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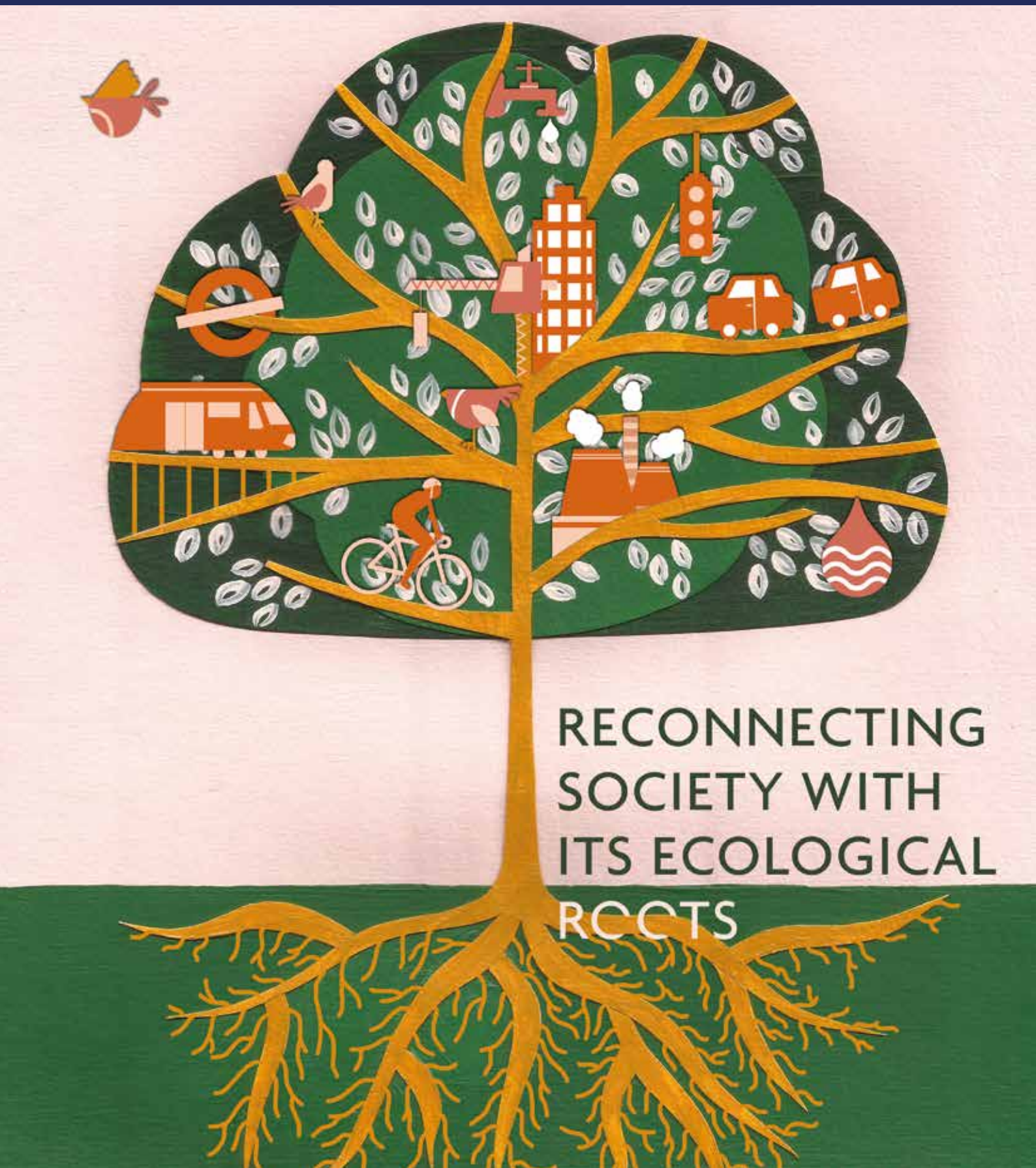

RECONNECTING SOCIETY WITH ITS ECOLOGICAL ROOTS

EDITORIAL

Reconnecting society with its ecological roots

We depend wholly upon the Earth's ecosystems for our basic requirements for clean air, water and food, and for economic resources including those we consume and those we rely on for the dissipation and reintegration of wastes. Nature's services also inspire us spiritually and artistically, and constitute familiar places where we build homes, socialise and enjoy recreation. Often underappreciated in daily life, ecosystems cycle nutrients, carbon and energy, rebuilding soil health and the chemical balances of the atmosphere and the water environment. Nature does so ungrudgingly, 24/7, however much we use and, within limits, abuse it.

As co-evolved creatures of this planetary ecosystem, there are tight interdependencies between our activities and nature's supportive capacities. And, as we are increasingly aware, rising demands from a growing global human population with an increasing proportion of more-demanding consumers are overwhelming the finite supportive capacities of our single life-support system.

Commitments to marking a transition towards a pathway of development framed by sustainability, including agreements to embed the diverse values of ecosystems into the mainstream of policy development and implementation, are hardly new. Internationally, early examples include the acceptance of the 1981 World Conservation Strategy and the 1987 report from the Brundtland Commission. To these we can add ratification of many related treaties and strategies including the Ramsar Convention in 1971, the Convention on Biological Diversity in 1992, the UN Sustainable Development Goals in 2017 and the commitment to the UN 2021–2030 Decade on Ecosystem Restoration. National examples in the UK include The Natural Choice, the Natural Environment White Paper, in 2011, which set out commitments to recognise the multiple values of nature and to bring them into mainstream implementation, and also A Green Future: Our 25 Year Plan to Improve the Environment in 2018. A variety of workable decision-support frameworks have also been developed to guide sustainable choices and better inform potential synergies across areas of societal policy and interest.

However, notwithstanding sometimes generational timescales since their inception, the transposition and practical realisation of these bold aspirations and pronouncements remains at best preliminary. Meanwhile, growth in gross domestic product (GDP) still correlates strongly with declines in global forest cover and rates of species extinction, and national GDP tracks per-capita carbon emissions. Radical reform thus far eludes us, our window of opportunity for strategic and proportionate action ever narrowing.

We can, and must, reconnect society with its ecological roots. A new paradigm is required that places ecosystems and their processes at the very roots of societal thinking, policy, fiscal systems and resource use habits. There is nothing regressive about the required transformation. It is one based on opportunity and lasting value, recognising ecosystems and their services as foundational resources generating a wealth of linked values that are fully accounted for in the ways we think, plan, invest and trade. Rather than erode resources for short-term profit-taking, as per today's norms, investment takes the form of sustainable use habits that protect and ideally regenerate this currently much-degraded foundational natural wealth. Realisation of this new 'regenerative landscapes' model is not only feasible, but is already happening in fragmented instances across the planet: from local to wide landscape scales, in developed and developing nations, and in both rural and urban settings.

Dr Mark Everard has been a champion of the development of ecosystems thinking and its application for over 40 years, in academic, policy-development, NGO and business environments and in both the developed and the developing world. Mark, a Vice President of the IES, is also a prolific author and broadcaster, committed to science development and its understanding and uptake.
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Cover design: Lexie Mac is an artist and illustrator living and working in Ireland. She paints many animals and is passionate about the environment. For more of her work, visit www.lexiemac.co.uk.

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The environmental SCIENTIST provides a platform to discuss key issues within the environmental sciences, hosting original articles written by professionals, academics and experts working across the sector.

INTRODUCTION

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Our underpinning ecosystems

Gary Kass highlights the importance of systems thinking.

The ever-growing number of studies, assessments and analyses at all scales – from local to global – give us little doubt that the current trajectories of human activity put at risk visions for a sustainable future.[1,2,3] These assessments and many others make it clear that transitions are needed across of our core systems of production and consumption, such as energy, food, mobility and infrastructure.[2] We need system change not climate change.[4] But it is becoming clear that the window of opportunity to make deep changes to societal habitats is closing rapidly. On current trajectories, we are increasingly less likely to meet our near and longer-term goals for climate, biodiversity, waste, social inequality and many other issues across the environmental and sustainability agendas.[2,3]

We can welcome the sheer weight of this evidence, and the growth and worldwide spread of awareness and activism – from Greta Thunberg and Extinction Rebellion to the Dalai Lama – and we can celebrate a blooming of governmental and international bodies releasing increasingly stark statements and promoting radical new legal instruments, such as international agreements and conventions related to redressing our relationship with the natural world.

Yet the irony is clear: we now know beyond any reasonable doubt that protecting and allowing the regeneration of damaged ecosystems will result in a more stable and richer future, but we still lack the application of this knowledge into effective actions that can break

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through decades of inaction and inertia. Powerful entrenched vested interests seek to resist change and maintain the status quo. Since the Covid-19 pandemic, calls have widened to build back better, coming from politicians, the United Nations, business groups and civil society. Perhaps now we have an equally unprecedented opportunity to make that breakthrough.

PROMOTING THE BREAKTHROUGH

This issue of the environmental SCIENTIST is all about promoting that breakthrough. 'Ecosystems: from single-use to multiple values' outlines how change is happening in fragmented ways across the planet and providing us with lessons on how to embed ecosystem protection and recovery as a foundational resource for regeneration of human opportunity. 'Urban systems and their impacts' progresses this thinking by looking at the trajectory from the original circular economies of urban settlements, through contemporary over-reliance of fossil energy with all its problems (including disconnections of resource use and reuse), and now aspiring towards a novel 'ecopolis' model re-establishing circular patterns in modern contexts. Practical progress with urban sustainability is outlined in case study cities in 'Cities with a plan'. The gradual distancing from localised, nature-centred solutions for water management, and the future need to rediscover these traditional wisdoms in contemporary settings to shape the future direction of water management is outlined in 'Relearning water wisdoms'. It may seem counterintuitive to consider the 'Water and the defence and security agenda', but peace clearly ultimately depends on adequate and shared resources. Equally, so does our health, a topic addressed by 'Embedding ecosystem services to support human health'.

'The natural basis for meeting human needs – a reality check' shows how our long-term wellbeing ultimately depends on our relationship with ecosystems. Similar observations arise from the consideration of 'Green infrastructure and ecosystems as strategic public-health interventions'. 'The benefits of nature's recovery' highlights evolving thinking in nature conservation linked to human wellbeing. A multi-beneficial, ecosystem-based approach to tangible benefit realisation is also a feature of 'Natural flood regulation and rail infrastructure'. 'Ecosystems, Covid-19 and other zoonotic diseases' provides recent insights into the role of ecosystem degradation and regeneration in the transfer of zoonotic diseases, including Covid-19, from animals to humans, and the further role in the security of water resources vital for controlling human-to-human transmission as well as treatment of infected individuals.

WHOLE-SYSTEM SHIFTS

In the end, achieving sustainability requires whole-system shifts, with an explicit focus on all of the five Ps: people, planet, prosperity, peace and partnerships.[5] As we look to the post-Covid-19 renewal, we have a significant and unprecedented opportunity to create a future over which we can exercise huge discretion. As governments seek to rebuild their economies, billions of pounds will be invested in hundreds of thousands of projects and programmes at every scale from the local to the global. Myriad adjectives are being used to describe the kind of recovery and renewal we want: clean, green, fair, just, dynamic, sustainable, innovative, resilient, people-centred.

As we shift our focus from continuing to describe and track the decline of the natural world to developing new approaches and implementing solutions to turn the tide quickly, there is also a clear need to take a more system-level focus to achieve radical transformations, rather than picking off individual problems and making small incremental steps forward.

This transitions-based approach focuses on large-scale socio-technical systems, such as how we create and consume energy, food and infrastructure. These systems consist of multiple elements: technologies, markets, user practices, cultural meanings, infrastructures, policies, industry structures, and supply and distribution chains.[6] Taking such a systems approach is needed to address sustainability.[7] Doing this will help to explain how a system evolves from the influence of the system components on one another and also from the ways in which human intent shapes the evolution and dynamics of the system. This approach also helps in recognising influential, deep leverage points: places at which interventions are difficult but likely to yield truly transformative change.[8] A systems approach enables us to examine the interactions between shallow and deep system changes, and how shallow interventions may pave the way for deeper changes, while deeper changes may also be required for shallow interventions to work. Finally, a systems approach to sustainability provides ways for different disciplines, sectors and stakeholder groups to work together.[7]

This way of thinking is at the heart of the IES vision and mission. We have long advocated the application of robust knowledge from across multiple disciplines, taking a systems-level perspective and focusing on finding and implementing practical solutions.

We hope you enjoy this issue of the IES journal, so wonderfully curated by our guest editor, Dr Mark Everard. I have pleasure in thanking him for his tenacity and perseverance in bringing together the numerous people, ideas and words to turn them into a coherent whole. Ideally, you will find this issue of the journal helpful in driving forward the embedding of systems thinking and environmental sciences into policy and practice in a future defined by the greater opportunities enabled by the regeneration of our underpinning ecosystems. All of us have agency in brokering that sustainable societal transformation. ES

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FEATURE

Ecosystems: from single-use to multiple values

Mark Everard argues for a more intelligent use of ecosystem services.

There is growing evidence from attitude surveys and data on resource flows through the economy that we are beginning to see and respond to the wisdom of rejecting single-use plastics. However, ironically, we are still failing to see the dangers in exploiting ecosystems in a single-use way.

MINING GLOBAL ECOSYSTEMS

The potential for negative outcomes to arise from a myopic, single-purpose focus on ecosystem exploitation is well illustrated by the US Dust Bowl. In an effort to boost agricultural outputs following the Great Depression, vast tracts of prairies in the midwest of the USA were turned over to agriculture, for which novel, deeper ploughing technologies were used. The promise was rich returns from productive farmland, but the outcome was exactly the reverse.

The value of the protective cover of prairie vegetation for landscape stability had been completely overlooked. As the stabilising root systems of the prairie vegetation were removed, soil was stripped from the land in huge quantities through wind and water erosion. Instead of being converted to productive croplands, the formerly fertile soils of the midwest prairies were converted into dust clouds that swamped farmsteads and rural towns. The fundamental resource of soil was lost, stripped from the land and dumped in drifts on settlements, driving people into severe poverty. The Dust Bowl led to the migration of 3.5 million people away from plains states in the 1930s and 1940s, the largest forced migration in US history.[1]

There are other examples of this type of short-sighted behaviour. Across India, there has been a move away from water-management methods that are millennia old, community based and ecosystem centred towards overreliance on technological solutions, including a proliferation of unregulated boreholes and the development of large dam-and-transfer schemes.[2] In China, the waters of the Yangtze River system, for example, have been diverted more than 1,000 km northwards to serve the economic powerhouse of the North China Plain. All this at the expense of species extinctions in the Yangtze catchment, erosion of the Yangtze delta, including its food-producing potential and associated cultures, and many more hardships besides. Even the often narrowly focused British government is warning that our current exploitative, intensive agricultural practices are risking 'eradication of soil fertility' in the UK over the coming 30–40 years[3] unless reforms are enacted.

MINE, USE, DISPOSE OF

Many of our economic and resource-use practices are still geared to the linear resource-use practices – mine, use, dispose of – that served as a powerful accelerant of the European Industrial Revolution. They still serve that purpose in industrialising nations today, and many of these less-developed nations are used by the developed-world markets as sources of primary resources (such as forest and mineral assets) as well as finished products.

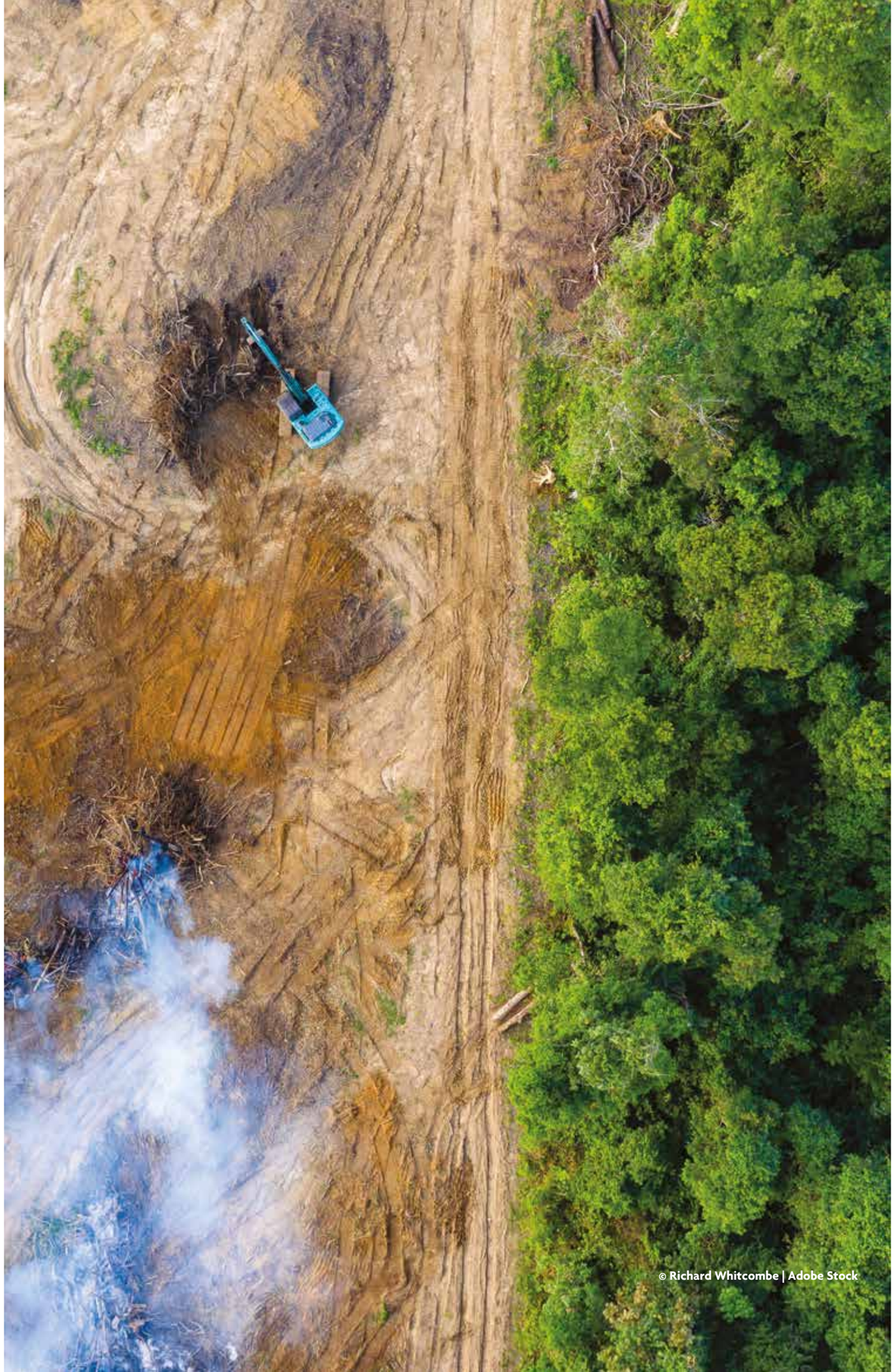
We are, in essence, mining the whole planetary ecosystem through extractive practices that overwhelm natural replenishment rates and, through this, contribute to a raft of unintended and perhaps unforeseen though predictable consequences.[4] This habit places us in a degrading socio-ecological cycle, as the supportive capacities of ecosystems inevitably decline under the pressures of our exploitation-focused lifestyles and economic norms. Metrics such as gross domestic product (GDP) measure economic activity yet fail to account for the foundations of markets and other elements of continuing human security and opportunity. So these metrics blind governments, markets and business decision-makers to the long-term starvation of roots nourishing future wellbeing.

These degenerative landscape habits founded on the maximisation of output through increasingly efficient exploitation, blind to their impacts on supporting ecosystems and their services, may yield short-term gains. However, they drive progressively degenerative socio-ecological cycles by ignoring the importance and multiple values of underlying ecosystem processes. As the capacities of the ecosystem to sustain a linked set of human needs gradually erode, we are hurtling ever faster towards a metaphorical global dust bowl.

TOWARDS SYSTEMIC SOLUTIONS

Emerging approaches such as natural flood management (NFM) and an increasingly catchment-based approach to the protection of raw water quality are examples of a shift towards valuing the services provided by ecosystems to address societal needs on more sustainable, nature-based foundations. This is in opposition to defining problems in narrow spatial, temporal and disciplinary terms, and applying equally narrowly framed technical fixes to localised and, in these cases, downstream problems. In these two instances, building a flood wall or spending money and other resources to cleaning up contaminated water at the point of abstraction, have been common fixes applied to address narrowly defined problems. However, neither solution works to alleviate the causes.

By contrast, nature-based solutions tend to enhance catchment functioning and address the focal problem.



They simultaneously:

- Contribute to carbon sequestration rather than the emission of climate-active gases;
- Support wildlife including natural recruitment of fish populations;
- Protect valued landscapes; and
- Reduce flood risk downstream that could only be exacerbated by lost storage if flood banks are erected or land drained.

These are just a subset of the closely linked ecosystem service benefits likely to arise from solutions to the issues of flood-risk management and water-quality protection at source. The same observations could be made of the multiple values of urban green spaces that include:

- Natural contributions to breaking down heat islands;
- Providing wildlife with habitats and stepping stones across the built environment;
- Cleaning the air;
- Providing visual and noise buffering; and
- Potentially enhancing adjacent property values.

ANCHOR SERVICES

Strategic and economic benefits arise from considering desired outcomes, not in isolation, but as anchor services – metaphorical anchors for decision-making. Addressed in this multi-dimensional way, management options and exploitation techniques can be considered in systemic terms, potentially co-delivering a range of linked ecosystem services of optimal societal value.[5] The optimisation of overall societal benefits then may be achieved by solutions that are generally ecosystem based, or that at least work in sympathy with natural processes and include the maintenance of the providing ecosystem. These intentionally multi-beneficial management measures constitute systemic solutions, defined as 'low-input technologies using natural processes to optimise benefits across the spectrum of ecosystem services and their beneficiaries'.[6]

Systemic solutions recognised under this initial definition include wetlands, washlands and urban ecosystem-based technologies optimised to achieve multiple ecosystem services. They are simultaneously generated by focusing, not solely on narrow ends, but upon the foundational ecosystem processes that provide them. The principles implicit in systemic solutions are that all ecosystem services, along with the rights of beneficiaries to those services, are systemically considered in any decisions. Such an approach encourages the optimisation of net societal value from ecosystem services; the benefits are not skewed towards a favoured few at the cost of benefits to any other overlooked beneficiaries (including future generations). A systemic solutions strategy implies a transition towards a more participatory and collaborative approach that seeks optimal and sustainable outcomes.

FEATURE

REGENERATIVE LANDSCAPES

And thus, we change the paradigm, stepwise, from one of a degenerative cycle of declining ecosystem and human wellbeing towards a 'regenerative landscapes' socio-ecological cycle, in which increasing human security and opportunity are founded on the protection or enhancement of natural processes and carrying capacities.

This is no idle conjecture. The need for a rapid transition from today's degenerative norms is pressing and the window of opportunity is rapidly narrowing. But there are many exemplars of this transition in action right across the world. In addition to the slow spread of NFM and the increasing use of the catchment protection of raw water quality (as exemplified by the Upstream Thinking programme in the south-west of England[7] and New York City's unfiltered water supply[8]), a wide range of other instances are summarised in a RICS Report[9] and a new book *Rebuilding the Earth*[4] that also translates lessons learned into practical decision-support frameworks. *Rebuilding the Earth* elaborates examples from the very localised to large landscape scales, from the developed and the developing worlds, and in rural and urban settings.

One example is the reanimation of rural catchments in Rajasthan (India) through the promotion of groundwater recharge during monsoon rainfall to restore water security. A small-scale urban example is provided by vegetated valleys in highly urbanised Tokyo that are metered to display their contribution to creating cool microclimates. At the massive landscape scale, the regreening of the Loess Plateau in China has stabilised rapidly eroding soils to bring millions out of poverty; ecosystem regeneration in the Ethiopian Highlands has reversed huge erosion rates, also bringing livelihood security to local people; and Africa's Great Green Wall is arresting and reversing desertification right across the southern Sahel.

Though currently fragmented, rather than constituting a pervasive cultural movement, these exemplars are repositioning ecosystem functioning at the core of socio-economic security and opportunity. There are many more examples besides, all demonstrating tangible and valuable outcomes, as well as providing transferrable principles to guide future policy and practice that is more systemic.

MULTIPLE-VALUE POLICY AND PRACTICE

This connected world view needs to progressively supersede the legacy patchwork of narrowly framed technical, legal and fiscal fixes. The solutions span all areas of developed world perception and practice: finance, the law, business assumptions and norms, education and research, and ultimately all policy areas. All of us have influence and agency in brokering change from the immediate and consumption-based to the enduring and renewable.

At the very worst, a more systemically informed approach helps to recognise, and ideally avert, negative consequences for formerly overlooked ecosystem services. Governance systems embodying this connected approach are easier to recognise at local scales, such as traditional village governance arrangements that have been historically adapted to achieve sustainable, enduring outcomes where people live in close proximity to supportive ecosystems. We in the developed world have a great deal to learn from the practitioners of sustainability that we might otherwise regard as undeveloped. We need to take those lessons forwards and apply them in rethinking an onward journey of greater sustainability, security, innovation and enduring profitability. ES

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FEATURE

Urban systems and their impacts

Herbert Girardet maps out a regenerative future for cities.

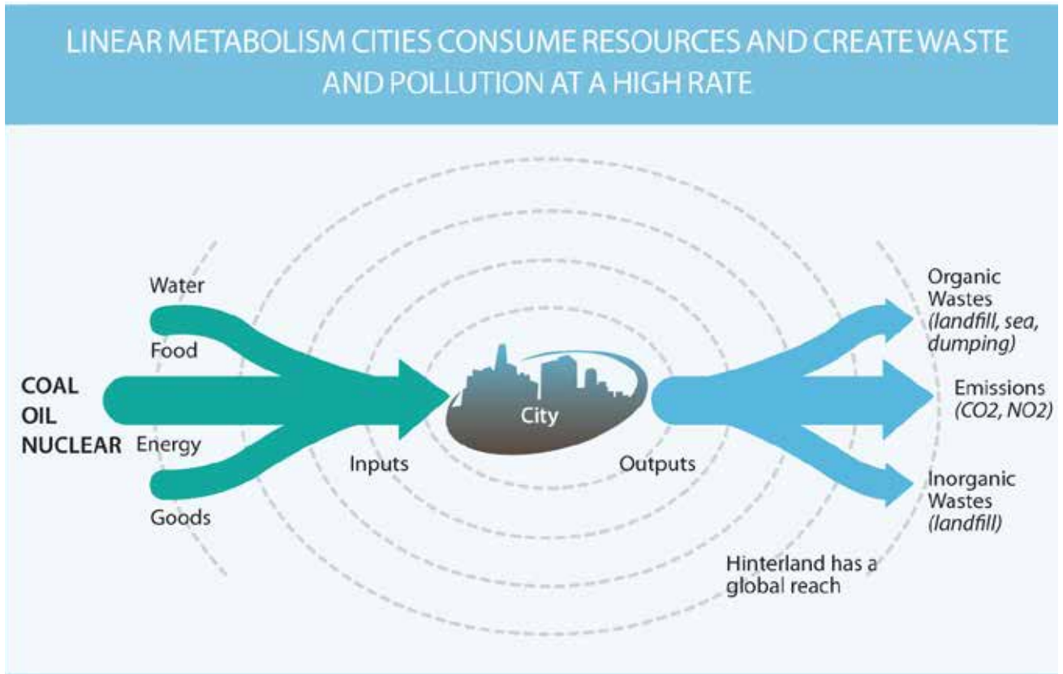
We now live in the age of the city, with well over 50 per cent of the global human population being urban, and this figure is expected to reach 68 per cent by 2050.[1] Cities are inherently dependent systems, as their functioning relies on supplies of a large variety of resources from beyond their built-up territory, most notably food, water and wood products. The linkages between cities, soils and ecosystems have morphed over the centuries, depending on levels of technological development and cultural practices. Most notably, the geographical range of their consumption patterns has expanded, from largely local to increasingly global arrangements.

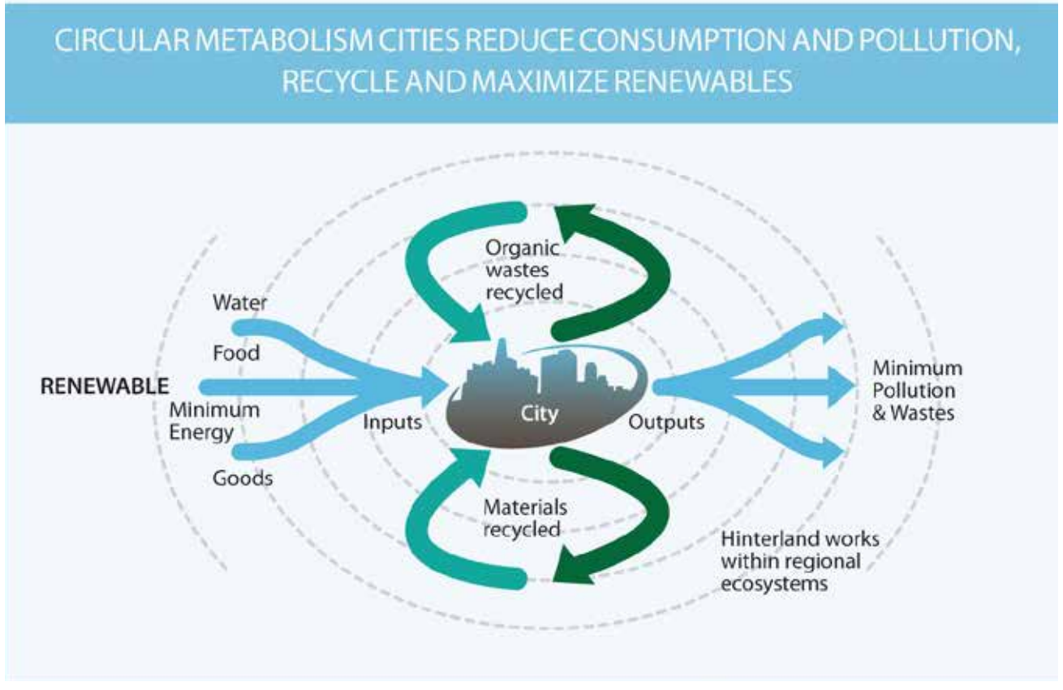
Current urban impacts on the global environment need to be better understood if we are to make progress towards a sustainable world. The central contradiction we currently face is this: humanity is building an urban future, yet urbanisation in its current form is threatening the very future of humanity and the natural world. With ever-larger numbers of people living in cities that are ever-more resource hungry, we are risking the long-term chances of human wellbeing and even survival. What positive initiatives can we take to address such fundamental systemic problems?

SMALL AREA, GROWING FOOTPRINT

Modern cities, with their large human populations, occupy a relatively small surface area: today some 4 billion people live on just 3–4 per cent of the world's land surface. This can arguably result in some sustainability benefits, particularly with regard to transport efficiencies. But as they grow into preeminent centres of national economies and of popular consumerism, cities develop ever-larger global ecological footprints. In developing countries, as villages and small towns grow into large cities, their per-capita resource consumption can increase three to four times due to increased incomes and the ready availability of fossil fuels and manufactured products. This has huge implications: in the process of urban growth, cities develop increasingly global tendrils for supporting their resource demands. Urbanisation, as practised today, thus becomes a feature of the ever-greater impact of humanity on the biosphere.

A fundamental systems problem of the modern city is its essentially linear metabolism: resources are taken from nature in huge quantities, embedded in products that are used by consumers and then discarded as waste in the natural world. Ecosystems have become the sinks in which we dispose of our poisons and other technical and chemical wastes that cause havoc in nature. For an urbanising world to have a long-term future, cities need to develop a circular metabolism, as suggested in **Figure 1**. This change, of course, has to be driven by appropriate policy measures.





▲ **Figure 1. Modern cities have an essentially linear metabolism, taking resources from nature and dumping gaseous, liquid and solid waste into the biosphere. For a long-term sustainable future, cities have to learn to mimic the circular, regenerative processes that define natural systems. (© Herbert Girardet)**

THREE PHASES OF URBAN EVOLUTION

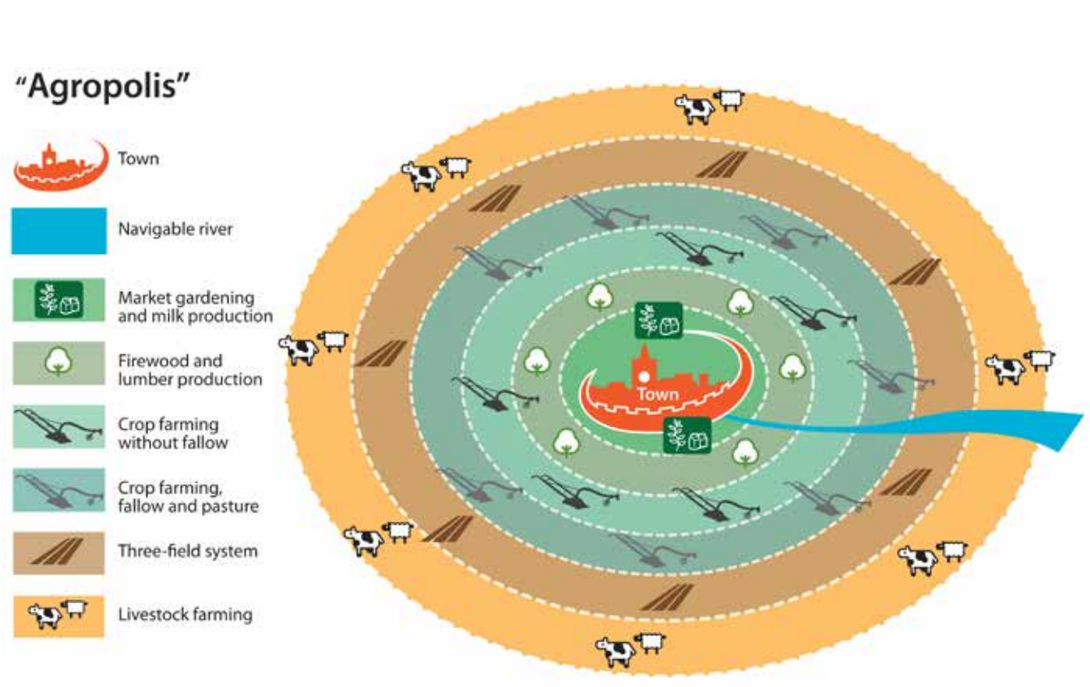
It seems useful to develop some theoretical concepts of the character of urban systems. I have summarised their development with respect to their resource dependencies into three distinct phases.[2]

Agropolis. The traditional town, in the absence of well-developed transport links, had essentially agrarian roots. Energy supply, and resource use and reuse, were necessarily localised. The town was reliant on crop and livestock farming systems that were peripheral to the settlement (see **Figure 2**).

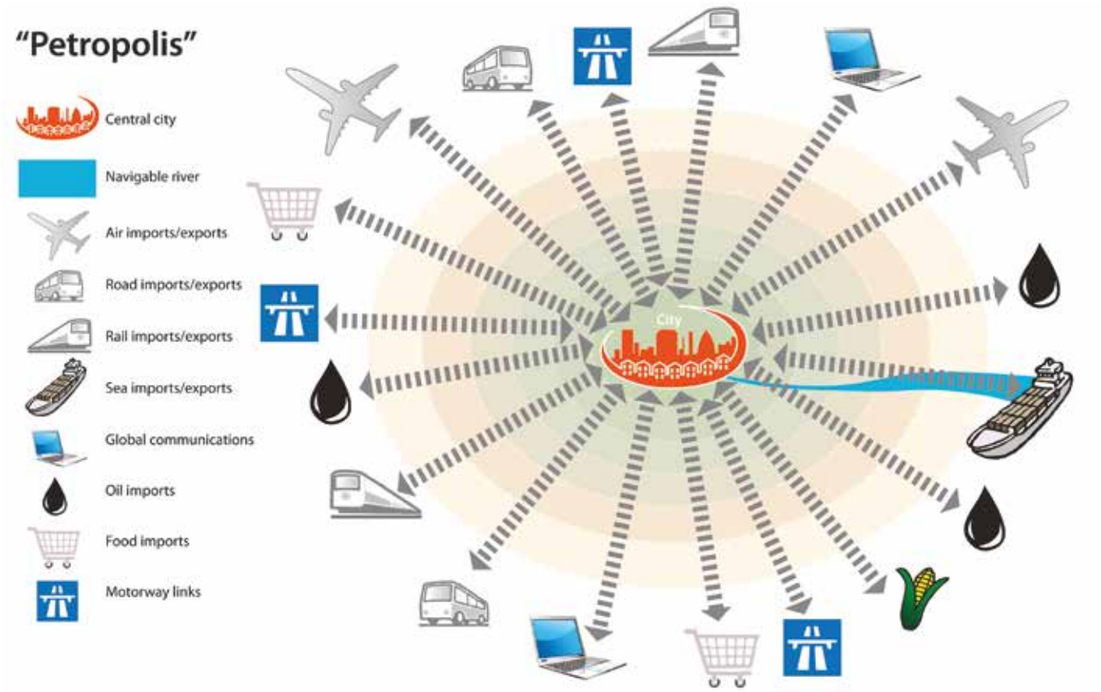
This model required a well-developed understanding of the conditions for sustainable interaction with supporting natural systems, such as soil husbandry, crop cultivation, the uses of farm animals, and water management. Of necessity it was based on an inherently circular metabolic arrangement: long-term viability necessitated that organic waste from within the city, with its associated nutrient and carbon content, was returned for productive use in the surrounding land.

Petropolis. The modern city, in contrast, represents a different urban reality. It is powered for all its functions by non-renewable fossil fuels, and food and other essential resources are brought in from remote locations rather than from places peripheral to the city. Its fundamental existential dependence on daily petrochemical inputs (to resource supply, manufacturing and transport) results in a problematic relationship to the world's ecosystems. So the existence of today's cities is dependent on huge amounts of resources drawn through worldwide supply chains and over-extensive ecological areas. This situation creates a one-way flow of plant nutrients from distant ecosystems that are not then replenished at source. The impacts of greenhouse gas emissions and prevailing extractive practices lead to climate change and the progressive loss of soil productivity and biodiversity in the source ecosystems (see **Figure 3**).

At the same time, urban sprawl leads to the progressive urbanisation of local landscapes. Unidirectional resource flows contribute to waste-related nutrient and chemical pollution of land and water systems peripheral to the settlement. River systems become depleted and polluted, contributing to distant dead zones in coastal seas around the world. Other long-distance impacts include the huge land take, such as in the Amazon region, for the



▲ **Figure 2. This diagram draws on the work of the 19th-century geographer Heinrich von Thünen. Agropolis is embedded in a horticultural and agricultural hinterland. Its existence depends on a continuous give-and-take: reaping an annual harvest for its inhabitants in exchange for returning human and animals waste back to the land. (© Herbert Girardet and Rick Lawrence)**



▲ **Figure 3. The modern city, Petropolis, depends on massive daily inputs of non-renewable fossil fuels for all its internal functions as well as its external transport connections. Critically, food is often brought in from distant locations, causing cities to have vast global ecological footprints. This future of this kind of urbanisation looks highly problematic. (© Herbert Girardet and Rick Lawrence)**

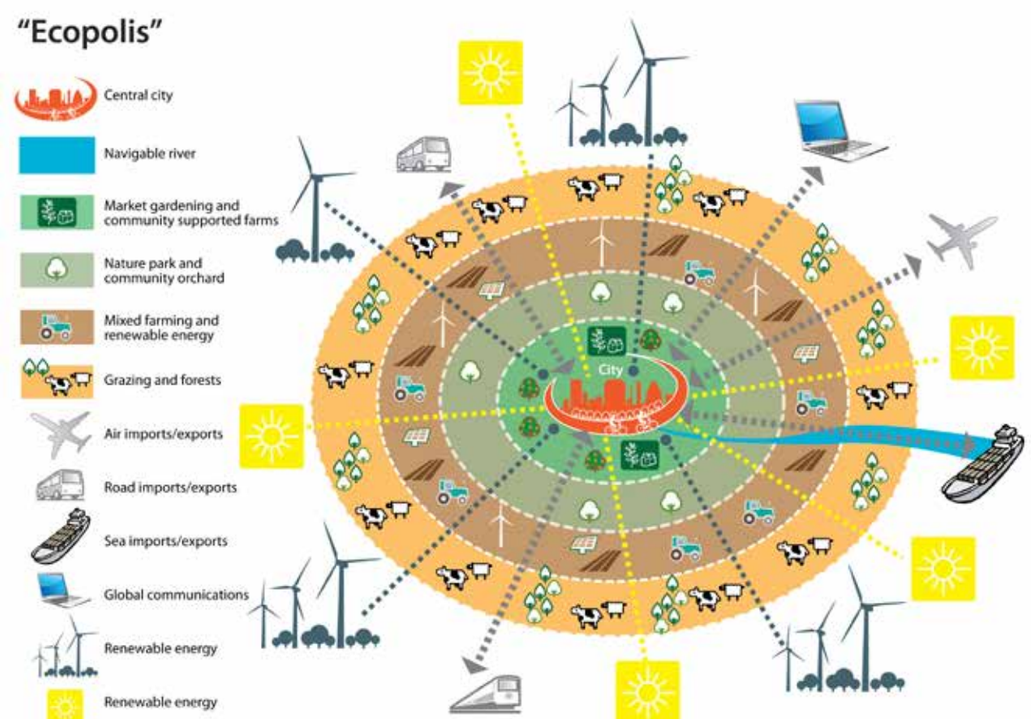
production of soya beans used for feeding pigs in other global regions and in turn feeding humans in yet another place. The lack of cyclic systems then results in fertiliser run-off, and slurry and sewage pollution in rivers, causing excess nitrification.

As just one of many, almost uniform, global examples, 18th-century London was largely fed from its hinterland, but as it grew, it became ever-more dependent on remote sources of food and nutrients. A major downside of a world in which Petropolis has become dominant is that it is profoundly vulnerable to disruptions across a broad spectrum of supporting ecosystems, geopolitical regions and supply chains.

Ecopolis. This new urban paradigm has to be the model of the nature-compatible city of the future. It should not be regarded as a retrograde concept, but one of dynamic innovation and progress. Fossil-fuel dependence will give way to efficient use of renewable energy technologies. And, crucially, the urban system needs to be designed to be compatible with its supporting ecosystems, so as to develop a regenerative, circular metabolism (see **Figure 4**). This entails emulating the circularity of natural ecosystems, recycling waste resources from human consumption back into the environment where they are safely reintegrated and regenerated through natural processes. Among other measures, this entails applying the nutrients and carbon contained in human excrement and organic wastes to the farmland supplying food to cities. Recycled plastics from the urban waste stream would be used in road construction and other long-life infrastructure. The emphasis is on ceasing the linear 'take, take, take' model of the modern economy and learning from nature about the necessity of cyclic systems for the achievement of sustainability.

TOWARDS URBAN SELF-RELIANCE

The essential paradigm shift towards an Ecopolis model is more profound than the biophilia approach, popularised by E.O. Wilson[3] and others, that reflects the innate human attraction to nature and natural processes built up through an evolutionary history of living in



▲ **Figure 4. A viable future for an urbanising world depends on cities using their built-up spaces and their hinterland to supply energy that is 100 per cent renewable and food that is local and regenerative. Ecopolis mimics the circularity of natural ecosystems, which would be embedded both in both ecological and economic practices of cities. (© Herbert Girardet and Rick Lawrence)**

forested and agrarian settings. Rather, it suggests an *eco*philia approach, which is broader based and takes into account the wider issue of the reliance of cities on distant ecosystems. Thus natural processes are embedded into the interactions between people and ecosystems, and are supported to create a regenerative urban agenda and economic model of progress.

The entire metabolism of cities needs to be taken into account: biophysical, technical, industrial and even financial. There is a pressing need to think and develop urban systems on the basis of nature's cyclic processes: the carbon, nutrient and water cycles. This applies to all areas of human activity, including the need to account for the wider geographical dependencies on water drawn from distant, upstream catchments, and the supply chains of food and other resources consumed by the urban metabolism. The Ecopolis concept can also form the basis for a new, resilient green urban economy, particularly for city regions currently caught in the downward spiral of depression and poverty as former industrial activities fall into decline.

There is nothing regressive about this change in paradigm. The innovative and forward-looking cyclic city thinks in terms of innovation as a basis for greater security and greater liveability for its citizens. A novel green economy, championing all aspects of regenerative development, would offer livelihoods to large numbers of people. It would convert organic waste into productive compost and recycle industrial waste into material of value for long-term uses. It would switch to regionally autonomous renewable systems instead of relying on dwindling, expensive and polluting fossil fuels drawn from remote and often politically problematic regions. It may, for example, conceive of drawing on methane from sewage for power generation, as Bristol did with its innovative 'poo buses'. The urban food system would become more localised and less reliant on high-energy inputs and international supply chains.

Pertinent urban examples of such transformations include concrete measures already implemented in Adelaide, Australia, where measures towards mainstreaming water efficiency, circular waste management, reforestation and

renewable energy have created a very substantial new green economy. This transition, aimed at South Australia becoming a sustainable region, was based on a 32-point plan that I put to the Australian government[4] and is discussed as a case study in the article 'Cities with a plan'. Further global exemplars of urban evolutions are seen in the Welsh government's Our Valleys, Our Future programme,[5] India's Smart City Mission,[6] South Korea's fourth industrial revolution,[7] and the USA's stimulus policies for renewable energy, including under the American Recovery and Reinvestment Act of 2009.

CHALLENGES AND SOLUTIONS

Urban societies today tend to have a profound lack of understanding about the impacts of their demands and actions. For instance, there is little understanding about how clean water is available on tap, and wastewater is flushed away with no sense of connection with water catchments that are both sources and sinks. In business, too, fresh water supply and wastewater disposal are generally conceived as matters of commercial transaction with water service companies, with little understanding of them as natural resource dependencies.

The same can generally be said of food chains and their associated waste streams, often procuring out-of-season or other cheaply produced crops together with their constituent nutrient, carbon and energy content through long international supply chains. Ironically, while global society heads towards peak phosphorus – global demand outstripping exploitable supplies – we also suffer a surfeit of nutrient pollution of fresh waters and in coastal dead zones as well as farming methods that drive loss of soil fertility and biodiversity. As one pertinent example: the nutrient content of soya beans grown on former forest soils in the Brazilian Amazon, and then procured on international markets, significantly contribute to pig manure pollution of the China's Yangtze River, in turn contaminating the water supplies of those who consume these pork products.

But there is now an increasing awareness of these matters from media reports. For instance, television documentaries highlighting the accumulation of single-use plastic items in the oceans, leading to the strangling of turtles and dolphins, triggered a strong emotional reaction in the general public, which helped to kick start some initial regulatory responses and business innovation. Reconnection of urban societies with their environmental dependencies and impacts is vital to stimulate proportionate responses.

Creating regenerative cities is a pressing priority in the urban world we are building, which is synonymous with the Anthropocene era. Biological and technical regeneration must necessarily work hand in hand, and the metabolism of cities must both re-localise but also develop sustainable, cyclic relationships with the broader

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hinterlands upon which they ultimately depend for their sustenance.

By and large, Ecopolis is still a vision in the making, but a necessary one, as human numbers and urbanisation continue to boom. We and our cities are, after all, living entities with metabolisms that are umbilically connected with this planet's supportive ecosystems. ES

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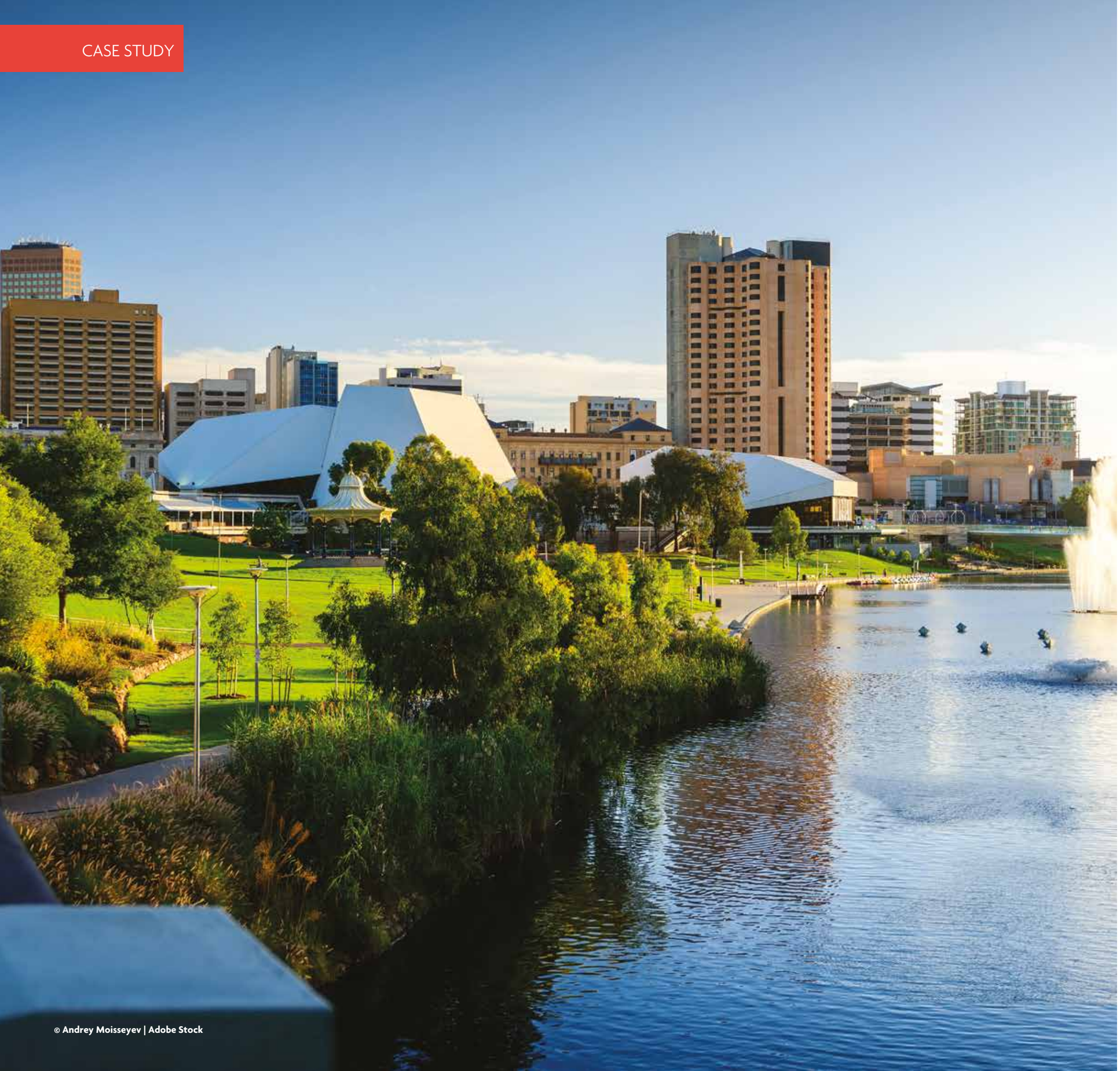

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CASE STUDY

Cities with a plan

Herbert Girardet and **James Longhurst** describe two city-related initiatives that are focused around sustainability goals.

CASE STUDY 1
ADELAIDE'S REGENERATIVE GREEN ECONOMY

By the 1990s, Adelaide, the capital city of South Australia, was facing a series of interconnected problems. As in many European and US cities, the industries upon which the city's wealth had been founded were in decline, causing unemployment and social tensions. And the Murray–Darling River, draining around one-seventh of the continent's land mass and serving as South Australia's main source of water, was in serious decline in terms both of water quantity and quality, due to multiple demands from agriculture and urban consumption, as well as the effects of a warming climate. This threatened not merely the security of water supply, but also of food and energy.

CREATING A NEW NORMAL

Simply trying to rebuild the region's old economy was manifestly not an option in the face of the sunsetting of former industries and increasingly grave natural-resource limitations. In 2003, the government of South Australia took the bold decision to initiate a thinkers-in-residence programme, inviting researchers from around the world to examine the situation and make proposals for change. I (Herbie Girardet) was the first thinker to be invited, and my task was to explore how South Australia's economy could be put on a sustainable footing: how water, food and resource efficiency and renewable energy could become the basis of a new green economy.

It quickly became apparent that the region was making very inefficient use of resources and that it was necessary to examine its 'metabolism'. How could an inefficient, petrochemically dependent urban model, with its many associated vulnerabilities, be replaced? How could new opportunities be found for new smart technologies and greener jobs? The focus of the work was not just Adelaide itself, with a population of 1.2 million, but the whole of South Australia, with its 1.7 million people.

▲ **Figure 1. In 2018, South Australia commissioned Tesla to install a 130 MV lithium battery system, then the world's largest, to smooth out the renewable energy supply from its wind farms and solar roofs. (© Liam West/Lightly Salted)**

The very special situation I found was that both the premier of South Australia, Mike Rann, and his entire cabinet and much of the civil service backed my work. In innumerable seminars over a 10-week period, people from all sectors of South Australia's society came together to discuss future prospects. It was soon clear that no single institution alone could achieve the systemic transformation needed, extending as it did beyond the authority, remit and perspective of each sector. Academics, non-governmental organisations (NGOs), politicians, business leaders, trade unionists and civil servants all came together to create a coherent vision for change. It became possible to develop deep, new partnerships and share learning across all affected bodies.

At the end of my stay, in May 2003, I submitted a 32-point plan called *Creating a Sustainable Adelaide*. This was examined by a cabinet committee and eventually approved in its entirety. It led to a multi-stakeholder implementation process to make substantial advances in building a substantial green economy for Adelaide and, indeed, for the whole of South Australia.[1]

GREEN OUTCOMES ACHIEVED

Seventeen years from its inception, outcomes of the work span multiple dimensions. The region has achieved greatly enhanced water and energy renewability. Its electricity system now boasts 60 per cent renewable supply from wind and solar, and the world's largest battery has been installed to deal with supply fluctuations (see **Figure 1**). South Australia has become a living demonstration that novel energy systems can form the basis of urban regeneration in a post-industrial setting, displacing damaging fossil-fuel-based technologies while also regenerating local economies. Water-efficiency measures have also been implemented across the region, with wastewater recovered from treatment plants used in park and farmland irrigation. Some 3 million trees have been planted for soil erosion control and carbon sequestration. Key outcomes of the new policies implemented by the South Australia government are summarised in **Box 1.**

The prospect of creating a major new green jobs sector was one of the primary triggers that influenced change by the government. Policy stimuli towards the development of an increasingly cyclical urban economy have proven to be a profitable enabler of progress towards sustainability. Regulation, markets, technological innovation, targeted impartial advice and other measures have all achieved demonstrable progress. In all this, government agencies have played key roles in establishing frameworks for cross-sectoral collaboration to achieve clearly framed, desirable outcomes.

Adelaide has also become an exemplar of what can be done to reconnect a city to its hinterland. Stimuli towards large-scale urban fringe agriculture and viticulture are also an integral part of the local scene. Progress made in Adelaide, and South Australia as a whole, demonstrates the powers of a collaborative approach extending beyond the authority, remit and perspective of any single societal sector.

South Australia now sets a global standard for the rebuilding of post-industrial city-regions and economies, based on the cyclical and efficient use of waste, water, food and energy, and the development of novel technologies. Cumulatively, these demonstrate the benefits of a more sustainable, or indeed regenerative, greener economy. Adelaide stands as the tangible and successful basis for transferrable lessons for the future development of other city-regions across the world.

BOX 1: KEY OUTCOMES IN SOUTH AUSTRALIA

- 60 per cent electricity supply from wind and solar;
- 300,000 photovoltaic (PV) roofs on 600,000 houses = 600 MW peak;
- PV roofs on most public buildings;
- The world's largest lithium battery: 130 MW;
- Solar hot water systems mandated for new buildings;
- 3 million trees planted on 2,000 ha for CO_2 absorption and biodiversity;
- 25 per cent reduction of CO_2 emissions since 2000;
- Water-sensitive urban development;
- Substantial extension of its tram system and its cycle lanes;
- 180,000 t of compost made from urban organic waste;
- 20,000 ha of peri-urban land used for vegetable and fruit crops;
- Reclaimed wastewater and urban compost used to cultivate that land;
- Large-scale programmes to improve the energy performance of buildings across the region;
- 60 per cent CO_2 emissions reduction by municipal buildings;
- Construction of Lochiel Park green village, with 106 eco-homes; and
- Thousands of new green jobs.[2]

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CASE STUDY

CASE STUDY 2
BRISTOL'S SUSTAINABILITY JOURNEY

Bristol is both a city and a county in south-west England. Its urban population was estimated at 463,400 in 2018,[3] but the wider city-region encompasses the 10th-largest population in England, estimated at close to 1 million people. It is one of the Core Cities of the UK[4] and is the only UK city to have been awarded the title European Green Capital.[5] Like many cities, both in the UK and globally, Bristol has faced daunting sustainability challenges, including reinventing itself with the decline of the traditional, heavier industries and sea-based trading on which much of its former wealth was based.

SUSTAINABILITY CHALLENGES

Bristol is the home of two universities with over 50,000 students between them, contributing to the development of a knowledge economy. Strategic support for the growth of important engineering and aviation industries, financial services, consulting and the Port of Bristol,[6] one of the UK's largest, has redirected the economic basis of the city. With a growing population, a revitalised economy and, for some, a high quality of life, Bristol is one of the most successful cities in the UK. However, the city has many gross inequalities, including: educational performance between different groups; large differentials in life expectancy between wealthy and poorer wards; and continuing areas of high under-employment and unemployment.

Despite the accolade of a European Green Capital designation, the city still confronts a range of environmental challenges. In 2016, as part of the Rockefeller 100 Resilient Cities initiative, the council published the resilience strategy for the city,[7] an innovative and forward-looking strategy looking out to 2065. The strategy sought to reconcile the sustainability and equity challenges faced by the city by developing a road map that progressively improved environmental performance and reduced inequalities.

Despite these initiatives, Bristol has continuing challenges with environmental performance. One example is air quality, with PM_{10} and NO_2 concentrations above legal limits in parts of the city.[8] The city's Air Quality Management Area has been in existence for some 20 years, and the more recent requirement to declare a Clean Air Zone (CAZ)[9] has been beset by problems and delays, but must come into force if legal requirements are to be met. The CAZ is one of the most ambitious in the country, with a stated intention to ban non-compliant diesels from the city centre for long periods of the day.

While the city has relatively low direct per-capita emissions of CO_2,[10] indirect emissions associated with consumption are likely to be significant. With rising concern about the impacts of climate change, Bristol City Council became the first UK local authority to declare a climate emergency in November 2018, and to state an ambition to become carbon neutral by 2030.[11]

THE BRISTOL ONE CITY INITIATIVE

The genesis of the Bristol One City initiative[12] arose from an awareness that Bristol City Council lacked all of the levers necessary to meet the city's aspiration to be an equitable and sustainable city. The mayor, Marvin Rees, published the city's first One City Plan in January 2019, uniquely adopting the UN Sustainable Development Goals (SDGs) to structure and direct actions and ambitions. This constituted a first written attempt to set out the key challenges, and to bring the city together as a concerted community to address common causes. The One City initiative is a city-wide strategy with a target date of 2050, and it builds on substantial progress across a number of policy domains.

The concept of partnership underpins the One City Approach and brings together a wide range of public, private, voluntary and third-sector partners from across the city. All share the aim of making Bristol a fair, healthy and sustainable city. The governance arrangements for the One City Approach are overseen by a unique One City office, providing advocacy, coordination, communication and administrative support for the One City Approach. A series of thematic boards have been established to oversee the currency and implementation of the plan and to lead the update of the plan's relevant sections:[13]

- Connectivity;
- Economy;
- Environmental sustainability;
- Health and wellbeing;
- Homes and communities; and
- Learning and skills.

These thematic boards are a mix of statutory functions (e.g. health and wellbeing) and voluntary endeavours (e.g. environmental sustainability). Each board brings together a range of civic actors, with the One City office providing coordination. Regular city gatherings review progress, challenges and opportunities. A city leaders' group provides strategic oversight and a further level of strategic integration and coordination.

In January 2020, a refreshed *One City Plan 2020*[14] was published to update the actions and timescales for Bristol's journey to 2050. The refreshed plan still uses the UN SDGs as its central integrative component of the approach. It addresses the interdependent challenges of growing an inclusive, sustainable city that resolves social fractures and inequalities while achieving carbon neutrality. One substantial change to the updated plan was the alignment of the carbon-neutral objective to 2030, a full 20 years earlier than the UK ambition. The 2020 iteration of the plan refreshes annual objectives related to this ambitious, longer-term objective.


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WHAT THE PLAN DOES (AND DOES NOT) DO

The One City Plan sets a broad context for planning a sustainable city – it is not a statutory plan in the sense of a land-use plan. Rather, it is an ambitious statement of intent and a strategy setting out the journey to that destination. The plan is intended to be updated on an annual basis, with intermediate goals moved forward or back according to external circumstances, but the 2050 goals remaining the absolute targets. The city office describes the plan as 'not perfect, acknowledging that by its nature it is an evolving process developing a uniquely Bristol-based approach to leadership'.[15] The plan is therefore best described as a set of shared, overarching goals and an invitation to partners to help reach those goals. The One City Plan sets out a vision of what Bristol will be like in 2050, and provides a route map for how the city may, through collective endeavour, make the journey to that destination. It serves as a way of engaging a wide spectrum of the city's inhabitants.

Bristol's carbon-neutral goal is central to the ambition vested in the One City Plan and, in 2020, Bristol launched its ambitious *One City Climate Strategy*.[16] This sets out the means to address the ambition to be carbon neutral by 2030 and to respond to the climate-emergency declaration. It sets out a framework for action to address direct and indirect carbon emissions, and to prepare for and adapt to the projected impacts of climate change.

The development of the *One City Climate Strategy* generated a significant evidence base on city climate resilience, direct and indirect emissions, and the identification of a pathway to 2030. The design and implementation of the strategy is supported by the Bristol Advisory Committee on Climate Change (BACCC),[17] an independent technical committee established by the University of Bristol and the University of the West of England at the request of the mayor. BACCC provides technical advice to help the city to understand and accelerate progress towards its ambition to be a carbon-neutral and climate-resilient city. It reviews evidence and provides independent advice and recommendations to the One City thematic boards on progress made against carbon-neutral targets and climate-resilience planning. It also provides critical commentary on the climate consequences of plans, policies and strategies affecting the city.

In February 2020, Bristol became the first major city to declare an ecological emergency.[18] This declaration builds on the declaration of a climate emergency, and recognises the close linkage between these two threats for the wellbeing of Bristol's inhabitants. The Environmental Sustainability Board is charged with working with the council and other city partners on a plan setting out the actions that the council and partners will take to give force to the declaration. The plan recognises the essential role nature plays in society and the economy – from clean water and air to food, timber, climate change, flood protection and other outcomes. It sets out the aim of protecting wildlife and providing a nature-rich city for the people of Bristol. The outcomes of the ecological emergency plan will be incorporated into the next iteration of the One City Plan, reframing dependencies and interconnections between the various ecological and other actions. The UN SDGs will continue to be a valuable integrating tool.

LOOKING TO THE FUTURE

Bristol has set out a pathway to 2050 that seeks to create a fairer and more sustainable city, reducing risks to the city and enhancing the wellbeing of its inhabitants. It has done this through the One City Approach and, in so doing, has catalysed civic engagement in a joint endeavour to imagine and deliver a better future. The approach is not without challenge and critique. For example, it is not yet clear if the priority targets within each of the six thematic boards are of equal importance or if some, because of statutory requirements, will be more important. Nonetheless, the One City Approach is innovative and well suited to the multiple challenges the city will face in the next 30 years.

Later in 2020, Bristol will publish its 5-year review on the long-term actions and impacts of its year as European Green Capital. The successes and challenges in this review will provide further impetus to the One City Approach, helping to accelerate the process of achieving a fairer and more sustainable city. ES

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Relearning water wisdoms

Mark Everard examines traditional Indian water-management techniques through the lens of modern needs.

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CASE STUDY

For 4,500 years, people in India have been stewarding water through communal action, adapting to their local climatic and geographical conditions, particularly in arid and semi-arid landscapes.[1,2] The wide diversity of water-harvesting structures found across India are geographically and culturally adapted. This is critical, as most of central India's rain falls during a short monsoon (rainy season), resulting in increasing dependence on groundwater throughout the long, dry seasons of high evaporation. Groundwater supports over 85 per cent of India's rural domestic water requirements, 50 per cent of urban and industrial water needs, and nearly 55 per cent of irrigation demand.[3]

Similar types of community- and nature-based solutions occur across the world. Just some include *phiri* pits in Zimbabwe and *zaï* pits in Burkina Faso, both of which accelerate the percolation of surface run-off into groundwater. *Bofedales* and *qochas* in Peru make use of natural wetlands, sometimes augmented in size, to intercept and store water in uplands (see **Figure 1**). *Qanat* systems across the Middle East tunnel into hillsides to tap aquifers, and sand dams in Kenya trap sediment and moisture in arid valleys. Some terracing systems across much of Asia are millennia old, efficiently retaining water, sediment and nutrients. These terraces are tended by communities that have endured while whole civilisations have risen and fallen around them.[4]

LOST WATER WISDOMS

A globally spreading technocentric worldview, allied with demographic, political, economic and other changes, has shifted the focus from communal stewardship to technically efficient water exploitation. Many traditional solutions have progressively been abandoned along with the traditional wisdoms behind them, including their underpinning community-based governance arrangements.

Since the late colonial period and after independence (1947), India has become increasingly dependent on engineering solutions focused on mechanised extraction and supply. While technically efficient, many large dam-and-transfer schemes and the huge increase in the uptake of unregulated powered tube wells (narrow tubes drilled into aquifers) tapping more and more deeply into groundwater[5] have tended to disregard the carrying capacity, resilience and quality of the supporting ecosystems. They have also bypassed the rights of those dispossessed of their local resources.

THE EXAMPLE OF THE BANAS RIVER CATCHMENT

The Banas catchment, in the state of Rajasthan, India, is a complex catchment encompassing substantial rural areas in the monsoonal drylands of northern India. There are substantial water diversions to urban centres, including the booming state capital of Jaipur, before the river discharges into the Chambal River to the east of the city of Sawai Madhopur.

Historically, a range of communal, nature-based water-stewardship solutions were found throughout the Banas catchment – many harvested monsoon run-off and stored it underground.[6] However, across north-western India, as indeed across India in general, dominant policies relating to the promotion of mechanised water extraction are contributing to ongoing groundwater depletion. Abandonment of communal practices across the Banas catchment and beyond in favour of competitive, mechanised extraction and water transfers now threatens surface water and groundwater quantity and quality, also depressing the water table to a level that traditional open wells cannot reach.[7] People lacking resources for deep pumping are dispossessed, and those with access to tube wells are at risk from water extracted from deep, geologically contaminated aquifers. This is a major contributor to outmigration from villages, particularly by young men seeking greater opportunities in cities, is commonplace throughout rural Rajasthan.

Jaipur had formerly subsisted on water captured from the monsoon rains and stored in lakes and groundwater, though the resource became substantially depleted and polluted. In 1952, municipal authorities reached out 32 km to the north-east to appropriate water from the Ramgarh Dam, originally built for local uses on completion in 1903. The Ramgarh Reservoir had dried up completely by 2000 due to over-abstraction and encroachment. This led on to decisions to appropriate water from the Bisalpur Dam (some 120 km to the south of Jaipur), which was constructed in 1987 approximately mid-way along the course of the Banas for the benefit of local irrigators and cities. There was violent opposition from local people in which protestors were killed.[8] In all of this, lack of attention to changes compromising the refilling of the reservoir has meant that all of the systemically linked urban and rural dependents of the Banas system are at increasing risk through declining water quantity and quality.[9]

In 2017, the Government of Rajasthan made preparations under a river-interlinking project to divert flows from the substantially more distant Chambal and Brahmani rivers into the Bisalpur Dam to meet growing drinking water and irrigation demands, including those of Jaipur city.[10] In essence, this apparently endless pursuit of water from increasingly further afield replicates the broken 'civil engineering paradigm' observed globally: as cities develop, they follow a pathway of 'taking more from further'.[11] Implicit in this paradigm is that there are always remote sources with a perceived surplus of water, and the rights of local people and ecosystems can be overlooked or disregarded.

There are no environmental flow releases from the Bisalpur Dam, compromising the viability of the whole lower river. This threatens river ecology, riparian settlements and livelihoods. It compromises the resources available for wildlife, particularly as the lower Banas flows past the Ranthambhore Tiger Reserve and into the Chambal River just upstream of the National Gharial Sanctuary. Water security for the city of Sawai Madhopur in the lower Banas catchment is also compromised, as water is no longer reliably extractable from the Banas River but is instead pumped from groundwater around the periphery of the Ranthambhore Tiger Reserve.

Urban/rural power relationships and resource use disparities are significant in Rajasthan, given the dense human population (68.5 million), of which 75.1 per cent is urban.[12] As a system, the Banas catchment is being overexploited by a limited sector of intensive users, extracting a limited set of ecosystem services to the exclusion of others, with substantial disparities in the distribution of benefits and costs. This fractured contemporary use of the system results in a cycle of degradation, from which the perceived (albeit flawed) solution is to look even further afield for resources from progressively more remote catchments that, in a crowded and growing nation, are likely to be increasingly contested and degraded.

RECOGNISING LOCAL SOLUTIONS

Recent initiatives driven by the Government of Rajasthan have included the flagship Mukhyamantri Jal Swavlamban Abhiyan programme (MJSA).[13] MJSA stimulates the reinstatement or innovation of localised rural solutions as a basis for self-sufficiency, recognising their importance for reversing systemic degradation driven by overreliance on technically efficient extraction. Climate-change modelling of the Banas catchment suggests a significant increase in the annual number of warm days and nights, a decreasing trend in the annual number of cool days and nights, and a significant decrease in the total annual precipitation,[14] indicating increasing water stresses. MJSA builds on grassroots movements driven by local and regional non-governmental organisations (NGOs) to enhance local rural water security through the restoration of traditional methods and wisdoms for the sustainable management of water.

The Banas system was the subject of a case study of how technological approaches can be hybridised to address impacts on catchment processes.[15] Different forms of water management infrastructure were crudely divided into four categories: natural; traditional solutions; green infrastructure; and heavy engineering. This categorisation recognised a progressive increase in the technical efficiency of the delivery of an increasingly narrow subset of desired services. These were the result of an increasing departure from solutions that work in synergy with natural processes and the needs of local communities. All techniques have their strengths and externalities. Natural and traditional solutions work efficiently at small scale, as they have for millennia, but are unable to service concentrated centres of demand. Conversely, heavy engineering solutions such as the Bisalpur Dam and water-diversion schemes tend to work against natural processes and to destroy overlooked ecosystem services. The proposed solution is not simply an overreliance on any one type of solution – it seeks to explicitly recognise the externalities of each approach using the ecosystem services framework, and to invest in a hybridised set of solutions that protect or restore natural processes at the catchment scale, and the benefits that flow from them.

For the Banas, solutions can include recycling money from intensive water users reliant on heavy engineering techniques into support for a dispersed water capture-and-recharge approach modified from traditional practices in small-scale communities. This cyclic flow of money to incentivise self-beneficial recharge is returned in terms of improved security of water available for diversion to intensive users, working

▲ **Figure 1. Natural and modified *bofales* wetlands in the Peruvian highlands intercept, store and purify water. *Bofales* are used as direct water sources as well as to enhance resources in catchments serving downstream intensive urban and irrigation needs. (© Raúl Loayza Muro)**

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with catchment-scale processes that cumulatively restore overall water-resource capacities. The cyclic economic model emulates the circular nature of the water cycle. Ideally, this might provide sufficient water to enable environmental flow releases from the Bisalpur Dam, reanimating the ecosystems and dependent livelihoods of the lower catchment that are today largely disregarded.

The Banas is a microcosm of the degrading socio-ecological cycles observed globally. However, it is also a catchment for which a vision and some initial proposed steps are in place to restore systemic functioning as a wise investment in water security. It is certainly a far wiser and more sustainable approach to achieving water security than taking another step down the blind alley of the flawed 'civil engineering paradigm' model. Ultimately, it is also better longer-term value per unit investment. Learning from the Banas case study has a far wider generic relevance to the management of a catchment-wide socio-ecological system.

TRADITIONAL WISDOMS IN THE MODERN WORLD

Despite their widespread abandonment, there is now growing awareness of the importance of nature- and community-based measures that replenish aquifers in western and southern parts of India, most effectively enacted by the adaptation of traditional water-management practices at a local scale.[16]

The course of historic and desirable future water management in Rajasthan and beyond in many ways mirrors the model noted for the three-phase trajectory identified in 'Urban systems and their impacts':

- The urban Agropolis phase depended on crops and livestock peripheral to settlements, reflected in water-resource terms by working with natural processes to secure local and near-catchment supplies. Water harvesting, storage and sharing was innovative and locally geographically, climatically and culturally nuanced.
- The urban Petropolis phase, supported by importing resources from increasingly remote places without cyclic use or recompense for the damage caused, is mirrored in the 'civil engineering paradigm' dominant in contemporary water-management approaches, diverting and depleting donor water systems and dispossessing the communities they support.
- The urban Ecopolis ideal of meeting future needs on a cyclic basis is mirrored in ongoing thinking about water self-sufficiency through methods that potentially rebuild catchment-scale hydrology and ecosystem functioning, including the reuse of wastewater and its chemical constituents. These methods can also be integrated with engineered water-management approaches to protect or enhance catchment-scale functioning and resources.

WISE USE OF PRECIOUS WATER

The manipulation of flows of life-giving water for various uses, critically including food security, enabled the formation of settled civilisations. Water enabled us to trade and travel, to power machinery, to create defences and to inspire art and spirituality. People have found ever-more ingenious ways of harnessing the many benefits provided by the vital resource of water, benefitting us biophysically and underwriting our cultural evolution. And yet, throughout so much of our more recent development trajectory, we have then proceeded to over-exploit, pollute, build over, transfer and in so many other ways degrade the very water resources upon which our settlements were founded.

If we always think that more water can forever be found from further away, appropriated directly to quench our thirst or embedded in our imported food, fibres, and mined and forestry products, we are naïve to its finite if renewable nature and its foundational values. As an ever-thirstier, booming human population imposes unsustainable pressures on water systems through a myopic approach to technically efficient exploitation, at the same time overlooking the need to balance use with replenishment of this life-giving resource, we place ourselves in grave danger.

The challenge is to relearn water wisdoms, particularly those developed by civilisations thriving in drier environments. This is no retrograde step, as these wisdoms of working *with* natural processes and development of sound stewardship principles are as valid in the most advanced modern contexts as they were in the past. Learning to value each drop, to use it efficiently, to find ways to replenish as well as extract water, to optimise what we have, and to share it equitably are timeless principles. They are also essential underpinnings for a more water-secure future, wherever we are on this small blue planet. ES

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ANALYSIS

The natural basis for meeting human needs – a reality check

David Tickner suggests some shifts in the approaches that conservationists take when advocating for change.

Early nature-conservation paradigms often posited people and nature as separate, implying that nature should be conserved primarily out of an altruistic concern for the fates of other species. While this altruism remains a powerful motivation for many conservationists, awareness has grown that, far from being isolated from nature, human societies and economies are in fact deeply intertwined with the vitality of ecosystems. This concept has, at least rhetorically, been echoed by political leaders and captains of industry. Yet precipitous declines in biodiversity and the condition of ecosystems have continued, suggesting that prevalent approaches to nature conservation are insufficient. If we are to 'bend the curve of biodiversity loss'[1] in a world of 7.8 billion people (and rising), all of whom have a right to live safe and satisfying lives, and in the face of a shifting climate, we must contemplate new approaches.

While points of connection have been found, persistent disjuncts in philosophy and language separate those in the social science and human development spheres who research and advocate for people, and those who do so for nature. If better care of ecosystems is to become

integrated throughout public policy, business practice and daily life, conservationists must build more effective, mutually supportive alliances across disciplinary boundaries. Successful outcomes for ecosystems and biodiversity will also depend on conservationists becoming more tactically astute and better at making the case for conservation to decision-makers whose priorities lie elsewhere. The challenges are as great for environmentalists as for those we wish to influence. If we wish to shift paradigms so that nature is more central to society, the first step might be for the environmental sector to shift its own paradigm so that society is even more central to our work with nature.

JOINING UP

Evidence from the water-resources arena suggests that disconnects between different disciplines and specialist networks hamper coherent research, policy and planning for ecosystem management.[2] Between and within the natural sciences and social sciences, experts have focused separately on, among other aspects, freshwater fisheries, river-ecosystem functioning, ecosystem valuation, water pricing, the political economy of river management, technical water-infrastructure planning, equity in water governance and the geopolitics of transboundary river management. These specialisms seldom cross-fertilise, yet insights from all of them can support the management and conservation of freshwater ecosystems.

Contemporary understanding of the interdependence of humans and ecosystems within highly integrated socio-ecological systems demands that we reconnect researchers and practitioners from across the social and natural sciences with each other. We need a new generation of polymaths, or at least facilitators who can support cross-disciplinary discourse. This may be a far-from-novel idea, but it has yet to be mainstreamed through research funding and policy. Given the speed of decline in ecosystems globally, a shift in paradigm and in academic and professional training is more urgently needed than ever.

THE HUMAN DIMENSION

Until relatively recently, the environment was a secondary issue for governments or business. It has taken energetic campaigning, often centred on simple and compelling arguments, to move the issue, at least in some places, from the periphery towards the mainstream of policy-making. How should conservationists best use necessarily simple campaigning arguments while also acknowledging the complexity inherent in ecosystem management? And how should they deal with the trade-offs, and the related politics, that come with all decisions about human use of nature?

Evidence suggests that, at a broad scale, better care of nature can provide substantial benefits to societies and economies. However, simplistic assertions that nature conservation brings only benefits, for everyone and everywhere, fail to recognise that conservation sometimes delivers mixed outcomes. For instance, wetland conservation can benefit wildlife and provide useful services for people, such as flood attenuation, groundwater recharge and the maintenance of fisheries. But a wetland in the wrong place, or managed in the wrong way, might also generate dis-services for some people, such as increased risks from waterborne diseases. Opportunity costs might accrue to, say, farmers or city planners if the conservation of wetlands or other ecosystems precludes the use of land for crops or urban development. If such dis-services and trade-offs go unacknowledged, the credibility of conservation experts and institutions can be undermined. Conservationists thus need to be skilled at layering and nuancing messages.

An understanding of the distributional aspects of services and dis-services generated by ecosystems is also important in terms of equity and justice. Truly inclusive and open-minded conservation processes can ensure that all groups in society, including the vulnerable and disadvantaged, have their voices heard and their rights protected in decisions about ecosystem management. Such processes can also enhance the effectiveness of conservation programmes because they maximise opportunities for different groups – including those who hold important knowledge, those who will be most affected by conservation, and those who hold political influence – to feel ownership of the conservation approach that emerges.

Inclusive conservation incurs transaction costs and can be messy. It is not always possible to gain agreement from all groups of people for any given pathway. Trade-offs are sometimes unavoidable. Conservationists, working in harness with social scientists, can shed light on the choices available, and on their consequences for different groups in society. They might legitimately advocate for a particular choice, based on the available evidence. However, they will seldom have a monopoly on wisdom. A useful rubric is that science has to be 'on tap, not on top'. Humility is an essential characteristic of the 21st-century conservationist.

THE TRAGEDY OF THE HORIZON

In his September 2015 speech at Lloyds of London, Mark Carney, the governor of the Bank of England, described climate change as 'the tragedy of the horizon'.[3] Carney warned that climate change increases risks from financial crises, falling living standards and food and water insecurity, with knock-on implications for political stability. He outlined the challenges of reconciling the frequent perception (perhaps misplaced) of these as longer-term risks with the shorter time horizons of monetary policy, the credit cycle and corporate reporting. The implication of Carney's warning is that, by the time the risks from climate change manifest in economic and financial instability, it might already be too late to take effective action. A definitive shift in regulatory and strategic perspectives is needed now to avoid the tragedy.

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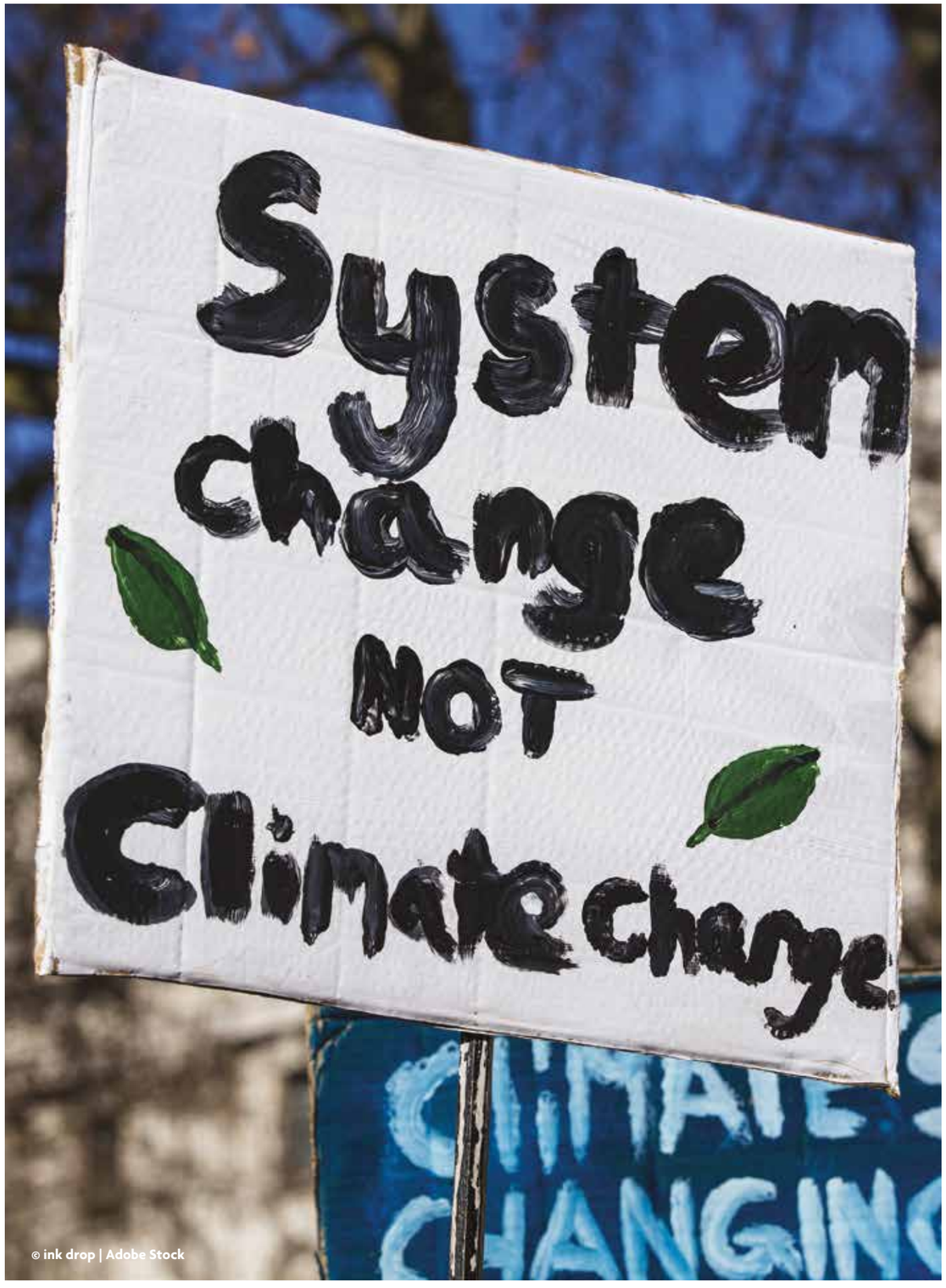
Ecosystem conservation suffers from the same tragedy of horizons. Conservation is often perceived as prioritising long-term benefits that might be gained from better stewardship of ecosystems over short-term benefits to be gleaned from their unsustainable exploitation. Economists, psychologists and sociologists tell us that most people would prefer £1 now over £2 later on. And current market forces tend to discount the benefits to be gained over time from ecosystem conservation and restoration, rather than recognising the potential for increasing aggregate value to future generations of people. How should conservationists respond to this dilemma?



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System change is one avenue. Increasingly, conservation non-governmental organisations (NGOs), researchers and thinktanks are arguing that regulatory, reporting and financial frameworks – and even legal definitions of the purpose of business – should be altered to reflect a wider perspective of a company's performance, incorporating its impacts on nature. While necessary, such system change will take time. In the interim, conservationists are faced with the challenge of identifying compelling arguments that appeal to the immediate priorities and mindsets of institutions and people.

HOT MOMENTS

The late Professor Jay O'Keeffe, a water expert at Rhodes University in South Africa, coined the phrase 'hot moments' to describe points in time during which it might be possible to achieve a step change in policy and practice. It often takes disasters to trigger such moments. For example, the drying of long stretches of the Murray–Darling River during Australia's millennium drought (which extended through the late 1990s and into the 2000s) led to a profound rethink of basin-wide water allocations. Powerful images championed by high-profile personalities can also stimulate hot moments, as evidenced by recent public reaction to television images, and Sir David Attenborough's narration, illustrating the awful impacts of plastics on ocean wildlife. Sometimes a generational shift in political regime can provide the hot moment. The end of apartheid in South Africa triggered a flood of policy development, including a landmark 1998 National Water Act, which is still lauded as a global exemplar even if its implementation has proved challenging.

Hot moments can bring about change quickly in comparison to the steady accumulation of scientific evidence (although accumulation of that evidence is important in its own right). However, hot moments bring risks too. In the rush to be seen to be doing something, political expediency can often lead to quick action that defies scientific advice, such as dredging rivers in a flawed attempt to address flood risk. So conservationists need to invest in preparation for hot moments, especially if – as is often the case with floods and droughts – the question is when, rather than whether, they will occur. Having compelling evidence to hand of the benefits of ecosystem conservation and restoration can help. More crucial still is the cultivation of relationships and joint exploration of solutions with relevant stakeholders so that, when political leaders feel the need to be seen to be doing something to address a crisis, the easiest and most popular option is to do the right thing for ecosystems.

THE WAY YOU TELL IT

Framing and language can greatly influence the extent to which arguments resonate with stakeholders and decision-makers.[4] Effective conservation demands self-explanatory and politically savvy terminology that presents investment in healthy ecosystems as the obvious option. Yet, like many specialists, conservationists often default to language that is incomprehensible to other people. Terms such as 'ecosystem services' and 'integrated water resource management' have specific and useful meanings, but my own experience is that government ministers, among others, often find them off-putting.

During a review of climate adaptation projects some years ago, a colleague from Central Europe related the difficulty of persuading farmers and other stakeholders along a tributary of the Danube River to consider the causes and consequences of climate change. They were far happier to discuss what action should be taken to tackle floods and droughts. Effective framing can even guide policy direction by itself. 'Single-use plastics' is a topical example of a term that has entered the public discourse and that has contributed to the perception of plastic packaging as wasteful and demanding action. ES

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New members and re-grades

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Sarah Allen – Associate Director
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Lisa Ashari – Environmental Consultant
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Graham Beaven – Associate Director
Tom Benson – Senior Consultant
Zoe Bickley – Senior Pollution Control Officer
Phoebe Carter – Chief Ecologist
Izabela Caskie – Senior Environmental Advisor
Gareth Chugg – Senior Geo-environmental Consultant
Richard Claxton – Senior Consultant
Ashley Copestake – Principal Engineer
Mae'r Davis – Volunteer Coordinator
Clare Dean – Assistant Technical Officer
Mark Douglas – Environmental Consultant
Robert Fadden – Environmental (EIA) Coordinator
Richard Flynn – Principal
Laura Franklin-Donnelly – Environment Officer
Lynne Gemmell – Senior Consultant
Andrew Gillett – Project Manager
Paul Hatton – Environmental Social Governance (ESG) Advisor
Kevan Holbrook – Principal Environmental Consultant
Alexandra Houldsworth – Principal Consultant
Paul Howlett – Environmental Manager
Robert Hughes – Geo-environmental Engineer
Timothy Kelly – Environmental Consultant
Erica Kemp – Director
Jess Kinchington – Senior Environmental Consultant
Laurence Lovell – Environmental Consultant
Amanda Lynnes – Director of Environment & Social Coordination
Tafida-Isa Maulud – Senior Environmental Consultant
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Richard Ogden – Lead Environmental Scientist
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Stuart Dunlop – Acting Principal Pollution Control Officer
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Tatenda Hanyani – Environmental Consultant
Andrew Harris – Junior Geo-environmental Engineer
Oscar Holden – Sustainability Consultant
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FEATURE

Green infrastructure and ecosystems as strategic public-health interventions

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Tim Sunderland and **Amanda Craig** make the case for integrating the natural world into our planning for human health.

Health, wellbeing and nature are all integrally interlinked, and many layers within each of these factors – personal, relational, natural and material – contribute to health outcomes. We know that green spaces are important for physical recreation and physical and mental health conditions. Other physical benefits of green infrastructure include improved air quality, lower noise pollution and reduced risks from flooding or heatwaves. Connecting people with nature at a local scale is also vital for social networks and sustainable communities. Formally recognising all of these benefits is important as it provides support and evidence for strategic cases to preserve, improve and extend areas of green space and our natural capital.

FEATURE

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THE ROLE OF NATURE-BASED SOLUTIONS

A report carried out for the Department for Environment, Food & Rural Affairs (Defra)[1] summarised the links between health and the natural environment, recognising that human health and wellbeing depend on the quality of air, food, shelter, water and ecosystem goods and services. All of these are partly or fully derived from the natural environment. There are linkages to human physical and mental health outcomes at individual to population scales, and at city, ecosystem, landscape and even catchment spatial scales. Evidence also suggests that health inequalities in mortality may be reduced by greener living environments.

Exposure to nature may also be important for the development of the human microbiome, the maintenance of a healthy immune system and the reduction of inflammatory diseases, as well as reductions in obesity and diabetes. Positive relationships have also been found between social contact and community cohesion and natural environments. Natural England estimates that £2.1 billion would be saved annually through averted health costs if everyone in England had good perceived and/or actual access to green space (relative to a conceptual no-contact baseline).[2] Growing recognition of the links between natural environments and human health and wellbeing highlight a need for more integrated policy and delivery across the health and natural-environment sectors, at a wide range of spatial scales.[3]

The green infrastructure challenge is not a lack of evidence, but one of integrating this evidence into policy and planning.

ACTING ON THE VALUES OF NATURAL CAPITAL

Though natural capital is an important foundation for the health of any population, instigating effective policy change remains a major challenge. Making this evidence available and resonant with decision-makers outside the environmental or health sectors is a major part of this challenge. Systems mapping can be useful to determine the important criteria to contribute to strategy. For example, integrating determinants of wellbeing, and the impact of the city on the wider environment, should ideally be an expected part of developing city climate initiatives that address transport, health, nature, sustainability and climate-change policy objectives. The Glasgow & Clyde Valley (GCV) Green Network,[4] for example, is aiming to enhance the urban environment to transform the lives of 1.8 million people through providing well-connected, high-quality, multi-use green spaces throughout the region, from cycle paths to allotments, wildlife habitats and raingardens.

Requirements for high levels of burdens of proof can also be obstacles. It is hard to promote changes in policy when the evidence base is limited or uncertain. This reduces the support of decision-makers seeking absolutes, even if we know in broad terms what the issues, solutions and benefits are. Arguably, the similar issues apply to benefits from conventional development, where long-held assumptions lead to less severe scrutiny.

However, there are precedents to environmental factors being integrated into policy change while the evidence base is being developed. Indeed, the urban parks we now have were developed without the contemporary evidence base about their importance for human health. For many of today's challenges, working out cause and effect to the finest level of detail can not only take too long, but may in many instances not be possible. Consequently, we need to ask broader questions that we can answer faster and more efficiently and, critically, look at the win–wins across policy areas.

ENOUGH AVAILABLE EVIDENCE

As a generality, we have sufficient evidence that natural capital and public health are interrelated and that investing in our natural capital will have public-health benefits and reduce healthcare costs. A no-regrets approach to investment in natural solutions and capital should also reflect the fact that lack of these benefits may have profound public-health, healthcare and wider costs. We already have sufficient evidence that, while they may not solve all problems, our natural environment plays a key role in improving people's wellbeing by reducing exposure to environmental pollutants, moderating environmental hazards, improving mental health, and providing opportunities for physical recreation.[1]

Proponents of environmental investment can emphasise links between natural solutions and public-health benefits when seeking funding from research organisations, national and local government, the NHS and public-health commissioners. Local authorities have significant roles to play in protecting, maintaining


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and improving local green spaces, requiring joint work across different parts of the local authority and beyond, particularly public health, planning, transport, and parks and leisure.[5] It remains important to address economic outcomes: environmental advocates can more proactively stress links between local economies and environmental quality, and ask searching questions about what the future might or ideally should look like.

ACTING STRATEGICALLY, NOT REACTIVELY

Wise action is based on a full appreciation of the state of our knowledge, including uncertainties and being clear about what we do not know. However, policy-makers tend to be over-confident in their understanding of the present and predictions about the future.[6] So biases in favour of the status quo, new technology and accepted ways of doing things lead to unequal burdens of proof. The European Environment Agency's 2002 *Late Lessons from Early Warnings* report[7] contains 14 case studies of issues as diverse as fishery collapse, the health impacts of asbestos, the destruction of the ozone layer by halocarbons, and BSE. Each case study shows a societal mistake with very high costs. For example, asbestos poisoning has killed thousands through mesothelioma, one of the most painful and terminal of cancers. In each case there was not enough evidence to prove the risk, but there were credible early warnings for asbestos as early as 1898. The report concludes with 12 principles for careful and wise consideration of potential risks, with a particular focus on understanding ignorance, capturing the broadest possible spectrum of opinion and paying attention to vested interests.

The health consequences of the degradation or regeneration of ecosystems, including the embedding of green infrastructure, are largely known, or at least acknowledged. Yet, as for the abundant stated commitments to sustainable pathways of development, proportionate action to embed these realities across societal policy areas and sectors has yet to become mainstream and standardised.

The challenge is not one of lack of knowledge about the values of ecosystems and of green infrastructure, though this knowledge can always be deepened. The key obstacle is one of spanning societal policy areas, not only to have regard for the environment for altruistic reasons but also for the tangible benefits – and importantly the cumulative cross-policy area co-benefits – that functional ecosystems deliver. Human health is one of those tangible outcomes, and it can be demonstrably promoted by healthy ecosystems. These include natural ecosystem processes that can be protected or restored through human-made green infrastructure that is as diverse as green roofs, nature-based flood risk management solutions, open spaces in urban areas and street trees. Acting strategically on ecosystems as public-health interventions requires more than just an improved evidence base. It requires a change in the way we plan cities, so that ecosystems are considered simultaneously and integrally, and on an equivalent priority, with other contributors to public-health outcomes (such as jobs, transport and communities). This integrated planning would ensure that all of these factors face a common, and appropriate, evidence base, and also that all of these elements are considered on a fully integrated basis to deliver desirable outcomes of greater cumulative value. ES

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FEATURE

Water and the defence and security agenda

Mark Everard looks beyond common misconceptions to show how cooperation over water issues is more common than conflict.

Sufficiency of basic resources is recognised as a key contributor to peacekeeping and peacemaking. Conversely, competition for a limited, critical resource of any kind – especially in combination with weak governance and/or corruption – brings with it the potential for conflict, whether presented as a matter of ideology, race, religion or in any other guise.

ECOSYSTEMS AND CONFLICT

There is a strong and growing recognition of the central role that ecosystems and natural resources play in the defence and security agenda, in the UK and globally. The UNESCO From Potential Conflict to Cooperation Potential (PC>CP) programme[1] addresses natural

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resources as key to conflict cessation and sustained peacekeeping. The United Nations Security Council also recognises climate change as a major threat to peace and stability. Competition for a limiting, critical resource of any kind is a driver of stress and, consequently, represents a potential source of conflict. The converse is also true: sufficiency of basic resources and their equitable distribution is a crucial contributor to peacekeeping and peacemaking.

The need for harmonious co-governance of fundamental natural resources for the securitisation/peacekeeping and peacemaking agenda is reflected in the sixth edition of the *Global Strategic Trends* (GST6) report[2] by the UK's Ministry of Defence (MoD). Like its predecessors, GST6 explores potential future threats to global security over a 30-year horizon. Amongst the diverse considerations in successive *Global Strategic Trends* reports is the potential for ecological tipping points, as well as how critical natural resources such as food and soil interconnect with global stability. Throughout GST6, water is mentioned 228 times. The UK is one of seven nations carrying out global trend assessments for defence. The US National Intelligence Council's *Global Trends: Paradox of Progress*[3] report also reflects a growing awareness of the role of critical ecosystem resources in the security agenda, mentioning water 82 times.

Figure 1. The transboundary Mekong River basin in south-east Asia has a total area of 795,000 km² and flows through six countries: China, Myanmar, the Lao People's Democratic Republic, Thailand, Cambodia and Vietnam.[13] (© Seanglerd | Adobe Stock)

WATER AND CONFLICT

The 2009 prediction by then World Bank Vice President, Ismail Serageldin, that 'many of the wars of the 20th century were about oil, but wars of the 21st century will be over water unless we change the way we manage water',[4] is often repeated. This prediction rather overlooks the water-related conflicts throughout not only decades but millennia.

The first recorded resource war occurred in the Middle East 4,500 years ago, when Urlama, the king of the city-state of Lagash, diverted water from near the confluence of the Euphrates and Tigris rivers into canals, thereby depriving the neighbouring city-state of Umma of their fresh water supply. This sparked battles in the Gu'edena ('edge of paradise') region of Sumer in modern-day Iraq.[5] Water was also at the heart of the bombing of dams during the Second World War, the 1967 Six-Day War between Israel and the Arab League, and the diversion of the Tigris and Euphrates rivers away from the Mesopotamian Marshes as a weapon of war by Saddam Hussein's Sunni-led Ba'athist regime against the Shi'a insurrection from 1991. The poisoning of public water supplies is a continuing perceived threat in the post-911 era, so it is monitored in a number of US cities by, for example, the behaviour of fish retained in influent water from abstraction points.[6] A 2006 UN report found that, throughout the preceding half-century, more than 500 conflict-related events had water at their core, and seven of them had involved violence.[7]

Worldwide, there are more than 286 transboundary river basins, including 14 with the highest levels of economic dependence on water resources by 1.4 billion people.[8] Around 600 aquifers cross sovereign borders,[9] and 154 states have territory in these transboundary surface and groundwater basins, including 30 countries that lie entirely within them. Furthermore, 40 per cent of the world population lives within shared river basins, with almost 90 per cent of the world population living in countries sharing transboundary waters.[10] Without transboundary water cooperation, the potential for

▲ **Figure 2. Water resources from the Jordan River basin in the Middle East are shared by Lebanon, Syria, Israel, Jordan and the Occupied Territories of Palestine.[13] Pictured is a section of the Jordan River that lies on the border between Jordan and the West Bank. (© Lucy | Adobe Stock)**

inclusive sustainable development is severely curtailed. As water is one of the most fundamental natural resources, its scarcity can represent a significant risk to maintaining peace and civil order if not addressed.

WATER AND PEACE

Despite water's potential as a spark for conflict, cooperation over its management, as one example of natural resource co-management, has been found far more often to be a vehicle for peacemaking and peacekeeping than it has of conflict.

A substantial and growing body of evidence demonstrates how water can play, and very often has played, a key role as a catalyst for cooperation. The 2006 UN report *Ten Stories the World Should Hear More About*, which highlighted international issues deserving greater media attention, contained a subsection titled 'From water wars to bridges of cooperation – exploring the peace-building potential of a shared resource'.[7] It was intended to promote water security in the 21st century by focusing on the development of tools for the anticipation, prevention and resolution of water conflicts. More than 3,800 unilateral, bilateral or multilateral declarations or conventions on water were identified across the world; 286 of them were treaties, of which 61 referred to more than 200 international river basins. Case studies included Bolivia and Peru working together on the management of water-basin resources around Lake Titicaca through the creation of an autonomous water authority, and progress with restoration of the Northern Aral Sea through cooperation between countries sharing its drainage basin (Kazakhstan, the Kyrgyz Republic, Tajikistan, Turkmenistan and Uzbekistan).

The findings of this international appraisal are backed up by a critical assessment of the southern African hydropolitical complex, which provides heartening evidence that international agreements on water sharing were a catalyst for dialogue, enduring agreements (even through periods of armed conflict) and also a mechanism for negotiating peace between countries at war.[11]

WORKING FOR PEACE

The securitisation of water resource management – the raising of this and other issues from a political concern to one requiring action – can become a driver of future conflict if not managed by measures such as investment in collaborative management. The de-securitisation of water resources is far more than a technical management challenge, necessitating the brokering of engagement of all affected parties around win–win goals, and their political prioritisation.[12] More open dialogue based on benefit-sharing between nations sharing common drainage basins could promote positive-sum outcomes, going beyond simple competition for limited resources. Nations would instead work collaboratively to manage catchment systems to enhance overall water volume and, with it, an increased potential for both hydropower and trade in food.

A *Global Development Study*[13] commissioned by the Ministry for Foreign Affairs in Sweden took evidence from three case studies (the Jordan River [see **Figure 2**]; the Kagera River, which is an upper tributary of the White Nile; and the Mekong River, which spans south-east Asia [see **Figure 1**]) amongst other studies of transboundary river systems and groundwater. The study demonstrated the unique considerations in each case, and also how vested interests had often already appropriated more than a fair share of resources, whether through colonial-era agreements (in the case of Egypt) or by military intervention (in Israel). Different types of political and securitised engagement can lead to differing outcomes, whether peaceful or contested. Water sharing cannot therefore be dissociated from the securitisation agenda, respecting the sovereignty, rights (particularly of poorer and frequently marginalised people) and aspirations of bordering countries.

WATER FOR ALL

The oft-cited inevitability of water wars is therefore far too simplistic, and is in fact widely contradicted by water-sharing arrangements around the world. Political arrangements are fundamental to this process of engagement and sharing, and must address the behaviour of whole catchments rather than allowing local or solely national demands to fragment the broader-scale processes upon which the benefits of all depend.

The key investment here is in dialogue to recognise and address complex and potentially conflicting needs, yet to be open to win–win innovations and departures from traditional technical, political, economic, land-use and other solutions. The building of these forms of capacity represents more insightful and useful targets for funding by development aid agencies, international development programmes and other international financing. ES

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ANALYSIS

Embedding ecosystem services to support human health

Jim Stewart-Evans and **Harmony Ridgley** explain how a range of social, economic and environmental factors influence people's mental and physical health.

A focus on interactions between natural systems and human health characterises research in the field of planetary health, a concept encompassing 'the health of human civilization and the state of the natural systems on which it depends'.[1] Established conceptual frameworks such as Barton and Grant's Health Map[2] recognise that the global ecosystem and natural environment underpin people's activities, local economies, communities and lifestyles.

In the professional domain of public health, health promotion and disease prevention interventions aim to minimise the burden of diseases, and actions to

improve health include changing the impact of social and economic determinants of health. Health policies emphasise the case for investment in preventative interventions,[3] and the natural environment is a potential resource for both disease prevention and therapeutic services. Health promotion services, on the other hand, often depend on intersectoral actions, and the health and environmental sectors share a common interest in how interactions with the natural environment influence risk factors such as obesity, diet and physical inactivity, and mental health. Progressive environmental policies seek to protect and grow natural capital and realise the vision of a healthy environment.[4] Health and environmental policy objectives are naturally aligned.

THE CASE OF AIR QUALITY

Ambient air pollution contributes substantially to the global burden of disease, and poor air quality is the largest environmental risk to public health in the UK.[5] Through processes such as deposition, acidification and eutrophication, air pollution also affects the ability of ecosystems to function and grow, undermining the ecosystem services on which life depends. In common with conservationism, action to improve air quality and health is supported by awareness-raising and behavioural change, and all sectors – from industry to agriculture, transport and the built environment – have a role.[5]

Public Health England (PHE) have proposed an intervention hierarchy:

- First, prioritising the prevention or reduction of emissions of pollutants to air;
- Next, reducing the concentration of air pollution once in the environment; and
- Third, individual avoidance of exposure.[5]

Nature-based interventions can moderate people's exposure. Ecosystem services include air quality regulation and, at a more local scale, vegetation can influence the dispersion of pollutants or be used as a buffer or barrier between people and pollution sources. However, green infrastructure can provide wider health co-benefits beyond any effect on air pollution and exposure. If a broader range of environmental and health benefits are recognised when interventions are evaluated, they can inform options appraisals, decision-making and the design of future interventions.

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THE ROLE OF GREEN SPACES

Use of and exposure to natural environments has direct benefits for health and wellbeing at the individual and population levels.[6] There is now substantial evidence of a range of physical and mental health benefits linked to living in greener communities and having greater exposure to green space. All demographic groups benefit, but evidence indicates that deprived groups gain the most health benefit and that socio-economic inequalities in health are lower in greener communities. Providing greener environments in deprived areas could, therefore, be an important way of helping to reduce health inequalities.[7]

As evidence of links between the natural environment and health grows, public health outcomes become a stronger driver for those responsible for green spaces in our countryside and cities. Conversely, there is a growing impetus for those responsible for the public's health to maximise the positive contribution of natural and healthy environments. This increases the overlap between environmental and health advocacy and the shared case for action as policies refocus on improving the wider determinants of the health of places and people to realise benefits upstream, not just responding to impacts as they occur. This requires joint working across local government and beyond and presents an opportunity for innovative thinking about funding for green infrastructure. The incorporation of air quality considerations in spatial, housing and transport planning and policy reflects the important contribution of disciplines that may not traditionally have considered environmental or health outcomes as relevant objectives.

PLACE-BASED APPROACHES TO INEQUALITIES

The fact that a remodelled system for health and wellbeing demands a broader focus than healthcare services is recognised in efforts to address health inequalities. These are largely preventable, and 80 per cent of health outcomes are estimated to be driven by wider determinants of health, which include environmental factors.[8] Degraded local environments have a lower potential to support good health, and poor-quality environments may adversely affect health.[9] Impacts are compounded when deprived communities face a combination of higher risks from social, behavioural and environmental determinants of health and inherently greater susceptibility to the impacts of pollution.

An alignment of environmental and health policy objectives is reflected in the *Marmot Review*'s objective of creating and developing sustainable places and communities.[9] A bottom-up, place-based approach, emphasising local needs and assets rather than deficits, is increasingly recognised as central to delivering measurable change at the population level. Multifaceted strategies grounded in engagement and involving multiple, complementary interventions are most likely to bring success. This approach and principles underpin health needs assessments and wellbeing strategies but are not unique to the health sector: they are shared by local nature partnerships seeking to improve natural environments across England.

NET GAINS FOR THE ENVIRONMENT AND HEALTH

The UK's *25 Year Environment Plan*[4] sets out an aspiration to 'embed an "environmental net gain" principle for development, including housing and infrastructure'. This is a subtle but significant development because it embeds a focus on realising benefits, rather than just mitigating impacts. It also has clear practical applications in the realms of procurement, environmental regulation and spatial planning, where it is acknowledged in the *National Planning Policy Framework*. New tools and practices are being introduced to realise biodiversity net gain aspirations in the Environment Bill, but longer-term aspirations are much broader. Environmental net gain potentially encompasses natural capital, its components, and a range of ecosystem services.

Natural capital approaches value the supporting, regulating, provisioning and cultural services provided by our ecosystems. As such, they have the potential to ensure that environmental costs and benefits are addressed. The value of benefits to health is already prominent in national and local assessments that recognise the interactions between the natural environment and environmental determinants of health. Air quality is one example: natural capital accounts attribute substantial savings to the health sector from vegetation reducing air pollution.

The extent to which different aspects of natural capital affect health varies, and ecosystems are not the only factor influencing environmental determinants of health. Our green spaces have some role in regulating air quality, but the burden on health of pollution greatly depends on levels of emissions and people's exposure to it. PHE's *Review of Interventions*[5] suggested that environmental net gain principles could be applied outright to health outcomes through a 'health net gain' principle that embedded the assessment and improvement of the environmental determinants of health. If this was applied to air quality in local spatial plans, for example, new development would aim to incorporate measures to reduce emissions and people's exposure, and maximise

wider health co-benefits, such as those associated with access to quality green space and physical exercise, to deliver an overall benefit to public health. Net gain principles support a focus on improvement. The framework also provides a means of visualising and integrating different environmental assessments and understanding trade-offs and relationships between elements.

JOINT WORKING TOWARDS SHARED OBJECTIVES

Net gain principles provide complementary opportunities to realise environmental and health policy objectives. Health net gain leads to a focus on the environmental determinants of health and improvement of environmental quality. Environmental net gain leads to a focus on improving environmental measures that are sometimes directly linked to health. While each may incompletely account for the other, there are many synergies. Conflicts can be reduced if an environmental net gain principle includes a secondary net gain or no net loss for health requirement and vice versa. Incorporating other outcomes can maintain a broader focus if applying net gain to a narrow field, illustrated by good practice principles for ensuring no net loss for people as well as biodiversity.[10] This encourages engagement between specialisms and helps recognise and align complementary policies and practice.

Strength of evidence and level of effect are critical considerations when making decisions about interventions to improve the natural environment and health. It remains important to develop evidence of the links between them. While establishing causal links between environmental factors and health outcomes can be challenging, quantitative evidence of effects on morbidity, mortality or costs to the healthcare system can make a powerful argument for environmental change.

Monetised impacts, such as the costs to society of defined emissions of air pollutants, can be persuasive and are readily suited to economic cost–benefit analyses that underpin spending decisions and environmental and health policies, legislation and regulation. Alignment with improvement objectives is clearer when impacts are reframed as savings or benefits from improved environmental quality. These can strengthen when benefits to environmental and health outcomes are combined, not considered in isolation. However, it is not always possible, or necessarily desirable, to monetise impacts and benefits, and the wider challenge is to translate evidence from one discipline's language and context to another's so that it can more readily inform the debate and case for action. This is especially true of the wider public conversation.

Incentives for joint working and shared arguments for interventions are greatest when one discipline appeals to another's objectives. While the case for health is often recognised by environmental professionals, wider environmental considerations can sometimes be lost when the outright focus is on public health. There is a pressing need for adaptable frameworks that reflect underlying natural processes while reconciling compartmentalised perspectives and interests, drawing out the trade-offs and the shared benefits across disciplines.

There are potential opportunities to find common ground – both literal and metaphorical – between the place-based needs assessments, strategies and objectives of public health professionals and ecologists. Existing forums may enable collaboration, but the mutual challenge is to mobilise the different specialisms to present an accessible, balanced view of environmental and health considerations to others outside these domains. Synergies often relate to links between the natural environment and the environmental determinants of health, but links between the natural environment and the broader determinants of health – such as education, healthcare, housing, social and economic factors – are more challenging and require new bridges between professions. It will be important to make these connections in future and raise awareness of the system-wide benefits of environmental improvement if we are to fully reflect the dependence of our health on our natural environment.

The views expressed in this article are those of the authors and do not necessarily reflect the views of the organisations involved. ES


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FEATURE

The benefits of nature's recovery

Gary Mantle makes the case for landscape-scale conservation and explores its future.

A preservationist approach to nature conservation, seeking to protect, as far as possible, special areas of high biodiversity, may have been effective in protecting some of the most threatened species and habitats. It was also a useful tool for establishing nature conservation as a priority, particularly in the face of burgeoning land-use changes, population growth and associated environmental pressures following the Second World War. However, this approach is now widely seen as having been insufficient to prevent big declines in the area of most types of wildlife habitat and the abundance and diversity of species. A landscape-scale approach is now more widely recognised as essential if we are to prevent further losses and begin to see nature's recovery.

HISTORICAL NATURE CONSERVATION

The National Parks and Access to the Countryside Act 1949 was a watershed in British legislation, creating the National Parks Commission and providing a framework for the creation of national parks and areas of outstanding natural beauty (AONBs) in England and Wales. The Commission has since morphed substantially, its duties in England and Wales now respectively subsumed into Natural England and Natural Resources Wales. The first 10 British national parks were designated in the 1950s, with more following in succeeding years. Most recently, the South Downs national park was designated in March 2009. Another important introduction under the 1949 Act, since superseded by a range of legislation, was the introduction of sites of special scientific interest (SSSIs), granted special protection status for their nature and geodiversity conservation values.

◀ **Figure 1. North Meadow National Nature Reserve in Cricklade, north Wiltshire, hosts 80 per cent of the UK population of snake's-head fritillaries. (© Gary Mantle)**

▲ **Figure 2. Several long periods of flooding at North Meadow National Nature Reserve over the past 10 years have severely impacted the population of snake's-head fritillaries. Flooding at the North Meadow site is shown in 2016 (top left), 2018 (top right) and 2020 (bottom). (© Gary Mantle)**

Today, there are more than 4,000 SSSIs in England, covering about 7 per cent of the land area, with more than half by area also recognised as internationally important for their wildlife under European legislation. Wales has over 1,000 SSSIs covering just over 12 per cent of the country's land surface, Scotland has 1,423 SSSIs covering 12.6 per cent of the land area, and Northern Ireland has 392 areas of special scientific interest (ASSIs, which are under different legislation) covering 7.7 per cent of the land area. Some are large, others extremely small. Not all important wildlife sites are designated as SSSIs. Indeed, SSSIs are only meant to be a representative sample. Designation as a SSSI is no guarantee of wildlife protection – figures for the whole of England show that only 39 per cent of SSSIs are in a favourable condition.[1]

Increasingly, charities are playing a critical role in protecting and maintaining important wildlife habitats. The area of land now managed as nature reserves by charities is substantial and continues to grow as new sites are acquired.

Valuable as they have been, protected isolated natural spaces do not ultimately work in heavily modified wider landscapes if they result in fragmented islands of species-rich habitats. These relatively small parcels of land and water may become unhealthy due to lack of genetic diversity, with wildlife unable to move across surrounding hostile landscapes and being generally vulnerable to local extinction events from which small isolated populations simply cannot bounce back. Vulnerability is further exacerbated by climate change. Furthermore, fenced nature reserves may also be regarded as socially unfavourable, rather than as valuable assets, if they are perceived as being off limits to people.

The vulnerability of isolated nature reserves is exemplified by the impacts of severe, winter-long flooding – part of a pattern of weather instability consistent with predicted climate change – on North Meadow National Nature Reserve in Cricklade, north Wiltshire (see **Figure 1**). This single field hosts 80 per cent of the UK population of snake's-head fritillaries *(Fritillaria meleagris)* and is a special area for conservation as well as a SSSI. However, over the past 10 years, several long periods of flooding prevented the traditional cutting and grazing management required for the fritillaries to flourish (see **Figure 2**). In some years the impact on the fritillaries has been dramatic, with the expected 2 million flowers reduced to virtually nil. So far, each bad year has been followed by a better year, allowing the population to recover. But without the ability to spread beyond this single field, some of the principal conservation benefits of the tightly bounded North Meadow site are in increasing jeopardy as an indirect consequence of climate change. Contemporary pressures can increase risks for other vulnerable species and habitats constrained in small parcels of land or water, fragmented across wider landscapes.

THE LIVING LANDSCAPES APPROACH

One strategic solution proposed by The Wildlife Trusts is the creation of living landscapes. In essence, the living landscapes approach means that wildlife habitats are not only bigger, but also better managed and more joined up. This is consistent with principles subsequently promoted in the 2011 Lawton review of nature conservation.[2] Under this vision, nature reserves serve not only as vital refuges for wildlife, but also as elements of a more permeable landscape in which species can spread and interact. The living landscapes vision also includes bringing people closer to nature by engaging them in wildlife-rich land and seas.

As part of the approach to creating living landscapes, The Wildlife Trusts in south-west England developed a nature map showing areas of high biodiversity value across the whole region. The nature map was co-created by local groups of wildlife experts, land owners and farmers, and was adopted by the South West of England Regional Development Agency and incorporated into the regional spatial plan. The benefit of such a nature map is that it can be used by, and further refined with, farmers, housing developers, planners and conservation groups to guide habitat creation. In conjunction with local authorities and government conservation agencies, the nature map supported evidence-based decisions about where development could happen.

The need to shift from site-based nature conservation to working at a landscape scale has gained widespread acceptance and is now widely adopted throughout the UK environmental sector.

NATURE RECOVERY NETWORKS

This map-based approach[3] is proposed as a foundation for optimising the potential of nature recovery networks, as introduced in the Environment Bill going through parliament at the time of writing. The Environment Bill has the stated objective of making provision for targets, plans and policies for improving the natural environment. The role of nature recovery networks is to enhance the interconnectivity of natural spaces, thereby boosting their resilience. Interconnectivity does not stop with thinking about wild spaces to help biodiversity become more resilient. It also considers the need to influence interconnection within and across government departments, such as between economic, environmental, public health and other sectors recognising the multiple values of ecosystems services on human wellbeing that derive from a more functional landscape.

Connecting habitats is important within urban and rural areas as well as between them; it is also important at both local and landscape scales. More connected green areas

▲ **Figure 3. Lakeside Care Farm, run by the Wiltshire Wildlife Trust, provides an opportunity for children, young adults and people with individual needs to engage safely with nature and receive meaningful education and work-based experiences. (© Dean Sherwin)**

yield many benefits, exceeding the sum of the parts in isolation by increasing the likelihood of nature surviving and thriving in a rapidly changing environment.

BIODIVERSITY NET GAIN

Another requirement introduced in the Environment Bill is that of biodiversity net gain. If biodiversity net gain is achieved, all development schemes should not only automatically offset harm from urban encroachment but go beyond that to contribute positively to the enhancement of biodiversity. One of the recommendations of the UK's Natural Capital Committee in 2020 is that this vision is raised to *environmental* net gain, proposing that 'government should urgently work towards replacing biodiversity net gain with marine and terrestrial environmental net gain in the Environment Bill'.[4]

If we are to create landscapes containing stable or regenerating habitats that are both healthy and able to survive for every generation to come, we need clear and auditable direction and metrics. We also need to better express the multiple values to other societal sectors that stem from reconnecting people with wildlife, as well as the cross-policy area benefits of the many functions of healthy ecosystems. Wider societal benefits include contributions to air quality regulation with acknowledged health gains, improved water, buffering of flood and drought risks, protection of valued species and landscapes, erosion prevention and active soil formation, carbon sequestration and nutrient cycling, amongst others. Personal benefits from contact with nature are demonstrated, for example, through the Trust's education programmes[5] and by the Lakeside Care Farm run by the Wiltshire Wildlife Trust, where people can engage safely with nature to help address mental health, behavioural and other issues (see **Figure 3**).[6]

ACTING AT LANDSCAPE SCALE

Bold innovations may be required to restore ecosystem functioning, by thinking at far wider landscape scales than formerly. Bison, for example, expunged from European landscapes, have been reintroduced in The Netherlands; they are restoring the dynamic nature of sand dune landscapes and, with it, increasing biodiversity. In a similar way, scientific monitoring of sites into which European beavers have been reintroduced in the UK has shown that these ecosystem engineers create functionally rich and more natural landscapes as part of long-lasting solutions. They do this by enhancing water retention and thereby contribute to improved flood resilience, water quality and biodiversity. Another pertinent example is Knepp Castle Estate in Sussex. Rewilding the intensively farmed land has yielded many societally valuable co-benefits, including the natural recovery of threatened and rare species.

Pettorelli *et al.* (2018)[7] define rewilding as 'the reorganisation of biota and ecosystem processes to set an identified social–ecological system on a preferred trajectory, leading to the self-sustaining provision of ecosystem services with minimal ongoing management'. Despite it being increasingly considered as an environmental management option, rewilding is subject to practical uncertainties and difficulties. Everard (2020)[8] defines and regards rewilding as a more fluid approach, progressively embedding ecosystem processes into a diversity of rural and urban settings. He cites examples as diverse as regreening the vast landscapes of China's Loess Plateau and the Ethiopian Highlands, modest agricultural field borders hosting pollinators and predators of crop pests, and green walls and street trees proving multiple benefits in heavily urbanised centres. The key distinction of a rewilding approach is that it is not based on the preservation of a perceived historical condition, but on the restoration of ecosystem processes – natural, restored or emulated, for example, by nature-based urban drainage systems – that are simultaneously beneficial to wildlife and people.

NATURE RECOVERY FOR NATURAL BENEFITS

Successful case studies show that nature is capable of recovery if granted the space and time to do so. It is also possible to rebuild networks for wildlife across the wider landscape, reconnecting hotspots and 'islands' to reanimate wider landscapes.

Valuable though many reserves are, their fragmented legacy (the result of more than 70 years of narrowly framed nature conservation legislation) is echoed in the fragmented nature of research disciplines, government departmental remits and ring-fenced funding streams. All of these approaches need to become more integrated to address the greater value of systemic, cross-disciplinary and cross-landscape benefits that are all too often lost through legacy myopia. Far greater awareness needs to be promoted across policy areas. For example, a more permeable landscape with greater tree density and earthworm populations can provide substantial cross-disciplinary benefits through addressing flood risk, groundwater recharge, storm buffering and regeneration of soil fertility. A better balance is required, with bottom-up approaches, sensitive to local contexts, landscapes and histories, as used to inform the nature maps. Monolithic top-down approaches very rarely achieve optimal results.

Obstacles remain to be overcome, as in any sphere of paradigm change. The beneficiaries of historic land management grants may be unwilling to change practices without articulated descriptions or demonstrations of self-benefit or the receipt of alternative payments from a more ecosystem-centred subsidy system. Partnerships and community working also take time to develop. The challenge for conservationists is to reverse former perceptions that nature and its processes are a constraint of freedoms. Instead, working with, and promoting, the recovery of nature can yield tangible benefits for the land or water manager and for wider society. ES

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Natural flood regulation and rail infrastructure

Nevil Quinn, Rob McInnes, Graham Parkhurst, Ben Clark, John Parkin and **Mark Everard** advocate solutions that amalgamate floodplains and wetlands, sustainable drainage and traditional hard engineering drainage infrastructure.

CASE STUDY

Transport infrastructure is often portrayed as a victim of flooding. Yet planning of mass transport infrastructure, such as roads and rail networks, has historically paid little attention to natural processes such as landscape hydrology. By cutting across drainage lines or through aquifers, transport routes are automatically exposed to higher flood risks, potentially also contributing to wider landscape flooding.

The costs of weather-related disruption of England's rail transport network have been estimated to range from £100 million to £520 million per day of disruption (at 2010 prices).[1] The 2014 *Transport Resilience Review*[2] acknowledged scientific consensus that climate change will increase the likelihood of 'sustained' rainfall in UK winters and 'intense localised rain storms' in the summer months. It recommended that Network Rail (responsible for running 'a safe, reliable and efficient railway'[3] in the UK) should identify routes significantly at risk from future flooding and then develop and apply solutions 'proactively rather than reactively'.

RAILWAY CUTTING AND TUNNEL CASE STUDY

The current flood risks and potential ecosystem-based opportunities for flood management were addressed by the case study of a mainline railway cutting and tunnel in southern England.[4] The upper tributary of a significant river crosses the cutting in an open-box aqueduct that regularly overtops during heavy rainfall, compounding localised ponding in the cutting (see **Figures 1** and **2**). Immediately downstream, the river runs adjacent to urban development that is subject to flood risk.

▲ **Figure 1. This small, open-box aqueduct over the railway cutting carries the headwater of a significant river. It overtops regularly during high flows, which contributes to flooding in the cutting. (© Mark Everard)**

Flooding in the cutting is considerably exacerbated by the fact that the railway tunnel is in a major aquifer, which means that constant pumping is needed to remove seepage. However, pumping rates are limited to 300 L/s under an Environment Agency discharge consent to limit the flood risk to downstream residential areas. Increasing pumping is therefore not a permissible solution to avert flood-related rail service disruptions. Realignment of the railway had been ruled out as being too expensive. Furthermore, the jurisdiction of Network Rail is limited to a narrow corridor of land through which the rail network passes. The railway line was in the early stages of being electrified, and for this the open-box aqueduct would have to be raised. Novel solutions were required.

The economic costs of rail disruption at the site are far from trivial. Using standard transport analysis procedures, wider economic costs of up to £264,000 per day have been estimated for tunnel and cutting closure based on routine passenger train services and accounting for train delays and rerouting.[4] Disruption costs include:

- Compensation payments for lost rail network availability under track access contracts (required by railway operators wanting access to the railway network controlled by Network Rail);
- Delays to rail passengers on rerouted services;
- Rail passenger transfers to private cars;
- Indirect tax benefits of passenger transfers to private car (based on tax receipts accrued indirectly to government through fuel duty that are subtracted from the costs of tunnel closures);
- Wider welfare impacts; and
- Wider dis-benefits of inadequate network resilience.

WHOSE PROBLEM?

In the case study, consideration of the rail network's resilience to flooding was broadened to critically examine the nature and ownership of the flooding problem, identifying who had differing perceptions of the issue and who would need to be engaged in practical solutions. Stakeholders affected by both flooding and potential solutions include: Network Rail, landowners, housing developers, local authorities, the Environment

▲ **Figure 2. On a major intercity route, a high-speed train passes under the open-box aqueduct in the railway cutting. Groundwater and surface flooding of the cutting frequently disrupt services at substantial cost. (© Mark Everard)**

Agency and the local community. Consideration was also given to their vested interests in whether and how the problem is solved.

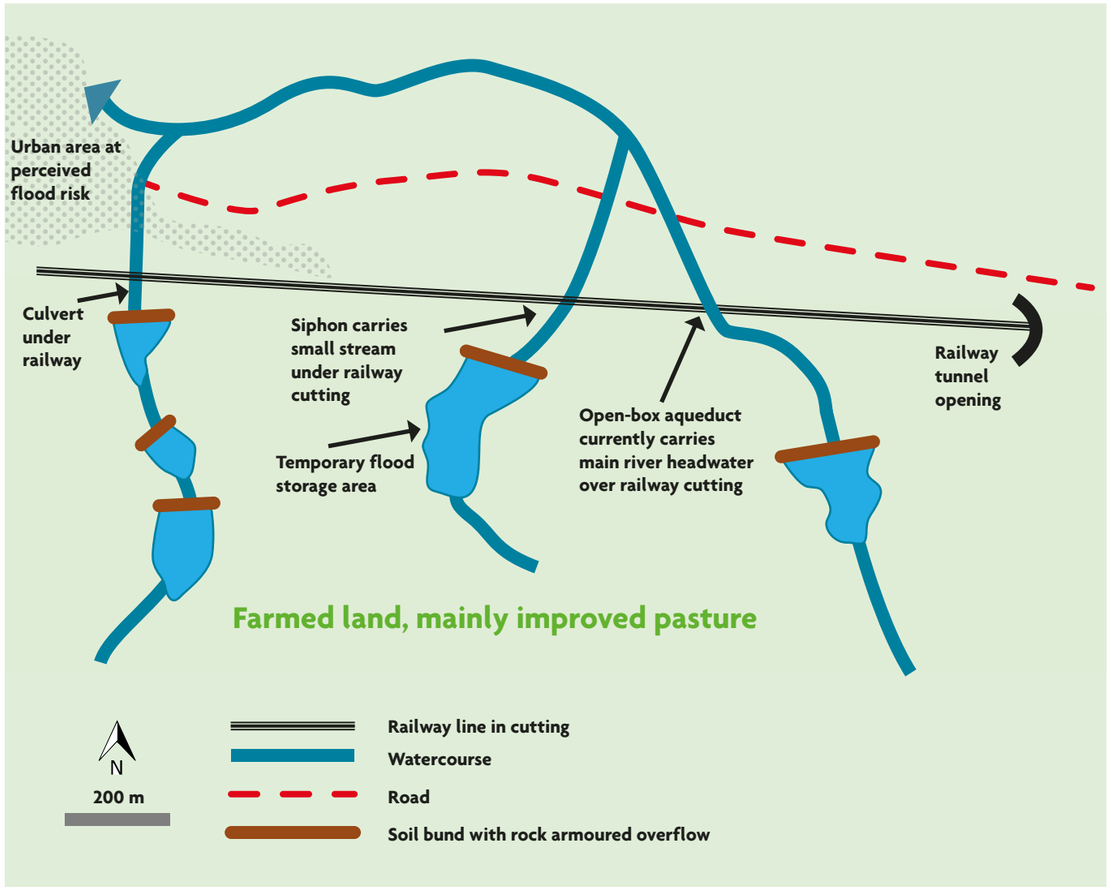
This expanded analysis took account of the fact that the railway passes through a built and farmed landscape with a number of owners, and that there was the potential to address flooding by modifying landscape-scale hydrological processes. Significantly, the buy-in of local landowners, particularly the adjacent farmers seeking to maximise the economic value of their land through agricultural production, would be critical for the implementation of any landscape modification.

Limitations imposed by the regulatory environment and authorities would also need to be addressed, to garner their support for a multi-dimensional solution. Local communities subject to flood risk downstream of the cutting, as well as local authorities accountable to those communities, would need to accept novel solutions that also delivered a good standard of service for the travelling public.

AN INTEGRATED BLUE–GREEN–GREY SOLUTION

Solutions to manage such challenges are generally driven by single, narrowly framed perceived needs. Instead, the solution can be an anchor service[5] – an ecosystem-based solution yielding additional linked ecosystem benefits. This strengthens the business case for a more integrated approach based on optimising overall societal benefit and encompassing multiple ecosystem services (including avoidance of unintended negative externalities). An integrated approach can also promote the pooling of linked budgets (for example for the management of biodiversity, downstream flood risk and public access) and agri-environmental subsidies.

Informed by site walkovers and extensive analysis of digital data about the terrain, soil, geology and hydrology, and taking account of a wider range of ecosystem services, the research team developed proposals for a mixed 'blue–green–grey infrastructure' approach. The constituent elements were: the use of floodplains and wetlands (blue), sustainable drainage (green) and traditional hard engineering drainage infrastructure

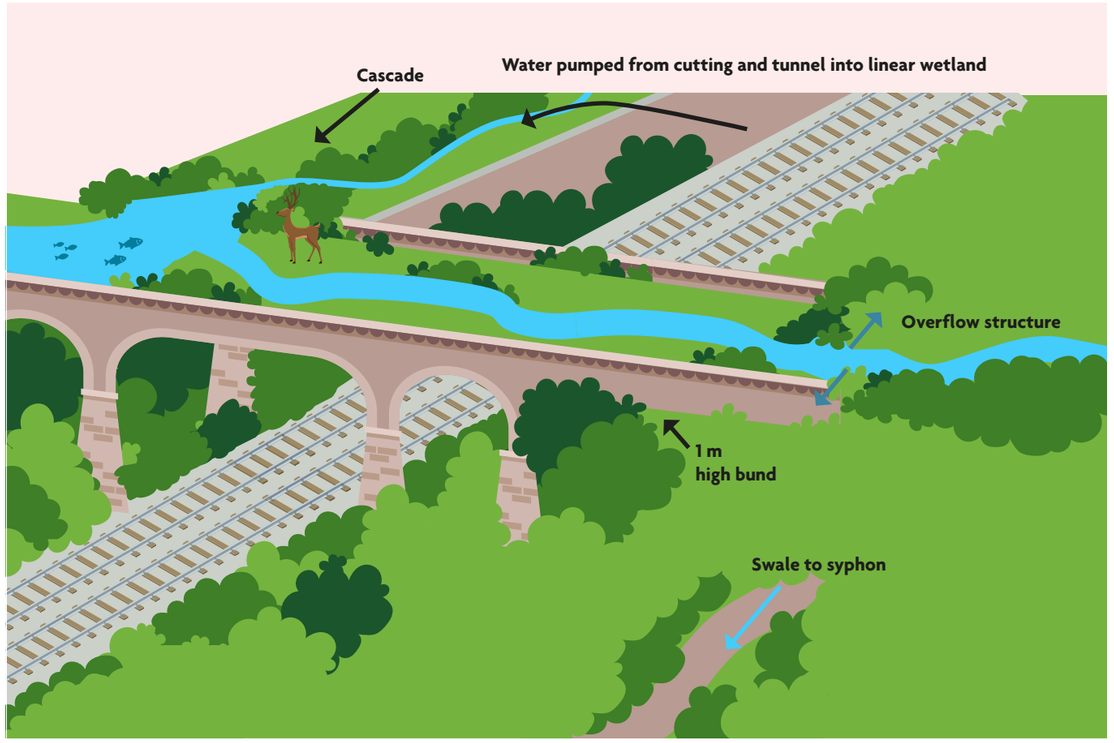


▲ **Figure 3. Illustrative map of potential constructed wetland floodwater detention basins upstream of the cutting to slow and moderate flows over critical pinch points (culvert, siphon and box aqueduct) crossing the railway cutting. These would have additional benefits for downstream flood-risk management, potential amenity and biodiversity gain. (© Mark Everard, Nevil Quinn, Rob McInnes, Graham Parkhurst, Ben Clark and John Parkin)**

(grey). Central to this broader view was the rehabilitation of floodplains and wetlands upstream of the cutting to retain excess water and reduce flood peaks, supported by natural flood management techniques and integrated where necessary with traditional engineered drainage methods, including sustainable drainage systems (SuDS).

The goal was to address the anchor service of flood regulation, so as to reduce flooding at the railway cutting pinch points (see **Figure 3**). A nature-based approach had the potential to simultaneously realise benefits across a wide range of linked ecosystem services, optimising net societal benefits. This approach follows the systemic solutions paradigm, defined as 'low-input technologies using natural processes to optimise benefits across the spectrum of ecosystem services and their beneficiaries'.[6] The aim is to link ecological, amenity, landscape aesthetics, carbon storage, nutrient cycling and additional co-benefits. It was recognised that some form of payment for ecosystem services (PES) would be required to compensate the owners of the farmed land for potential lost production; the PES would be funded by the beneficiaries of ecosystem services enhanced by landscape modification.

Figure 3 shows the illustrative siting and sizing of wetland attenuation features, detailed design of which was informed by modelling, that could potentially retain peak surface run-off in three agricultural watercourses upstream of the cutting, relieving surface water contributions to flooding of the cutting by groundwater. The attenuation features would release the water slowly via the watercourses within 10 hours of the rain stopping. Additional storage sites were also identified downstream of the railway to further attenuate flood



▲ **Figure 4. A 'flying floodplain', a co-beneficial solution to enhance the conveyance of water, improve river connectivity, create additional floodplain habitat and overcome obstacles for wildlife movement. A rerouted footpath could also be incorporated. (© Mark Everard, Nevil Quinn, Rob McInnes, Graham Parkhurst, Ben Clark and John Parkin)**

peaks resulting from both groundwater pumping and surface run-off; these would reduce peak flood risk for the railway and downstream properties. As these additional storage sites would be able to store enough to decouple land-based flooding from groundwater flooding, a further benefit would be to allow Network Rail to pump more groundwater-derived floodwater within their discharge consent limit without worsening the downstream flood risk. The detention basins, wetlands and reprofiled watercourses could potentially be designed to host greater biodiversity and for nature reserves, local amenity and recreation. Capital costs for implementing these integrated blue–green–grey measures were estimated at significantly less than £100,000. Additional payments to the owner of the farmed land would be needed although, as inundation of most detention basins would only be during periods of high rainfall, there may only be limited impact on access to grazing on the improved grassland.

The need to raise and rebuild the river conduit for the electrification of the line presented a further opportunity to enhance hydrological, amenity and biodiversity outcomes. A novel 'flying floodplain' aqueduct was designed as a potential replacement for the existing open-box aqueduct, acting as an engineered floodplain that could not only carry much more water, but could also be a habitat in its own right and a corridor for wildlife over the otherwise hostile barrier of the railway cutting (see **Figure 4**). A footpath, currently on an adjacent bridge, could also be integrated into the 'flying floodplain' design.

TAKING FORWARD THE LEARNING

This ecosystem-based approach differs significantly from traditional engineered solutions: both the problem and the solution are contextualised within the natural functions and services of the landscape. The social and technical dimensions of the problems and potential benefits are addressed, engaging a range of interdependent stakeholders. The ecosystem-based approach offers the possibility of innovative management solutions that could generate a wide set of linked co-benefits. Economically, the approximate capital costs of £100,000 for the blue–green–grey solution (excluding the 'flyover floodplain') and the operating costs are meagre compared to the estimated costs of up to £264,000 for each day that the tunnel and cutting are closed. This establishes the foundation for

CASE STUDY

the development of a novel approach to cost-effective flood resilience schemes that are potentially transferable to other high-risk locations.

Obstacles remain, including the resistance of established transport options appraisal schemes, the assumptions and default options of traditional engineering consultants, and the need to develop a more flexible discharge consent. It requires confidence to embark on an open engage–deliberate–decide (EDD) approach that includes stakeholders from the outset. Although it is generally cheaper and more effective, it runs counter to established decide–announce–defend (DAD) approaches that only involve other sectors once solutions are largely set in the sunk capital of engineering designs.[7] But this more collaborative approach to decision-making is essential for sharing the ownership of, investment in and benefits from flood management.

Further research is required to estimate the wider economic benefits and costs of flood-management solutions, both engineered and nature-based, on a level playing field that acknowledges all linked ecosystem service impacts. Consideration of the full spectrum of ecosystem services affected by decisions would offer greater insight into net societal benefits and the overall distribution of costs and benefits across affected stakeholder groups. It could lead to greater uptake and innovation of multi-beneficial and societally cost-effective schemes. It is also consistent with the biodiversity net gain requirements in the UK's Environment Bill (2020).

This case study demonstrates the greater potential linked co-benefits of merging nature-based and technical solutions to address the anchor service of railway flood management. To date, the proposed blue–green–grey solution has not been implemented, but the potential benefits are clear. They highlight the need for real-world trials to demonstrate the benefits and provide a basis for learning about new knowledge-based, planning, regulatory, financial, partnership and multi-benefit solutions. ES

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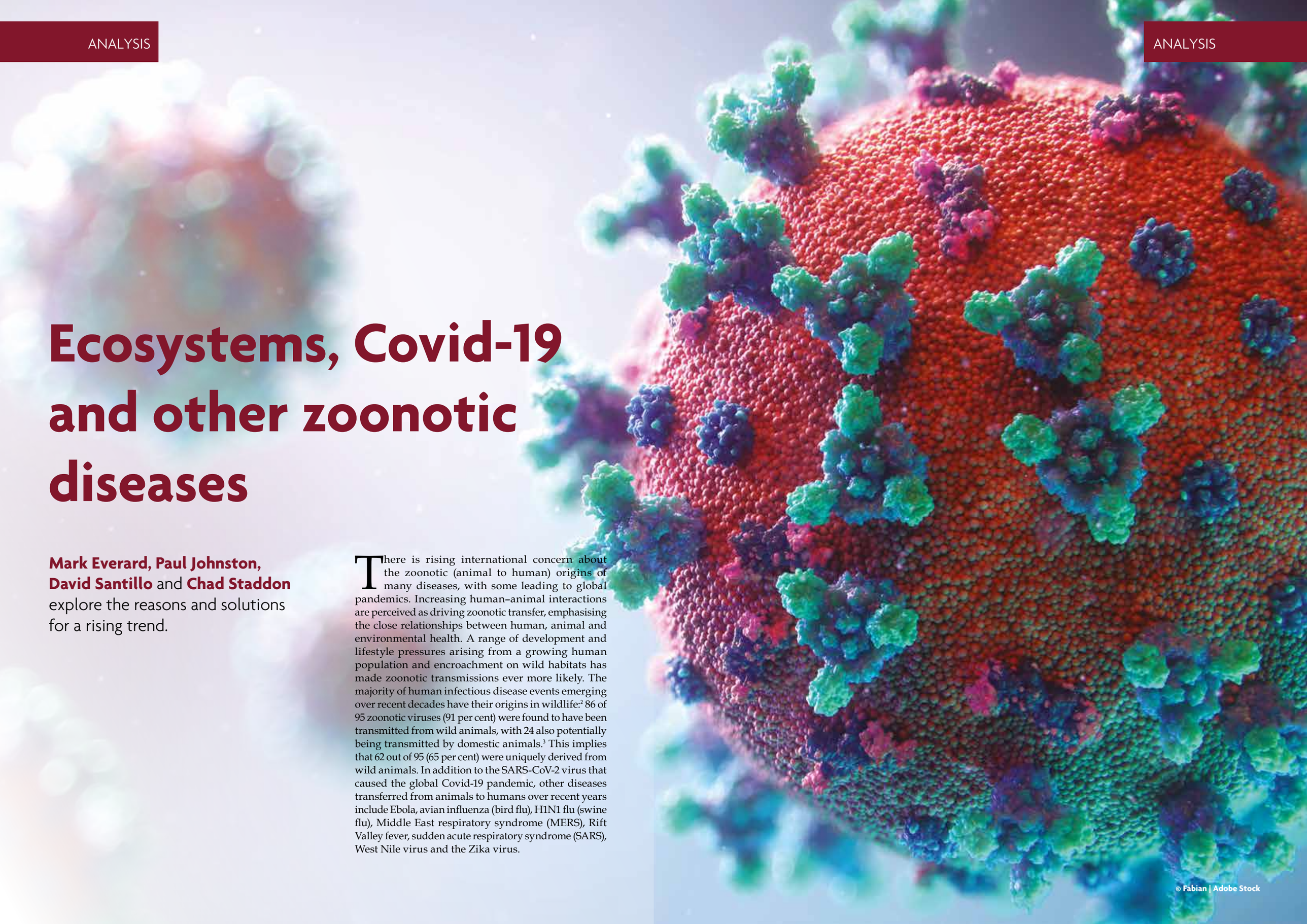
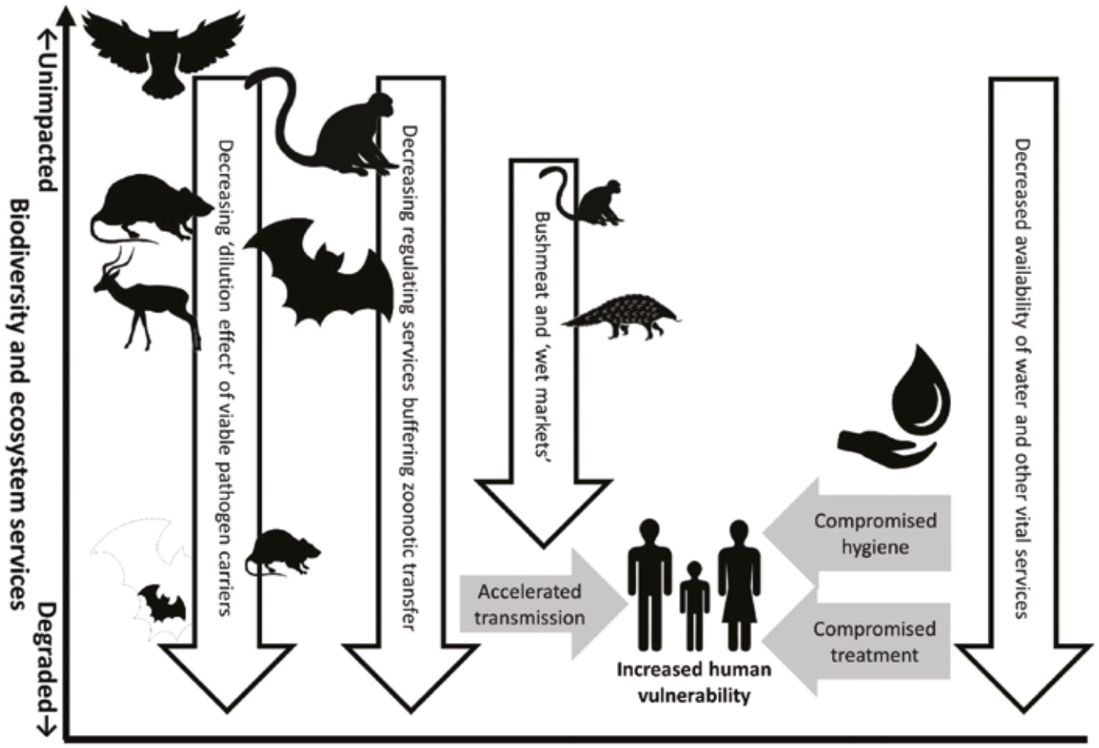
ANALYSIS

Ecosystems, Covid-19 and other zoonotic diseases

Mark Everard, Paul Johnston, David Santillo and **Chad Staddon**
explore the reasons and solutions for a rising trend.

There is rising international concern about the zoonotic (animal to human) origins of many diseases, with some leading to global pandemics. Increasing human–animal interactions are perceived as driving zoonotic transfer, emphasising the close relationships between human, animal and environmental health. A range of development and lifestyle pressures arising from a growing human population and encroachment on wild habitats has made zoonotic transmissions ever more likely. The majority of human infectious disease events emerging over recent decades have their origins in wildlife:[2] 86 of 95 zoonotic viruses (91 per cent) were found to have been transmitted from wild animals, with 24 also potentially being transmitted by domestic animals.[3] This implies that 62 out of 95 (65 per cent) were uniquely derived from wild animals. In addition to the SARS-CoV-2 virus that caused the global Covid-19 pandemic, other diseases transferred from animals to humans over recent years include Ebola, avian influenza (bird flu), H1N1 flu (swine flu), Middle East respiratory syndrome (MERS), Rift Valley fever, sudden acute respiratory syndrome (SARS), West Nile virus and the Zika virus.





▲ **Figure 1. The depleted state of ecosystems and their services increases the likelihood of zoonotic transfer. (© Mark Everard)**

Ecosystem degradation also results in reductions in natural resource availability. As many as one-third of the world's population lacks access to the safe and reliable water services that support basic standards of consumption and hygiene.[4] Frequent handwashing is a key factor in slowing the spread of Covid-19 and other pathogens,[5] with water also essential for good sanitation and the treatment of people who are infected. Limitations on access to water can therefore compromise the management of human-to-human transmission of zoonotic and other communicable diseases, as well as their treatment.

DRIVING GREATER ZOONOTIC VULNERABILITY

Human activities resulting in ecosystem degradation have feedback loops. Undermining natural supportive processes inevitably results in the degeneration of socio-ecological cycles, compromising human security, opportunity and resilience, including to diseases. The accelerated growth of the human population, particularly since the early 20th century, is a significant compounding factor. This growth has correlated strongly with declining global forest cover, increasing land conversion and degradation, and elevated rates of species extinction. Depletion of natural resources and ecosystem service flows also increases pressures that lead people to exploit alternative food sources.

In addition, it is estimated that 96 per cent of all mammalian biomass on Earth now comprises humans and livestock,[6] with human consumption patterns transgressing planetary boundaries beyond which abrupt global environmental change becomes ever more likely,[7] threatening the viability of the natural world and the diversity of ecosystem services essential for humanity. Urbanisation, globalisation, the rising proportion of people consuming more resources, and dominant consumerist market forces are all aggravating factors. Booming smaller cities further reduce functional distances between wild animals, farmed animals and people.

Increasing travel related to globalisation, including improved connectivity to more areas of the Earth, can also clearly act as a potent vector for subsequent human-to-human transmission. Antimicrobial resistance, climate change, intensified agriculture and livestock production, and the illegal and poorly regulated wildlife trade all act as compounding factors. Poor governance amplifies all of these pressures.

The resultant depleted state of ecosystems, their natural resources and the associated disease regulation services cumulatively contribute to declining resilience to potential pandemics (see **Figure 1**). There is growing recognition of the underpinning importance of ecosystem health for human health, albeit that this is still poorly represented in human health management strategies.[8]

The impacts of all of these pressures include heightened human health threats, particularly for the least affluent and most vulnerable in society. These people are also often the most deprived of infrastructure facilitating access to adequate water. Even in higher-income countries, water insecurity extends into poorer and neglected constituencies such as the homeless, refugees, prisoners, undocumented migrants and displaced people. In general, there is still an over-reliance on technically efficient solutions such as the conversion of forests and other landscapes solely for narrow purposes yielding immediate economic returns, intensified production on farmed land and in marine fisheries, and mechanised water resource abstraction. Benefits may accrue to some sectors of society, but many narrowly framed solutions tend to overlook and, indeed, serially undermine ecosystem structure, diversity, functioning and services.

ECOSYSTEM RESTORATION

If it is true that ecosystems in a disturbed or depleted state can accelerate the emergence of zoonotic diseases and weaken control of them – and there are major complexities in those simplified narratives beyond the scope of this article – then it is also true that ecosystem protection and restoration can play roles in their regulation and management.

Some drivers of currently degenerating socio-ecological trends – population growth, urbanisation and globalisation amongst them – may be harder or impossible to arrest, so mitigation measures are required. However, responses to address many of the pressures they generate – deforestation and other land-use changes, unsustainable farming, declining biodiversity, climate change, and the largely unregulated wildlife trade – are all in one way or another already subject to international and national pronouncements, conventions and other commitments.

Some of these signed commitments are generational in timescale, ranging from ratification of the 1971 Ramsar Convention and the acceptance of the 1981 World Conservation Strategy, the 1987 Brundtland Commission, the 1992 Convention on Biological Diversity and the 2005 Millennium Ecosystem Assessment. Regrettably, delivery on these promises has been spectacularly underwhelming. Destructive climate change, biodiversity loss, disparities between rich and poor, and other manifest trends towards planetary ecocide continue barely abated or, very often, at an accelerating pace.

"The foundational role of ecosystems and their services in providing resilient solutions to current and likely future zoonotic emergence and management ... must not be overlooked."

The global Covid-19 shock exemplifies a consequence of ecosystem depletion driving degrading cycles in tightly linked socio-ecological systems. It should stimulate urgent recognition that causal linkages between pressures on natural systems and outcomes for people are far from theoretical. This is relevant across the spectrum of human endeavour and interests such as industrial supply chain stability, urban air quality, recreational and commercial fisheries, flooding consequent from converted landscapes, and food and water security.

STRATEGIC RESPONSES

Some specific responses relating to zoonotic disease management include the need to reduce or halt wildlife trafficking and consumption, including through much tighter scrutiny and controls of wet markets and trade in bushmeat (see **Figure 2**). Continued diminution of wild gene pools need to be halted as greater genetic diversity tends to dilute the proportion of potential disease reservoir organisms in wild populations, making a significant contribution to damping down the tendency for emergence of zoonotic diseases. Equally, reform is required in many dimensions of livestock farming in both the developed and developing worlds, as the rate of future zoonotic disease emergence or re-emergence has been assessed as heavily dependent on the ways the agriculture–environment nexus evolves.[9]

The foundational role of ecosystems and their services in providing resilient solutions to current and likely future zoonotic emergence and management, linked with a wide range of connected outcomes of benefit across all policy areas, must not be overlooked. Recognition that the Covid-19 pandemic is also linked to biodiversity and water crises is central to strategic responses both to the immediate pandemic and to reduction of future zoonotic

▲ **Figure 2. Wet markets and trade in bushmeat increase the risk of animal–human contact and have been strongly implicated in many recent zoonotic transfers, highlighting the need for much tighter scrutiny and controls. (Top: © tostphoto | Adobe Stock; bottom: © Wikiseal | Wikimedia Commons)**

risks. This is entirely consistent with the aspirations of the UN Decade on Ecosystem Restoration 2021–2030,[10] the UN Sustainable Development Goals and particularly Sustainable Development Goal 6 (SDG6), which relates to water and sanitation. Meeting SDG6 would cost only a fraction of the amounts wealthy countries have already pledged as stimuli to help them recover from the Covid-19 pandemic.[4]

There will doubtless be downward pressure on donor country budgets in the wake of the global recession following the Covid-19 pandemic. However, it would be foolhardy to miss the opportunity to change the collective view of ecosystem stability and universal access to safe, clean water from something that would be good to have into something vital for the wellbeing of all – there will be an ongoing risk of retransmission to donor countries if disease reservoirs persist or emerge overseas.

THE NEED FOR REGENERATION

In essence, the Anthropocene has unwittingly created new disease propagation pathways by overriding or degrading ecosystem services that might otherwise help suppress zoonotic emergence and transmission and aid treatment. Covid-19 is recognised as part of a pattern of increasingly frequent disease outbreaks coinciding with globalisation, urbanisation and climate change, and rooted deeply in ecosystem depletion. Strategic responses must include regeneration of the foundational resources of ecosystems and their services for greater future human security.

The scale and pace of induction of emergency legislation and stimulus packages in response to the Covid-19 pandemic demonstrates institutional and societal capacity for substantial and timely response in the face of existential threats. The pressing issues of climate change and the biodiversity crisis are no less, and are arguably more, existential in nature, even if they are perceived as approaching at a different pace.

The contents of this article are summarised from the paper 'The role of ecosystems in mitigation and management of Covid-19 and other zoonoses',[1] rapidly developed and published by the four authors immediavtely following the February 2020 symposium 'Reconnecting society with its ecological roots', from which other articles in this issue are also derived. ES

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Concluding thoughts

James Longhurst, Chad Staddon, Herbert Girardet, Paul Johnston, Amanda Craig, Harmony Ridgley and **Kevin Austin** issue a call to action for environmental regeneration.

We know that the Earth's ecosystems are the ultimate underpinning resource of all our continuing needs – biologically, economically and for life fulfilment. We have also enshrined that dependence in a plethora of conventions, consensus statements, strategies and laws both internationally and nationally. Furthermore, we know that these vital planetary life support systems are in precipitous decline, and much more urgently needs to be done to halt this increasingly desperate prognosis.

We also know that halting and then reversing this trend can rebuild the roots of our future security and improve the prospects for all life on this planet. We lack neither awareness nor stated commitments and tools. Furthermore, we can draw inspiration and lessons from exemplars in fragmented pockets right across the planet of best practice and policies yielding tangible benefits. Moreover, the global Covid-19 pandemic has created an unexpected opportunity to further consolidate pro-environmental gains in the new economic normal.

This issue of the environmental SCIENTIST, bringing together influential players from across government departments and associated agencies, national and international non-governmental organisations (NGOs), academia and learned societies, is all about breaking through the inertia that has served only to compound risks to ourselves and the future. Its examples and findings are relevant right across the full spectrum of societal policy and practice. As the authors of the article on ecosystems, Covid-19 and other zoonotic diseases underline, the scale and pace at which emergency legislation and economic stimulus packages were implemented demonstrates that we have the institutional capacity for prompt and substantial responses that can be deployed to existential threats including climate change and the biodiversity crisis.

A new paradigm is necessary, enacted in meaningful policy and practice, to recognise and embed the real values, vulnerabilities and opportunities provided by ecosystems to all policy areas and spheres of human interest, from defence to railway management, urban design, farming, forestry, nature conservation, public health and many others.

Significantly, we argue that we need to go beyond merely protecting our much-degraded and fragmented ecological inheritance. Rather, the higher priority is to seek to develop more proactive ways to regenerate our much-degraded inheritance of supportive ecosystems as a crucial investment – perhaps the only really meaningful investment – to assure continued human security and expanding opportunity. ES

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