

CHAPTER 3

Dynamics of Social-Environmental Systems

Social well-being rests on many factors. As we saw in [chapter 2](#), education and employment opportunities; technologies and manufactured goods; well-functioning governments, corporations, and institutions to support the workings of society; and the goods and services provided by the planet's natural capital—humanity's “life support systems”—all matter. For sustainable development, they all have to work together—they are part of a tightly coupled system.

In the framework for understanding sustainability introduced in [figure 2.1](#), we followed convention in portraying that tightly coupled system in terms of its production (supply) and consumption (demand) processes. This perspective is useful for analyzing how particular goods and services (e.g., food, energy, housing, etc.) can be produced and consumed in a manner more consistent with sustainable development. If we were writing a text centered on one group of those goods and services (e.g., on the role of the food system in sustainable development), we would almost certainly stick with the production-consumption framing. As we suggested in [chapter 2](#), however, one drawback of that framing is that production and consumption processes are seldom as distinct as they seem when set up in opposition to each other. Rather, each is a cause and a consequence of the other. Another disadvantage is that a focus on particular production-consumption systems tends to obscure the competing demands of other such systems on the capital asset base (e.g., food and energy systems competing for the same water). Finally, the production-consumption framing implies that human choices are all that matter, downplaying the role of nature's own dynamics (e.g., evolution, natural climate change). For all these reasons, we have found it important in the pursuit of sustainability to look beyond particular production-consumption systems to the general properties of the social-environmental systems that set the stage for sustainable development. Those properties, and the dynamics that flow from them, are the topic of this chapter.¹

Understanding how social-environmental systems work is needed to improve predictions of how specific interventions (e.g., new policies, new technologies, new management approaches) are likely to add to or detract from social well-being. However, most scientists, managers, and decision makers have tended to focus on one or another part of social-environmental systems, with little attention to their coupled nature. Development organizations and social scientists have most often focused on human, social, and economic issues, activities, and interactions, setting environmental concerns aside and considering resource issues only in the near term. Conversely, conservation groups and natural scientists in the past have often focused on and given precedence to the environment and “natural world,” with people considered largely as negative pressures that put ecosystems and environmental systems at risk. To meet the goals of sustainable development, the knowledge gained from these narrow perspectives has to be merged. Without an integrated appreciation and understanding of the social-environmental systems in which decisions are being made, unintended and negative consequences will too often result.

The cases introduced in [chapter 1](#) provide some good illustrations of well-intentioned approaches that while succeeding in improving some aspects of human well-being have fallen short in their long-term contribution to inclusive social well-being. In our case study about the Yaqui Valley, the home of the Green Revolution for wheat, the dramatic increase in food production between the 1950s and 2000s rested on the intensification of agriculture through the use of improved cereal varieties, industrial fertilizers, and irrigation. The Green Revolution was all about meeting the needs of a growing human population for food—a very important, well-intentioned objective! Unfortunately, that intensification was sometimes accompanied by leakage of fertilizer and pesticides with resulting negative effects on air and water and human health; overuse of water resources; degradation of soil resources; social inequities; and displacement of communities and indigenous groups. Today’s challenge in the Yaqui Valley and elsewhere around the world is to continue to increase food production on land already under agriculture while reducing the negative consequences that will undermine the well-being of future

generations.

Similarly, the problem with stratospheric ozone started with an effort by scientists to improve the well-being of people. The search for safe refrigerants led to the invention of a wholly new class of chemicals, called CFCs, that seemed safe as well as useful for many other critical manufacturing processes and products. The story up to that point was a great example of science and engineering innovations focused on social challenges and human well-being. Scientists working for the manufacturing companies conducted extensive tests of CFCs to make sure they raised no environmental concerns, and gave them a clean bill of health. Unfortunately, however, they and everyone else missed (because the science of the day lacked a system perspective and didn't consider or measure what happens to CFCs high in the atmosphere) the fact that CFCs could destroy a critical protective layer high in the atmosphere, with potentially negative outcomes for human and ecosystem health. The emerging knowledge of that potential led, over time, to an international agreement that limited the use of CFCs and other ozone-depleting substances. Loss of ozone was no longer considered an "environmental problem" but was acted on because it threatened human health and well-being. (That is, the framing of the problem shifted from "Save the ozone layer!" to "Save us!")

In the long history of London's attempts to manage the needs of a growing city, misunderstandings about social-environmental systems led to human suffering and environmental damage. For example, Londoners of the early nineteenth century did not understand that cholera was caused by bacteria that could be spread through contaminated water supplies. Thinking such diseases were caused by foul odors, the city expended major efforts to drain human waste out of backyards and cesspools into the Thames River. Given that the Thames was a central source of water for residents, this effort in trying to clean the city's environment inadvertently led to the death of thousands of residents from cholera and other diseases. Eventually, through sustained, collaborative, and interdisciplinary work by scientists and citizens, the source of disease was discovered and action followed.

In the case of irrigation in Nepal, consider what happened when

government interventions in irrigation did not take the engagement and concerns of small social communities into consideration. Clearly, not recognizing or, worse yet, ignoring the linkages and interactions in social-environmental systems can cause problems.

How, then, should we think about these systems? What do we know about coupled social-environmental systems and how they can be analyzed and managed?

UNDERSTANDING SYSTEMS

The recognition that humans, their institutions and infrastructure, and their environmental life support systems are part of a coupled system leads those of us pursuing sustainability to ask, how do those systems work? and how do policies, management practices, and other interventions affect the workings of the system? Social-environmental systems are **complex adaptive systems**—systems that have multiple interconnected components that interact in diverse ways. They exhibit positive and negative feedbacks, connections across space and time, and nonlinearities and tipping points that influence the way the system works and the way it changes with each new intervention. But before diving into some of what is known about social-environmental systems—the topic of this chapter—let’s take a brief look at characteristics of systems in general.

Whether used by an engineer describing a car or a wastewater treatment plant, by an ecologist describing a forest, or by an urban planner describing a city, the term **system** generally means a bounded area with a set of elements or components that are connected to and interact with each other. A fisherman and his boat can be considered a system for fishing. But putting them on a lake or ocean creates a new system that now includes water, fish, the food they eat, the predators that eat them, the other organisms that compete with them, the range of fisher communities and the gear that harvest them, and a set of regulations to govern the fisherman’s actions. To analyze and explain what’s happening in and to manage a particular system, one needs to define the system. In other words, the boundaries of the system have to be described.

Social-environmental systems can be defined, studied, and

evaluated at many spatial and temporal scales. Our case study of London, for example, focused on an “urban” scale of tens of kilometers but looked “down” from there to the scale of households and neighborhoods and “up” to the metropolitan area and larger hinterland from which the city drew its capital assets. Our ozone case, in contrast, focused on the global scale, from the surface of the planet to the outer atmosphere and all around the planet. Our Nepali irrigation case focused on the watershed scale but, again, needed to consider both household and national phenomena. In the Yaqui Valley case, scales ranged from the field and farm scale to the agricultural district to the ocean-land regional scale to the state, national, and global scales (figure 3.1). Moreover, connections that link across and between each of these scales are important. In the Yaqui Valley case, for example, decisions made at the field and farm scale made great sense there but were connected—with sometimes unfortunate consequences—to other places and scales through the transfer of water, air, people, other species, and money, among other things. Thus, farm-scale actions led to unintentional effects on downstream water quality in streams, aquifers, and ocean; and upstream air quality, including in populated urban areas of the valley, as well as at a global scale.

Time scale is also important in defining systems of interest. One of the reasons we included the London case in this book is to emphasize the importance, and the difficulty, of seriously grappling with the long time scales inherent in the intergenerational concerns of sustainability analysis. Given the multiple catastrophes that have befallen London over its two thousand-year history, what does it mean today to say that London’s development has (or has not) been sustainable over that period? Looking to the future, should an evaluation of London’s prospects for sustainable development try to look ahead a generation, a millennium, or another period? What time frame should a sustainability analysis of London have considered had it taken place in 1670, in the immediate wake of the Great Plague and Great Fire and with one of its leading citizens bemoaning that “the City [was] less and less likely to be built again, every body settling elsewhere, and nobody encouraged to trade”?²

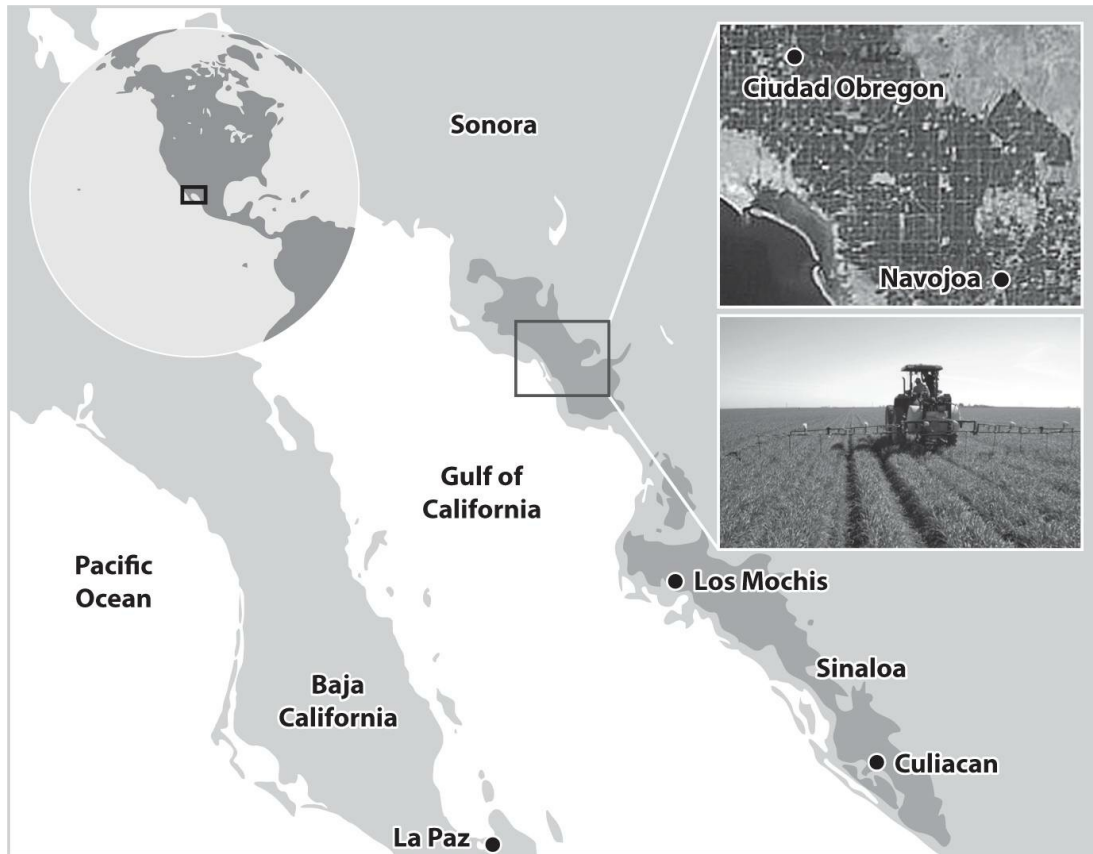


FIGURE 3.1. Various scales in the Yaqui Valley. (Farm field $\approx$ 20–50 hectares; agricultural region: 233,000 hectares; 100 hectares equals 1 square kilometer.)

What is known is that the functioning of systems is very much influenced by what happened to and within it during its earlier history. Economic development has always had a sense of history and temporal dynamics. The study of ecosystems was dramatically changed when ecologists began to realize that ecosystems are not often in “equilibrium” but that past events (like land clearing or hurricane disturbances) influence how the system functions today and will continue to do so in the future.

Spatial and temporal changes in systems can be understood and tracked by measuring the changes in stocks (or amounts, such as the amount of biomass in the trees of a forest, the amount of water in a storage tank or aquifer, the number of people in an office building or city, or the stocks of capital assets introduced in [chapter 2](#)) of particular components of the system over space or

time. In any system, the size or amount of the stock is controlled by inputs and outputs (or inflows or outflows). In a classic example, the amount of water in a bathtub at a particular point in time (the stock of water), and its change over time, is a function of how much water is flowing in minus how much water is flowing out. Opening or closing the faucet influences the amount of water coming in, and opening or closing the drain influences the amount of water going out; together, these inputs and outputs control the stock of water. For Nepali farmers hoping to control water flows into and out of their fields, this becomes a very real exercise—how large the stock of water is relative to inputs and outflows can make the difference between a failed harvest and a successful one. In some systems, the size of the stock is very large compared with the inputs or outputs or their difference. In these systems, there may be a long time lag before the effect of changing the controls is seen. Thus, there is said to be inertia in the system. Inertia in critical stocks sometimes means that “the ship can’t turn on a dime,” and planning is needed (as is the case with climate change).

UNDERSTANDING COMPLEX SOCIAL-ENVIRONMENTAL SYSTEMS

With these characteristics of all systems in mind, how can social-environmental systems be understood and evaluated? In such systems, the five capital assets that we described in [chapter 2](#) (natural, manufactured, social, human, and knowledge capitals) are the relevant “stocks.” The flows into and out of those asset stocks are controlled by many natural processes but also by society’s processes of production and consumption. As we suggested in [chapter 2](#), sustainable development is in many ways a challenge of managing assets to promote inclusive social well-being. Before a course of action is set or an intervention made, it therefore behooves us to evaluate how those actions are likely to change the flows into and out of the asset base of the social-environmental system, and thus the size and composition of the asset stocks and their capability to support sustainable development.

The ability to understand the consequences of different production and consumption decisions for the state of the asset

base seems essential for the informed pursuit of sustainability. Unfortunately, however, complete understanding of those consequences is seldom within reach. Why is this the case? It is because social-environmental systems are complex adaptive systems.

Complex adaptive systems are widely studied in ecology, biology, physics, mathematics, computer science, anthropology, and planning. As we noted earlier, the term denotes systems that have multiple interconnected components with feedbacks affecting their interactions, and that are characterized by self-organization and emergent behavior (in which the system as a whole is more complex and organized than would be predicted by the behavior of the individual parts). The following sections discuss some of the most challenging features associated with complex social-environmental systems—factors that make the informed pursuit of sustainable development difficult indeed.

Feedback Interactions in the System

One of the most important ways that elements of systems interact is through **feedback loops**. Feedbacks result when change in one part or component of a system—a particular process or variable—affects other parts in such a way as to loop back to influence that original component, either by reinforcing the change in that component (a positive feedback) or dampening the change (a negative feedback). Feedbacks result from a chain of events that can sometimes be very hard to measure or predict. Let's look at a few examples of feedbacks that are relevant to sustainable development.

In underprivileged communities lacking in adequate public services, efforts have been undertaken to improve infrastructure and services—through the building of roads and schools and playgrounds and safe water infrastructure, perhaps. These efforts are designed and undertaken purposefully to improve the quality of living for the residents of the community; all else being equal, they should do so. However, a feedback is possible: with better infrastructure and support, the area becomes a draw for people in need, leading to a re-creation and possibly worsening situation of inadequate public services. Only ongoing investment to improve

infrastructure and services can save the place from declining more.

Likewise, the presence of a pristine or high-quality ecosystem (such as a coral reef surrounding a remote tropical island) can positively affect local and national economic well-being through tourism, but overdevelopment of the tourism industry and resulting overexploitation of the ecosystems goods and services can make those benefits very short-term, eventually feeding back to degrade the ecosystem and reduce tourism benefits—and ultimately reducing economic well-being. Similarly, new fishing technologies (including the use of satellite tracking of fish stocks) put in place by commercial fisheries have been incredibly successful in improving catch per fishing effort, thus temporarily improving fishers' economic well-being, but at the same time have contributed to dramatic levels of overfishing that have caused some fish stocks to crash and have ultimately put some fishermen and fisher-women out of business. Clearly, feedbacks can lead to unintended consequences if they are not anticipated and managed.

Our case studies, not surprisingly, illustrate a number of feedback mechanisms. The most severe ones are evident in London's record of population growth ([appendix A, figure A.1](#)): periods of rapid growth were invariably followed by long periods of little change, each reflecting feedbacks from overstressing one resource or another that decreased the viability of the city as a place to prosper. In the Nepal case, successful farmer-managed irrigation systems constructed a crucial feedback to address the “free riding” that was lacking in the failed government managed systems. The farmers did this by negotiating among themselves clear rules for what each household needed to contribute and put in place an agreed-upon system for how members of the community would monitor and enforce compliance. In the ozone story, some feedbacks can be found in atmospheric chemistry (recall the chain reaction that leads to ozone breakdown), but it also involves a fascinating example of a social feedback mechanism. The Montreal Protocol was successful in part because its agreements built in the possibility that new information—from monitoring, scientific studies, or technological advances—could be used to adjust the timeline for reductions in use of ozone-depleting

chemicals. Such feedback proved invaluable, resulting in a series of updates to the protocol that repeatedly strengthened it as new, increasingly worrisome evidence became available.

Invisibilities in Space and Time

The job of making smart choices that promote inclusive social well-being is further complicated by the fact that the parts of social-environmental systems are linked with each other across space and time. Decisions made in one place or time can have consequences in places and times far distant. When those consequences are “visible”—known, understood, and believed—to all concerned, there is at least some prospect that governance agreements can be negotiated to assure that one group’s well-being is not advanced at the expense of others. But what if local choices affect other communities or generations in ways that the decision makers can’t see? Such **invisibilities** abound in social-environmental systems and are often discussed as **externalities** by economists and decision analysts. We’ll come back to the governance of externalities in [chapter 4](#). Here, we focus on the role of science in making them visible to decision makers and concerned citizens so that governance is possible.

The first dimension of invisibility is simply ignorance. When the natural capital asset coal was first exploited to fuel the production of energy services like heat and light in twelfth-century London, no one knew that some of the pollutants emitted through its use could cause dangerous climate change. It would take 700 years for science to mature to a state in which the greenhouse effect was well understood, and another century for that science—and the monitoring it led to—to advance to the point that it made the risks of climate change resulting from fossil fuel use sufficiently “visible” to society that its leaders began to address the problem. The ozone issue moved faster, but when CFCs were first synthesized and added to the world’s stock of knowledge capital in the 1930s, the state of scientific understanding was such that no one could have any idea that this discovery posed risks to the stratospheric ozone layer and thus to human and ecosystem health. Forty years would pass before research and monitoring efforts—both pursued for

reasons largely unrelated to CFCs—would make those risks sufficiently visible to begin stirring political action.

Invisibilities caused by ignorance are ubiquitous in social-environmental systems. Some are made visible as a result of targeted search, such as the quest of epidemiologists to discover whether particular chemicals in the environment pose a risk to health. At least as important for the pursuit of sustainability are curiosity-driven research and monitoring that cast light into the dark spaces of our ignorance, thereby making visible the new dangers as well as the opportunities hidden there.

A second sort of invisibility results when decision makers in one place can't see the damages (or benefits) of their actions to people who live someplace else. Since the overall social consequences of their actions are invisible to them, decision makers are therefore likely to make “selfish” choices that may undermine inclusive social well-being and thus sustainable development. The Nepal irrigation case provides a good example of problems that arise when upstream water users do not see, and cannot be held accountable for, the downstream damages resulting from their decisions to withdraw more than their share.

At a larger scale, transboundary air pollution poses similar challenges. Consider, for example, efforts to deal with this problem in Europe. As shown in our London case, the deleterious local effects of air pollution resulting from the use of fossil fuels were visible to and acknowledged by people there as early as the thirteenth century. Over time, decision makers in London (and Great Britain more broadly) mitigated these unwelcome effects in a number of ways, including by switching fuels and improving technology but also by erecting increasingly taller smokestacks that sent much of the noxious pollution far away: out of sight, out of mind. It was not until the mid-1950s, however, that Swedish scientists began to make visible where that pollution was going, that is, across national borders to be deposited over the rest of Europe. Thirty years of intensive research and monitoring was required, however, before Great Britain's responsibility for significant air pollution damage to others in Europe became irrefutably visible to its public and political leaders. Faced with this

evidence, Great Britain agreed to join other countries in signing an international agreement to reduce the pollution burden that each imposed on the others through its own consumption of energy derived from fossil fuels.

A third dimension of invisibility arises when decision makers in one place can't see the damages (or benefits) of their actions to future generations. Once again, since the overall social consequences of their actions are invisible to them, decision makers are therefore likely to make "selfish" choices that may undermine inclusive social well-being and thus sustainable development. Many examples exist, ranging from the depletion by agricultural production practices of natural capital essential to future generations (e.g., soil and groundwater) to the buildup of slow-acting carcinogens in our water supply. The classic case, however, is again that of greenhouse gases and climate change.

Contemporary science, such as that reported by the Intergovernmental Panel on Climate Change,³ paints a pretty devastating picture of what the future climate could look like if present practices of energy production are not radically changed. Yet, for many political leaders (and the interest groups that fund them), today's benefits from continuing to use fossil fuels are far more visible and compelling than the dim and distant specter of a sizzling and sunken future. Many sectors of society—including social activists, novelists, and filmmakers—are working hard to make more visible the scientific knowledge about the likely future consequences of a continuing carbon-based energy economy, and increasingly, the effects themselves are becoming visible.

Making the invisible visible is an essential task in the pursuit of sustainability. Essential contributors to this process are scientific research, analysis, measurements, and monitoring. It is therefore not surprising that those who would prefer to realize their immediate self-interests while keeping the consequences of their selfishness invisible to people in other places and times also try to undermine science at every turn. Pursuing sustainability is not for the faint of heart.

Complexity

The most important implication of the complexity of social-environmental systems is that “You can’t do just one thing.” The phrase is attributed to many people, but its meaning is clear: feedbacks, invisibilities, and the sheer number of interacting components in social-environmental systems mean that any intervention is likely to have consequences well beyond its intended target.⁴ In our case studies, we see multiple examples. The new “water closets” of early nineteenth-century London achieved their purpose of ridding houses and their adjoining alleys of foul-smelling human wastes. But by conveying those untreated wastes into Thames River, they inadvertently poisoned the city’s principal source for drinking water. The innovation of CFCs greatly enhanced society’s ability to provide safe refrigeration of food, but through a perversely complex chain of unforeseen connections it also put the world at risk by causing depletion of the stratospheric ozone layer. With the introduction of modern technology into the headworks of Nepal’s irrigation system, it indeed worked better at controlling water. However, because the system was under the control of new technology and nonlocal managers, the local farmers lost their incentive to cooperate with one another, which led to a decay of overall system productivity. Numerous additional cases can be drawn from today’s headlines—for example, the unintended effects on food prices of government subsidies to promote biofuels over fossil fuels.

The complexity of social-environmental systems means that all the consequences of new policies or technologies introduced in pursuit of sustainability cannot be predicted with confidence. Better science can help, but it needs to be science imbued with humility. The pursuit of sustainability in complex social-environmental systems needs to be an adaptive process in which the best possible interventions are tried, the results carefully monitored, and the course corrected when things don’t go as planned.

Tipping Points, Regime Shifts, and Surprises

Even a careful adaptive approach with excellent monitoring has its limitations, however. Drive off a foggy road in the prairies, and a

bit of adaptive backing up lets you continue on your way. Driving off a foggy road in the mountains is a very different situation indeed.

Social-environmental systems, like all complex systems, are more like mountains than prairies, characterized by nonlinearities and thresholds beyond which different relationships hold.⁵ A broad and growing literature suggests that social-environmental systems can cross thresholds or **tipping points** at which even a small perturbation can alter the state and functioning of the system, leading to regime shifts. **Regime shifts** are large, persistent, and often abrupt changes in the dynamics of a system that occur because of substantial changes in interactions and forcings in the system. Such shifts are not readily seen until they are upon us, and they can cause quick and surprising transitions from one state or regime to another, with the new one functioning quite differently from its predecessor.⁶ Figure 3.2 illustrates critical thresholds or tipping points that link the different regimes or domains.

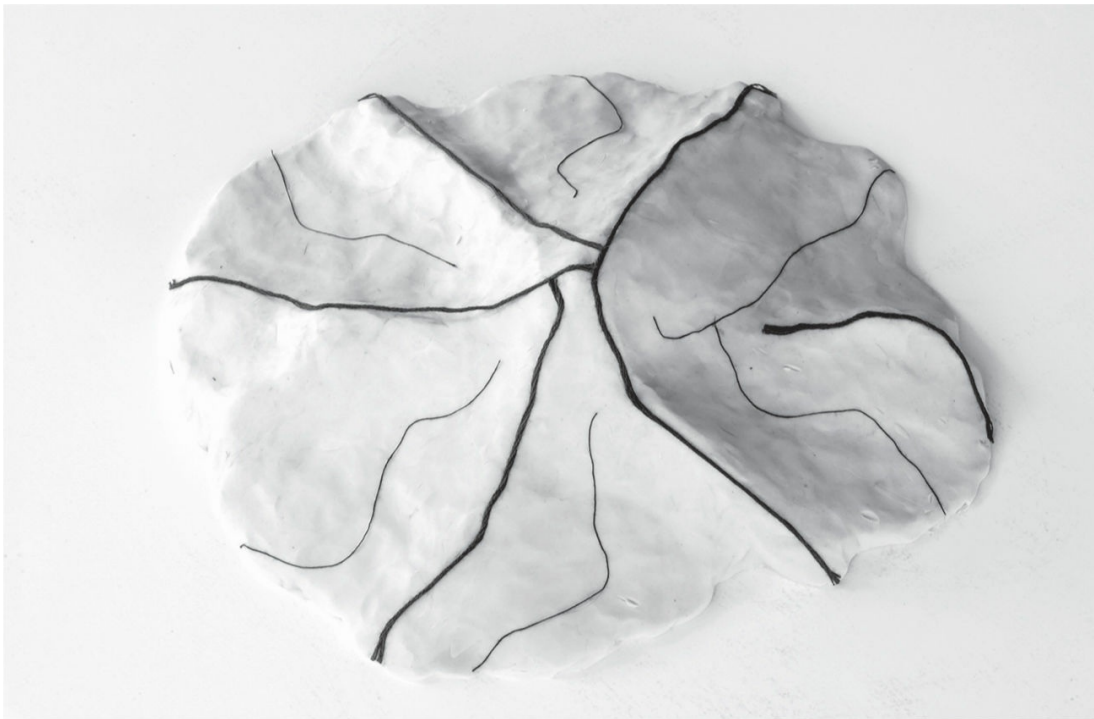


FIGURE 3.2. The regimes in this figure are the six drainage basins, each (let us assume) emptying into a different sea. The “critical thresholds” or “tipping points” are the ridges or divides separating

the basins. A drop of water on a ridgeline (an “unstable equilibrium”) has two or three possible trajectories and destinations awaiting it, depending on which basin (“domain of attraction”) it happens to enter. But as long as the raindrop is still near the crest of the divide, a small “push” can move it back across the divide into the neighboring drainage with consequences for where the drop ends up. In typical landscapes, as the drop moves farther down a particular drainage, most “pushes” won’t be large enough to move it over the increasingly higher ridges (more distant “tipping points”) separating it from neighboring valleys. (In systems speak, its basic trajectory, though not its exact position, is “stable” to a wide range of perturbations.) Of course, a sufficiently large perturbation, whether from a strong wind or a particularly willful water drop, can lift the drop over even a very high divide and “tip” it into the neighboring drainage. Equally important, other forces can progressively erode or lower the divide (“tipping point”), making it easier and easier for the droplet to cross into a neighboring drainage basin and a new trajectory (regime). (© St. Johns River Water Management District)

Regime shifts and tipping points are hot topics of study in some areas of biophysical science. For example, Stephen Carpenter and his colleagues showed how gradual changes in nutrient enrichment slowly influence biological processes in lakes, but with very little apparent change in the way the lakes look. At some point, however—perhaps after a heavy rainstorm that washes large amounts of fertilizer phosphorus to the lake—the system reaches a threshold and tips into a new regime—from a lake with crystal clear water to one that is turbid and green with algae—with implications for drinking water quality as well as recreational use and other ecosystem services.⁷ Recent carbon and climate-related changes in coral reefs, too, provide an archetypical example of regime shift—from hard corals to algae and soft corals—that has been extensively studied and mathematically modeled, and that has serious implications for human well-being. Many other tipping points and regime changes have been observed or hypothesized to be possible as a result of climate change. Some, such as the collapse of the West Antarctic ice sheet, could have serious implications for social-

environmental systems worldwide and for intergenerational social well-being.⁸

Tipping points and the potential regime changes that lie beyond them are also key to understanding social aspects of systems. For example, they are essential to understanding how so-called poverty traps function and how they might be surmounted. In a poverty trap, poverty in a social-environmental system persists over time, “trapping” people and their descendants in a seemingly endless state of poverty. (Imagine a crater at the top of the mountain in [figure 3.2](#). The “trap” would be water stuck in the crater, unable to get over its walls and thereby take advantage of the multiple development paths represented by the descending valleys.) Despite a variety of political and economic interventions, some areas of long-term poverty persist both within developed countries (e.g., the rural Appalachian region in the United States) and on a more global scale (e.g., within many sub-Saharan African nations). Much effort has been focused on finding effective ways to help people cross tipping points from regimes of persistent poverty into more dynamic trajectories of improving well-being. There is growing evidence of “critical asset thresholds” that people must cross to escape poverty.⁹ Though the exact makeup of such thresholds will vary among places, this means that people need certain combinations of assets—human, knowledge, social, manufactured, natural—before their own hard work can help them get ahead. Significantly, natural capital deficits and degradation play a central role in many of today’s deepest poverty traps, a fact that emphasizes the importance of comprehensive asset-based perspectives on sustainable development efforts such as the one we have presented here.

Vulnerability and Resilience of Social-Environmental Systems

Social-environmental systems are exposed to many different kinds of perturbations or external forces—stresses or disturbances or intentional interventions—that ultimately can make them function or work differently and can even lead to regime change. Changes in temperature and precipitation and storminess; land degradation

and changes in soil quality; alternations in the numbers and types of plant, animal, and microbial species; policies that affect economic or financial opportunities; new technologies; and many others can all perturb how social-environmental systems function, with good or bad results for sustainability. Ultimately, perturbations interact with the dynamic characteristics of complex systems that we discussed earlier: feedbacks, invisibilities, tipping points, and regime shifts. The following are several possible results for the overall social-environmental system and for humanity's efforts to manage the assets of those systems in pursuit of sustainability:

- The system can absorb the perturbation and make some adjustments but continue much as before. (Our case study shows London doing this throughout most of its history.)
- It can collapse into its component parts and reassemble its core capacities very slowly if at all. (Following the double whammy of the Great Plague and Great Fire in the late 1660s, London grew hardly at all for a century and was characterized by contemporaries as “less and less likely to be built again, every body settling elsewhere, and nobody encouraged to trade.”)
- It can transform the shock into an opportunity to do things in new ways that allow it to prosper as never before. (London responded to the Great Stink and cholera epidemics of the mid-nineteenth century with innovations in finance, governance, and infrastructure that helped to launch a doubling of its population and its emergence, by the end of that century, as the greatest city in the world.)

What determines the capacity of social-environmental systems to cope with shocks and surprises? While the answer to that question is far from clear, it is the subject of a very active area of sustainability science that focuses on the themes of vulnerability, resilience, and adaptive management. **Resilience** is the ability of the social-environmental system faced with stresses, shocks, or surprises to continue to perform its current functions or even to extract benefits from those disturbances. **Vulnerability** can be

defined as the likelihood of suffering harm. In the context of sustainable development, vulnerability is particularly useful as a lens through which to identify particular social-environmental systems and their component parts—people, infrastructure, ecosystems, resources, economic and governance systems, and so on—that are most likely to suffer damage when stresses, disturbances, and surprises occur. Even when the overall system is coping pretty well, a vulnerability perspective helps us see who or what is left out and needs particular attention if inclusive measures of well-being are not to decline.

How vulnerable a system or its parts happen to be depends on exposure to stresses but, just as important, also depends on access to capital assets: who can and who can't draw on which assets in an effort to cope? In our Yaqui Valley case, for example, the agricultural community managed to grow at least some crops even during a prolonged drought because it had large surface reservoirs as well as groundwater resources to partially tide it over, and government support to fill in financial gaps. That social-environmental system was less vulnerable to climate-related stresses than others that lack natural capital in the form of groundwater resources, or social capital in the form of government policies that support agriculture. Access to institutional structures and networks, education, insurance, and/or new knowledge and technologies for more efficient water use could also reduce vulnerability. More generally, it is largely differential lack of access to assets that make the poor, children, and the elderly more vulnerable in the face of acute disasters like floods and chronic ones like climate change.

What makes a social-environmental system resilient? While there is no definitive set of characteristics, there's a short list of features supported by many scientists and much experience in this field.¹⁰ Among features commonly discussed are diversity, redundancy, and connectivity, all referring to both the social and environmental components of the system. On the environmental side, diversity encompasses biological diversity of species and genes and ecosystems and landscapes, but it can also include diversity in available resources (e.g., both groundwater and surface

water). On the social side, diversity includes variety in cultural groups, livelihood strategies, management arrangements, centers of innovation, and other institutional forms (e.g., building and health codes or poverty alleviation measures). Redundancy or replication of some elements is also important to resiliency in that it provides some insurance against loss of others.

Examples of the importance of diversity in social-environmental system are broad ranging. Agroforestry systems, for example, are valued in many places because they have a range of crop and tree species that are harvested discontinuously over time so that a particular pest or drought or other stress does not lead to failure of the entire food production system. Likewise, diversity in types of organizations (e.g., government, non-governmental, community based, private) provides for some substitutability of support for social-environmental systems under economic, social, or environmental stress.

Connectivity denotes the ways in which resources, species, decision makers, and other components of social-environmental systems are collocated and interact across ecological or social landscapes. The presence of wildlife corridors that link different patches of habitats are one such example of connectivity; communication networks and early warning systems that link people and communities are a second. In the conservation world there is considerable evidence that connectivity—for example, through corridors that link remnant patches of coral reefs or forests—is critical for recovery from disturbance and maintaining population viability and genetic diversity. Likewise, improved and increased methods of sharing information and new ideas have been shown to be essential to the development of solutions to social and technological challenges.

As with most things, it is possible to have too much diversity, redundancy, and connectivity, and end up with exactly the opposite result of the one expected. How much is too much, of course, depends on the particular system and requires contextual research and experience to disentangle. For our purposes, however, it is enough to realize that these structural properties matter and deserve attention in the pursuit of sustainability.

Given that social-environmental systems are so complex, and that vulnerabilities and tipping points abound, the knowledge capital that we discussed in [chapter 2](#) is critically important. Because our best sources of reliable knowledge are not just science but also real-world experience in trying to manage for sustainability, the capacity to learn needs to be viewed as one of society's most important assets. **Learning** can usefully be thought of as the process of acquiring new or modifying existing knowledge, skills, and behaviors.¹¹ It is of fundamental importance in building resilient systems. Likewise, effectively managing a social-environmental system and maintaining or increasing its resilience to disturbance requires continuous revision and updating of knowledge. Experimentation and monitoring are examples of the way learning occurs; equally important are the ways that knowledge is produced and shared among researchers and decision makers. [Chapter 5](#) will focus exclusively on this topic.

EVALUATING COMPLEX SYSTEMS

Given all these complications that play out in complex social-environmental systems, how can their dynamics be better understood and evaluated? Can the connections, interactions, and feedbacks be well enough mapped out to prevent unintended negative consequences or unpleasant surprises as a result of society's or nature's interventions? Unfortunately, the answer now and for the foreseeable future is no. Sustainability science is a young field and is far from having either a comprehensive, integrated understanding of social-environmental systems or the tools to evaluate them quantitatively. Nevertheless, we believe that deploying even a limited knowledge of such systems within the sustainability framework adopted for this book can change mental models and ultimately the ways in which decision makers manage for sustainability. Moreover, much more is being learned as the field continues to develop. Efforts that approximate and predict the dynamics and functioning of particular social-environmental systems in particular contexts and then follow the interventions with cycles of testing, learning, and revising are expanding our knowledge. It is therefore important to understand what kinds of models, tools, and approaches can help decision makers assess their

choices and then monitor, evaluate, and learn from them.

A variety of such approaches allow analysis of social-environmental systems and the consequences and trade-offs that occur within them under different scenarios. While these approaches rarely encompass the entire social-environmental system, they can nonetheless be useful in articulating at least part of the system in the context of the whole. It is not the purpose of this chapter to provide in-depth background on these tools and approaches, but we hope the reader will be intrigued enough to pursue them in further study.¹²

Analytical Models

Within many fields, system dynamics modeling is used to conceptualize and then formalize an understanding of the interactions in a system. Analysts might start with a simple story or drawing that provides a qualitative picture of the system, its most important elements or components, and flows among them. Once they have sketched such a picture, the analysts can test their understanding of the system and explore hypotheses about how the system functions and how components of the system change in response to changing decisions or interventions.

Mathematical models that attempt to integrate social and environmental dynamics are increasingly becoming part of this analysis. For example, agent-based models mathematically represent the aggregate of decisions made by a group of individual “agents” as they use resources or allocate assets in a social-environmental system. Combined with spatially explicit information on the natural capital of the place (e.g., the land or resource base), as well as other assets, such models can be used to better understand the workings of the system and how it is likely to change over time as a consequence of management decisions or policies.

One modeling approach that is useful at regional to global scales is integrated assessment, used, for example, to project climate change and its impacts under various assumptions about the future. Using different scenarios of energy use, population dynamics, technology, and development trajectories, such models

project future greenhouse gas emissions and use the resulting atmospheric concentrations of greenhouse gases to drive climate models, which are ultimately linked to social and environmental impact models. These linked models allow exploration of the effect of energy policy scenarios in terms of human well-being and of the assets of the productive base on which well-being relies. Importantly, these models are moving toward increasing integration of model subcomponents and improved ability to evaluate the coupled system.

A variety of ecosystem services models are in use or under development to help decision makers understand how management of natural capital assets affects the goods and services that can be produced using those assets. These models range from sophisticated simulation approaches to structured survey approaches. They are all intended to evaluate the effects of different choices on the value of ecosystem services produced. They are decision-support tools in that they provide decision makers with information about trade-offs and co-benefits that occur under different scenarios (e.g., different choices about how to use and manage land or water in a given place). Results from such analyses do not tell decision makers what to do but do provide them with information they may use to make choices in the context of their broader values and concerns (see [box 3.1](#) for an example of an ecosystem services model that has made a difference for decision making).

Likewise, multi-criteria analysis (MCA) develops spatial data from satellite or ground-based databases on different land characteristics and overlays those data layers so that decision makers can identify options for the land uses that allow for the most benefits, or the lowest costs, in the context of their goals and values. For example, companies or municipalities selecting sites for deployment of solar arrays or wind turbines might use MCA to identify locations that are already limited with respect to biodiversity or conservation or cultural value but have the greatest resource (sun or wind) value, appropriate land ownership, and good access to electricity grids.

BOX 3.1. Evaluating Ecosystem Services for Decision

Making

Hawaii's largest private landowner, Kamehameha Schools, invited the Natural Capital Project in 2007 to map and value ecosystem services on its unused agricultural land to help make decisions about the land's future. The Natural Capital Project (www.naturalcapitalproject.org), a partnership between Stanford University, the University of Minnesota, The Nature Conservancy, and the World Wildlife Fund (WWF), engaged with Kamehameha Schools and the surrounding community for two years. Working closely with the key stakeholders, scientists in the Natural Capital Project grew to understand the social-environmental system within which the lands were situated.¹³ The project team was then able to create (using their modeling software known as InVEST) spatial models of what would happen to carbon storage, water quality, water yield, income earned, biodiversity, and other services under three different development scenarios (sugarcane monocrops, diversified agriculture and forestry, and residential development). These models were then shared with Kamehameha Schools and the affected communities so that they could discuss the potential trade-offs.

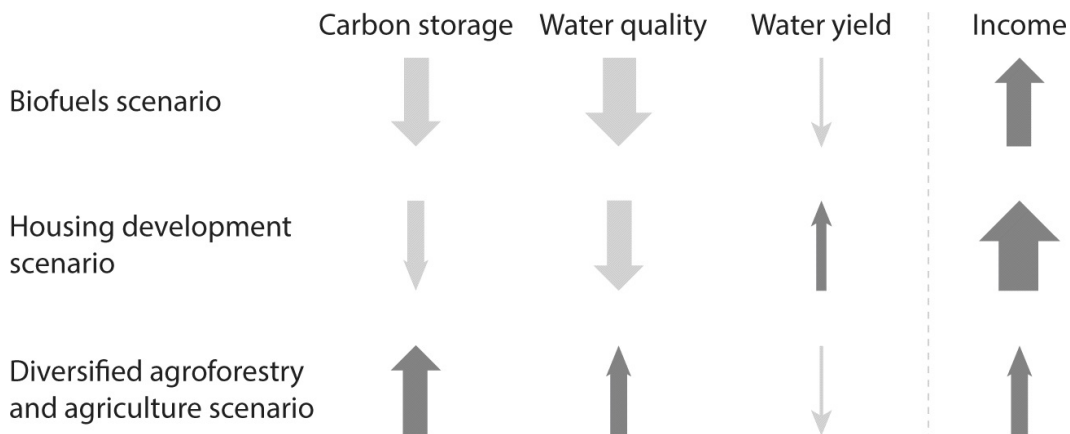


FIGURE 3.3. Projected changes in ecosystem services under three scenarios of future land use using the InVEST ecosystem services model on Oahu, Hawaii. Size of the arrow indicates relative size of the cost or benefit. (Modified from Goldstein, J. H., G. Caldarone, T. K. Duarte, D. Ennaanay, N. Hannahs, G. Mendoza, S. Polasky, S. Wolny, and G. C. Daily. 2012.

“Integrating Ecosystem-Service Tradeoffs into Land-Use Decisions.” *Proceedings of the National Academy of Sciences of the United States* 109[19]: 7565–70; a part of the Natural Capital Project: www.naturalcapitalproject.org)

The models showed that the highest near-term income from the land would result from the residential development scenario, but that carbon storage and water quality would suffer. The sugarcane scenario actually showed the worst carbon storage rating (because of forest clearing that would have to occur) and also had water-quality impacts. The diversified agriculture and forestry scenario positively affected carbon storage and water quality but offered the lowest immediate income. In the end, Kamehameha Schools chose the diversified agriculture and forestry option, because it aligned best with their mission to balance environmental, economic, cultural, and community values. Besides the decision itself, the real benefit of the project was to bring out the key trade-offs “into the open,” where the landowner and stakeholders could see and talk about them. In part because of the Natural Capital Project’s work, Kamehameha Schools won the 2011 National Planning Excellence Award for Innovation in Sustaining Places from the American Planning Association.

Long-term spatially explicit data on all components of the social-environmental system are crucial to constructing conceptual and mathematical models, empirically testing relationships, and tracking change as it occurs. Data acquired from ground-based, airborne, and satellite-based remote-sensing techniques have dramatically improved the measurement and understanding of regional- and global-scale changes in the biophysical parts of the system—including shifts in land use, soil and water quality and quantity, infrastructural patterns, ecosystem status, and many other variables. Data from ground-based observations and experiments can be related to these remotely sensed data and statistically evaluated, including in a spatially explicit context (for example, using geographic information systems [GIS]).

Likewise, data from corporate, local, state, and national surveys

and assessments contribute to an understanding of social-economic parts of the systems. Census data and household surveys, along with aggregated data from a variety of other sources, provide information on health, education, population size and demographics, migration patterns, income, land tenure and ownership patterns, and many other variables. Such data are less easily expressed spatially, and challenges in linking biophysical and social data often center on the mismatch in spatial and temporal characteristics of the databases. The development and linking of such databases, and the use of models and new “big data” analytics to interpret them, will ultimately improve the ability to evaluate and track trends in sustainable development.

Life cycle assessment (LCA) attempts to quantify the system impacts on the capital asset stock of alternative production processes. Its special contribution is in systematically mapping the implications of such processes “from cradle to grave.” That is, LCA seeks to tally (1) how much the production process draws down the raw materials and other capital assets that it uses for inputs; (2) how much the process generates both goods and “bads” like pollution and wastes that damage the capital asset base; and (3) and the extent to which the goods so produced can be recovered at the end of their useful life to once again enhance the capital asset base.¹⁴

An LCA starts with setting out the goals and scope for a particular analysis and then generally includes three core stages: an inventory, in which basic measures of energy, raw materials, and emissions are calculated; an impact assessment, in which the inventory information is translated into the possible environmental or social harms they represent (e.g., logging forests for building materials can lead to habitat reduction and erosion); and an interpretation and analysis of results with recommendations for improvements in the manufacturing process or changes in public policy.¹⁵

LCA enables people to make more informed choices about the trade-offs among different products or processes, though it does not necessarily simplify those decisions. For instance, plastic bags last much longer in the environment than paper and can harm marine

life, but they take much less energy and water to produce. Deciding which impacts are of greatest concern may require public discussions and values assessments, which in turn can be enhanced by appropriate investments in the relevant social capital.

Accounting and Indicator Systems

How can communities, corporations, governments, and non-governmental organizations (NGOs) predict and track their success in managing social well-being? In the last several decades, substantial effort has focused on the development of accounting systems and appropriate and reliable indicator systems for components of a system. Such accounting and indicator systems can estimate environmental damages, the value of natural resources, or national wealth and well-being using measures of gross domestic product (GDP) or gross national income (GNI). These and related measures tend to have at least two weaknesses from a sustainability point of view. First, they measure flows (what is happening now) rather than the stocks or assets that are central to sustainability (what's left to draw on in the future), analogous to flying across the ocean and monitoring only airspeed while neglecting the readout of the fuel gauge. Second, they fail to recognize and integrate the social and environmental as well as the economic determinants of well-being.

Measures of GDP and GNI, as widely used, suffer from other limitations as sustainability metrics. In general, they do not incorporate recognition of or account for externalities, nonmarket assets, wealth distribution issues, and future costs and benefits. They may fail, for example, to account for transboundary effects, as when one country's air pollutants are carried across national boundaries and harm another, or upstream resource use by farming communities affects downstream fisher communities. Importantly, these measures also exclude negative impacts of current activities on the well-being of future generations, such as degradation of natural capital and other capital assets. These indices represent a measure of the current situation, not of the sustainability of that situation.

Increasingly, however, accounting and indicator systems are

becoming more integrative, and although the field is far from mature, progress is being made. In a thorough review of a subset of indicators that represented the breadth of diversity in the group, Parris and Kates evaluated the motivations and goals along with metrics and scale of operation of a large set of indicators.¹⁶ Their review and others like it conclude that while indicators abound and are used widely by governments, corporations, and others—from local to global scales—there is little consistency among them: they are used for very different purposes, with different terminologies, data, and methods of measurement. Moreover, there is not much evidence that they have been used effectively over time to track progress toward sustainability goals. Nevertheless, decision makers are seeking ways of understanding the state of play for all the capital assets in our sustainability framework.

In recent years, a number of new types of social/economic progress metrics have been developed that show promise for measuring trajectories of inclusive well-being. For example, a team of scholars at Yale¹⁷ developed a framework for integrating externalities (in this case, industrial pollutant emissions and the damages they cause to natural, human, and manufactured capital) into national economic accounts. They developed a “gross external damages” (GED) metric that shows how much harm is done by emissions from various industries and compared this measure with the market value (referred to as value added, VA) of those industries. The analysis (which we discuss in more detail in [box 3.2](#), with data in [table 3.1](#)) shows that for industries with a GED/VA greater than one (such as solid-waste incineration and coal and petroleum-fired power plants), society is paying too low a price (assigns too low a value) for the goods and services produced by the industry. For rational policy, either the damages need to come down (e.g., by incorporating different fuels or technologies in the process of producing electricity) or the market price needs to go up (e.g., via taxes to reflect the social damages and lower consumption) or both.

BOX 3.2. Framework for Integrating Externalities

In their framework for integrating externalities into national

economic accounts, Yale researchers developed a “gross external damages” (GED) metric showing how much harm is done by emissions from various industries, compared with the market value (VA) of those industries, that is, how much people are currently paying as consumers for what the industry produces. The analysis is backed by exquisitely detailed science that identifies the emissions of each industry at each place in the country, then distributes and transforms those emissions over the country using state-of-the-art atmospheric chemistry and transport models, and finally assesses damages by comparing pollutant deposition at each point around the country to “dose-response” curves showing the relationship between concentration and impact. They then sum these numbers across the entire country to compute the GED resulting from all the industry’s air pollution. Finally, they create a GED/VA ratio ([table 3.1](#)). (The damages to society from greenhouse gas emissions and the resulting climate change are not included in the numbers reproduced in [table 3.1](#), though they are discussed in the original paper. Other pollution damages, e.g., those associated with water pollution by the same industries, are also not included. The GED/VA ratios reported in the table are therefore certainly underestimates of the true values.)

TABLE 3.1. U.S. INDUSTRIAL PERFORMANCE: GROSS EXTERNAL DAMAGES (GED) INFLICTED ON SOCIETY BY AIR POLLUTION (IN \$BILLION, 2000 PRICES) AND ITS RATIO TO VALUE ADDED (GED/VA)

Industry	GED/VA	GED
Solid-waste combustion and incineration	6.72	4.9
Petroleum-fired electric power generation	5.13	1.8
Sewage treatment facilities	4.69	2.1
Coal-fired electric power generation	2.20	53.4
Dimension stone mining and quarrying	1.89	0.5

Marinas	1.51	2.2
Other petroleum and coal product manufacturing	1.35	0.7
Steam and air conditioning supply	1.02	0.3
Water transportation	1.00	7.7
Sugarcane mills	0.70	0.3
Carbon black manufacturing	0.70	0.4
Livestock production	0.56	14.8
Highway, street, and bridge construction	0.37	13.0
Crop production	0.34	15.3
Food service contractors	0.34	4.2
Petroleum refineries	0.18	4.9
Truck transportation	0.10	9.2

Source: Muller, N. Z., R. Mendelsohn, and W. Nordhaus. 2011. "Environmental Accounting for Pollution in the United States Economy." *American Economic Review* 101(5): 1649–75.

So what? For industries with a GED/VA of more than one, the straightforward conclusion is, "since you are in a hole, stop digging." That is, with each additional unit of production from those industries (e.g., electricity from coal), society emerges worse off than if the production hadn't happened at all. Industries in this category are the ones at the top of the list in the GED/VA rankings of [table 3.1](#), most notably, waste treatment and electric power production based on coal or petroleum fuels. (The GED column shows that by far the biggest factor is excessive production of electricity from coal.) Sane people (or societies) would stop doing—or do less of—things that hurt them. More precisely, this rigorous research

shows that for industries with a GED/VA value greater than one, given the damages caused by each additional unit of production from that industry, society is paying too low a price (and assigns too low a value) for the goods and services it produces. For rational policy, either the damages need to come down (e.g., by incorporating different fuels or technologies in the process of producing electricity), or the market price needs to go up (e.g., via taxes to reflect the social damages) or both. In either case, the (much) higher market price (from required technologies, or an emissions tax) should lead to (much) lower emissions and GEDs. At some point, the price would be sufficiently high, the technology sufficiently clean, and the demand sufficiently low that society would not perversely destroy its own well-being to continue utilizing the industry. To get to that point, however, will require that (1) policy making recognizes that “free markets” often create the sort of externalities that the Yale team so carefully documented; (2) scientific research to make those externalities “visible” to producers and consumers is essential; and (3) turning visibility into real corrective action requires governance structures that protect the rest of society from those who deplete inclusive well-being.

At the scale of national accounting, the Inclusive Wealth Project is of particular interest and promise. The project is an international UN-based effort to extend an approach initially developed at the World Bank to measure changes in the capital asset base of countries through time.¹⁸ In particular, it develops an Inclusive Wealth Index (IWI) that is intended to show how an aggregate measure of the social value of society’s capital assets changes over time. The theory behind the IWI—like that behind the sustainability framework presented in this book—holds that so long as the per capita inclusive wealth of society is not decreasing, neither is its per capita inclusive well-being, and thus its development can be tentatively judged to be “sustainable.” The project’s *Inclusive Wealth Report 2014: Measuring Progress toward Sustainability*¹⁹ compiles data on a selection of the natural, human, and manufactured capital assets of 140 countries over the period

1990–2010. (Although the current approach is far from complete, ongoing work of the project seeks to incorporate additional dimensions of the assets already included and to address changes in social and knowledge capital.) Some of the results published in the 2014 report are reproduced in [figure 3.4](#). These suggest that the development trajectory for the world overall is (barely) increasing its inclusive wealth per capita and thus is (barely) sustainable. Not surprisingly, the IWI data on trajectories of individual regions and countries suggest that some are on development paths that are comfortably sustainable (e.g., Western Europe), while others are on paths that—if continued—will leave their grandchildren impoverished (e.g., East Africa). Less obviously, it highlights for each country which capital assets are on trends that most support sustainable development, and which are on trends that undermine it. The IWI is, of course, incomplete. It explicitly tracks only the “tangible” capital assets (natural, human, and manufactured or, as IWR calls it “produced”) while estimating the difficult-to-measure “intangible” assets of social and knowledge capital. And, constrained by limitations of data and theory, the IWI includes only a few of the many elements that should eventually be enumerated in calculating values of the broad tangible asset stocks. It therefore seriously underestimates the true wealth of nations, though the trends it reports are not obviously biased in one direction or another. Nonetheless, the IWI is a beginning, and for pursuing sustainability it is a huge improvement over previous metrics such as the GNP or the human development index (HDI). A vigorous program of research and monitoring is under way to improve future editions of the report.

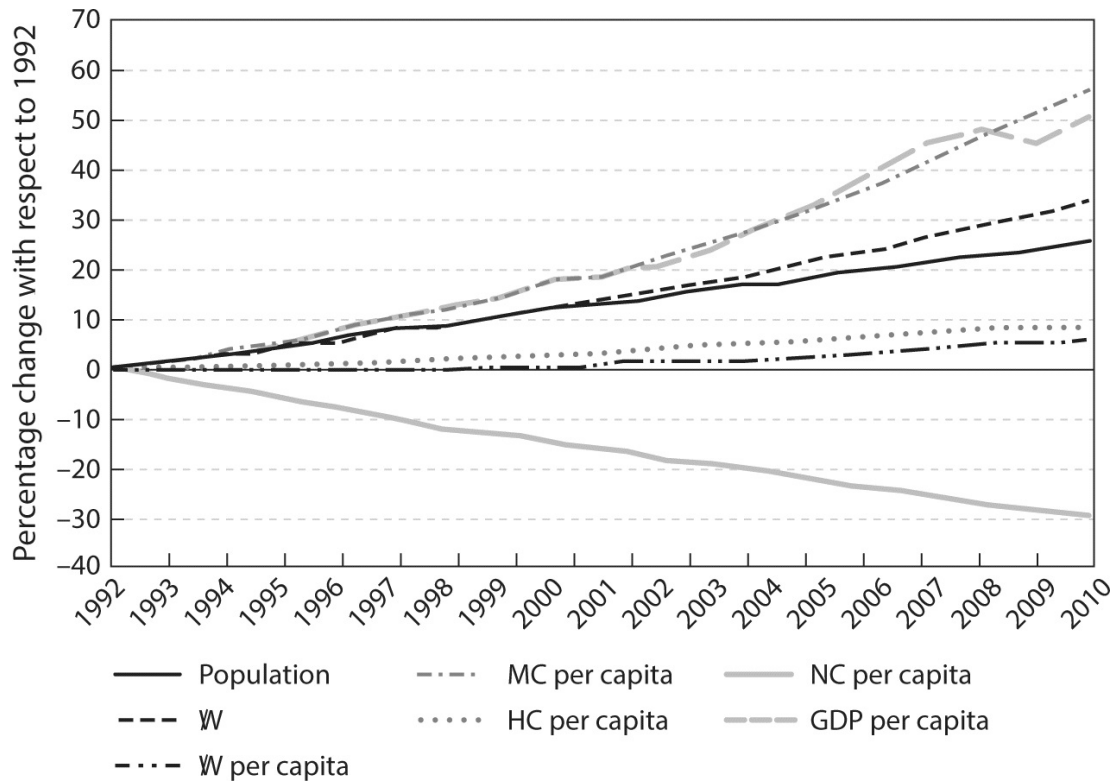


FIGURE 3.4. Changes in worldwide inclusive wealth per capita and other indicators for 1992–2010. Lines represent different types of capital: HC, human capital; MC, manufactured capital; NC, natural capital; and GDP, gross domestic product. $\mathbb{W}$ is the inclusive wealth index. (UNU-IHDP and UNEP. 2014. *Inclusive Wealth Report 2014: Measuring Progress toward Sustainability*. Cambridge, MA: Cambridge University Press)

THE NEED FOR INTERDISCIPLINARY RESEARCH AND PROBLEM SOLVING

Reflecting on what we’ve discussed in this chapter, it is easy to see why understanding and managing coupled social-environmental systems for inclusive well-being is such an enormous challenge. These are complex systems with many interactions among many parts, and analytical frameworks for comprehending them are in early stages of development. To understand social-environmental systems, and to pursue sustainability within them, researchers, decision makers, and concerned citizens have to draw on many kinds of knowledge and know-how. Science for sustainability is a big tent, and many different kinds of expertise are needed (recall

the range of scholarly disciplines and professions listed earlier in [table 2.1](#)).

However, all these different kinds of expertise and knowledge would fall far short if they operated alone. Researchers and practicing professionals need to understand each other's languages, respect and appreciate each other's methods and approaches, and recognize where and how their limited knowledge can make a difference. Ultimately, understanding and managing social-environmental systems for sustainability requires team efforts with both disciplinary expertise and specialists who work purposefully at the interfaces among components of these complex adaptive systems. We illustrated the challenges and rewards of such teamwork in our case study of the Yaqui Valley. We dig more deeply in [chapter 5](#) into what is known about the kinds of partnerships among decision makers and researchers that can successfully link knowledge with action for sustainable development. First, however, we turn in [chapter 4](#) to the governance systems within which those partnerships must operate and through which experts—and also the other “actors and agents of change” highlighted in our framework ([figure 2.1](#))—must learn to work in their pursuit of sustainability.

CHAPTER 4

Governance in Social-Environmental Systems

The concept of **governance** includes the decision-making process that creates and enforces rules about what people may, must, and must not do in interactions with one another and with the rest of the social-environmental system.¹ In the context of the framework for understanding sustainable development and working toward sustainability that we use in this book ([figure 2.1](#)), the governance process, and the rules that it produces, are an important part of a society's assets of social capital. Governance and the resulting rules might address very concrete questions, such as, How much pollution is a company allowed to emit? Who is entitled to unemployment benefits? What is the punishment for breaking a given rule? The rules will also define who has the right to participate in governance decision making and who is in charge of enforcing the rules.

When the social “actors and agents of change” of our framework agree to create, implement, and abide by rules, they are thus engaged in processes of governance. Those **governance processes**, together with other production and consumption processes we discussed in previous chapters, determine the dynamics of social-environmental systems.

Governance is important in the pursuit of sustainability in that its rules or arrangements are among the core components of social capital and thus are among the determinants of inclusive wealth and well-being. Governance processes provide a means through which people can change the nature of social-environmental interactions so that human activities do not drive down the overall asset base on which future generations depend. Through a mix of “carrots and sticks,” governance can produce rule systems that sway citizens, corporations, governments, and other organizations to contribute to the goals of sustainable development.

To govern a social-environmental system effectively, however, is easier said than done. Pursuing sustainability will require better integration, more coordination, and cooperation at an

unprecedented scale. Many of the problems discussed in this book—such as overfishing, rural poverty, and pollution—have come about because of limited or failed efforts to govern our shared social-environmental systems. Societies with weak governance processes are prone to generate production and consumption patterns that degrade capital assets while improving the well-being of only a select few members of those societies.

It is not just the *lack* of governance that poses a problem for sustainable development. Sometimes governance itself is the problem. One of the challenges in creating governance arrangements more consistent with the goals of sustainable development is that the actors most influential in shaping the existing processes—such as nation-states, corporations, political parties, and sometimes special-interest groups—rarely hold the same goals and often disagree on how social-environmental systems ought to be governed. Some of these actors benefit enormously from unsustainable practices and resist any effort to change business as usual because such changes might jeopardize their privileged positions in society. Individuals and organizations pursuing sustainability thus face a serious challenge: how can the existing governance processes and arrangements, which are shaped by powerful actors with vested interests, be reshaped so that they are more conducive to achieving inclusive social well-being?

Strategies for overcoming such challenges can benefit from a deeper understanding of governance and how it can promote social change. Simply saying “we need to change things” or “we need to cooperate more” is rarely helpful. More nuanced strategies that address some of the fundamental barriers to social change are needed. The goal of this chapter is to outline some of the concepts and lessons learned about understanding and influencing governance in social-environmental systems. It ends with a discussion about how a better understanding of governance can help the quest to organize concerned citizens and scientists in ways that contribute to the pursuit of sustainability.

CONCEPTS AND A FRAMEWORK FOR ANALYZING GOVERNANCE

Several conceptual foundations underlie our understanding of what governance is and why it is important for sustainability. In this section, we discuss these concepts and propose a conceptual framework for diagnosing governance problems and for exploring possible options for addressing such problems.

Core Governance Concepts

Three concepts are useful for developing a better understanding of governance and how it affects sustainable development efforts: (1) collective action and collective-action problems, (2) externalities, and (3) common-pool resources and the “tragedy of the commons.”

Collective action occurs when two or more individuals cooperate to accomplish a goal they cannot achieve individually. For example, the group of farmers described in our Nepal case engaged in collective action when they decided to work together to build and maintain their own irrigation system. Groups of citizens concerned about loss of ozone acted collectively to urge their government leaders to keep the negotiations leading up to the Montreal Protocol moving forward. A group of students act collectively when they organize a campaign to put pressure on their university to adopt a zero-carbon emission goal. Many of the traits or “goods” of a functioning society—such as law and order, public safety, economic growth, and environmental protection—require coordinated collective actions at a very large scale. Because these “goods” will not evolve automatically, it is necessary to develop a structured process for agreeing on and implementing rules to steer individual behavior in ways that promote outcomes that are good for society as a whole. We refer to this decision-making process as governance. Governance is an important part of a society’s social capital because it can produce the rules needed to address collective-action problems.

A **collective-action problem** occurs when a group of individuals fail to accomplish their common goal. People can fail to cooperate with one another for many reasons. They may lack motivation to cooperate or lack the information needed to accomplish the goal, or they may engage in a power struggle over who should control the decision-making process. Collective-action

problems are common in all efforts to make changes in society. For example, students who are mobilizing to persuade their university's leadership to act on climate change will try to get other students to participate in the campaign, but some of those other students may not be motivated to join the collective action. In that particular case, there are several possible causes for the collective-action problem: students may not believe that the protest will actually make a difference, or they may have other activities that are more important to them, or they may think climate change is not caused by humans, or they may agree with the greater cause of the protest but prefer that others do the protesting. Student organizers need to figure out a way to overcome these collective-action problems, or their efforts will fail.

Sometimes, the failure to act collectively leads to individual actions that have significant consequences for people who are not directly involved with the decisions. When these consequences cause damage, they are referred to as **negative externalities**, because decisions adversely affect third parties who are external to the setting in which the decisions were made. As we discussed in [chapter 3](#), this is one form of the “invisibilities” common to complex social-environmental systems. Pollution is a classic example of a negative externality. Because the polluter—a business, for example—does not bear the full cost of its actions (in an unregulated scenario), it is therefore likely to pollute more than would be the case if it had to take the costs of the damages into account.

Negative externalities are particularly difficult to address when the affected party is not well organized politically or has limited opportunities to influence the governance process that could potentially correct the externality. Nevertheless, substantial progress has been made in the governance of the use of some resources susceptible to negative externalities. Harkening back to our case studies, the damage to the stratospheric ozone layer caused by the production and consumption of CFCs has been effectively addressed by a global treaty. Forceful governance responses to the Great Stink of London managed to clean the Thames River of many of the wastes it collected as it passed

through the city. These examples are a historical record of real progress on governance in social-environmental systems, although there is much more to be done.

Positive externalities also exist. The form most relevant to sustainable development may be technical innovation. Inventors often see the fruits of their work adopted by others who did not bear the costs and risks of research and experimentation. While such widespread, relatively costless adoption can be an effective way of assuring that the benefits of a particular innovation are accessible to all (especially the poor), it can also undercut the profit motivation for future inventions. Managing such positive externalities—assuring that inventors will continue to have an economic incentive to produce the innovations societies need but also that the results of their labors will be widely accessible on terms that everyone can afford—likewise requires creative governance processes to promote collective action. An early response to such challenges was the system of international agricultural research centers that invented and then gave away for free the seeds that launched the Green Revolution. The centers could do this in part because they were staffed by idealistic researchers and funded by public-spirited private foundations and, later, by national governments working through the UN system and the World Bank.

In a more recent situation, effective drug therapies for HIV/AIDS were finally created through investments of rich governments and profit-making pharmaceutical firms. But firms seeking to recoup their research costs filed patents on the drugs and then charged prices that could not be afforded in poor countries—a classic positive-externality dilemma. The tension between the need to incentivize future research and the responsibility to provide access to essential drugs presented a dilemma for governance. That dilemma was resolved, however, after political clashes between international civil society networks and developing-country governments on one side and the pharmaceutical industry on the other gradually produced an unwritten political bargain: wealthy countries would continue to pay high prices for HIV medicines to reward research and

development investments, while developing countries would purchase generic drugs at close to the cost of production through exceptions made to patent rules.² More such inventive governance arrangements—which almost always involve collective action among activists, entrepreneurs, scientists, and lawyers—are needed in the pursuit of sustainability.

One of the most well-known collective-action problems related to social-environmental systems is described in Garret Hardin's 1968 classic paper, *The Tragedy of the Commons*. Hardin argued that people who share resources are trapped in a collective-action problem that produces competition for resources that can spin out of control until the resource eventually collapses.³ The analogy he used in his paper is that of two farmers who share a meadow where they graze their individually owned cattle. Each farmer sees it in his own interest to keep adding more animals to the shared meadow. And even though the farmers know they would both be better off in the long run if they maintained a limited and stable population of grazing animals, they are unable to reach such an agreement, leading to a degradation of the grazing system and a bad outcome for both.

What Hardin describes is a specific type of collective-action problem that sometimes occurs in situations where multiple individuals share a **common-pool resource (CPR)**. Many of our natural resources such as clean air, forests, and groundwater may be considered CPRs. They are particularly challenging to manage, because they are finite resources, and it is difficult to prevent anyone from using them. Because of these attributes of CPRs, a rule system that is recognized by the resource users is needed to control access to and regulate use of the shared resources. In that sense, governance can be thought of as a strategy for addressing behavioral problems that threaten the condition of the shared resources. If such arrangements are not created and enforced, the CPR is at risk of overuse, and a tragedy of the commons becomes more likely.

In a nutshell, the significance of governance in the social-environmental system is that it can help overcome collective-action problems in society by producing rule systems that steer individual

actors (people, corporations, states) so that their behavior is consistent with the long-term goals for a society as a whole.

Unpacking Governance: A Conceptual Framework

Conceptual frameworks and models help analysts think more systematically about complex issues. In [chapter 2](#) we discussed a broad framework for thinking about sustainability goals and linking them through the dynamics of the social-environmental system to the capital assets that are their underlying determinants. That framework identified governance as an important component of the social-capital assets. While the framework in [chapter 2](#) is comprehensive, a more detailed framework “nested” within it is helpful for assessing the specific factors and characteristics that influence the ability of governance to alter existing unsustainable behaviors. We present such a framework in [figure 4.1](#) and hope it will help the reader appreciate how governance matters for sustainable development, as well as diagnose potential shortcomings related to governance in specific contexts.

Our governance framework consists of six main components. Starting from the left-hand side in [figure 4.1](#), the first component is *actors and agency* (compare with the leftmost box of our more general sustainability framework in [figure 2.1](#)). These are the people, groups, organizations, or states involved in the decision-making process or affected by the decisions. **Actors** can be as large as countries or multinational organizations and as small as households or individual people. Their particular characteristics include values, beliefs, power, agenda, interests, capacity, and motivation. One of the goals of this part of the analysis is to assess the degree to which different actors have **agency**, that is, the degree to which individual actors have the capacity to act independently and to make their own decisions. Agency is an abstract concept that is difficult to measure directly, but it is possible to characterize an actor’s degree of agency relative to that of other actors by comparing access to political power, financial resources, and information. In sum, this stage of the governance analysis seeks to identify the main actors, their interests, and main characteristics—and how these affect their degree of agency.

In the Yaqui Valley case, researchers eventually mapped the actors who were associated in some way with decision making related to farming practices (see [appendix A, figure A.8](#)). In doing so, they discovered that it was the lending policies of one category of the non-individual-farmer actors in the valley—the farm credit unions—that effectively discouraged farmers from adopting more sustainable fertilizer techniques. Once this actor was identified as being an important influence on local farming practices in the valley, targeted efforts were made to understand the credit unions’ concerns and to engage them in the creation and testing of technologies that could lead them to policy change.

Mapping out the actors, how they interact with one another, and assessing the main attributes of the political process can be helpful for understanding the sources of existing problems of sustainability as well as for identifying potential levers for change. Another benefit of mapping out the actors—the who’s who in a particular context—is that it can help locate potential allies with whom to collaborate to become more effective in the decision process that may eventually produce change.

In the next step of the governance framework, the focus is on the ways in which the identified actors interact with one another through a **political process** in which collective decisions are made. As shown in [figure 4.1](#), this political process can exhibit varying degrees of transparency, accountability, representation, and legitimacy. The knowledge gained from this stage of the governance analysis is often important for assessing the degree to which these existing processes are appropriate for addressing a particular problem. For example, in the case of the Nepali irrigation systems, the national government of Nepal decided in the 1960s to invest in the expansion and improvement of the country’s irrigation infrastructure. However, the decision-making process for designing many of these systems involved mostly engineers, government officials, and international donor representatives. The political process failed, at least initially, to involve and be accountable to the farmers themselves, and this shortcoming led to poor design decisions (see [appendix A](#) for more details).

It is important to recognize that political processes exist at

multiple levels and that decisions at one level are often influenced by decisions and governance processes at higher levels of political authority. For example, the rules created by the governance process at the national level may be influenced by international treaty negotiations, as was the case for the ozone treaty. Governance (and for that matter, most other social-environmental system processes) is often a nested enterprise.

One of the essential outcomes of the political process is **institutional arrangements**, the next stage in the governance framework. Institutional arrangements, or rules, can be either formal or informal. Examples of rules include policy, regulations, local norms and customs, contracts, and property-rights arrangements. Rules specify not only the rights and responsibilities for using and managing a resource but also the agents whose responsibility it is to monitor and enforce rule compliance.

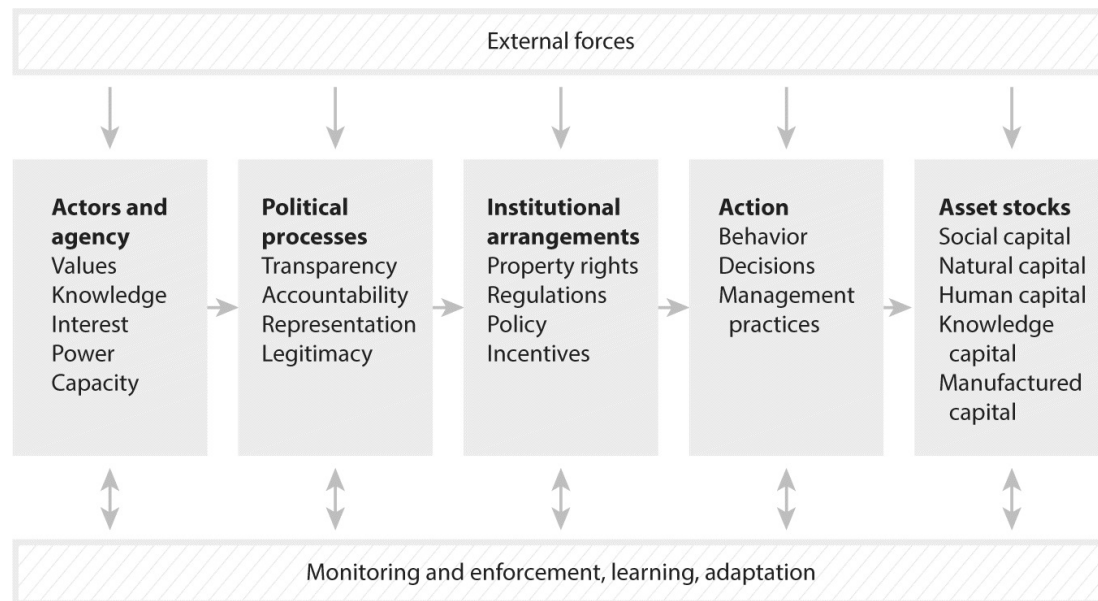


FIGURE 4.1. The governance framework for social-environmental systems. This is a higher-resolution framework to complement that introduced in [figure 2.1](#). Its purpose is to help in the assessment of the effect of governance on human interactions with capital assets.

This may be the most important part of the governance analysis, because so much of the effectiveness of the human responses to a problem depends on the specific characteristics of

the rules introduced and how they are enforced (if at all). The farmers in Hardin's *The Tragedy of the Commons*, for example, were not constrained by any regulations or policy about how many animals they could add to the meadow, and no effective property rights to the land or the resources appear to have been enforced in that case. As a result, the farmers pursued their narrow, short-term self-interest until their social-environmental system collapsed.

One intention of introducing new institutional arrangements is to affect people's **incentives**. In governance analysis, the term *incentive* refers to expected rewards and punishments that individuals perceive to be related to their actions and those of others.⁴ Rules define when, how, and to whom different rewards or punishments should be applied. Rewards can be monetary, such as a wage, tax credit, rebate, or a bonus. Rewards can also be nonmonetary in nature and include earning the respect of one's peers, the satisfaction from learning new skills or knowledge, affection, and the feeling of having done the right thing. The threat of punishments of different kinds can also function as incentives. Such punishments may be the threat of a lawsuit, consumer boycott, fine, jail sentence, social exclusion, or loss of employment. These are all external stimuli that may encourage more of some kinds of behavior and less of others.

In the subsequent stage of the governance process, the focus is on human **action**, including the behavior, decisions, and day-to-day practices that people choose to pursue. For institutional arrangements to affect these decisions and actions, people need to know about the arrangements, understand them, and choose to abide by them. That is unlikely to happen unless the governance processes enable actors to monitor and enforce rule compliance. For example, in the Nepali case, the local rule system laid the ground rules for what each family was expected to contribute for the building and maintenance of the irrigation canals and what would happen if an individual did not meet those expectations. The village elders monitored and enforced the agreements. It is hard to imagine that the villagers would have been able to build the canals, maintain them, and pay off the loan on time had it not been for the enforcement of these elaborate rules.

In the analysis of governance in social-environmental systems, special attention is paid to institutional arrangements that seek to regulate behavior related to human use of the asset base. As a result, it is useful to consider how the different **capital assets** are likely to respond to the introduction or modification of a particular institutional arrangement, which in turn will sway an actor to decide to take a certain action or behave in particular ways. These actions may have a direct effect on asset indicators, such as pollution levels (natural capital), people's health (human capital), the condition of road infrastructure (manufactured capital), the level of interpersonal trust in a society (social capital), and the creation of new inventions (knowledge capital).

The different uses and exploitations of the capital assets permitted or forbidden by institutional arrangements can lead to very different outcomes in the condition of these assets. Simply put, *the condition of the capital assets is unlikely to improve unless a critical mass of actors work together to change the rules about how the asset base is accessed and used.*

External forces also shape governance. At all levels of governance in a society, there are factors beyond the control of the actors at any given level (e.g., household, community, region). Examples of external forces include solar radiation, climate change, global population growth, natural disasters, global price fluctuations, decisions higher up in the political hierarchy, international agreements, and any other factor external to the governance system at any given level. Some of these forces are surprises, while others are predictable trends. When there is no apparent way to change these forces through the governance process at their scale, actors' best response to these external forces may be just to accept that they exist and adapt to them as best they can. At other times, it may be possible for actors to appeal to higher levels of governance, where collective action among actors may be able to respond more effectively to these external forces.

Each of our four cases described different types of external forces that affected how people interacted with the rest of the social-environmental system. For example, in the Nepali irrigation case, changes in climate—more frequent droughts and irregular

monsoons—represented very disruptive external forces that prompted the local farmers to take collective actions. In the London case, the various epidemics that wreaked havoc among the city's dwellers were caused by a combination of the arrival of disease organisms from the outside (e.g., the plague and cholera) and the existing socioeconomic and biophysical conditions in London that facilitated the spread of the diseases.

But external forces can also have a positive effect, as was illustrated by the creation of chemical refrigerants to replace the ozone-depleting CFCs. This innovation—which perhaps wasn't completely external to the governance system, because the innovator (e.g., DuPont) was arguably one of the key actors—was nevertheless very important for the outcomes because it allowed people and companies to satisfy their demand for inexpensive coolants and aerosols without inflicting more harm on the stratospheric ozone layer.

The box at the bottom of [figure 4.1](#) depicts feedback loops to monitor and enforce the governance process, to learn from experience, and to adapt future iterations of the governance process. In [chapter 3](#) we discussed feedback loops as critical aspects of complexity in social-environmental systems. They function similarly here in reference to the governance process. In cases where actors are surprised by the way the governance process plays out—perhaps the new institutional arrangements didn't affect human behavior as expected—these actors may want to reassess the appropriateness of those arrangements. This adaptation and learning process may continue over time with varying degrees of success, as was clear from all the case studies introduced in [chapter 1](#). As one hurdle is cleared, another often appears, and so the work to promote sustainable development continues.

The real challenge in applying this conceptual framework for governance is to determine which particular approaches to governance will work in specific contexts and situations. This framework will not produce one right answer on how to improve governance. It can, however, help analysts systematically assess the strengths and weaknesses of a given governance process and formulate more thoughtful strategies that can serve as the starting

points for governance reform. Practitioners trying to develop such strategies will also benefit from several take-home lessons gleaned from contemporary research on governance.

LESSONS FOR GOVERNANCE IN SOCIAL-ENVIRONMENTAL SYSTEMS

Research on governance in social-environmental systems has produced several potentially useful findings applicable to governance reform efforts. The following five of those lessons are discussed next: (1) diagnose barriers to cooperation; (2) figure out what makes people tick; (3) assess multiple possible governance responses; (4) consider interventions to be experiments to learn from; and (5) recognize that knowledge is power.

Diagnose Collective-Action Problems

Before trying to fix something, one needs to understand what is broken. Understanding what the problem is and why good outcomes are not materializing is the most important goal of any governance analysis. A collective of any size—whether a local user group or a nation or even the global community—that is falling short of its expectations to achieve certain collective outcomes needs to understand why collective action is failing before it can design an effective solution. All efforts to mobilize collective action face a large variety of challenges, which may be grouped into motivational problems, asymmetries of power, and information problems. A brief description of each of these common barriers to collective action follows.

One of the most common sources of breakdowns in collective action is related to weak individual motivation to contribute to the common good. The better off an individual is in the current system, the weaker his or her motivation to invest in a process that might change it. Even if an individual would like to see a change in the status quo, that person is tempted to let others do the heavy lifting in the change process. **Free-riding**, or attempting to benefit from a shared good or service without contributing to its provision, is a common barrier to cooperation. The larger and more heterogeneous the group, the harder it is to overcome this barrier.

But people may not be motivated to engage in cooperation for many other reasons. They may not see the proposed cooperation as relevant enough to warrant their support or may not perceive the real costs of continuing with business as usual. They may be oblivious to the risks associated with their existing behavior and fail to see the looming crisis. Most of these motivational barriers have to do with the beliefs and values people hold and the ways in which people perceive themselves and the world around them. In our Nepali case, farmers shared a perception of crisis and high costs of inaction that ultimately brought them together. In essence, they were motivated to set aside their differences and instead focus on their common interest in building a common irrigation system. Actors who seek to facilitate collective action will be more effective if they understand the sources of people's motivation, or the lack thereof.

Asymmetries of power exist when some actors are more powerful than others. The basis for holding power can be economic, social, or political. Most collective-action situations occur in contexts shaped by preexisting distributions of power, in which elites may make decisions that give them a disproportionate share of available assets, and they resist any initiative that seeks to change the status quo even if such an initiative would mean higher productivity for society as a whole.

What implications do such asymmetries have for sustainable development? When actors do not have a say, or even a seat, at the decision-making table, they lack power in the governance process. As a result, the needs of marginalized groups may not be taken into account when collective decisions are made. Regarding sustainability, future generations face similar asymmetries, because they have neither money nor political clout and thus can have a seat and a voice only through people today who take it upon themselves to speak on their behalf.

While asymmetries of power remain a significant barrier to governance reform and collective-action efforts in many societies, several recent developments demonstrate that they can be overcome. For example, in several Latin American countries, a deepening of the democratic process has allowed indigenous

groups to reclaim ownership of significant parts of their ancestral lands.⁵ A second example relates to persons who are displaced by the building of dams. The World Commission of Dams—a group created in 1997 consisting of members from civil society, academia, the private sector, professional associations, and one government representative—was charged with assessing the social, economic, and environmental impacts of large dam projects around the world and issuing a series of recommendations. Their first very influential report, published in 2000, made ten recommendations that are still considered the gold standard for how large dam projects ought to be conducted.⁶ Among the commission's recommendations are those calling for protecting the rights of the people who would be displaced by the dam projects and allowing such people to have a say in the decision-making process.

Collective action may also break down because of informational problems. These arise in situations where actors do not share the same information about available choices, the consequences of those choices, or the characteristics and preferences of other actors with whom they interact. As we saw in the case of farmer-managed irrigation systems in Nepal, ill-designed government irrigation projects that failed to make good use of the farmers' local expertise led to decreases in productivity.

Once again, however, information problems can be overcome. The ozone case provides an illustration of how international scientific assessments can, if sensitively conducted, do the job. In the wake of the discovery of the Antarctic ozone hole in the mid-1980s, a controversy arose over whether significant declines in stratospheric ozone were occurring globally. Different models and data sets gave different results. The potential existed for an information war in which various stakeholders (countries, industries, environmentalists, etc.) would have been championing—or been expected to champion—the data set and models that most supported their own policy preferences. Instead, however, the U.S. National Aeronautics and Space Administration (NASA) established the International Ozone Trends Panel with a goal of making an independent and authoritative assessment available to all. The organizers included on the panel a diverse group of

recognized experts drawn from ten different countries and from a cross section of industry, academia, and government. The panel members, who participated as scholars rather than representatives, managed to produce a rigorous consensus report showing that a significant downward global trend in stratospheric ozone was indeed under way, and that it was almost certainly caused by human emissions of ozone-depleting chemicals. The panel's report was highly influential, cited by government and industry leaders alike with providing a common foundation of scientific information that supported and necessitated action. The inclusive approach of the panel in producing this assessment that could then support governance processes has since been widely emulated, for reasons we explore in more depth in [chapter 5](#).⁷

Understanding which particular collective-action problems are threatening human well-being provides the basis for devising more effective governance strategies. The more precise this diagnosis is, the more targeted the governance response can be. The chances of overcoming problems are greatly enhanced by an appreciation of the factors that motivate different governance actors to come together and actively contribute to governance responses that represent the common good. In other words, understanding what motivates individual group members allows groups to invent incentives to encourage engagement and cooperation.

Figure Out What Makes People Tick

Research on human behavior distinguishes between two sources of motivation: intrinsic and extrinsic. Intrinsic sources of motivation include moral and spiritual values, personal freedom, as well as a sense of autonomy. Extrinsic sources of motivation include cash payments, threats of punishment, and social exclusion. Most public policies make use of extrinsic sources of motivation to sway the behavior of individual members of society in a predetermined direction. If you get caught running a red light, you will have to pay a hefty fine and may even have your driver's license temporarily suspended. If you buy a fuel-efficient car, your government may give you a tax credit. These extrinsic sources of motivation often work quite well to induce desired group behavior,

but recent scholarship has shown that conventional policy instruments that rely on top-down solutions and cash payments can sometimes be problematic. The following three studies illustrate this clearly.

Experimental evidence suggests that paying people money to encourage them to contribute to the common good can backfire and sometimes actually produce *less* willingness to contribute. Bruno Frey, a Swiss economist, conducted an experiment in which he asked a sample of Swiss citizens about their willingness to host a nuclear waste facility in their municipality under two different conditions.⁸ He started by asking them the straightforward question whether they would be willing to host the facility in their municipality, and he found that a little over half of the respondents said yes. As a follow-up question he asked respondents whether they would be willing to host the facility if the central government paid them a substantial amount, between USD \$2000 and \$6000, as compensation for their services to the public. What is quite astonishing is that the percentage of citizens who were willing to host the facility dropped by half when a cash payment was offered. What explains this result? When asked, citizens' answers ranged from "hosting the facility is the right thing to do" to "the government cannot bribe us to do this" to "our support is not for sale." The finding suggests that use of cash payments can sometimes weaken people's motivation to do what is best for society.

Just as cash payments can backfire, cash fines can also be problematic. An example comes from a study of day-care centers in Haifa, Israel, that tried to make parents show up on time to pick up their children.⁹ To do so, the day-care centers introduced a small fine of three dollars each day parents showed up late. The surprising result was that after the fine was introduced, *more* parents started to show up late, not fewer. Even more surprising, when the centers stopped issuing the fine after twelve weeks, the number of latecomers did not change at all. Before the fine was introduced there was only social punishment for late pickups: the day-care personnel would simply acknowledge the parents' tardiness and perhaps criticize them for making the personnel work

longer hours. Once the parents paid the fine, however, it seems most of them no longer viewed themselves as ethically obliged to show up on time: they may have felt they had bought the right to show up late. In this particular situation, the social punishments produced more compliance than the relatively small cash fines.

Colombian economist Juan Camilo Cardenas conducted an experiment with members of rural communities in Colombia. The experiment sought to reproduce a recurring collective-action problem that these communities face in the management of forest resources.¹⁰ In the experiment the villagers were asked to make individual harvesting decisions. The payoffs offered to participants depended on their performance in the experiment and were designed to capture the tension that exists in the real world between what is best for the individual in the short term and what is best for the group as a whole over the longer term. At the start of the experiment no communication was allowed, and participants ended up harvesting at unsustainable rates. The experimenters then changed the rules, introducing two different interventions to deal with the overharvesting problem, applied to two different groups participating in the experiment. One of the interventions allowed participants to communicate with one another before making their individual harvesting decisions, and the other simulated a government-imposed regulation: participants were not allowed to harvest above a certain level. Their behavior was monitored, and if they were caught overharvesting, they were issued a fine. The result: the participants that were permitted to communicate sacrificed five times more of their personal short-term profits to protect the forest than participants who were regulated by the government. In fact, the government intervention led participants to overharvest even more than during the first eight rounds, when there was no communication and no regulation.

These research findings highlight three things about the challenge of developing effective governance strategies to encourage people to pursue sustainability in their production and consumption decisions. First, the factors that motivate human behavior vary from one context to the next, but people often respond to a mix of both intrinsic and extrinsic sources of

motivation. Second, the effectiveness of using extrinsic incentives—such as fines or cash awards—often depends on individuals’ social norms, beliefs, and values. And finally, interventions are more likely to succeed when they acknowledge the autonomy and problem-solving capabilities of people whose behavior the interventions are trying to change.

Explore Multiple Governance Responses

In *The Tragedy of the Commons*, Hardin suggested that the only way to avoid the tragedy of overharvesting would be for a governmental authority to intervene. The outside intervention, he suggested, could happen in one of two ways—either by having a governmental authority coerce the resource users to limit their resource use or by privatizing the resource to individual owners, who would then see it in their individual self-interest to manage the resource more sustainably. For years, these two options dominated the policy instruments used to deal with common-pool resource problems. More recent scholarship has shown, however, that there is a third policy alternative that does not necessarily call for a top-down intervention à la Hardin: local resources users can, and often do, craft their own, home-grown solutions to commons problems. There is evidence that not only are locally crafted arrangements possible, but they sometimes even outperform national governments in natural resource governance.

Research on the governance of common-pool resources provides several lessons on what works and what doesn’t when groups of people—from small local groups to the global community—try to manage fragile resource systems. A summary of three key findings follows.

Elinor Ostrom, who won the Nobel Prize in Economics in 2009 for her work on commons governance, examined hundreds of cases that involved local users seeking to manage a common-pool resource. Looking at both failures and successes, and systematically examining a host of factors that could help explain the variation in local outcomes, she found that there are a limited number of specific conditions under which resource users are more likely to be successful in coming up with their own institutional

arrangements that can sustain their shared resources.¹¹ She proposed a list of eight principles, often referred to as “Ostrom’s design principles”:

1. The boundaries for the resource *and* user-group rights are clearly defined.
2. The rules governing use of commons match the local needs and conditions.
3. Those affected by the rules can participate in decisions about those rules.
4. There is an effective local monitoring system, in which local community members monitor one another’s behavior.
5. There are graduated sanctions for people who don’t comply with the rules.
6. Mechanisms for conflict resolution are cheap and easily accessed.
7. Higher-level authorities respect the autonomy and self-determination of the local user group.
8. In the case of larger common-pool resources, organization is in the form of multiple layers of nested enterprises, with local user groups at the base level.

Since Ostrom’s original study was first published in 1990, hundreds of empirical studies have been carried out to test her original propositions in a variety of contexts. While these studies have produced some refinements to the original design principles, their core ideas have withstood the test of time.¹² Local self-governance is possible but is always a challenge.

A number of empirical studies from developing countries suggest that local governance processes can be more cost-effective than top-down governmental interventions in managing natural resource systems. These studies compare the performance of national governmental programs with local voluntary community-based initiatives to manage shared natural resources, such as forests and rivers. In one such study, Somanathan and colleagues

collected data on the cost-effectiveness of different approaches to forest conservation activities in a large number of forests in India.¹³ They found that local communities, on average, are better at conserving forests in terms of maintaining stable forest conditions compared with governmental organizations, and they do so at a fraction of the cost of the governmental programs. The homegrown, bottom-up approach to environmental problem solving is sometimes incomplete, however, especially when it comes to dealing with problems that are larger than the reach, or jurisdiction, of the local governance system (recall our invisibilities problem discussed in [chapter 3](#)). To address those broader problems, multilevel governance approaches may be needed.

Multilevel problems require multilevel policy responses. There are no panaceas for addressing the big, persistent challenges of governing for sustainable development. In other words, there is no such thing as a cure-all blueprint policy prescription that will ensure sustainable outcomes. And there is now a substantial body of evidence showing that to address common-pool resource problems effectively often takes more than a single policy actor.¹⁴ It is rare that a single policy actor is in a position to respond effectively to complex social-environmental systems problems, because (1) an actor rarely possesses all the knowledge needed—scientific, operational, or local contextual—to come up with an effective response and then implement it; and (2) the effectiveness of the response will depend on how those affected by the policy response perceive its legitimacy. If a government agency unilaterally designs a policy without active contributions from affected parties, it may not be perceived as a legitimate response, which may complicate enforcement.

These ideas have implications for how governance responses to social-environmental system problems are constructed in that they question the traditionally dominant role of the national government in the governance process. But these ideas also question the ability of local users always to produce effective homegrown responses. One of the insights from the research on multilevel governance is that if a problem spans several levels—in the case of climate change, from individual behavioral choices at

the local levels to decision-making processes at the global level—governance efforts to address the problem require contributions from actors that operate at all those levels. This does not mean, however, that a global consensus needs to be reached among all these actors before responses can be implemented. Speaking of multilevel approaches to address climate change, Elinor Ostrom argued that “simply recommending a single governmental unit to solve global collective-action problems—because of global impacts—needs to be seriously rethought.”¹⁵ According to Ostrom, the contributions of smaller-scale efforts to reduce emissions need to be recognized. One of the advantages of a multilevel approach to addressing a problem like climate change is the ability to learn from experimental efforts at multiple scales that will benefit all.

Consider Interventions as Experiments to Learn From

Any particular institutional arrangement is an imperfect human construct that will produce partial solutions at best. Because of the large number of uncertainties involved in any social-environmental system—there are so many moving parts that will influence outcomes, and these are not only hard to foresee but also often beyond the governance actors’ control—mistakes in the design and implementation of these policy responses are inevitable.

The way London first responded to the increased accumulation of human waste in the streets and back alleys provides a useful illustration. The innovation of flush toilets plus the rules that all houses should use them channeled vast quantities of untreated human waste into the river Thames (the primary source of the city’s drinking water). Once it became clear that this was destroying human health, London’s policy makers changed the rules, requiring that drinking water be sourced upstream of London and that wastes be discharged downstream of the city. (Of course, this example also shows the limits of governance structures that don’t match the physical scale of the problem: growing communities upstream of London could not be compelled by London’s governance structures to keep their wastes out of the Thames; the downstream communities that received London’s waste had no voice in the governance processes that cleaned

London at their expense.)

The lessons learned from policy interventions can be used to improve on the design and implementation features of the policy in an interactive and incremental fashion. Thus, one of the keys to effective governance of complex social-environmental systems, which are full of surprises, is to be able to learn from policy interventions. We will discuss this topic in some depth in the next chapter.

Knowledge Is Power, and Sharing Knowledge Can Be Empowering

The phrase “knowledge is power” suggests that improving one’s knowledge through education opens doors and increases one’s potential and abilities in life. Students of sustainability, for example, will become more powerful and effective advocates of social change after learning how students, professionals, and individual citizens can make a difference for sustainable development outcomes.

The phrase also suggests that knowledge can be used as a tool of domination and to increase an individual’s resources at the expense of others. The sharing of knowledge with fellow citizens can therefore act as a counterweight to existing power asymmetries in society. Sharing knowledge can be empowering, as the new knowledge gained can help level the political playing field, improving the credibility, trustworthiness, and legitimacy of groups that push for social change. Nevertheless, knowledge alone is seldom sufficient to achieve social goals. It can certainly play a large role, but ultimately it is how knowledge is used that matters. Part of that use involves who it empowers in the governance process, and thus how it influences resource allocation, the design of interventions, and learning about outcomes. Knowledge *is* power. And knowledge about sustainable development—how well its goals are being achieved, what invisibilities are misguiding production and consumption processes, which capital assets are being built up or degraded, and which are accessible by whom—can empower those committed to pursuing sustainability. The conditions under which individuals, empowered by this knowledge,

are able to contribute to a sustainability transition is the topic of the next chapter.