What is resilience?

An introduction to social-ecological research









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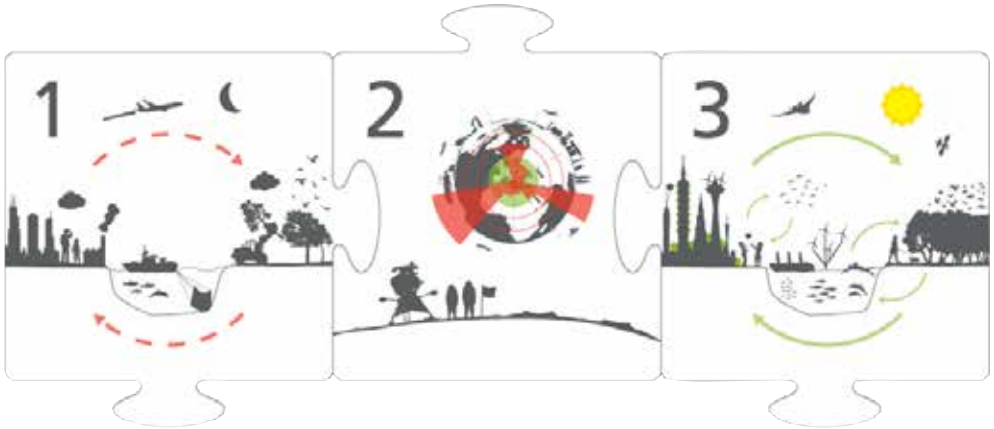

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Introduction

Resilience is the capacity of a system, be it an individual, a forest, a city or an economy, to deal with change and continue to develop. It is about the capacity to use shocks and disturbances like a financial crisis or climate change to spur renewal and innovative thinking. Resilience thinking embraces learning, diversity and above all the belief that humans and nature are strongly coupled to the point that they should be conceived as one social-ecological system.

There is no doubt humans have been successful in modifying the planet to meet the demands of a rapidly growing population. But the gains achieved by this spectacular re-engineering have come at a price. It is now widely apparent (and acknowledged) that humanity's use of the biosphere, that sphere that embraces all air, water and land on the planet in which all life is found, is not sustainable.

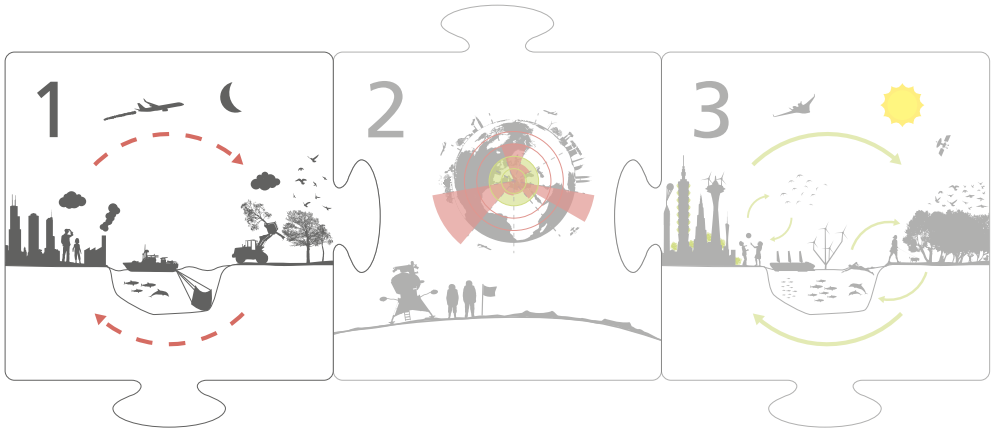
To continue to live and operate safely, humanity has to stay away from critical 'hard-wired' thresholds in the Earth's environment and respect the planet's climatic, geophysical, atmospheric and ecological processes. Resilience thinking is about generating increased knowledge of how we can strengthen the capacity to deal with the stresses caused by climate change and other aspects of global change. It is about finding ways to deal with unexpected events and crises and identifying sustainable ways for humans to live within the Earth's boundaries.

This publication presents three major strands within resilience thinking and social-ecological research. It describes the profound imprint we humans have had on nature and ideas on how to deal with the resulting challenges. Based on the research conducted at the Stockholm Resilience Centre, the three chapters illustrate how we can use the growing insights into the many challenges we are facing by starting to work with the processes of the biosphere instead of against them.

Chapter One of this publication describes in detail the complex interdependencies between people and ecosystems. It highlights the fact that there are virtually no ecosystems that are not shaped by people and no people without the need for ecosystems and the services they provide. Too many of us seem to have disconnected ourselves from nature. A shift in thinking will create exciting opportunities for us to continue to develop and thrive for generations to come.

Chapter Two takes us through the tremendous acceleration of human enterprise, especially since World War II. This acceleration is pushing the Earth dangerously close to its boundaries, to the extent that abrupt environmental change cannot be excluded. Furthermore, it has led scientists to argue that the current geological period should be labeled the 'Anthropocene' – the Age of Man.

Chapter Three highlights the fascinating paradox that the innovative capacity that has put us in the current environmental predicament can also be used to push us out of it. It introduces the term social-ecological innovation, which essentially strives to find innovative ways to reconnect with the biosphere and stay within planetary boundaries.



Reconnecting to the Biosphere

1. Linking people and ecosystems

In our globalised society, there are virtually no ecosystems that are not shaped by people and no people without the need for ecosystems and the services they provide. The problem is that too many of us seem to have disconnected ourselves from nature and forgotten that our economies and societies are fundamentally integrated with the planet and the life-supporting ecosystems that provide us with a hospitable climate, clean water, food, fibres and numerous other goods and services. It is high time we reconnect to the biosphere and start accounting for and governing the capacity of natural capital to sustain development.

Since early 1800 the human population has increased massively from one billion then to the nine billion we are committed towards 2050. During the last 200 years, and particularly after World War II, economic development, international collaboration, technical and social innovation, improved health and wealth have all contributed to boost the standard of living of most people, although the world still hosts one billion absolute poor and three billion people living on less than 2.5 USD a day.

Within the same period of time, the Earth's ecosystems have started to show serious signs of fatigue. In 2005, the UN Millennium Ecosystem Assessment (MA) published the first 'global health control' of the world's ecosystems. The diagnosis was clear: the rapidly growing human demands for food, freshwater, timber, fibre and fuel have changed the Earth's ecosystems faster and more extensively in the past 50 years than ever before. The assessment showed that some 60 percent of the ecosystem services that support human well-being are being degraded or used unsustainably.

This ecosystem degradation could grow significantly worse during the first half of this century and is a barrier to reducing global poverty and achieving the Millennium Development Goals.

Everything is connected

Amidst gloomy forecasts, the MA also brought with it good news. The assessment represented a major shift towards a better understanding of the relationship between human progress, economic development and governance of the world's ecosystems. Rather than separating human development from environmental governance, the MA has helped clarify that people and societies are indeed inseparable parts of what we call the biosphere – the global ecological system that embraces all living beings on Earth and in the atmosphere. The MA emphasises the importance of extending the economic notion of financial value to include nature's goods and services. The bottom line is that poverty alleviation and future economic development can only be achieved with a stronger emphasis on management and governance of ecosystems and their capacity to generate essential services.

A striking example is the Goulburn-Broken catchment in the Murray-Darling Basin, which has become one of the principal income providers for the State of Victoria in Australia. Thanks to widespread and seemingly well-adapted dryland cropping, grazing and fruit production, the region has apparently thrived. However, if the analysis is broadened to include the resilience of the landscape to sustain these activities, the picture looks different: Widespread replacement of deep-rooted native trees with crop and pasture plants that need less water, in combination with irrigation, have resulted in rising water tables. This in turn has brought salt normally held deep within the soil profile to the surface and is causing severe salinization problems in the region.

Another example of the delicate interactions between social and ecological systems is the global market demand for palm oil and tropical timber, which has changed large parts of Borneo from biodiversity-rich tropical rainforests to a simplified oil palm landscape. The situation becomes critical when the role of El Niño is included in the equation. This climate phenomenon is tightly linked with the reproduction of trees in the Dipterocarp family, which dominate the rainforests. Up to 90 per cent of Dipterocarp species synchronise their flowering with the onset of dry weather conditions, which traditionally occur during El Niño on a roughly four-year basis. The mass blooming and subsequent fruiting involve thousands of species across millions of hectares and represent a strategy that intermittently starves and swamps seed predators, so that at least some seeds survive to germination. This dynamic relationship

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between Dipterocarp trees and El Niño has lasted for millennia, but the growing global thirst for palm oil is now breaking the system down.

Intensive logging of the trees has reduced the local density and biomass of mature trees below a critical threshold that limits masting. In addition, the introduction of fires in a region that had no prior fire regime has exacerbated drought stress and caused a radical transformation in forest ecology, which has made El Niño a destructive rather than a regenerative force. In the process, Borneo has turned from being a carbon sink into becoming a carbon source, with fires releasing massive amounts of carbon dioxide, making Indonesia one of the largest greenhouse gas polluters in the world.

Resilience thinking

One increasingly relevant scientific approach to deal with analysis of interwoven systems of humans and nature is through the concept of resilience. This concept is not only used as a framework for research, but also applied in practice. Examples range from city planning to small-scale water innovations to combat poverty in drought-prone areas in the developing world (see case study map, page 16). Resilience is the long-term capacity of a system to deal with change and continue to develop. For an ecosystem, such as a forest, this can involve dealing with storms, fires and pollution, while for a society it can involve an ability to deal with events such as political unrest and natural disasters in a way that is sustainable in the long-term.

Low resilience may lead to undesired shifts in a system. Examples include savannah systems that turn into shrub-deserts, coral reefs that shift into algae-covered rubble and lakes that become over-enriched with nutrients and shift into a state with blooms of toxic algae and fish kills. The outcome tends to be biodiversity-poor ecosystems that are vulnerable to change and generate fewer ecosystem services to human societies. Increased knowledge of how we can strengthen a desired resilience in both society and nature, or rather interconnected social-ecological systems, is becoming increasingly important when grappling with climate change and other environmental impacts. Investing in resilience can be seen as insurance against future shocks. By safeguarding diversity and critical resources, the chances of 'riding through' shocks – such as extreme events – increase. This is of critical importance considering future uncertainty and limited understanding of the vulnerability generated by human-induced change. In essence, resilience theory argues that the nub and kernel of the problem is that many of the serious, recurring problems in natural resource management stem from a lack of recognition that ecosystems and social systems are dynamic and inextricably linked.

Accounting for nature's capital

A substantial challenge is to ensure that the value of ecosystem services becomes more visible in society. Assigning a value to ecosystem services is gaining increasing interest among researchers and policy makers. Although the scientific basis and financial and political mechanisms are still under development, there are several promising efforts. For instance, The Economics of Ecosystems and Biodiversity (TEEB) study calls for wider recognition of nature's contribution to human livelihoods, health, security and culture by decision makers at all levels (local, regional and national policy makers, business leaders and private citizens). For instance, the report shows how the annual costs of forest losses alone (2,5 trillion USD) dwarfed the financial crisis in 2008. In other words, the world lose more money from the disappearance of forest ecosystem services alone than through a banking crisis. The TEEB study has helped place biodiversity management on the high end of the political agenda, showcasing the enormous economic value of forests, freshwater, soils and coral reefs, to name but a few.

Acknowledging the key insights of the TEEB study, India is in the process of implementing a new set of accounts, which track the country's natural capital and include the value of nature's services alongside GDP in decision-making. China is another country where natural capital investments and payments for ecosystem services are now being integrated into governance on a remarkable scale (see case study map, page 16). The TEEB report also emphasises the message that failure of business to account for the value of natural capital, particularly in sectors such as mining, can pose significant economic and social risks. Estimates show that the negative environmental impacts of the world's top 3,000 listed companies amount to around 2.2 trillion USD annually.

The nub and kernel of the problem is that many of the serious, recurring problems in natural resource management stem from a lack of recognition that ecosystems and social systems are dynamic and inextricably linked.

One example of better integration of ecosystems and their services into business activities is the Corporate Ecosystem Services Review (ESR), developed by the World Resources Institute and others. This is a five-step methodology for corporate managers to proactively develop strategies for managing business risks and opportunities arising from their company's dependence and impact on ecosystems. The ESR has been translated into six languages and over 300 businesses have put it to use. For instance, the international paper and packaging company Mondi conducted an ESR for three of its South Africa tree plantations. This resulted in new strategies to use invasive species cleared from its plantations for power and heat generation, a decision to co-finance water efficiency improvements of upstream landowners, and promotion of coppiced woodlots for biomass fuel that provide additional revenue for villagers.

Another example is the Reducing Emissions from Deforestation and Forest Degradation (REDD+) programme. In terms of dollars per ton of carbon, it is an economically attractive option for reducing CO2 emissions. REDD+ expands the scope of previous REDD programmes beyond avoided deforestation and degradation activities to include e.g. rehabilitation, planting of trees, sustainable management and an explicit aim to ensure the full and effective participation of indigenous peoples and local communities. Although by no means a perfect solution, estimates show that financial flows for greenhouse gas emission reductions from REDD+ could reach up to 30 billion USD a year. In addition to climate change mitigation, REDD+ can also generate a number of other benefits, including biodiversity conservation and a multitude of ecosystem services. Such ecosystem services are essential for the livelihoods of many millions of people and include erosion control, stabilisation of water supply and many wood and non-wood forest products.

The governance of global dynamics

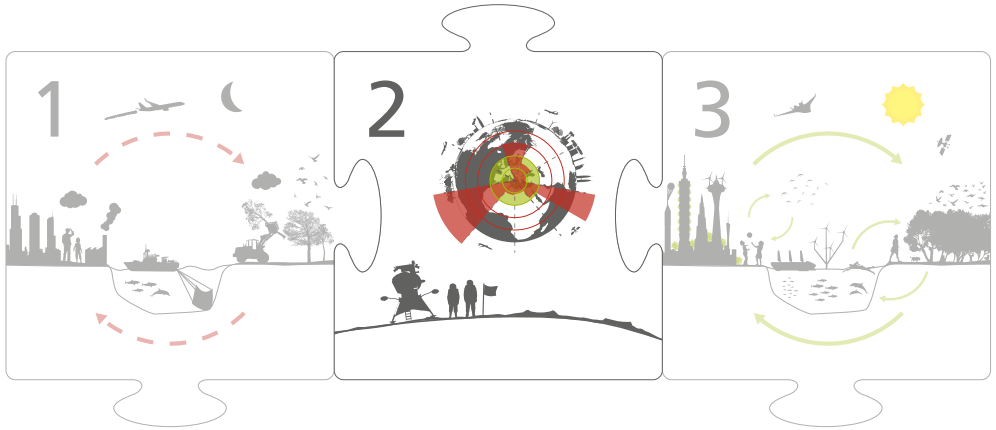
Raising awareness about the dynamic interactions between social and ecological systems is one challenge, coming up with new ways to govern them is quite another. Governing complex social-ecological systems requires an institutional ability and zeal to cope with, adapt to and shape sudden changes. Such a move from rigid sector-based resource management to more adaptive ecosystem-based management is slowly gaining momentum, e.g. through the 'ecosystem approach', which is the primary framework for action under the UN Convention on Biological Diversity. Ecosystem-based management is an adaptive management approach that does not simply seek to manage human impacts on ecosystems. It also recognises that the capacity of an ecosystem to generate goods and services is shaped by humans and acknowledges the importance of their actions, including collaboration among individuals, networks, organisations, agencies, researchers and local resource users. Research suggests that flexible social networks and organisations built on adaptive learning are in a better position to sustain and manage ecological systems. Adaptive governance approaches must be able to coordinate relevant actors at multiple scales, but also to achieve meaningful collaborations and collective action before essential ecosystem services are depleted or critical thresholds are transcended. Key individuals provide trust and visions, while so-called bridging organisations lower the costs of collaboration and conflict resolution. They also connect groups that would otherwise not be connected and enhance learning among stakeholders.

Such adaptive governance systems are increasingly appearing at regional and global level. The wetland area of Kristianstad in southern Sweden is one such case where ecosystem-based management structures have been successfully implemented. This wetland, which provides important ecosystem services such as flood control, cultural and recreational values and flooded meadows for grazing and haymaking, was increasingly degraded until the Ecomuseum Kristianstads Vattenrike (EKV) organisation was established in 1989. Although it has no authority to make or enforce legal rules, EKV has brought about changes in management and is playing a highly active and influential role in managing the wetlands. In June 2005, the wetlands were formally designated a Biosphere Reserve under the UNESCO Man and Biosphere scheme.

Examples of adaptive governance have also appeared on an international level, with measures taken to curb illegal and unregulated fisheries in Antarctic waters. Effective international collaboration between states was initially hampered by political sensitivity, but non-state actors (NGOs and the fishing industry itself) and their engagement in the Commission for the Conservation of Antarctic Marine Living Resources enabled the emergence of new ways to address the problem. A small number of key individuals living in countries remote from Antarctica mobilised personal networks and produced reports, which in turn raised political awareness, produced voluntary monitoring schemes and imposed informal pressure on states and corporations involved in the industry. Although illegal and unregulated fishing has not completely disappeared, it has been considerably reduced through the complementary roles filled by state and non-state actors.

Key messages:

1. In spite of immense technological development and progress, our economies and societies still fundamentally depend on ecosystems to provide us with a hospitable climate, clean water, food, fibres and numerous other goods and services.
2. It is time to fully realise that our societies and economies are integral parts of the biosphere, and to start accounting for and governing natural capital. Poverty alleviation and future human development cannot take place without such a wider recognition of nature's contribution to human livelihoods, health, security and culture.
3. The issue at stake extends beyond climate change to a whole spectrum of global environmental changes that interplay with interdependent and rapidly globalising human societies. Science has a great responsibility in this respect to provide a better understanding of the multiple challenges facing humanity and to explore solutions for sustainable development in an increasingly unpredictable world.
4. Resilience thinking is an important part of the solution, as it strives at building flexibility and adaptive capacity rather than attempting to achieve stable optimal production and short-term economic gains.
5. It is time for a new social contract for global sustainability rooted in a shift of perception – from people and nature seen as separate parts to interdependent social-ecological systems. This provides exciting opportunities for societal development in collaboration with the biosphere; a global sustainability agenda for humanity.



The human dominated planet

2. From hunter-gatherers to planetary stewards

Believe it or not but for most of human history we have existed as hunter-gatherers. Now, thanks to the dramatic fossil fuel-driven expansion since the 1800s, our imprint on the global environment is so large that we risk triggering a number of abrupt or even irreversible global environmental changes. The question is how we can become planetary stewards instead, and strike a long-term balance between human well-being and sustainable use of the Earth's ecosystems.

We have had a good run, but business-as-usual cannot continue. Humanity has begun to emit more than nature can absorb and acquire more than the Earth's resources can provide. In other words, we are beginning to live off the Earth's capital, rather than the interest. The good news in all this is that we are the first generation with the knowledge of how our activities influence the whole Earth System. We are also the first generation with the power and responsibility to change our relationship with the planet.

21st century crossroads

The evidence that the Earth is warming and that human emissions of greenhouse gases have been responsible for most of this warming since the middle of the 20th century is unequivocal. However, just as distressing as climate change is the increasing erosion of the Earth's goods and services. There is a growing acknowledgement that humans must be seen as part of and not apart from nature, and that the delineation between social and ecological systems is artificial and arbitrary (see Chapter 1 for more details).

A further realisation of the strong correlations between human actions and the Earth's life-supporting system is reflected in the term Anthropocene. This indicates that the human imprint on the planet is now so great that the Earth seems to have entered a new geological epoch. It is leaving the Holocene, the remarkably stable period within which human societies as we know them have developed, and it is entering a stage where humanity itself has become a global geophysical force. In other words, we have gone from being primitive hunter-gatherers to a force that can tip the Earth's future into the unknown. In the worst case scenario this new state of the Earth is much warmer, with more sea and less land, impoverished ecosystems, mass extinction of species and a number of severe socio-economic consequences.

The Great (fossil fuel-driven) Acceleration

About 10,000 years ago, agriculture was developed roughly simultaneously in four different parts of the world. This set humanity on a trajectory that led to a more sedentary lifestyle, the development of villages and cities and the creation of complex civilisations that eventually spanned large regions. Around 1800 AD, however, something dramatic happened. Our ancestors at that time learned to access and exploit fossil fuels as a new energy source and dramatic changes came about at a pace never experienced before. Fossil fuel based agricultural and manufacturing systems enhanced the production of foodstuffs and other goods, and consumption began to grow along with an increasingly healthy and expanding population. Little did they know that the rapid expansion of fossil fuel usage was slowly raising the CO_2 concentration in the atmosphere above the limits of the Holocene. The exit door from the Holocene had been opened. The increased pace of just about everything after World War II marked a further threshold in humanity's history called the Great Acceleration. While the human population tripled, consumption in the global economy grew many times faster. With foreign direct investments, international tourism, cars, telephones and above all the internet, the connectivity of humanity has grown at an astounding rate since 1950. Not surprisingly, the acquisition and use of natural resources – as well as the pressure on our climate and ecosystems – has also risen dramatically during this period. The UN's Cities and Biodiversity Outlook, which is the world's first global analysis of how projected patterns of urban land expansion will impact biodiversity and crucial ecosystems, states that production and consumption activities heavily concentrated in cities have contributed to some 80 percent of all greenhouse gas emissions. Furthermore, over 60 percent

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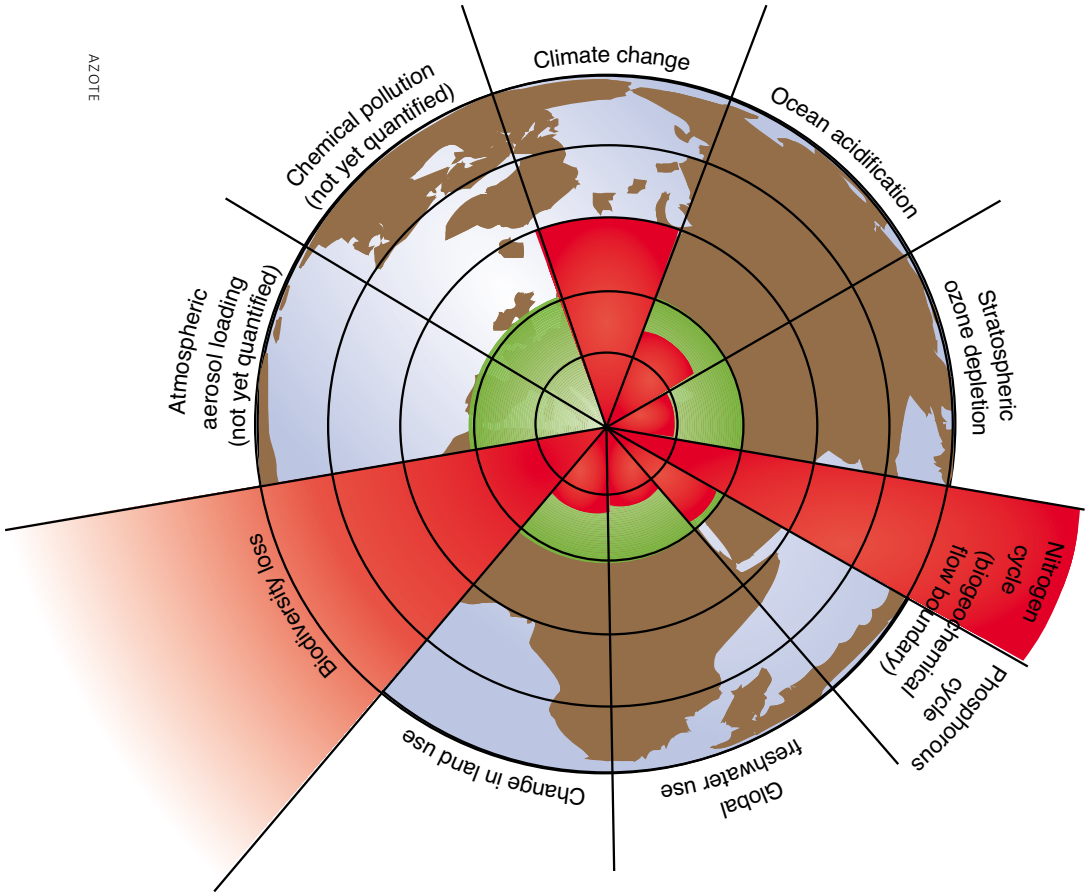


Planetary Boundaries: the nine red wedges represent an estimate of the current position of each boundary. The inner green shading represents the proposed safe operating space (see p. 11 for details).

of the land projected to become urban by 2030 has yet to be built. This presents great challenges, but also major opportunities to improve global sustainability by promoting low-carbon, resource-efficient urban development that can reduce adverse effects on biodiversity and improve quality of life.

It is clear that the Great Acceleration has not been an environmentally benign phenomenon. It has driven large changes to the Earth System and human activities are eroding the Earth's resilience. This is due to overfishing, extensive deforestation, a dramatic increase in domesticated land, increasing nitrogen fluxes and a profound loss of biodiversity, to name a few. However, one other aspect deserves particular attention.

The forgotten sea

Being terrestrial creatures, much of human concern about changes in the planetary environment is focused on the land, the coasts or the atmosphere. In reality, the ocean is in many respects more important than both land and atmosphere in the functioning of the Earth as a whole. The ocean, particularly the coastal seas, provides an important support by absorbing and recycling human-generated waste products. Much of the nitrogen and phosphorus waste produced by human societies from e.g. agricultural fertilisers and animal and human excrement ultimately ends up in the coastal oceans, where it is metabolised. Problems occur when the compounds produced exceed nature's capacity to absorb them. Excess nutrients can generate a number of negative environmental effects.

We know the Earth's resilience and resource base cannot be stretched infinitely and we are uncomfortably aware that we are heading in the wrong direction. The question that remains is how we can better manage our relationship with nature.

The ocean's ability to absorb carbon dioxide also slows the rate of climate change and consequently acts as a climate regulator. However, the most important regulating service the ocean provides for humanity is probably its global distribution patterns of heat and moisture via ocean circulation. For example, most of the rainfall over land that supports agriculture and cities originates through evaporation from the ocean. Humans are crucially dependent upon access to this freshwater and any changes to these climate conditions will have knock-on effects for human societies. Another example is ocean acidification via increasing amounts of atmospheric CO2 reacting with the ocean water to form carbonic acid. The resulting higher acidity, mainly near the surface, has been proven to inhibit shell and

skeleton growth in many marine animals and is suspected to cause reproductive disorders in some fish.

Ultimately, this renders ocean ecosystems less resilient to extreme events and human pressure. This can have drastic consequences on coral reefs and other marine life, with cascading impacts on the fishing and tourism industries. Understanding the human trajectory, from hunter-gatherers to the drivers of the Great Acceleration and beyond, is an essential element in the process of transforming our role on Earth from resource exploiters to resource stewards.

Working within planetary boundaries

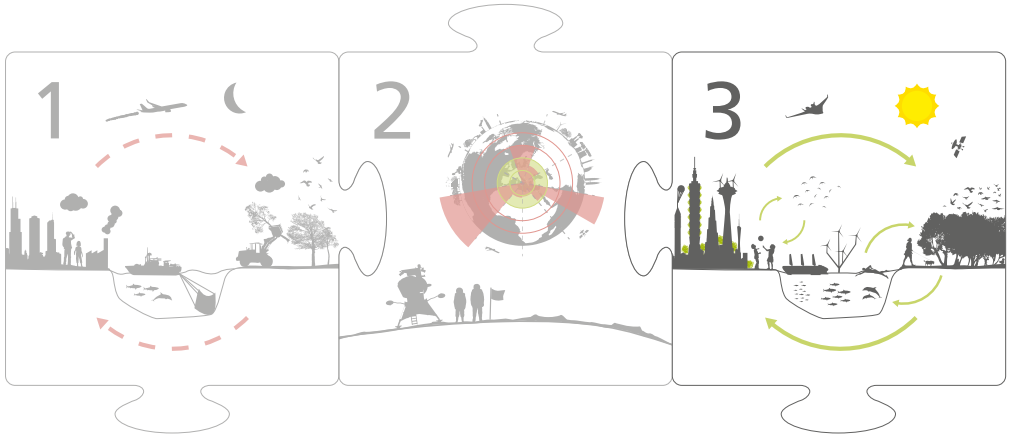
So, here we are. We know the problem, we know the Earth's resilience and resource base cannot be stretched infinitely and we are uncomfortably aware that we are heading in the wrong direction. The question that remains is how we can better manage our relationship with nature. We are not only the first generation with the knowledge of how our activities influence the Earth System, we are also the first generation with the actual power and responsibility to change our relationship with the planet as a whole. Clearly, we have an uneven distribution of power and responsibility, which means that developed countries that were the engines of the Anthropocene, and especially the Great Acceleration, need to demonstrate leadership in bearing the cost of transformation.

One of the most significant attempts to provide scientific guidelines for such improved stewardship came in 2009 when a group of 28 internationally renowned scientists identified and quantified a set of nine planetary boundaries within which humanity can continue to develop and thrive for generations to come. Respecting these boundaries reduces the risks to human society of abrupt or irreversible environmental changes. The nine processes with boundaries (see illustration p. 10) include climate change, stratospheric ozone, ocean acidification, the nitrogen and phosphorus cycles, biodiversity loss, land use change and freshwater use. There was insufficient knowledge to suggest quantitative boundaries for two other processes – aerosol loading (airborne particles such as sulphur and soot) and chemical pollution (e.g. mercury, flame retardants and dioxins). The 28 scientists estimated that three of the boundaries – those for climate change, the nitrogen cycle and biodiversity loss – have already been transgressed. Several others are in the danger zone. The approach was first and foremost designed to advance Earth System science not to offer a complete roadmap for sustainable development. It has indeed been criticised for not being well adapted to policy and many have rightly pointed out that the governance implications of the planetary boundaries concept is a research challenge in its own right. This is why the original framework cannot simply be taken off the shelf and translated directly to operational policy. What it can do already at this stage, however, is to be used as a framework to guide the formulation of new Sustainable Development Goals, which are to replace the Millennium Development Goals after 2015.

An interesting added perspective has also been the social boundaries suggested by Oxfam in their "Doughnut model". This model demonstrates the importance of ensuring that every person has the resources they need to meet their human rights, while we collectively live within the ecological means of this one planet. The Planetary Boundaries approach also helps shift the focus from the slightly one-sided emphasis on climate change to a more complex systems perspective acknowledging that the desired stability of the Earth systems is dependent on a variety of factors. This means the need to address overfishing, deforestation, loss of biodiversity just as much as dealing with increased greenhouse gases. In fact, a more holistic approach in dealing with climate change can create synergy effects where actions to reduce greenhouse gas emissions globally can also improve air quality in metropolitan areas.

Key messages:

1. The human imprint on the planet's environment is now so vast that the current geological period should be labeled the 'Anthropocene' – the age of man.
2. Human pressure has reached a scale where the possibility of abrupt or irreversible global change can no longer be excluded.
3. The challenges of the 21st century – resource constraints, financial instability, inequalities, environmental degradation – are a clear signal that 'business-as-usual' cannot continue.
4. We are the first generation with the knowledge of how our activities influence the Earth as a system, and thus the first generation with the power and the responsibility to change our relationship with the planet.
5. Formulation of new sustainable development goals can be guided by the 'planetary boundaries' concept, which aims to create a scientifically defined safe operating space within which humanity can continue to evolve and develop.



Creating a good Anthropocene

3. Social-ecological innovations for planetary opportunities

There are ample examples out there to demonstrate the tremendous capacity we humans have to find innovative solutions to improve our lives. However, innovation is not always for the better. Aspects of innovation may be driving the world in the wrong direction, directly opposed to a sustainable future. The challenge we face is to use this innovative capacity to reconnect ourselves with the biosphere (Chapter 1) and stay within the safe boundaries of the planet (Chapter 2) in order to safeguard equitable human development in the long term. It is time to introduce innovations that are sensitive to the fundamental bonds between social and ecological systems.

It is a fascinating paradox that the same innovative capacity that has put us in the current environmental predicament is actually what can be used to push us out of it. History has shown that humanity has managed to adapt to a wide range of complex challenges. However, the current predicament might just be the greatest ever. For decades, concerned scientists, environmental NGOs and others have been calling for urgent changes (or transitions) that are large enough to transform our unsustainable way of living. Politics, the corporate world and civil society are increasingly getting the message and there are indeed an immense number of ideas on how to shift to more sustainable trajectories (green urbanism, renewable energy, agro-ecological farming and ecosystem-based fisheries, to name but a few). The problem is that we not only have to collectively speed up our efforts, but also look at ways to solve several problems at the same time. An ambitious plan admittedly, but nonetheless necessary and by all means possible.

Halting a steam-powered train of thought

Despite decades of calls for change, a clear understanding of the mechanisms and patterns under which global transformations can actually happen is still lacking. The growing concern about this has led to an increased focus on the role of innovation, but the question remains: Can we innovate sufficiently rapidly and intelligently to tip our socio-economic system out of the current paradigm and into a more sustainable one?

Historically, humanity has placed great faith in technological innovation to help transform societies and improve the quality of life. The most obvious example is the industrial revolution, while the most recent example is the fast-changing way we communicate across the world. There are good reasons why we place faith in our capacity to innovate, because it has traditionally been associated with a better quality of life. Questioning innovation therefore goes against the grain of the prevailing worldview and the governance structures that rule our lives, but we cannot deny that the last five decades or so of high innovation have also caused some serious damage to the planet. Moreover, we appear to be locked on a technological path that is not only accelerating tremendously rapidly, but also carries with it unintended and undesired social and environmental consequences. In other words, we have for long seen a decreasing degree of control over the impact of our innovations, but a change is coming.

Mind the ingenuity gap

The problems we are facing are so complex that some argue that we are caught in an 'ingenuity gap', where the world's problems have become so difficult to solve that we lack the ingenuity required to solve them.

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Along the same lines is the argument that the 'technosphere', the innovative engine that has driven our modern economy, is organised along lines that are very different, if not downright contrary, to the functioning of the world's ecosystems. Ecosystems are based on non-linear mutual independency and one part cannot be separated from another, while the technosphere, whether in terms of machines or structures, is based on a linear, means-to-an-end logic. Putting it bluntly, most current economic and technological solutions are ecologically illiterate and too linear and single problem-orientated. There is a need for a change of mindset.

The private sector is in many respects one of the main suppliers of innovative thinking and is consequently fundamental in carving out new directions for more sustainable innovations. Businesses can make a huge difference, and there is a growing global movement of promising social entrepreneurs with new ideas who want to contribute to a sustainable society, and build companies based on strategies such as "Ubiquity first, worry about Revenue Later". At the core of this movement is the idea that entrepreneurship is a way of achieving social change. Interest in social innovation and social entrepreneurship has literally exploded in recent years with training

PHOTOGRAPHY TOM HERMANSSON SNICKARS/AZOTE

programmes, conferences, competitions and awards, and special funds for entrepreneurs who take social responsibility and put societal benefits at the core of their enterprises.

The essence of social-ecological innovation

The outlook need not be too gloomy. Ongoing large-scale transformations in e.g. information technology, biotechnology and energy systems have huge potential to significantly improve our lives in a sustainable way. However, this can only happen if we start working with, instead of against, nature. This is the idea behind the new concept of social-ecological innovation, which has been defined as "social innovation, including new technology, strategies, concepts, ideas, institutions, and organizations that enhance the capacity of ecosystems to generate services and help steer away from multiple earth-system thresholds". However, in order to boost our capacity to innovate in this way, there needs to be support and incentives in place, particularly in the private sector. The transformation needed must include the creativity and ingenuity of users, workers, consumers, citizens, activists, farmers and small businesses alike.

The XPRIZE Foundation, an American non-profit organization once known for competitions for spaceflight innovation, is one example, which has turned its attention to ocean health. In 2013 it announced a 2m USD competition for devices that can monitor the changing chemistry of the oceans due to climate change – the first time the XPRIZE has decided to concentrate on a specific research area.

Law also plays its part. Law is traditionally characterised by 'thou shalts' rather than opening doors for new approaches. As a reaction to this, the concept of reflexive law has emerged. Reflexive law is less rule-bound and recognises that as long as certain basic procedures and organisational norms are respected, participants can arrive at positive outcomes and correct their projects along the way, basically learning by doing. In response to growing complexity, detailed rules are replaced by procedures for regulated entities to follow. Reflexive law is a social innovation which seeks to promote multi-level governance and preserve diversity and experimentation at local level.

Bottom-up responses to crises are a central element in all of this. There are enormous reservoirs for learning and innovation that are often revealed in moments of crises. In fact, some of the best and most constructive innovations often come from disaster-hit (or disaster-prone) communities. In 2007 the Coral Triangle Initiative (CTI) was formed to address the many threats facing coastal and marine ecosystems in the western Pacific Ocean. What is unique about this initiative is the role of so-called "institutional entrepreneurs" in the emergence of the CTI. Such entrepreneurs are individuals and groups of individuals who succeed in creating new institutions (the norms and rules that shape human interactions) or transforming existing ones. Studies of the network revealed that a small network of approximately ten institutional entrepreneurs was key to initiate the process. They developed the scientific concept of the CTI into an integrated framework for marine governance. These ten entrepreneurs came from both inside and outside the region and predominantly, but not solely, from conservation NGOs with a long history of working with marine conservation. Together with a number of underlying driving forces, including demands for social and economic development, a window of opportunity emerged to create a network better suited for regional cooperation.

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Studies on innovative responses to social and natural disasters increasingly stress the need for governments and institutional aid mechanisms to take a step back and 'listen and engage' with communities rather than 'orchestrate and plan' on their behalf. Termed "inclusive innovation", this involves listening to local communities for ideas, informing local populations of resources and possibilities available, trusting them and allowing a diversity of innovative responses to emerge, as opposed to insisting on a top-down planning process. One example

is the Honey Bee Network in India. It has received international praise for the way it supports grassroots innovators in the rural poor of India who are rich in knowledge and talent, but poor on resources to scale up and convert their ideas into viable products, The network's founder, Dr. Anil Gupta, describes the network as taking the nameless, faceless innovators of India (and beyond) and bringing them into a network where they get an identity.

Resilience scholars have also focused on the role of informal shadow networks – groups of stakeholders that work outside the fray of regulation and implementation in places where more formal networks and structures fail. One of the most celebrated examples comes from Chile, where a combination of fisheries collapse and the move to democracy provided the opportunity to try out some newarrangements for managing fisheries. The experiments were based on informal partnerships and trust between fishers, scientists and managers. There was a general recognition that Chile's fish stocks were in trouble, things were turbulent and people were open to new approaches. There was also a good scientific understanding of coastal ecosystems in the region on which to base a new management plan. All this eventually led to the testing of new co-operative models for fishery management, based on the latest science concerning fish stocks and the surrounding marine ecosystem. The end result was a revamped national system of marine tenure that allocates exclusive ocean territories to local and small-scale fisheries. The system excludes the major industrial fishing fleets, which have their own exclusive fishing zone. By cutting the number of large vessels in distinct territories, fishing pressure has been reduced.

Getting stuck in the MUD

Tapping shadow networks such as those in Chile is a key challenge to governance. Traditional, expert-driven, top-down approaches to problem solving are not nimble enough to effectively address convergent, non-linear and rapidly changing problems. There are also lessons to be learned from innovation studies in the domain of business, technology and organisational behaviour. These have long established the importance of approaching innovation from a top-down and bottom-up perspective, sometimes referred to as 'management up-down' (MUD). This basically refers to a company's ability to efficiently connect those drawing up company strategy with the sources of innovation, most commonly taking place at the front line, on the shop floor or in small designated teams. This in turn produces the cascade of resources required to bring innovation to markets and scale up the innovation itself. Key individuals in this process are the so-called connectors, who are able to understand the overall strategic direction the company wants to take, frame that to those working on the 'front line', identify promising innovations and sell these back to the strategic apex of the company.

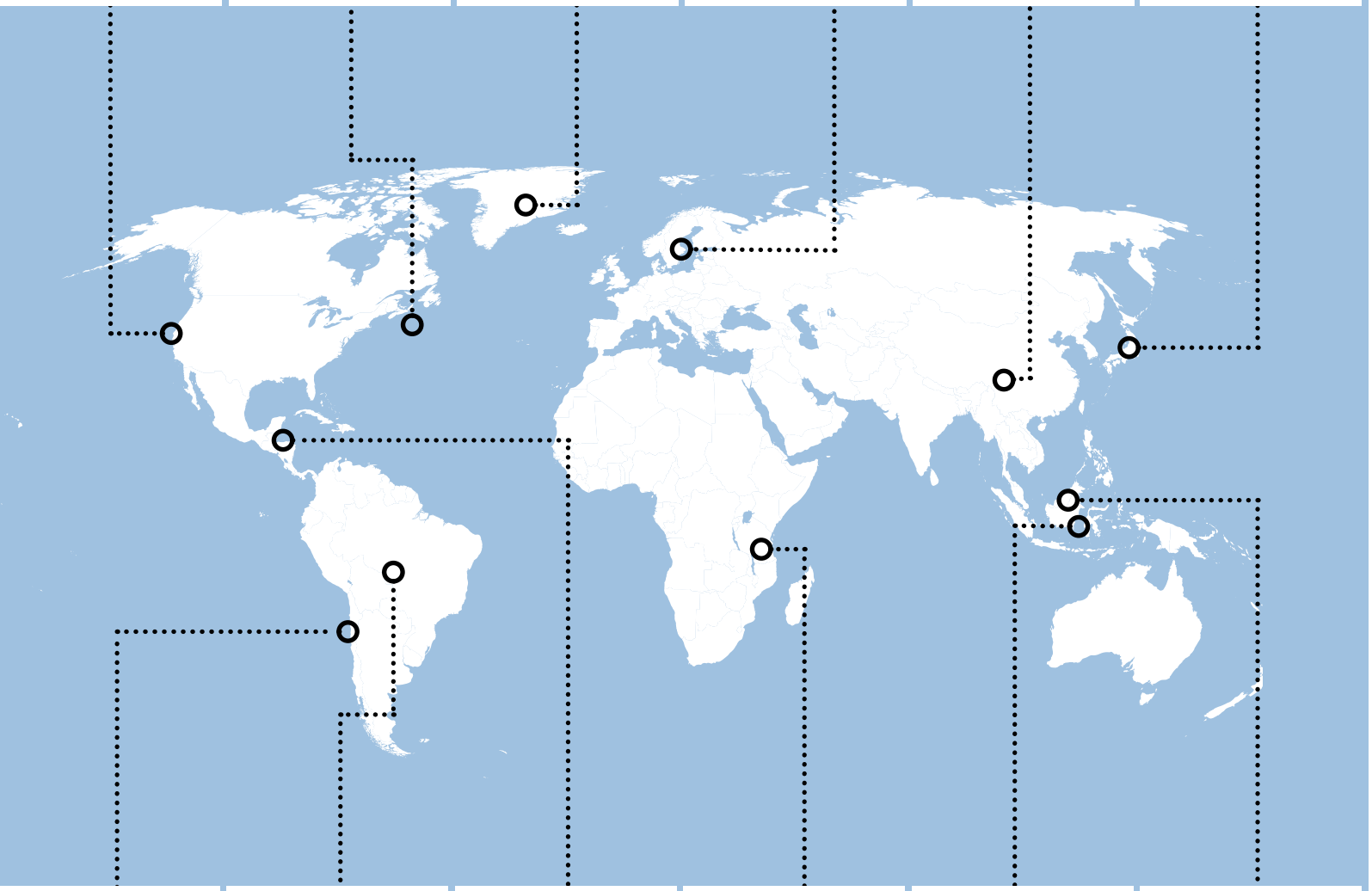
Overall, economic and technological solutions must become more ecologically literate and see the numerous possibilities in investing in sustainable use of ecosystems and their services. This requires us to organise innovation and technology development in new ways that are more networked, open-sourced and inclusive, while working more directly for social justice, poverty alleviation and environmental sustainability. The planetary risks we are facing are so large that business-as-usual is not an option.

Emerging social innovations and technological transformations involve enormous opportunities with huge potential to improve our lives in a sustainable way. But creating a good Anthropocene means going beyond solutions that merely reduce negative impacts and rather develop a mindset where we acknowledge that we are part of this planet, not conquerors of it. There are numerous examples of major socio-technological advances that have improved human life. The flipside is that too many of them have degraded the life-supporting ecosystems on which human well-being ultimately depends. What we need are innovations that can increase human well-being and at the same time enhance the capacity of ecosystems to produce services. That is what social-ecological innovation is all about.

Key messages:

1. An immense number of sustainability initiatives are emerging (transition towns, clean energy, agroecological farming, ecosystem-based fisheries management, etc.). Such initiatives need to be upscaled through e.g. innovation funds, seed money, structural adjustment funds and other incentives in order to have a global impact. Social media and associated advances in information and communication technologies can play a role in this process.
2. Ongoing large-scale transformations in e.g. information technology, biotechnology and energy systems have the potential to significantly improve our lives in a sustainable way, but only if we incorporate knowledge of social-ecological systems and planetary boundaries in risk assessments and development strategies.
3. Most current economic and technological solutions are ecologically illiterate and too linear and single problem-orientated. What is needed is financial and political support for safe-fail experiments in communities around the world, using diverse technologies, organisations and ideas, for instance in 'Policy Laboratories' or 'Change Labs'.
4. Policy makers around the world need to adopt a new systems thinking that pays much more attention to the negative side-effects of quick fixes and recognises the numerous possibilities in investing in sustainable use of ecosystems and their services.
5. We need a new type of 'social-ecological' innovation and technologies that work more directly for social justice, poverty alleviation, environmental sustainability and democracy, while including the creativity and ingenuity of users, workers, consumers, citizens, activists, farmers and small businesses alike.

CASE 11 | CASE 1 | CASE 4 | CASE 9 | CASE 10 | CASE 3



CASE 7 | CASE 5 | CASE 8 | CASE 12 | CASE 6 | CASE 2

The three chapters in this publication discuss issues of global concern, but with local and regional implications and solutions. The world map features 12 case studies that can illustrate many of these issues.

CASE 1: THE GULF OF MAINE LOBSTER FISHERIES, USA

This case illustrates a failure to see the full integration of socio-economic and ecological systems. In the Gulf of Maine the American lobster comprises over 80 per cent of the total marine resource value, but this economic success does not equal ecosystem success. Rather, the long-term sequential depletion of cod, hake, haddock, halibut and sea urchins has resulted in a vulnerable near monoculture of lobsters. Elsewhere, such high lobster densities have preceded an outbreak of shell disease. A similar collapse in Maine would be devastating for the over 7,000 lobstermen and their support industries.
PHOTOGRAPHY OSKAR HENRIKSSON/AZOTE

CASE 2: EL NIÑO AND RAINFOREST RENEWAL, BORNEO

Global market demand for palm oil has led to an expansion of monoculture plantations and an increasingly fragmented forest landscape in the rainforests of Borneo. This has altered the resilience to droughts induced by the recurring weather phenomenon El Niño, which previously triggered mast reproduction among trees, regenerating forest biodiversity. In the new situation, El Niño events

Twelve case studies on the application of resilience thinking and social-ecological research

disrupt fruiting, interrupt wildlife reproduction and trigger wildfires that contribute significantly to global carbon emissions.
PHOTOGRAPHY RAINFOREST ACTION NETWORK/FLICKR.COM

CASE 3: ECOSYSTEM SERVICES OFFSETTING IN THE 'SATOYAMA' CULTURAL LANDSCAPE, JAPAN

In the Japanese city of Nagoya, urban sprawl is challenging the traditional agricultural 'Satoyama' landscape. Under a new system of tradable development rights, developers that exceed existing limits on high-rise buildings can offset their impacts by investing in the conservation of Satoyama areas threatened by urban exploitation. Favourable bank loans are also offered for building projects scoring high on a green certification system.
PHOTOGRAPHY MOOKE/FLICKR.COM

CASE 4: MELTING OF THE GREENLAND ICE SHEET APPROACHING A THRESHOLD

The Greenland ice sheet, which has melted at an increasing rate during the past 30 years, is an example of how the Earth's subsystems risk moving outside their stable Holocene state. As the planet warms the ice melts, leaving more water and land exposed to the sun. Those surfaces in turn absorb more of the sun's heat, leading to a self-enforced process with accelerated melting of snow and ice. There are fears that melting of the entire sheet could raise sea levels globally by about 7 m.
PHOTOGRAPHY BENT CHRISTENSEN/AZOTE

CASE 5: LARGE-SCALE SHIFTS IN THE AMAZON RAIN FOREST

We are approaching serious thresholds, or tipping points, in major ecosystems. One example is the projected changes in the vegetation of the Amazon Basin, from tropical forest to dry savannah or grassland, due to climate change and deforestation. The concern is that the Amazon might be caught in a vicious circle – with altered rainfall patterns and increased wildfires – that could bring it to the point of no return, with massive impacts on the world's biodiversity and climate.
PHOTOGRAPHY NICOLAS DESAGHER/AZOTE

CASE 6: ACIDIFICATION AND OTHER THREATS FACING INDONESIAN CORAL REEFS

The world's oceans are steadily becoming more acidic due to increasing amounts of atmospheric CO_2. Ocean acidification in combination with global warming, declining water quality and overexploitation of key species is predicted to drive coral reefs increasingly toward the tipping point for functional collapse. This will involve cascading impacts on local livelihoods as well as the fishing and tourism industries, not least in Indonesia, which has the largest area of threatened reefs in the world.
PHOTOGRAPHY TONY HOLM/AZOTE

CASE 7: TRANSFORMATION OF CHILEAN FISHERIES

New transformational changes in governance are urgently required to cope with overfishing, pollution, climate change and other drivers of degradation in the marine environment. One example arose when fisheries collapses and the move to democracy in Chile after a 17-year dictatorship, quite by chance, opened the way for reforms and new laws that excluded large industrial fishing fleets and gave exclusive ocean territories to local 'artisanal' fishers. Scientists and the small fishers then worked out a shared vision and voluntary agreements on how to manage these territories.
PHOTOGRAPHY CLAUDIUS PRÖßER/FLICKR.COM

CASE 8: INNOVATION IN LAND MANAGEMENT IN HONDURAS AFTER HURRICANE MITCH

Innovation often comes as a result of crisis and sustainable solutions often from community level. Studies in north-eastern Honduras after the powerful Hurricane Mitch hit the country in 1998 showed how the disaster led to substantial changes in land management. These changes were facilitated not by established aid organisations, but by initiatives that spread almost 'virally' from household to household. This resulted in a shift to a more equitable land distribution and protected forests that helped the community cope with similar flooding 10 years later.
PHOTOGRAPHY APES_ABROAD/FLICKR.COM

CASE 9: ECOSYSTEM SERVICES IN STOCKHOLM

The Stockholm region is of great international interest when it comes to urban ecological research. Green spaces extend from the countryside into the city centre where the world's first National City Park is situated. Researchers at the Stockholm Resilience Centre have since the 1990s been studying the ecosystem services that the National City Park provides to Stockholm, and analyzed how users of the park prioritize and value green spaces and biodiversity. These studies are part of a larger social-ecological analysis in which the social sciences, humanities and natural sciences collaborate to investigate how ecosystem services are used, maintained and is dependent on the surrounding landscape.
PHOTOGRAPHY STEVEN ZEFF/AZOTE

CASE 10: NATURAL CAPITAL INVESTMENTS IN CHINA

Ecosystem service investments in China today are remarkable in their goals, scale, duration and innovation. Following severe droughts in 1997 and massive flooding in 1998, China implemented several national forestry and conservation initiatives, exceeding 100 billion USD over the current decade. Targeted investments aim to secure natural capital and alleviate poverty through wealth transfer from coastal provinces to inland regions, where many ecosystem services originate. Over 120 million farmers are directly involved in programmes with the intention to reduce the loss of soil, reduce desertification and protect biodiversity and ecosystems for e.g. flood control, more productive agriculture and ecotourism.
PHOTOGRAPHY UNITED NATIONS PHOTO/FLICKR.COM

CASE 11: THE NATURAL CAPITAL PROJECT (NATCAP)

A movement that started off on the west coast of the US is today an international effort to motivate greater investments in ecosystems and human well-being by helping decision makers visualise the impacts of potential policies (e.g. InVEST toolkit, which will soon be on Google's new Earth Engine platform). NatCap is also helping to build evidence and policy innovation through a shared programme of research and policy support. In addition, it is magnifying the impact of these demonstrations by engaging key institutions and thought leaders, disseminating tools and lessons and creating an informed community of leaders and practitioners.
PHOTOGRAPHY ÅSA GALLEGOS TORELL/AZOTE

CASE 12: SMALL-SCALE WATER INNOVATIONS BREAK DRYLAND POVERTY TRAPS IN TANZANIA

Improved water management in rainfed agriculture can build resilience to cope with water-related risks and uncertainties. Conventional solutions have been to develop large-scale irrigation systems, but recent studies in e.g. Makanya, Tanzania, have shown that small-scale innovations, such as rainwater harvesting and conservation tillage, have enormous potential for increasing on-farm productivity and ecosystem services output in areas where people live in poverty and are vulnerable to climate change.
PHOTOGRAPHY JERKER LOKRANTZ/AZOTE

Glossary

ADAPTIVE GOVERNANCE: Governance approaches that are collaborative, flexible and learning-based and rely on networks of people and organisations at multiple levels.

ANTHROPOCENE: The Age of Man, a new name for the present geological epoch defined by our own massive impact on the planet's climate and ecosystems. Coined in 2000 by Nobel Laureate Paul Crutzen.

BIODIVERSITY: Short for biological diversity – the variety of all forms of life on earth, including the variability within and between species and within and between ecosystems.

BIOSPHERE: The sphere of all air, water and land on the planet in which all life is found; the global ecological system integrating all living beings and their relationships.

ECOSYSTEM: All the organisms in a given area, along with the physical environment with which they interact (e.g. a forest, a coral reef or a rock-pool).

ECOSYSTEM-BASED MANAGEMENT: A management approach that recognises the full array of interactions within an ecosystem, including humans, rather than considering single issues, species or ecosystem services in isolation.

ECOSYSTEM SERVICES: The benefits people obtain from ecosystems, e.g. provision of clean water, regulation of climate, pollination of crops and fulfilment of people's cultural needs.

GREAT ACCELERATION: Refers to the dramatic acceleration of human enterprise after World War II and the resulting pressure on the global environment.

HOLOCENE: The postglacial geological period, which began approximately 9600 BC and continues to the present.

INSTITUTIONS: A central concept within the social science of natural resource management whereby institutions are defined as the norms and rules governing human interactions. These can be formal, such as rules and laws, but also informal (unwritten), such as norms and conventions of society.

MILLENNIUM ECOSYSTEM ASSESSMENT: Global review launched by the UN and carried out between 2001 and 2005 to assess the consequences of ecosystem change for human well-being.

NATURAL CAPITAL: An extension of the traditional economic notion of capital, coined to represent the natural assets that economists, governments and corporations tend to leave off the balance sheets. It can be divided into non-renewable resources (e.g. fossil fuels), renewable resources (e.g. fish) and services (e.g. pollination).

PLANETARY BOUNDARIES: A concept developed by a group of researchers in 2009 to describe nine safe biophysical boundaries outside which the Earth System cannot be pushed without disastrous consequences.

RESILIENCE: The capacity of a system – be it a forest, city or economy – to deal with change and continue to develop; withstanding shocks and disturbances (such as climate change or financial crises) and using such events to catalyse renewal and innovation.

SOCIAL-ECOLOGICAL SYSTEM: An integrated system of people and nature with reciprocal feedback and interdependence. The concept emphasises the humans-in-nature perspective and that delineation between the social and ecological is artificial and arbitrary.

SOCIAL INNOVATION: An initiative, product, process or programme that profoundly changes the basic routines, resource and authority flows or beliefs of any social system.

SOCIAL-ECOLOGICAL INNOVATION: Social innovation, including new technology, strategies, concepts, ideas, institutions and organizations that enhance the capacity of ecosystems to generate services and help steer away from multiple earth-system thresholds.

TRANSFORMATION: The creation of a fundamentally new system when ecological, economic or social conditions make the continuation of the existing system untenable.

Useful Reading

See more publications on resilience here:www.stockholmresilience.su.se/publications

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