Natural capital informing decisions: from promise to practice

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Abstract

The central challenge of the 21st century is to develop economic, social, and governance systems capable of ending poverty and achieving sustainable levels of population and consumption while securing the life-support systems underpinning current and future human well-being. Essential to meeting this challenge is the incorporation of natural capital and the ecosystem services it provides into decision-making. Here, we explore progress and crucial gaps at this frontier, reflecting upon the 10 years since the Millennium Ecosystem Assessment. We focus on three key dimensions of progress and ongoing challenges: raising awareness of the interdependence of ecosystems and human well-being; advancing the fundamental, interdisciplinary science of ecosystem services; and implementing this science in decisions to restore natural capital and use it sustainably. Awareness of human dependence on nature is at an all-time high, the science of ecosystem services is rapidly advancing, and talk of natural capital is now common from governments to corporate boardrooms. However, successful implementation is still in early stages. We explore why ecosystem service information has yet to fundamentally change decision-making and suggest a path forward that emphasizes: 1) developing solid evidence linking decisions to impacts on natural capital and ecosystem services, and then to human well-being, 2) working closely with leaders in government, business, and civil society to develop the knowledge, tools, and practices necessary to integrate natural capital and ecosystem services into everyday decision-making; and 3) reforming institutions to change policy and practices to better align private short-term goals with societal long-term goals.

Introduction

Since the start of the Industrial Revolution, a massive expansion of economic activity has transformed the planet. From 1820 to 2003, world GDP increased nearly 60-fold in real terms (1). This expansion resulted in a dramatic increase in the average standard of living even as human population rose six-fold. But economic expansion has come with large costs. Global environmental changes—including loss of biodiversity, climate change, and ocean acidification—and further population expansion (possibly reaching 10 billion people by 2100), threaten to undermine future prosperity (2–7). Improving living standards for the approximately two billion people presently living in dire poverty and achieving a sustainable population size, while also securing the life-support systems that underpin human well-being and the rest of life on the planet, is the central development challenge of the 21st century.

Our current global economic, political and social systems are not well suited to meeting this sustainable development challenge. There is a fundamental asymmetry at the heart of economic systems that rewards the short-term production and consumption of marketed commodities but does not reward the stewardship of the natural capital assets necessary for sustaining human well-being in the long-term. With a majority of people now living in urban areas (expected to be two-thirds of the global population by 2050) (8), this asymmetry is at risk of being accentuated further, as connections to nature become less evident, though no less important. Correcting it will require transforming human-nature interactions and the use of natural capital, better understanding the values of natural capital for sustaining human well-being, integrating this information into multiple

decision and policy contexts, and changing institutions, policies, and incentives to reward long-term stewardship (6, 9–12). Conservation and economic development have been considered in separate spheres for too long. Sustainable development in the 21st Century requires explicit recognition that social and economic development are part of, and dependent upon, a stable and resilient biosphere. The United Nations' new focus on Sustainable Development Goals (13) is an encouraging attempt to recognize and prioritize the interconnections among economic, social and environmental spheres, but achieving these goals will require significant alterations of current practices and policies.

When the Millennium Ecosystem Assessment (MA) published its summary of the state of the biosphere a decade ago, it drew attention to the importance of natural capital and ecosystem services in supporting human well-being (2). It also amassed powerful evidence that human actions were leading to declines in a majority of ecosystem services. The intent of the MA was to help catalyze efforts, from local to global scales, to reverse these declines. Currently hundreds of such efforts are underway, engaging individuals, communities, businesses, non-governmental organizations, governments, and international organizations (14). After defining central concepts, we explore progress in the 10 years since the MA. We highlight critical knowledge gaps and impediments preventing fuller incorporation of natural capital into decision-making and suggest a path to overcome some of these barriers and accelerate progress toward sustainable development.

Defining natural capital, ecosystem services, and other key terms

Natural capital refers to the living and non-living components of ecosystems—other than people and what they manufacture—that contribute to the generation of goods and services of value for people. Capital assets take many forms, including manufactured capital (buildings and machines), human capital (knowledge, skills, experience, and health), social capital (relationships and institutions), and financial capital (monetary wealth), as well as natural capital. Multiple forms of capital interact to generate goods and services. For example, fish harvesting depends on the availability of fish stocks (natural capital), which depend on high-quality habitat (natural capital), fishing vessels (manufactured capital, backed by financial capital), the skills and experience of fishers (human capital), and fisheries governance (social capital).

Ecosystems sustain and fulfill human life through *ecosystem services*. Forested riparian buffers hold soil in place and improve water quality for people downstream; aquatic habitats support populations of fish caught for food; mangroves stabilize shorelines and decrease damage to people and property from storms; forests and oceans store carbon that helps regulate climate; lakes and mountains provide aesthetic views, opportunity for recreation, and spiritual inspiration. *Ecosystem services* are the conditions and processes of ecosystems that generate, or help generate, benefits for people. These benefits result from the interactions among plants, animals, and microbes in the ecosystem, as well as biotic, abiotic, and human-engineered components of social-ecological systems. Ecosystem services are produced along the full spectrum of heavily managed ecosystems (e.g., agroecosystems) through to "pristine" ecosystems with low human imprint. Ecosystem services can be *final* or *intermediate*—the former directly produce benefits for

people (e.g., the provision of food from fisheries), the latter underpin final services (e.g., the generation of habitat conditions that support fish populations) (15).

The pace of research on ecosystem services has increased greatly in the decade since the MA (16, 17). Rapid innovation and proliferation of approaches have been productive, but also have resulted in inconsistent use of terms in the literature, sometimes causing confusion (18) (Polasky et al. this volume). For example, *environmental services* and *ecosystem services* are used by different authors, but the intended meaning is the same. We have chosen to use the term *ecosystem services* for three pragmatic reasons: it is consistent with the considerable body of literature emerging from the MA, the word *ecosystem* connotes the integration of both biotic and abiotic components, and many people equate *environmental services* with waste and recycling services provided by local government.

Understanding who affects the generation of ecosystem services (called *providers* or *suppliers*) and who benefits from ecosystem services (*beneficiaries* or *consumers*) allows assessments of the costs and benefits from a given policy, including the distributional consequences across affected parties. Institutions such as property and access rights, and the nature of the services in question, frame the policy context and influence the set of incentives for the private and public use and provision of ecosystem services. Understanding the institutional landscape and incentive structures can inform effective management and governance. For example, carefully designed policies such as *payments for ecosystem services* (PES) can motivate potential ecosystem service suppliers by using payments for action, access, or maintenance of a service. Similarly, rights-based fishery management can incentivize fishers to be better stewards of the ecosystems that produce the fish they catch (19).

Concerns about how natural capital and ecosystem services will respond to climate change and other gradual or abrupt changes have led to greater efforts to understand their *resilience* from local to planetary scales (20–22). Natural capital with enhanced resilience has a greater ability to persist and adapt in the face of change, to continue to provide ecosystem services, and to adapt and transform in beneficial ways (23). This capacity of social-ecological systems to sustain natural capital and ecosystem services in the face of disturbance and ongoing changes is more likely to support development pathways in changing environments where uncertainty and surprise prevail (24, 25). Robust solutions that generate desired outcomes for people and nature under a wide range of potential futures can be enhanced by adopting a more integrated and dynamic systems approach to understanding complex social-ecological systems (21, 26–28) (Reyers et al. this volume). Such thinking also has fostered envisioning major shifts in potential future states, as opposed to incremental change, and places an emphasis on adaptive governance (e.g., Schultz et al. this volume).

Taking stock: Progress and remaining challenges since the Millennium Ecosystem Assessment

There has been remarkable progress in elevating these concepts over the past decade. Influential actors in public and private sectors now routinely talk about the importance of

natural capital, scientific research on natural capital has advanced significantly, and new institutions to account for and secure natural capital are emerging (29–31). However, while some progress is underway, translating that progress into policy and management decisions is a slower process. Tangible, real world changes in the operation of businesses and governments have not been dramatic, especially when compared to the scale and urgency of the issue. The fundamental asymmetries in economic systems leading to undervaluing natural capital remain largely unchanged, and many important forms of natural capital continue to erode. In this section we discuss progress and remaining challenges along three major dimensions: 1) increasing awareness of the interdependence of nature and people; 2) advancing interdisciplinary science through better understanding of the value of natural capital and the ecosystem services it generates, the effects of governance and behavior, and the impacts of policy or management interventions; and 3) incorporating consideration of natural capital and ecosystem services into policy and management.

(1) Increasing awareness of the interdependence of nature and people

A critical first step towards mainstreaming natural capital and ecosystem services into the world of public and private decision-making is to increase understanding of the fundamental linkage between ecosystems and human well-being. Several major efforts have attempted to do so (5, 12, 32, 33) and there are a number of examples stating the importance of incorporating the value of nature in both public and private arenas (e.g., (34–37), Kareiva et al. this volume; Schaefer et al. this volume). In many cases, interest from decision-makers has created demand for information and understanding that has outstripped the supply from science (38) (Polasky et al. this volume).

However, awareness of the interdependence of nature and people is not yet sufficiently widespread. Despite promising developments such as the World Economic Forum's identification of environmental issues among the top 10 global risks for business (39), environmental issues still often rank below a host of other public concerns (40). And current business and economic practice often ignores natural capital (41). A major limitation of the current framing of natural capital is its perceived isolation from other forms of capital and the mainstream of economic and social activity. This isolation relegates considerations of natural capital and ecosystem services to ministries of the environment rather than ministries of finance, agriculture, and industry; to corporate sustainability departments rather than corporate boardrooms; and to the rural poor populations rather than to the urban populations driving resource use.

Placing natural capital and ecosystem services into a broader decision-making context (Fig. 1) is a necessary step in effecting large-scale transformations in policies, practices, and investments. Natural capital considerations are not only the remit of natural resource and conservation decisions, though they are often talked about as such. In fact, natural capital plays an integral role in providing for human well-being across a range of contexts including health, agriculture, energy, water security, infrastructure, urban development, finance, and national security—arenas that extend well beyond classic conservation. Helping leaders in these sectors see their impact and dependence upon natural capital, and how its explicit consideration will benefit them, is critical. Societal decisions in these

contexts would often be different if natural capital considerations were incorporated (42) (Arkema et al., this volume; Cong et al., this volume). We foresee a time when governments and businesses routinely incorporate and report on ways they are reducing risk to their mandates or bottom lines through incorporation of natural capital into their practices and policies—not as an 'environmental,' 'conservation,' or 'sustainability' issue, but simply as a routine part of doing business—i.e., a useful approach to reducing liability and financial risks.

(2) Advancing science

Awareness of the interdependence of people and nature depends upon a robust scientific understanding of the myriad ways in which the two are connected, the effects of governance on decisions and the likely consequences of alternative decisions on natural capital and ecosystem services, as well as how changes in ecosystem services affect human well-being. Advancing science and creating accessible tools for analysis and decision-support can identify critical natural capital, quantify and map ecosystem service values, highlight spatial, temporal, and social differences in ecosystem service production and delivery of services to beneficiaries, and explore trade-offs. In this section we explore four key themes describing progress and challenges around the science of ecosystem services: the provision and resilience of ecosystem services, the value of natural capital and ecosystem services, governance, and the impacts of policy and management.

2.1. Understanding the provision and resilience of ecosystem services

New knowledge, metrics, data, and tools have made it easier to assess and account for nature's benefits to people and provide tangible ways to identify and weigh trade-offs resulting from different possible decisions. Progress has been made in quantifying, mapping, and exploring relationships among multiple ecosystem services and biodiversity (26, 43, 44); predicting changes in land use, climate and other drivers of ecosystem change (45); and spatial modeling of how changes in ecosystems are likely to lead to changes in the flow of services to people (29, 31, 42, 46–48) (Arkema et al. this volume; Chaplin-Kramer et al. this volume).

Less progress has been made to date in understanding complex, adaptive system dynamics, including feedbacks and the potential for climate change and other major disruptions to affect natural capital and the future provision of ecosystem services (49–51). Recent progress in the area of complex systems and resilience of ecosystem services (21, 52) uses both natural and social science to understand how environmental and social shocks disrupt systems, and in turn how those systems respond in ways that either undermine or maintain sustainability. Combining approaches to understanding resilience with ecosystem service modeling will assist evaluation and design of alternative management interventions so that ecosystem services are more secure in an uncertain future (Reyers et al. this volume).

2.2. Understanding the value of ecosystem services and natural capital

2.2.1 Ecosystem service valuation

Ecosystem services are defined as being beneficial for people; but often the value of those benefits is not clear to decision-makers or the general public. Monetary valuation of ecosystem services is sometimes helpful for communicating the importance of ecosystem services. Market and non-market valuation methods from economics are used to estimate ecosystem service values in monetary terms (e.g., Bateman et al. this volume). Numerous studies report values for a wide range of services across numerous locations (53) but these first-generation studies generally do not have the scope to enable robust extrapolation to other locations (51, 54).

Where monetary valuation is highly contested or lacks robustness, or where monetary value metrics are not relevant to decisions, it is often preferable to report outcomes in biophysical terms or directly in terms of impacts on human health or livelihoods (55–57). Though recent work has begun to describe the rich and varied ways in which natural systems affect human well-being (58, 59), the paucity of models and tools for exploring regulating and cultural services is a large research gap that needs to be addressed. Work integrating monetary valuation with qualitative and quantitative work on cultural ecosystem services will increase the likelihood that ecosystem service information resonates with decision-makers and their stakeholders.

2.2.2 Natural capital accounting

Maintaining natural capital is essential for maintaining future flows of ecosystem services. Focusing only on trends in the provision of ecosystem services is not sufficient for determining their long-term sustainability. Current provision of ecosystem service can be increased temporarily by reducing natural capital, such as by harvesting more fish or timber at the expense of depleting stocks. Natural capital accounts are an important additional tool for informing sustainable development (60). Such accounts highlight areas of developing 'natural capital deficit' (38) that may require policy intervention.

A number of accounting frameworks for natural capital have been developed including "inclusive wealth," which attempts to value all forms of capital assets: human capital, manufactured capital, social capital, and natural capital (10, 61). Increasing inclusive wealth means that future generations are endowed with a larger "productive base," capable of providing more goods and services to support human well-being. Inclusive wealth can be used as a gauge of sustainability, though accurate measurement of the value of capital assets is challenging (61).

Measures of the value of capital, which take account of future as well as present values, raise questions of how to properly aggregate values over time. Economists typically argue that future values should be discounted relative to current values. But the appropriateness of discounting in cases affecting natural capital with potentially profound influences on future generations is controversial. How to treat present versus future generations has ethical as well as economic components. Debates on discounting in the context of climate change policy highlight both the importance and lack of agreement on how society should aggregate benefits and costs over time (62, 63).

2.3. Understanding governance: social norms, policy, incentives, and behavior

Natural capital is degraded and ecosystem services are under-provided in large part because of a failure of markets and other institutions to provide proper incentives to conserve and value them (11). Reform of policies and institutions is needed to correct the fundamental asymmetry that rewards production of marketed commodities but fails to either reward potential ecosystem service providers or to punish those whose actions diminish these services. Incentives to maintain or enhance natural capital and increase provision of ecosystem services can be provided in a variety of ways, including payments for ecosystem services, environmental taxes, cap-and-trade schemes, environmental laws and regulations, product certification, and through encouraging social norms for stewardship of natural capital and ecosystem services.

Social-ecological systems are complex, characterized by multiple interacting processes with nonlinear and stochastic dynamics (64). Multiple scales of governance from local to national to international, and multiple forms of governance (e.g., social norms and policy rules) often overlap and intersect (65) and typically differ from the natural scales across which ecosystem services are generated. Policy design for governance of social-ecological systems should reflect the underlying complexity of such systems (66). Policy design should also account for the complex spatial patterns of ecosystem service supply and the spatial patterns that link such supply with ecosystem service beneficiaries (67) (Bateman et al. this volume).

Advances in designing effective policy could flow from integration of behavioral economics, psychology, and resilience theory. Behavioral economics and social psychology provide critical insights into how people make decisions and can be used to better understand how to design policy and management interventions to achieve desired results (68–70). A growing body of literature has also analyzed approaches for adaptive management, co-management, and governance of ecosystem services (25, 71) (Schultz et al. this volume). A better understanding of human motivations, preferences, and cultural norms surrounding nature and its benefits is a prerequisite to achieving changes in human-nature interactions. There is significant room for contributions from anthropology, behavioral economics, psychology, sociology, and other social sciences.

2.4. Understanding impacts of policy and management

Assessing the impacts of policies and decisions on the sustainable use of natural capital and the provision of ecosystem services is essential for testing assumptions, and enabling on-going learning and adaptive management to achieve desired results. Some advances have been made in evaluating the impact of protected areas (72–74) (Ferraro et al. this volume, Bateman et al. this volume) and payment for ecosystem service programs on biophysical and social outcomes (75) (Cong et al. this volume). Impact evaluation of conservation actions on aspects of human well-being is significantly behind other fields (e.g., education and health impact evaluation) and remains a critical area for further work (77).

Evaluating impacts requires monitoring of relevant biophysical and socioeconomic measures. Current monitoring data are inadequate for a variety of forms of natural capital and ecosystem services in many parts of the world. The obvious solution is more

comprehensive or more relevant data collection, but this is costly. Analysts must often try to make clever use of whatever data exist.

Assessing policy impacts is complicated because of confounding factors, complex feedbacks, and potentially long lags between policy action and the realization of impacts. Accurately assessing the impacts of a program requires comparison of actual conditions post-implementation and a counterfactual of conditions had the program not been instituted (77) (Ferraro et al. this volume). Since it is often difficult to design experiments at landscape scales, careful control both of the factors going into selection of areas for program implementation and for potential confounding factors is needed for relatively unbiased estimates of program impact (77).

Attribution of impacts from a policy intervention often involves trying to trace through a complex chain of causation, which can make it difficult to prove that it was policy that caused changes in the status of natural capital or the provision of ecosystem services. Understanding of complex causal links is often incomplete and is likely to remain so with the emergence of novel climate and ecosystem conditions. Complexity regarding causation of impacts can complicate implementation of policies such as payments for ecosystem services. In such circumstances, disputes are likely over who should pay for provision of services and how much, and who should bear the risks of underprovision. Having shared understanding of social-ecological dynamics can reduce disputes but is unlikely to eliminate them (e.g., Schultz et al. this volume).

For many recently instituted interventions it is simply too early to expect to see the full impacts. For example, habitat destruction (or restoration) can lead to eventual biodiversity loss (or increase) but the effect may take from decades to centuries to play out (78). However, program evaluation—even if interim and incomplete—offers immense value for the design and ongoing improvement of effective and sustainable policies (e.g., Ferraro et al. this volume, Cong et al. this volume).

The formal evaluation of how information about natural capital or ecosystem services affects policy or management decisions is largely uncharted territory (79). A real science need is to explore how ecosystem service understanding and tools improve decisions and their outcomes for long-term sustainability relative to business-as-usual approaches.

(3) Incorporating natural capital and ecosystem services into policy and management

Information about natural capital and ecosystem services is being integrated into policy and planning by governments, international organizations, businesses, and NGOs. Here we highlight a few of the many on-going public and private sector initiatives. Although these are promising examples, with potential for scaling, incorporation of natural capital and ecosystem services into policy and management is not yet standard practice.

China has announced ambitious plans to harmonize economic development with nature and transform itself into the "ecological civilization of the 21st Century" (80). Following massive flooding in 1997, China instituted the largest PES program in the world, the Sloping Land Conversion Program (SLCP), with 120 million households enrolled to

convert cropland into forest and grassland (ca. 9 million ha) and afforest barren land (ca. 12 million ha). The biophysical objectives of this program are being achieved (81) but progress on social objectives of poverty alleviation and opening of sustainable livelihoods in non-farm sectors is mixed (82). China is now in the process of establishing a network of "Ecosystem Function Conservation Areas" (EFCAs) to focus conservation in areas with high return-on-investment for public benefit, and to zone high-impact human activities to minimize impacts on natural capital (83). EFCAs now span ca. 35% of the country and are expected to expand to 45% in 2015 (80). China also announced plans to track natural capital and ecosystem services through a new metric, Gross Ecosystem Product (GEP), to be reported alongside wealth and income figures in traditional national economic accounts (84). Whether GEP receives as much attention in decisions as GDP remains to be seen.

Costa Rica was a true pioneer in instituting a national program of payments for ecosystem services (85). The program has increased forest cover on farmland —from a mean of 11% to 17% in the area under PES contract over eight years (75) – notable given the ongoing loss of tree cover on farmland globally. The program has also yielded numerous contracts to conserve or regenerate forest for the provision of watershed services, biodiversity, and carbon sequestration (85). Since implementation, Costa Rica has transitioned from being the country with the highest tropical deforestation rate in the world to one of the few with net reforestation. It is difficult, however, to disentangle the effects of this evolving program (and its predecessors) from other policy measures and broader economic trends (85).

Belize has incorporated the value of ecosystem services in coastal zone management to identify the preferred balance of tourism, fisheries, and coastal protection goals for the country (Arkema et al., this volume). The UK has conducted the first national-scale assessment of the status and trends of its ecosystems and the ways in which people depend upon and impact them (32). In direct response to its national ecosystem assessment, the UK set up a Natural Capital Committee (38); as an example of progress toward mainstreaming, this committee reports to the UK Government Economic Affairs Committee, not the UK Environment Department.

Across Latin America, there is a movement underway to secure water for cities that has exciting potential for scaling beyond one-off projects in individual cities or countries. Since 2006, more than 40 water funds (systems of payments for clean, ample water supplies) have been established or are under development in major cities. By design, these funds collect revenue from downstream water consumers to pay upstream communities to alter their land management to improve water quality and quantity (30). Standardized approaches are being co-developed with decision-makers for targeting investments in upper watersheds, for design of finance and governance systems, and for on-going monitoring (86, 87).

In South Africa, planning for ecosystem service provision has moved forward by more closely linking it with development planning. Ecosystem service information is now used to inform decisions in water management and allocation processes, poverty alleviation

programs (88), disaster management (Reyers et al. this volume), and land use planning (89, 90). Similar advancements are occurring in Sweden, from the incorporation of ecosystem services into urban planning and green area management as part of city development to making the value of ecosystem services visible across landscapes and seascapes (91).

A handful of federal agencies in the United States are actively incorporating information about natural capital and ecosystem services into their decision-making and natural resource damage assessment in both terrestrial and marine realms (37). A White House interagency committee is actively exploring natural capital and some recent legislation from the U.S. Congress directs consideration of ecosystem services in decision-making (Schaefer et al., this volume).

In a number of cases, governments have created policies that change the incentives for the private sector to sustain natural capital. In fisheries management, for example, success has been achieved by establishing a rights-based type of management called 'catch shares' that limits overall harvest, stops the 'race to fish,' reduces unwanted by-catch, and improves efficiency in fisheries (19, 92). Cap-and-trade for carbon emissions, taxes on activities that negatively impact natural capital or ecosystem services, payments for ecosystem services, and certification schemes that provide consumers with information about adverse environmental impacts, are all ways in which regulation and incentives can be provided to the private sector to protect and enhance natural capital and the provision of ecosystem services.

In the private sector, CEOs from around the globe have committed to including natural capital considerations into their business practices through a number of individual and collective initiatives (93–95) (Kareiva et al, this volume). Ruckelshaus et al. (55) summarized over twenty examples of ecosystem service approaches in both private and public spheres to inform decisions ranging from spatial planning to restoration, from payment for ecosystem service schemes to climate adaptation planning, and from corporate risk management to development and permitting of infrastructure projects. In many of these cases, natural capital understanding informed decision-makers, shaped the dialogue, and helped to design and assess alternate plans and policies.

Among development banks, the World Bank's Wealth Accounting and Valuation of Ecosystem Services initiative (WAVES) (60) is working to include considerations of natural capital in national economic accounts. The InterAmerican Development Bank aims to integrate ecosystem services into infrastructure investments that address water security for cities, transportation, and other decisions through the launch of their biodiversity and ecosystem services program. For all loans, the International Finance Corporation requires ecosystem service impacts in its environmental impact assessments (Polasky et al. this volume).

Similarly, the United Nations has advanced the accounting and monitoring of natural capital. The Statistics Division of the United Nations is experimenting with ecosystem services accounts as part of the revision of the System of Environmental and Economic

Accounts (SEEA). At the same time, the International Human Dimension Program of the United Nations University has developed the Inclusive Wealth Report that provides an overview of 140 countries on their drawdown or investment in some forms of natural capital over the past 20 years (96). The 2012 Inclusive Wealth Report (10) assessed the wealth of only 20 countries. Significant data gaps remain in that most non-market values are not included, and evidence that such information is being taken up in policy is needed (GDP, by comparison, is regularly calculated, reported, and cited for at least 180 countries and territories globally).

Beyond these nuclei of innovation and progress, explicit incorporation of natural capital and ecosystem service information into diverse decisions remains the exception, not the rule. In the next section, we suggest a three-part strategy for building on increased awareness and science advancements to bolster real-world implementation.

A path forward: Accelerating progress towards sustainable development

Moving forward, a strategy for future success includes: 1) developing solid evidence linking decisions to impacts on natural capital and ecosystem services, and then to human well-being, 2) working closely with leaders in governments, businesses, and civil society to develop and make accessible the knowledge, tools, and practices necessary to integrate natural capital and ecosystem services into everyday decision-making; and 3) reforming policies and institutions and building capacity to better align private short-term goals with societal long-term goals.

A growing number of cases suggest that incorporating natural capital and ecosystem service information into decisions is practical and can lead to decisions that secure a broader set of desired environmental and human well-being outcomes (e.g., Arkema et al., Cong et al., Reyers et al., Schaefer et al., this volume). Making better decisions requires solid and broad evidence that demonstrates how incorporating natural capital and ecosystem service understanding can lead to outcomes that improve human well-being in the short-term and the long-term, and how this can build support for the sustainable use of natural capital. This evidence will necessarily combine biophysical, economic, and social data. Most compelling will be a robust portfolio of well-documented studies that include both successes and failures, allowing the next generation of policy design to learn from past efforts.

Conducting ecosystem service science linked to specific decision contexts will provide invaluable learning opportunities. Some examples of promising decision contexts include: securing water for cities, national and coastal development planning, fishery management and ocean conservation, corporate supply chains, and infrastructure investment (Table 1). Refining and replicating these approaches to bring them into the mainstream can spur innovation and action on natural capital approaches that may drive deep, systemic change for sustainability.

Engaging and collaborating with leaders will help move from vision to action to achieve sustainable development. True engagement requires co-developing knowledge and understanding and co-creating tools that address real-world questions and challenges (97–

99). Different decisions require different types of information, at different temporal and spatial scales (Table 1). Co-creation of information and its incorporation within decision-making processes improves the salience, credibility, and legitimacy of the science (100) and its uptake (55, 101). Furthermore, leaders can encourage greater uptake of ecosystem service information by improving accessibility of science and data. A platform that reduces the time and cost associated with serving and sharing biophysical and social data that can be transformed readily into appropriate formats for use in modeling tools could greatly enhance transparency and trust needed among parties striving to balance multiple development and environmental objectives.

Perhaps the most difficult challenge in the path of success is changing policy and management to remove the fundamental asymmetry at the heart of economic systems, which rewards production of marketed commodities but does not reward the provision of non-marketed ecosystem services or the sustainable use of natural capital that supports these services. As discussed above, numerous policy approaches exist to correct this pervasive market failure (payments for ecosystem services, environmental taxes, cap-and-trade schemes, environmental regulations, product certification). Changing incentives that affect the bottom-line of businesses and consumers is a necessary condition for achieving sustainable development. Implementing these policy approaches requires the other two conditions for success, evidence to illuminate outcomes of alternative strategies, and engaged and committed leadership that will reform institutions and implement governance of natural capital to bring this about.

The eight Millennium Development Goals (MDGs) established by the United Nations in 2000 were one mechanism through which the international community hoped to encourage integration of well-being, poverty, and environmental objectives. In 2005, the MA concluded that policy interventions to improve human well-being through development were mixed in their outcomes and typically did not consider sustainable use of natural capital and ecosystem services (2). Achievement of the MDGs has been mixed, in part because of unclear metrics and poor integration between the environment and other targets (102–104). The United Nations is now working on a new set of Sustainable Development Goals (SDGs) that are intended to better integrate the three pillars of sustainable development: social, economic, and environmental. The true test, however, will be in their implementation. Actionable, easy-to-communicate goals, targets and indicators that include connections between nature and human well-being will be needed. As demonstrated by the papers in this special issue, the data, methods, technology, and body of evidence on the value of natural capital and ecosystem services have advanced rapidly over the past decade and are ripe for inclusion in the SDGs and the country plans that will follow. Many important building blocks are in place for achieving sustainable development by active stewardship of natural capital alongside human, manufactured, built, financial, and social capital.

The United Nations Secretary-General's High-level Panel on Global Sustainability argues that "by making transparent both the cost of action and the cost of inaction, political processes can summon both the arguments and the political will necessary to act for a sustainable future…to eradicate poverty, reduce inequality and make growth inclusive,

and production and consumption more sustainable, while combating climate change and respecting a range of other planetary boundaries" (7 p.6). Similarly, the World Business Council for Sustainable Development in its *Vision 2050* document defined their goal as "not just living on the planet, but living well and within the limits of the planet….This guiding star is an attempt to help leaders across governments, businesses and civil society avoid repeating mistakes of the past—making decisions in isolation that result in unintended consequences for people, the environment and planet Earth" (36). This vision has recently been translated to an Action 2020 agenda, defining guardrails for businesses to be able to thrive within a safe operating space on Earth; a similar framework has been proposed to guide the UN's SDGs (105). Progress since the MA—in increasing awareness, advancing science, and beginning the long and difficult road to implementation—suggests that we can indeed go beyond promise to inspire and empower leaders to include natural capital and ecosystem services in their decisions. As human populations grow, and grow increasingly disconnected from nature, sustainability requires no less.

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Table 1. Some promising opportunities to effect large-scale transformative change in the near future.

Opportunity	Geography/Possible key actors	Context	Specific questions	What is at stake?	Scalability
Securing water for cities	Africa, Latin America; Water Funds Platforms (including city water companies, local governments, development banks)	Prioritize investments in watersheds for ensuring access to clean water and associated benefits, by identifying areas most important to conserve or restore and how changes will enhance or secure water-related ecosystem services	1) To maintain/improve water purification and regulation, where in the watershed is most important to restore or protect 2) Which activities will promote the most cost-effective outcomes for desired benefits?	The 30 funds established or in development worldwide approach ~$1 billion in spending; targeted investments can produce 3-6 times more efficient outcomes	The number of water funds in operation has more than doubled in the past 5 years, another doubling is expected in the next decade
National development plans	China; Chinese government	Inform zoning of ecosystem function conservation areas to ensure most vital natural capital assets are secured and livelihoods are improved; focus on securing local surface water and water from W. China for Beijing as	1) What areas should be zoned for conservation to most cost-effectively secure key natural capital assets and improve livelihoods? 2) What magnitude of investment is needed? 3) How might eco-compensation policies be designed?	Essential to national and economic security (environmental degradation equivalent to 9% of China's Gross National Income)	Scalable throughout China and as an example for other nations

		well as Hainan Island pilot			
National development plans	South Africa; South African government	Invest in conserving Strategic Water Source Areas in South Africa for urban and agricultural water security	How and where should large national investments from South Africa's National Infrastructure Plan be directed?	Strategic water source areas are 8% of land area, securing 50% of national water supply	Replicable in other regions
Corporate supply chains with agricultural products	Global; International corporations (e.g., Unilever, Coca-cola)	Incorporate ecosystem services into sourcing, product development, or certification strategies by selecting the most sustainable regions/materials or adopting ecosystem service standards for agricultural practices	1) What are the relative impacts and dependencies for different sourcing locations or material ingredients? 2) Where should suppliers apply best management practices for optimal ecosystem outcomes at lowest production costs?	Top multinational corporations have larger GDPs than most nations, and demand significant portions of global agricultural product (e.g., Unilever purchases up to 12% of black tea globally)	The standards and approaches adopted by corporate leaders can be scaled throughout other companies in their sectors
Sustainable infrastructure investments	Latin America; Inter-American Development Bank (IDB)	Quantify and value impacts and dependencies of roads on ecosystem services; integrate into cost benefit analysis for road siting	1) Which projects should be prioritized across the portfolio (based on dependence and impacts)? 2) Within a project, how and where	IDB spending $5B/yr on infrastructure lending ($1.67B on transportation, 79% of that on roads)	Scalable across IDB and to other multi-laterals. Building capacity within IDB and with

		and investment and mitigation decisions to ensure compliance with in-country offset regulation and IDB standards	should development be designed to minimize impacts, and how does the environment affect infrastructure security?		consultants
National and international fishery reforms	National governments and international Regional Fishery Management Organizations	Reform management to incentivize sustainable fisheries and protection of habitat and biodiversity	1) Which fisheries are most appropriate for rights-based approaches that can incentivize sustainable fisheries and habitat/biodiversity protection? 2) How can use of high seas be sustainable?	Food and economic security for the billions of people who depend upon seafood for protein as well as poverty alleviation without eroding the resilience of ocean ecosystems in the face of continued exploitation, climate change, and ocean acidification	Scalable across nations

Figure Legend

Fig. 1. A framework for including natural capital in the broader context of formal and informal decision-making institutions along with other forms of capital: financial, human, manufactured and social capital. Formal and informal institutions influence decisions by both service providers and beneficiaries. Access to various forms of capital ("capabilities"; (106)) and preferences affect the decisions of service suppliers and beneficiaries. The joint actions of service providers and beneficiaries determine the flow of goods and services, including ecosystem services, changes to various capital stocks, including natural capital, and the well-being of different groups in society. Closing the loop from institutions to decisions to human well-being, and back to the top to inform institutional design and decision-making, has the potential to improve policy and management that lead to improvements in human well-being. Components in *italics* indicate factors that change on relatively long timescales.