extract microbiologically safe water in Bangladesh and parts of India (Smith et al. 2000) is another example of adverse technological surprise. On the positive side, TechnoGarden's proactive and learning-focused approach may help people in this scenario avoid some surprises.

New agricultural technologies are also likely to have unexpected results, not all of which will be benign. For example, genetically modified plants may spread new genes into wild species. Uncertainty about the scale of these changes exceeds our current ability to monitor them. Groundwater extraction may promote locally higher crop production but reduce production elsewhere by disturbing the underwater hydrology (Alley et al. 2002). Aquifers may also become excessively contaminated by pesticides and other substances with uncertain but potentially long-lasting effects. Clearing of water catchments and wetlands for farming and aquaculture may change micro-climates, reduce fish breeding, and make densely populated areas more vulnerable to disasters such as storm surges and flooding. New dams may reduce the productivity of downstream fisheries and agriculture.

In the absence of institutional changes that protect poorer populations, new technologies—including ones that facilitate the conversion of large areas of low value land for more productive uses—tend to have a disproportionately negative effect on women and marginal populations, including pastoralists and indigenous peoples.

Adapting Mosaic tends to avoid surprises by being proactive and by taking small steps and carefully monitoring the results. Some small-scale surprises do happen, particularly when experiments fail, but these generally do not affect large numbers of people negatively.

11.7.2 Social Surprises

Major adverse social surprises include large-scale violent conflict, governance failure, and increased fundamentalism

and nationalism. Global Orchestration is likely to have the greatest capacity to cope with social surprises and—in the absence of major adverse ecological surprises—the least chance of having them occur. This social resilience is fostered by the improvement of human, social, and physical capital in this scenario, but at the expense of natural capital. There is a belief in this scenario that as these nonenvironmental forms of capital improve, the self-organizational capacity of society to respond appropriately to various forms of stress—even ecological—will also improve (Johnson 2001). Reduced inequality (including of opportunity and respect) should also mean greater social cohesion and cooperation in the face of stress. On the other hand, the increasingly homogenous global culture in this scenario is likely to promote many forms of cultural reaction, especially among people who lag or resist identification with this global average. This could stimulate cults and religious and other forms of fundamentalism.

The amount of social surprise is highest in Order from Strength. Fundamentalism and other forms of extremism are likely to attract considerable support in this scenario, especially in poorer countries depleted of knowledge and human capital. Corruption and violent conflict are also likely to increase in these countries in Order from Strength, repeatedly undermining human well-being. In addition, grievance-motivated criminal and terrorist groups based in these countries are likely to attempt to wage a guerilla war against the heavily fortified richer countries. This could take the form of attacks on enclaves of rich populations in poorer nations or tourists who venture into such countries, cyberattacks, and the establishment of terrorist sleeper cells within rich countries.

11.7.3 Other Surprises

Other categories of adverse surprise, such as an energy shock, are also possible. While technological optimists and many economists (Johnson 2001) argue that higher energy prices are likely to drive a successful and rapid energy transition, this proposition is unproven. Even if methods to develop alternative portable fuels, including from renewable sources of energy, are technically feasible, there is no guarantee that the rate of this development and its diffusion will be sufficiently rapid to prevent widespread hardship, especially in poorer countries. Multiple interactions between adverse social, ecological, and other surprises are possible. These could have ripple effects, both temporally and geographically, that impair the response to crisis, causing a downward spiral.

11.8 Summary and Conclusion

Each scenario has different consequences and implications for the components of human well-being. (See Table 11.1 and Figure 11.1.)

The Global Orchestration scenario ostensibly has the greatest improvement in human well-being at the global level, especially for populations who are currently disadvantaged. (See Figure 11.2a.) Since the main focus of decision-makers in this scenario is enhancing the functioning of human systems via increased economic growth and improved social policies, improvements in the poor countries are expected to be quite substantial across all human well-being components. In rich countries especially, material well-being and health improve, but other components do not change significantly compared with today.

We believe many systematic obstacles will limit fulfillment of this scenario's promise, however. In particular, we think that the scenario underestimates the obstacles that will impede realization of its assumptions (such as the surprises that might be involved with the removal of agricultural subsidies; see Box 11.2). There is an inherent contradiction between its assumptions of both decreased regulation and increased privatization and the claim that this is consistent with policies that will improve the quality and structure of economic growth in ways that promote equity and good governance (Stiglitz 2003). In parallel, the benefits of "trickle down" promised by advocates for free trade are likely to be exaggerated in this scenario, even if subsidies are successfully lowered. Consequently, the institutional reform promised by this scenario is unlikely to lead to substantial increases in the ability of the poor to attain secure access to resources, including of ecosystem services.

We also find that this scenario has a high vulnerability to major adverse ecological surprise, such as runaway climate change. (See the Socioecological Indicators in Figure 11.1a.) Human well-being is predicted to improve because of a strong focus on increased provisioning ecosystem services, such as food and water availability, and the priority given to short-term goals over a long-term vision of how to deal with change. However, the maintenance and restoration of supporting and regulating services is comparatively ignored. This creates a high risk of eventual breakdown of key ecosystem functions, including provisioning services, with a direct impact on human well-being. In addition, this scenario is characterized by a lack of capacity to monitor and react quickly to adverse ecosystem changes, creating vulnerability to the passing of ecosystem thresholds. This vulnerability exists despite the improved education in this scenario, in part because there is little educational focus on the interaction of human systems with nature.

In the Order from Strength scenario, human well-being is clearly decreased. (See the HWB Indicators in Figure 11.1b.) The global distribution of resources and services that underpin human well-being is more skewed than at present. Wealthy populations meet material needs but experience increased psychological insecurity, while the resources of poor populations are depleted by more powerful groups. As Figure 11.2b demonstrates, there may be slight improvements in material well-being and health in rich countries, but social relations, freedom and choice, and security are likely to deteriorate due to huge inequalities between rich and poor populations both between and within countries. For poor countries, the picture looks even gloomier. Inequality, underinvestment in education, continuing population increase, and little regard for the maintenance of key ecosystems on which mainly poor people depend leads to an overall decrease in all components of human well-being.

Table 11.1. Benefits Compared with Risks and Costs for the Five Components of Human Well-being across the Four Scenarios

Component	Benefits	Risks and Costs
	Global Orchestration	
Material needs	increased incomes, employment, and food; convergence between wealthy and poorer countries; better education	adverse ecological surprises; privatization may act against some groups; food diseases if checks are not maintained in flow chain; more invasive species
Health	better nutrition; strengthened global health services; enhanced vaccine development and distribution; better mental health	increased obesity-related diseases, especially Type II diabetes; more cancer and osteoporosis
Security	proliferation of peace initiatives and civil societies; reduced crime as inequality narrows	increased violent conflicts over diminishing resources, at worst case transformation to Order from Strength
Social relations	convergence of cultures and aspirations between wealthy and poorer countries; greater democracy, friendship, and cultural exchange	lost traditions, cultures, knowledge, and valued ecosystems could trigger resentment or even terrorism against global culture; smaller families increase social isolation
Freedom of choice and action	increased political freedom, civil liberties, information flow, movement, expression, and association	more homogenous culture and ecosystems reduce choice
	Order from Strength	
Material needs	representative ecosystems will be maintained in rich countries to provide ecosystem services	increased material scarcity for poor populations; degraded ecosystems for poor populations; increased material inequalities
Health	improved health in rich countries that can afford health services and have expertise for technological breakthroughs	malnutrition; increased poverty-related diseases, drug resistance, violence, post- traumatic stress, and depression; increased anxiety disorders for rich and poor
Security	advanced technologies and services for those who can afford them	increased crime; hostility among and within nations; terrorism, civil wars, rebellions, fear, stigmatization
Social relations	reasonable among high-income populations, but overlay of anxiety	gangsterism, corruption, intimidation within poor populations; widespread fear, mistrust, intolerance, and hostility
Freedom of choice and action	limited freedom for protected high-income populations	increased surveillance and control; restricted freedom of speech, association, movement, travel, self-expression; censorship and propaganda
	Adapting Mosaic	
Material needs	engagement between ecosystem users and owners facilitates sustainable use; strong local resource institutions	reduced productivity from global commons due to misuse
Health	reduced stress; traditional health systems; better mental health, especially for indigenous populations	loss of global health capacity; uneven distribution of high technology medical services, including surgery and new vaccines and drugs
Security	lowered incidences of conflicts as spending on military action is reduced to cater to local development	increased risk of international criminal activity and hidden human rights abuses, including genocide
Social relations	strong local networks, regional pride; local alliances, local solutions for disputes	lack of global police force or strong influence of global social norms could lead to persistence of local forms of oppression for women and minorities
Freedom of choice and action	freedom to form partnerships, develop local solutions, maintain customs, and relate to and access local ecosystems	curtailed freedom and choice through continuation of existing traditions and customs that restrict freedoms for women and minorities
	TechnoGarden	
Material needs	increased income; ubiquitous computers and communication; robotics and intelligent buildings	increased unemployment due to robots; inadequate inclusion of displaced workers
Health	improved nutrition; cleaner air, water, and food: health informatics; better surgical techniques and new drugs; "nutraceuticals"	addiction to designer drugs and virtual reality; poor gross motor coordination; genetically engineered pathogens; adverse health effects of new foods and chemicals
Security	better surveillance technology and security systems; robotic guards	cheap, powerful weapons could allow small groups to threaten security; electronic fraud; arms races of many kinds and many scales
Social relations	better communication; more literacy; less conflict; technology links new groups; more understanding and trust	genetic-based discrimination; reliance on synthetic reality may create emotional vulnerability and antisocial behavior; weakened family links
Freedom of choice and action	diversified ecosystem services; choices for production systems; selection of desired genetic characteristics from ecosystems	new surveillance technologies (visual and electronic) could reduce freedom

BOX 11.2

How Global Orchestration Could Become Order from Strength

The benefits to well-being promised by Global Orchestration are likely to be greatly overstated if its key assumptions prove exaggerated or false. Rather then declining, multidimensional inequality could increase, leading to an increased "lock in" between rich and poor. Different rules, conditions, and feedbacks could be applied to and come to characterize wealthy and poor populations, exacerbating inequality. Developing-country debt burdens could increase, contributing to additional burdens on ecosystems—for example, through deforestation, increased erosion, ongoing biodiversity loss, and more pollution.

Mechanisms introduced to reduce inequality and to improve human capital could prove unexpectedly fragile and rapidly be abandoned. For example, attempts to increase education in poorer countries could be set back by an exacerbated "brain drain" or by a disease that particularly affects young adults. Funds pledged for development could be repeatedly diverted to address crises involving wealthy countries, such as wars, terrorism, or intractable difficulties in converting to post–fossil fuel energy.

Increased violent conflict or new diseases in poorer countries could also undermine development. Tensions and mistrust between rich and poorer countries could re-emerge if wealthy countries fail, despite repeated promises, to reduce their agricultural and other barriers to free trade. Tension and inequality could also worsen if it becomes clear that free trade, even though sincerely attempted by many parties, fails to surmount its zero-sum-gain obstacles, stubbornly creating new generations and populations of winners and losers (Mehmet 1995). As a result of such pathways, convergence between rich and poorer countries could weaken or even reverse. If this happened, then ecosystem services, especially in the latter nations, are also likely to continue to decline (Welch 2001).

Unanticipated adverse ecological surprise could interact with flawed human actors, greatly magnifying the destruction of built and other forms of capital. Nationalism, fundamentalism, protectionism, and terrorism could resurface, eroding the capacity of global institutions even if they are stronger than today. Because of these setbacks in development and human capital formation, population pressure may be even higher than currently anticipated, creating additional pressure on surviving ecosystems and also inhibiting the economically beneficial effects of the "demographic dividend" that an increasing number of observers have recognized, including as a crucial factor in China's growing prosperity (Williamson 2001; Vallin 2002). As the worst case, feedbacks could develop that lead to more corruption, more inequality, more material shortages, and additional famines and disease. In short, this could transform Global Orchestration to a scenario akin to Order from Strength even if in its early stages the trajectory follows that predicted in Global Orchestration.

(See the Socioecological Indicators in Figure 11.1b.) Poor people are repeatedly forced to give priority to the short-term survival of their families at the expense of ecosystem services and, ultimately, their long-term well-being. Little is done to foster the adaptation potential of societies to social and natural changes. As well, the resilience of these societies to adverse environmental change is likely to be low.

Like the others, this scenario is also probably unrealistic. While pessimists see considerable evidence of a nascent Order from Strength scenario in the present (Kaplan 1994), many countering forces exist that are likely to alleviate the most negative aspects of this scenario. These include the efforts by many governments, NGOs, and individuals to protect and improve governance and qualities such as human rights. The scenario also probably underestimates the "bootstrapping" capacity flowing from the self-organization of individuals and communities once they are given access to some resources, particularly education. That is, even in the generally dismal circumstances foreseen in poorer countries in this scenario, pockets of resilience and resistance are likely to remain, creating persistent hope for a reversal of the broader trends.

In the Adapting Mosaic scenario, most aspects of human well-being improve. Provisioning services in poorer countries are significantly increased through investment in social, natural, and, to a lesser extent, human capital at local and regional levels. (See Figure 11.2c.) In richer countries, provisioning services change little because a threshold of consumption has been achieved. Because of the partial devolution of decision-making power to smaller scales and increased cooperation and exchange at the local and subnational levels, social relations, freedom and choice, and security are also likely to improve. Furthermore, priority is given in this scenario to developing flexible management regimes that monitor, mitigate, or adapt to environmental change and that hence build social adaptive capacity. Decision-makers see maintaining ecosystems and the services they provide as key to human survival. This understanding is built on an overall long-term understanding of ecosystem changes and their impact on human systems and the recognition that these changes matter. Seen at the global level, human well-being improves, but not quite as quickly as in the Global Orchestration scenario. (See the HWB Indicators in Figure 11.1c.)

Yet this scenario makes the unrealistic assumption that populations of malcontented humans will either disappear or become of trivial importance within a very short period. This ignores history. In reality, substantial populations of raiders, pirates, criminals, and free-riders are likely to persist, and their influence is likely to impair successful realization of this scenario. Many such populations will have access to powerful weapons and other forms of coercion. In the absence of global policing implied by this scenario, it is likely that at least some of these "human predators" will forge complex, even if unstable, alliances. In response, this is likely to generate large-scale cooperation among the many human groups who would otherwise form vulnerable "prey."

The TechnoGarden scenario appears to offer many ways to improve human well-being. However, this depends crucially on the speed of institutional development. Turning again to history, it seems likely that institutional development will lag behind that of technology. Thus, social relations and freedom appear to be at particular risk everywhere in this scenario. (See Figure 11.2d.) Unless the distribution of the new environmentally friendly technologies is reason-

ably equitable, much of the potential for better human well-being in this scenario will remain elusive. Nevertheless, this environmentally pro-active scenario means that decision-makers focus on gaining a better understanding of the management of ecosystems. Consequently, this scenario shows improvements in social adaptive capacity, though not as great as in Adapting Mosaic. (See the Socioecological Indicators in Figure 11.1d.)

TechnoGarden also has a risk of a breakdown of many ecosystem and technological functions, potentially precipitating a cascading decline for human well-being if a limit is passed in the human capacity to control and successfully manage the complex hybrid of social, technological, and ecological systems that are foreseen.

In summary, each scenario exhibits a different package of benefits, risks, and adverse impacts for human well-being. They portray a range of trade-offs between development and ecological strategies currently discussed by policymakers at different levels. Figure 11.1 depicts and compares some of the main trade-offs. While no single scenario is best, the Order from Strength scenario is clearly the least desirable. People who are currently poor and vulnerable experience the highest risk of future poverty and vulnerability in this scenario.

While all scenarios are claimed to be equally plausible, this is true only in the sense that none are very likely. On the other hand, the future is likely to contain recognizable elements of all four scenarios, just as the present does. Given sufficient cooperation, information flow, preparedness, adaptivity, and technological breakthrough, the human future may respond to a dynamic interchange between various scenarios, at varying temporal and geographic scales, in ways that lead to sustainability.

References

Adams, W.M., D. Brockington, J. Dyson, and B. Vira, 2003: Managing tragedies: understanding conflict over common pool resources. *Science,* **302,** 1915–1916.

Alley, W.M., R.W. Healy, J.W. LaBaugh, and T.E. Reilly, 2002: Flow and storage in groundwater systems. *Science,* **296,** 1985–1990.

André, C. and J.P. Platteau, 1998: Land relations under unbearable stress: Rwanda caught in the Malthusian trap. *Journal of Economic Behaviour and Organization,* **34,** 1–47.

Anonymous, 2001a: Don't underestimate the enemy. *Nature,* **409,** 269.

Anonymous, 2001b: China faces AIDS [editorial]. *The Lancet,* **358,** 773.

Arrow, K., P. Dasgupta, L. Goulder, G. Daily, P. Ehrlich, G. Heal, S. Levin, K.-G. Mäler, S. Schneider, D. Starrett, and B. Walker, 2004: Are we consuming too much? *Journal of Economic Perspectives,* **18,** 147–172.

Beder, S., 1998: *Global Spin: The Corporate Assault on Environmentalism*. Scribe Publications, Melbourne, Australia, 288 pp.

Berkman, D.S., A.G. Lescano, R.H. Gilman, S.L. Lopez, and M.M. Black, 2002: Effects of stunting, diarrheal disease, and parasitic infection during infancy on cognition in late childhood: a follow-up study. *The Lancet,* **359,** 564–571.

BIO (Biotechnology Industry Organization), 2003: Biotechnology information, advocacy and business support: agricultural production applications. Washington, D. C. Cited 18 October 2004. Available at www.bio.org/speeches/pubs/er/agriculture.asp.

Birdsall, N., A.C. Kelley, and S.W. Sinding (eds.), 2001: *Population Matters Demographic Change, Economic Growth, and Poverty in the Developing World*. Oxford University Press, New York, xvi, 440 pp.

Bloom, D. and D. Canning, 2001: Cumulative causality, economic growth, and the demographic transition. In: *Population Matters: Demographic Change, Economic Growth, and Poverty in the Developing World,* N. Birdsall, A.C. Kelley, and S.W. Sinding (eds.), Oxford University Press, Oxford ; New York, 164–197.

Botkin, D., 2001: Ecological risks of biotechnology. Cited 18 October 2004. Available at http://pewagbiotech.org/events/1204/presentations/Botkin.ppt.

Buck, S.J., 1998: *The Global Commons: An Introduction*. Island Press, Washington, DC 225 pp.

Butler, D., 1998: British BSE reckoning tells a dismal tale. *Nature,* **392,** 532–533.

Butler, C.D., C.F. Corvalan, and H.S. Koren, in press: Human health, well-being and global ecological scenarios.

Butler, C.D. and A.J. McMichael, 2005: Environmental Health. In: *Social Injustice and Public Health,* V. Sidel and B. Levy (eds.), Oxford University Press, Oxford, UK, (in press).

Coale, A.J. and E.M. Hoover, 1958: *Population Growth and Economic Development in Low Income Countries A Case Study of India's Prospects*. Princeton University Press, Princeton NJ. 389 pp.

Cordell, L., 1997: *Archaeology of the Southwest*. 2nd ed. Academic Press, San Diego, CA. 522 pp.

Couper, R.T.L. and K.N. Simmer, 2001: Iron deficiency in children: food for thought [editorial]. *Medical Journal of Australia,* **174,** 162–163.

Cox, P.M., R. Betts, C.D. Jones, S.A. Spall, and I.J. Totterdell, 2000: Acceleration of global warming due to carbon-cycle feedbacks in a coupled climate model. *Nature,* **408,** 184–187.

Dauvergne, P., 1997: *Shadows in the Forest: Japan and the Politics of Timber in Southeast Asia. Politics, Science and the Environment,* MIT Press, Cambridge MA, 336 pp.

de Waal, A. and A. Whiteside, 2003: New variant famine: AIDS and food crisis in southern Africa. *Lancet,* **362,** 1234–1237.

Demeny, P., 2003: Population policy dilemmas in Europe at the dawn of the twenty first century. *Population and Development Review,* **29(1),** 1–28.

Dietz, T., E. Ostrom, and P.C. Stern, 2003: The struggle to govern the commons. *Science,* **302,** 1907–1912.

Eckersley, R., 2004: *Well and Good: How We Feel and Why It Matters*. Text Publishing, Melbourne, Australia, 311 pp.

European Environmental Agency, 2001: *Late Lessons from Early Warnings: The Precautionary Principle 1896–2000*. Environmental Issue Report No 22. Luxembourg Office for Official Publications of the European Communities, Luxembourg, 210 pp.

Ezzati, M. and D. Kammen, 2002: The health impacts of exposure to indoor air pollution from solid fuels in developing countries: knowledge, gaps, and data needs. *Environmental Health Perspectives,* **110,** 1057–1068.

Ezzati, M., A.D. Lopez, A. Rodgers, S.V. Hoorn, C.J.L. Murray, and C.R.A.C. Group, 2002: Selected major risk factors and global and regional burden of disease. *The Lancet,* **360,** 1347–1360.

Folke, C., S. Carpenter, B. Walker, M. Scheffer, T. Elmqvist, L. Gunderson and C.S. Holling, 2005: Regime shifts, resilience and biodiversity in ecosystem management. *Annual Review of Ecology Evolution and Systematics,* **35,** 557–581.

Frumkin, H., 2002: Beyond toxicity: Human health and the natural environment. *American Journal of Preventive Medicine,* **20,** 234–240.

Gao, W., A. Tamin, A. Soloff, L. D'Aiuto, E. Nwanegbo, P.D. Robbins, W.J. Bellini, S. Barratt-Boyes, and A. Gambotto, 2003: Effects of a SARS-associated coronavirus vaccine in monkeys. *The Lancet,* **362,** 1895–1896.

Glass, R.I., 2004: Perceived threats and real killers [editorial]. *Science,* **304,** 927.

Grantham-McGregor, S., 2002: Linear growth retardation and cognition [commentary]. *The Lancet,* **359,** 111–114.

Gunderson, L. and C. Holling (eds.), 2002: *Panarchy: Understanding Transformations in Human and Natural Systems*. Island Press, Washington DC, 507 pp.

Hales, S. and A. Woodward, 2003: Climate change will increase demands on malaria control in Africa. *The Lancet,* **362,** 1775.

Hamilton, C., 2003: *Growth Fetish*. Allen & Unwin, Sydney, Australia, 262 pp.

Hellin, J., M. Haigh, and F. Marks, 1999: Rainfall characteristics of Hurricane Mitch. *Nature,* **399,** 316.

James, K.C. and S.D. Foster, 1999: Weighing up disability (Commentary). *Lancet,* **354,** 37 87–88.

Jepson, P., J.K. Jarvie, K. MacKinnon, and K.A. Monk, 2001: The end for Indonesia's lowland forests? *Science,* **292,** 859–861.

Johnson, B., 1999: Genetically modified crops and other organisms: Implications for agricultural sustainability and biodiversity. Cited 18 October 2004. Available at www.cgiar.org/biotech/rep0100/johnson.pdf.

Johnson, D.G., 2001: On population and resources: a comment. *Population and Development Review,* **27(4),** 739–747.

Kaiser, J., 2000: Mercury report backs strict rules. *Science,* **289,** 371–372.

Kaisiti, H., 2003: Redistribution of Indonesian forests: impacts of decentralization of power in forest management. Paper presented at the Globalisation, Localization and Tropical forest management in 21st century. Amsterdam, Netherlands.

Kaplan, R.D., 1994: The coming anarchy. *Atlantic Monthly,* **273(2),** 44–76.

Kay, J.J., H.A. Regier, M. Boyle, and G. Francis, 1999: An ecosystem approach for sustainability: addressing the challenge of complexity. *Futures,* **31,** 721–742.

Kayambazinthu, D., F. Matose, G.C. Kajembe and N. Nemarundwe, 2003: Institutional arrangements governing natural resource management of the Miombo woodland. In: *Policies & Governance Structures in Miombo Woodlands in Southern Africa,* G. Kowero, B.M. Campbell and U.R. Sumaila (eds). CIFOR, Bogor, Indonesia, pp. 45–79.

Kelley, A.C., 2001: The population debate in historical perspective : revisionism revised. In: *Population Matters: Demographic Change, Economic Growth, and Poverty in the Developing World,* N. Birdsall, A.C. Kelley, and S.W. Sinding (eds.), Oxford University Press, Oxford ; New York, pp. 24–54.

Kydd, J., A. Dorward and C. Poulton, 2000. Globalization and its implications for the natural resources sector: a closer look at the role of agriculture in the global economy. An issues paper for the DFID Natural Resources Advisers Conference, Winchester, 10th July 2000.

Laurance, W.F., M.A. Cochrane, S. Bergen, P.M. Fearnside, P. Delamonica, C. Barber, S. D'Angelo, and T. Fernandes, 2001: The future of the Brazilian Amazon. *Science,* **291,** 438–439.

Levin, S.A., 1999: *Fragile Dominion: Complexity and the Commons*. Helix, Reading MA, 264 pp.

Lomborg, B., 2001: *The Skeptical Environmentalist*. Cambridge University Press, Cambridge, UK. 515 pp.

MA (Millennium Ecosystem Assessment), 2003: *Ecosystems and Human Well-being*. Island Press, Washington, D.C., pp. 71–84.

McCarthy, M., 2002: Unclear whether monkey virus in old polio vaccines caused cancer, says IOM. *The Lancet,* **360,** 1305.

McMichael, A.J., 2001: *Human Frontiers, Environments and Disease: Past Patterns, Uncertain Futures*. Cambridge University Press, Cambridge, UK, 413 pp.

McMichael, A.J., C.D. Butler, and M.J. Ahern, 2003: Global environment. In: *Global Public Goods for Health,* R. Smith, R. Beaglehole, D. Woodward, and N. Drager (eds.), Oxford University Press, Oxford, pp. 94–116.

McMichael, A.J., and C.D. Butler, 2004: Climate change, health, and development goals: needs and dilemmas *Lancet,* **364,** 2004–2006.

Mehmet, O., 1995: *Westernizing the Third World: The Eurocentricity of Economic Development Theories*. Routledge, London UK, 186 pp.

Murray, C.J.L. and A.D. Lopez, 1997: Alternative projections of mortality and disability by cause 1990–2020: Global Burden of Disease study. *Lancet,* **349,** 1498–1504.

Nepstad, D.C., A. Verissimo, A. Alencar, C. Nobres, E. Lima, P. Lefebvre, P. Schlesinger, C. Potter, P. Moutinho, E. Mendoza, M. Cochrane, and V. Brooks, 1999: Large-scale impoverishment of Amazonian forests by logging and fire. *Nature,* **398,** 505-–508.

Odum, H.T and B. Odum, 2003: Concepts and methods of ecological engineering *Ecological Engineering* 20, 339–361.

Palmer, M., E. Bernhardt, E. Chornesky, S. Collins, A. Dobson, C. Duke, B. Gold, R. Jacobson, S. Kingsland, R. Kranz, M. Mappin, M.L. Martinez, F. Micheli, J. Morse, M. Pace, M. Pascual, S. Palumbi, O.J. Reichman, A. Simons, A. Townsend, and M. Turner, 2004: Ecology for a crowded planet. *Science,* **304,** 1251–1252.

Pauly, D., J. Alder, E. Bennett, V. Christensen, P. Tyedmers, and R. Watson, 2003: The future for fisheries. *Science,* **302,** 1359–1361.

Piot, P., 2000: Global AIDS epidemic: time to turn the tide. *Science,* **288,** 2176–2178.

Powell, K., 2003: Fish farming: Eat your veg. *Nature,* **426,** 378–379.

Prabhakar, V.K. (ed), 2001: *Biotechnology and Pollution Control*. Anmol, New Delhi, India. 266 pp.

Price, T.D. and G.M. Feinman (eds.), 1995: *Foundations of Social Inequality*. Plenum Publishing Corporation, New York, NY, 280 pp.

Ramakrishnan, P.S., K.G. Saxena, U.M. Chandrashekara, 1998. *Conserving the Sacred: For Biodiversity Management,* UNESCO, New Delhi, 480 pp.

Raskin, P., G. Gallopin, P. Gutman, A. Hammond, R. Kates, and R. Swart, 2002: *Great Transition: The Promise and Lure of the Times Ahead*. Stockholm Environment Institute, Boston, 99 pp.

Ros-Tonen, M., 2003: Background document. Paper presented at the Globalisation, Localization and tropical forest management in 21st century, Amsterdam, Netherlands.

Sachs, J. and P. Malaney, 2002: The economic and social burden of malaria. *Nature,* **415,** 680–685.

Scheffer, M., S. Carpenter, J.A. Foley, C. Folke, and B. Walker, 2001: Catastrophic shifts in ecosystems. *Nature,* **413,** 591–596.

Sen, A.K., 1981: *Poverty and Famines: An Essay on Entitlement and Deprivation*. Clarendon Press, Oxford, New Delhi, 257 pp.

Sen, A.K., 1999: *Development as Freedom*. Oxford University Press, Oxford, UK, 336 pp.

Sheehy, J., 2001: A new plant for a changed climate. International Rice Research Institute. Cited 18 October 2004. Available at http://www.irri.org/publications/annual/pdfs/ar2001/sheehy2.pdf.

Smith, A.H., E.O. Lingas, and M. Rahman, 2000: Contamination of water supplies by arsenic in Bangladesh. *Bulletin of the World Health Organization,* **78(9),** 1093–1103.

Stauber, J.C. and S. Rampton, 1995: *Toxic Sludge is Good for You. Lies, Damn Lies and the Public Relations Industry*. Common Courage Press, Monroe, Maine, 236 pp.

Stiglitz J. 2003. *The Roaring Nineties*. Penguin Books, London, UK, 389 pp.

Tanser, F.C., B. Sharp, and D. le Sueur, 2003: Potential effect of climate change on malaria transmission in Africa. *The Lancet,* **362,** 1792–1798.

Teklehaimanot, A. and R.W. Snow, 2002: Will the Global Fund help roll back malaria in Africa? [commentary]. *The Lancet,* **360,** 888–889.

Tong, S., T. Prapamontol, and Y. von Schirnding, 2000: Environmental lead exposure: a public health problem of global dimensions. *Bulletin of the World Health Organisation,* **78(9),** 1068–1077.

UNEP (United Nations Environment Programme), 1999: Environmental impacts of trade liberalization and policies for sustainable management of natural resources: a case study of India's automobile sector. UNEP, Geneva, Switzerland.

Vallin, J., 2002: The end of the demographic transition: relief or concern? *Population and Development Review,* **28(1),** 105–120.

Vilchez, R.A., C.R. Madden, C.A. Kozinetz, S.J. Halvorson, Z.S. White, J.L. Jorgensen, C.J. Finch, and J.S. Butel, 2002: Association between simian virus 40 and non-Hodgkin lymphoma. *The Lancet,* **359,** 817–823.

WBCSD and UNDP (World Business Council for Sustainable Development and United Nations Development Programme), 2003: Eco-efficiency and cleaner production: Charting the course to sustainability., UNDP online library. Cited 18 October 2004. Available at http://www.iisd.ca/consume/unep.html, last accessed 10.18.04

Webby, R.J. and R.G. Webster, 2003: Are we ready for pandemic influenza? *Science,* **302,** 1519–1522.

Webster, P., 2003: For precarious populations, pollutants present new perils. *Science,* **299,** 1642.

Webster, R.G., 2004: Wet markets—a continuing source of severe acute respiratory syndrome and influenza? *The Lancet,* **363,** 234–236.

Welch, C., 2001: Structural adjustment programs and poverty reduction strategy. The progressive response, *Foreign Policy in Focus,* **4(15).** Cited 18 October 2004. Available at http://www.fpif.org/progresp/volume4/v4n15_body.html.

WHO (World Health Organization), 2002: The World Health Report 2002. World Health Organisation, Geneva, Switzerland.

Williamson, J.G., 2001: Demographic change, economic growth, and inequality. In: *Population Matters: Demographic Change, Economic Growth, and Poverty in the Developing World,* N. Birdsall, A.C. Kelley, and S.W. Sinding (eds.), Oxford University Press, Oxford, UK, 106–136.

Wilson, E.O., 1984: *Biophilia*. Harvard University Press, Cambridge, MA, 157 pp.

Wolfe, N.D., W.M. Switzer, J.K. Carr, V.B. Bhullar, V. Shanmugam, U. Tamoufe, A.T. Prosser, J.N. Torimiro, A. Wright, E. Mpoudi-Ngole, F.E. McCutchan, D.L. Birx, T.M. Folks, D.S. Burke, and W. Heneine, 2004: Naturally acquired simian retrovirus infections in central African hunters. *The Lancet,* **363,** 932–937.

Wright, R., 2000: *Non Zero. The Logic of Human Destiny*. Pantheon Books, New York, NY, 435 pp.

Zimmet, P., 2000: Globalization, coca-colonization and the chronic disease epidemic: can the Doomsday scenario be averted? *Journal of Internal Medicine,* **247(3),** 301–310.