An aerial photograph of a city, likely San Francisco, showing a dense urban grid on the left and a large, dark, forested area on the right. A large, dark, irregularly shaped lake or reservoir is visible within the forested area. The image is overlaid with several text boxes and semi-transparent dark bars.

LOCATION

LOCATION

LOCATION

THE GEOGRAPHY ECOSYSTEM

James Boyd

Images courtesy of GeoEye



OF SERVICES

CENTRAL PARK, NEW YORK, NY. © 2008 GEEYE WWW.GEEYE.COM

The study of ecosystem services involves two broad missions. The first is a *biophysical* one associated with ecology, hydrology, and the other natural sciences. How can we protect—or, ideally, enhance—the biophysical goods and services necessary to our well-being? If we want clean air and water, healthy and abundant species populations, pollination, irrigation, protection from floods and fires, how can we take action to preserve these things?

The second is an *economic* mission to measure and communicate the value of those goods and services. Quantitative measures help justify interventions to protect natural resources and systems. They also spur government and other decisionmakers to take ecological gains and losses into account.

Geography is essential to both missions. Ecologists and economists of ecosystem services are scrambling to develop skills in mapping, visualization, and the manipulation of data via geospatial information systems. These skills aren't optional. We eventually need to be able to see and manage what can be called the "missing economy of nature," which is absent for several reasons. In general, markets and business activity do not produce and trade ecosystem goods and services. Consequently, the information we use to measure the conventional economy doesn't capture the free public goods provided by natural systems. Besides, nature is inherently complex. How does an action taken in one place affect conditions in another?

In Nature, Some Things Move, Others Stay Put

From an ecological perspective, geography matters because *nature moves*. Air circulates. Water runs downhill. Species migrate. Seeds and pollen disperse. Not only that, the movement of one thing—say water—tends to trigger the movement of other things, like birds and fish. With the goal of managing and protecting ecosystem goods and services, we must understand this web of movement. You could say that in nature, *nothing stays put*. Ecologically, the constant movement and mixing of natural systems is what generates the need for geographic science.

Interestingly, you could also say that in nature, *everything stays put*—an apparent contradiction. A distinctive feature of ecosystem goods and services—once produced—is that they are unmovable. You can't move a lake, river basin, or forest. You can't ship clean air from one city to another. Birds will migrate where birds migrate. Beautiful mountain trails and scenery can be found in Colorado. Too bad, Kansas. To economists, it is this property of ecosystem goods and services that triggers the need for geography. As any realtor will tell you, three things matter: location, location, location. The same is true for ecosystem goods and services. They're just like houses: if you want to know their value, it's all about the neighborhood.

The Production of Ecosystem Services: Nature in Motion

Think about anything in nature you care about. It could be the beauty of a park, a species you fish for or hunt, or the quality of the air you breathe and water you drink. Now ask the following question: what do those things depend on?

Downstream water quality depends on upstream land uses. The health of Gulf of Mexico fisheries, for example, depends on agricultural practices in the upper Midwest. Air quality in the Adirondacks depends on pollution emissions from the Midwest. Coastal cities and towns depend on nearby wetlands to absorb flood pulses. The point is that the ecosystem goods and services we care about often depend on physical conditions at a great distance from the thing we actually care about. This is a consequence of the continual movement of nature's components.

Accordingly, the biophysical analysis of ecosystem goods and services must be geographic. Treating an ecological problem at the point where it occurs usually doesn't work. It's like putting a band-aid on a lesion caused by an underlying disease. Our ecological diseases—and their cures—are geographic, because ecological systems are geographic.

The challenge for ecosystem scientists and managers is to scientifically relate cause and effect when the cause-and-effect relationship is spatial. We call these relationships *spatial production functions*, because they tell us how an action (good or bad) in one place affects the production of ecosystem goods and services in another. Broadly, we need spatial production functions that describe the dependence of:

- species on the configuration of lands needed for their reproduction, forage, and migration;
- surface and aquifer water volumes and quality on land cover configurations and land uses;
- flood and fire protection services on land cover configurations;
- soil quality on climate variables and land uses; and
- air quality on pollutant emissions, atmospheric processes, and natural sequestration.

The science of these effects is already well underway. For example, we know that stream bank vegetation can improve water quality, help prevent soil erosion, and provide desirable habitat for certain species. But much more remains to be done. We know much less about the exact, empirical relationship between vegetation and water quality.

Why is it such a challenge? First, nature is a highly complex and non-uniform system. Complexity means that causal relationships can only be tested using rigorous, data-intensive empirical and scientific methods that are difficult and costly to perform. Second, non-uniformity means that even if you establish a causal relationship in

ECOSYSTEM GOODS AND

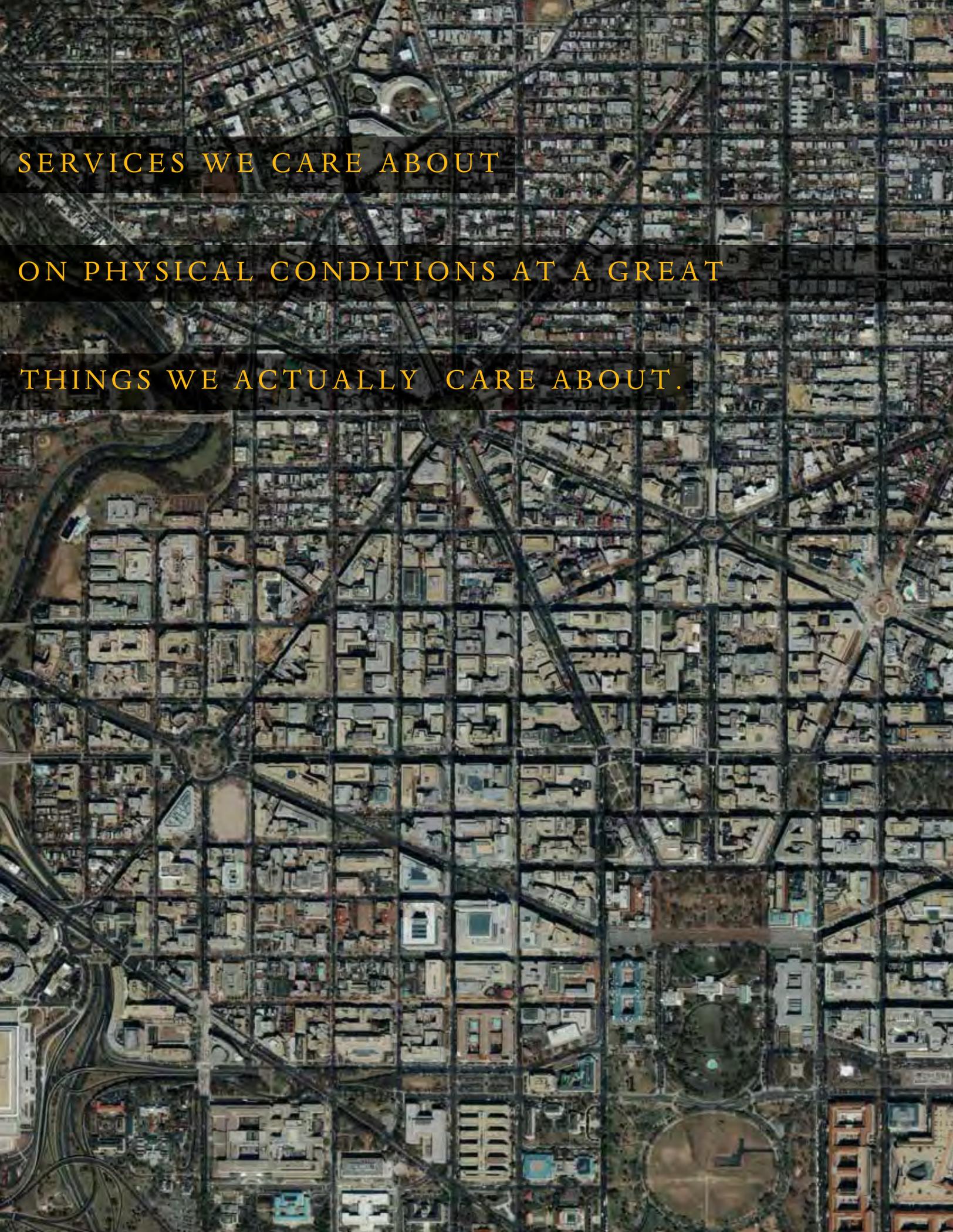
OFTEN DEPEND

DISTANCE FROM THE

one location, that relationship may not hold in other locations. Third, empirical analysis of causality requires collaboration between different disciplines (ecology and hydrology, for example). Cross-disciplinary collaboration in any scientific inquiry is always a practical barrier. Finally, the biophysical scientists have many other things to study and have limited financial support for all they are asked to do.

However, deeper understanding of these production functions is necessary if the ecosystem services agenda is to be taken seriously. Ecosystem protection and management will be ineffective at best, and dangerous at worst, if we cannot make credible claims about ecological cause and effect. And the only way to test ecological cause and effect is with spatial—that is, geographic—understanding of biophysical production functions.

The good news is that maps and mapping technology are increasingly capable of capturing and manipulating this data. Watersheds can now be categorized on the basis of their adjoining land uses. Geographic information system (GIS) tools allow us to “see” migratory pathways and design protections accordingly. As ecology becomes ever more sophisticated in its use of spatial science and data the practical ability to measure cause and effect will become more and more possible.



SERVICES WE CARE ABOUT

ON PHYSICAL CONDITIONS AT A GREAT

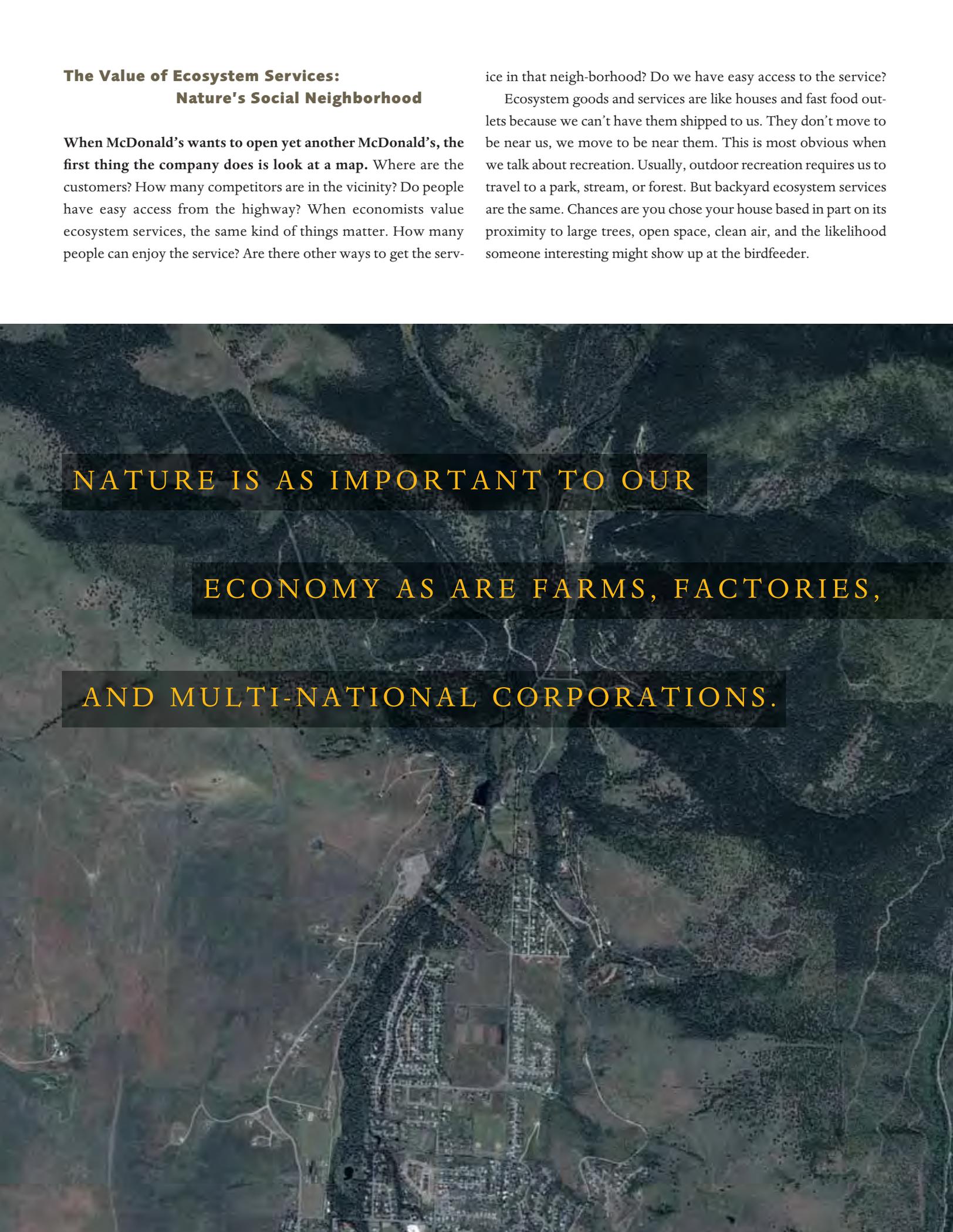
THINGS WE ACTUALLY CARE ABOUT.

**The Value of Ecosystem Services:
Nature's Social Neighborhood**

When McDonald's wants to open yet another McDonald's, the first thing the company does is look at a map. Where are the customers? How many competitors are in the vicinity? Do people have easy access from the highway? When economists value ecosystem services, the same kind of things matter. How many people can enjoy the service? Are there other ways to get the serv-

ice in that neighborhood? Do we have easy access to the service?

Ecosystem goods and services are like houses and fast food outlets because we can't have them shipped to us. They don't move to be near us, we move to be near them. This is most obvious when we talk about recreation. Usually, outdoor recreation requires us to travel to a park, stream, or forest. But backyard ecosystem services are the same. Chances are you chose your house based in part on its proximity to large trees, open space, clean air, and the likelihood someone interesting might show up at the birdfeeder.

An aerial photograph of a landscape, showing a town or village in the lower center, surrounded by fields, forests, and water bodies. The image is dark and has a high-contrast, almost monochromatic appearance, with the text overlaid in yellow.

NATURE IS AS IMPORTANT TO OUR

ECONOMY AS ARE FARMS, FACTORIES,

AND MULTI-NATIONAL CORPORATIONS.

We can make several broad statements about the value of ecosystem goods and services and all of them relate to geography:

- The scarcer an ecological feature, the greater its value.
- The scarcer the substitutes for an ecological feature, the greater its value.
- The more abundant the complements to an ecological feature, the greater its value.
- The larger the population benefiting from an ecological feature, the greater its value.
- The larger the economic value protected or enhanced by the feature, the greater its value.

New York's Central Park makes this point clearly. It is one of the most valuable sources of ecosystem services in the world. Central Park isn't particularly desirable ecologically, but it is nevertheless valuable because so many people live near it and have so few substitutes within walking distance. Geography tells us about all of the factors noted above. We can map population densities, measure distances to similar parks, and easily detect the presence of other types of recreational open space and forms of access like roads.

The general proposition holds for most kinds of ecosystem services. The value of irrigation and drinking water quality depends on how many people depend on the water—which is a function of where they are in relation to the water. Flood damage avoidance services are more valuable the larger the value of lives, homes, and businesses protected from flooding. Species important to recreation (for anglers, hunters, birders, and the like) are more valuable when more people can enjoy them.

Placing a value on ecosystem goods and services also requires us to analyze the presence of substitutes for the good. The value of any good or service is higher the scarcer it is. How do you measure the scarcity of an ecosystem good? If recreation is the source of benefits, substitutes depend on travel times. What are walkable substitutes? Driveable substitutes? The value of irrigation water depends on the availability (and hence location) of alternative water sources. If wetlands are plentiful in an area, then a given wetland may be less valuable as a source of flood pulse attenuation than it might be in a region in which it is the only such resource. In all of these cases, geography is necessary to evaluate the presence of scarcity and substitutes.

Finally, many ecosystem goods and services are valuable only if they are bundled with certain manmade assets. These assets are called "complements" because they complement the value of the ecosystem service. Recreational fishing and kayaking require docks or other forms of access. A beautiful vista yields social value when people have access to it. Access may require infrastructure—roads, trails, parks, housing. Note that these complements may themselves not be transportable. Again, neighborhood matters.

There are exceptions, in which geography is less important to valuation. For example, many of us value the existence of species and wild places *wherever they are*. When it comes to these kinds of ecosystem goods and services, location doesn't matter to our enjoyment, as long as the services exist somewhere. Another important clarification is that everything in nature is valuable if it contributes to the health of the overall system. Here, though, the value arises from the way nature produces services (the realm of the biophysical sciences). When it comes to the consumption of ecosystem goods and services, value tends to be determined by the social neighborhood.

Geographic Information as Technological Revolution

Geographic science will be challenging for both ecologists and economists of ecosystem services. The good news is that our technologies, data, and culture are becoming rapidly more map-focused. Armchair cartographers can already do amazing things with application platforms such as Google Earth. Government agencies and conservancies are making maps available that allow us to see both natural and social landscapes with remarkable detail. This technological revolution is having a cultural effect: maps are everywhere, changing the way we communicate and helping develop our spatial understanding of social and natural phenomena.

The growing deployment of geographic information systems is not without teething problems, however. This is particularly true when it comes to government creation and distribution of geographic information. The U.S. Census Bureau, for example, produces massive quantities of geospatial information on households and businesses. The integration of this information into widely shared, open-source software applications remains awkward, however. Private individuals are stepping in to help solve these problems, but much more could be done by government providers to aid the distribution of geographic information.

A larger worry is the lack of systematically and consistently tracked environmental information by our government trustees—a worry amply documented by the Government Accountability Office and other watchdog organizations. The greatest need facing us is to understand how we can protect and enhance ecosystem services and predict their loss. Geographic analysis of biophysical production functions is the key. But geographic analysis will rely on detailed ecological information tracked consistently over time. Unfortunately, agencies like the U.S. Environmental Protection Agency, NASA, the U.S. Geological Survey, and the Department of the Interior, among others, are given scant resources and authority to gather such information. Nature is as important to our economy as are farms, factories, and multi-national corporations. Geography is the key to understanding that economy. ■