Compendium of Scientific and Practical Findings Supporting Eco-Restoration to Address Global Warming

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About Biodiversity for a Livable Climate

Biodiversity for a Livable Climate, bio4climate.org, is a 501(c)(3) non-profit founded in 2013 whose mission is to support the restoration of ecosystems to reverse global warming. We are:

- ***A think tank***, creating research and reports (such as this Compendium), and presenting conferences on the science and practice of eco-restoration with speakers from around the world.
- ***An educational organization***, offering presentations, courses and materials, including over 200 videos of speakers (with over 185,000 views on YouTube) from our 12 conferences since November 2014 (bio4climate.org/conferences), with many restoration and climate-positive examples from both scientists and practitioners.
- ***An advocate*** that reaches out to other organizations to encourage and facilitate the incorporation of eco-restoration as a climate solution into their own messaging and actions. We seek to connect to other groups and projects to help nourish and advance their own growth, and carry messages among groups to collaboratively learn and build on each other's efforts, and occasionally facilitate the emergence of new groups. Since climate affects everyone, every organization has to deal with it in its own way, and we strive to help with the transition.
- ***An activist group*** that engages in non-partisan political processes. For example, we helped shepherd a bill through the legislative process in 2017 to establish a Maryland Healthy Soils Program.

We are a small 501(c)(3) non-profit with a major impact in addressing climate, and we rely on your generous contributions! Please go to www.Bio4Climate.org/Donate to join our monthly donor program, or to make a one-time donation, all tax deductible. Many thanks!

Suggested Citation

Compendium of Scientific and Practical Findings Supporting Eco-Restoration to Address Global Warming, Vol 3 No 2, January 2020, https://bio4climate.org/resources/compendium/. This is a collection of article summaries and commentary that will grow as new literature becomes available and as older literature is re-discovered.

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We are most appreciative of the support from our sponsors over the past six years. In particular, the 11th Hour Project provided significant funding for our first two years, and the new and important institution that it helped create, the Regenerative Agriculture Foundation, is continuing its strong moral and financial support. We are also pleased to acknowledge generous conference sponsorship from the Organic Consumers Association, Regeneration International, the Virgin Earth Challenge, Bristol Community College, the Tufts Institute of the Environment, Janelia Foundation, Margaret Roswell, the Overbrook Foundation and Foundation Earth. Additional important support has been kindly provided by the Nutiva Foundation, the Rockefeller Family Fund, the Savory Institute, Irving House and the Bionutrient Food Association. We also gratefully acknowledge support from several institutions, including Tufts University, Harvard University, Bristol Community College, and the University of the District of Columbia.

Conversion table

hectares vs. acres	1 ha ≈ 2.5 ac
megagrams vs. tons	1 Mg = 1 metric ton
teragrams vs. tons	1 Tg = 1 million metric tons
petagrams vs. gigatons	1 Pg = 1 billion metric tons (1 Gt)
weight[1] carbon vs. weight CO_2	12/44
parts per million CO_2 vs. weight of carbon[2]	1 ppm CO_2 ≈ 2 Gt carbon

Introduction

We begin this issue of the Compendium by exploring the role of cities in the era of climate breakdown. This section features “Heat Planet,” an essay by architect Christopher Haines, member of Bio4Climate's Leadership Team, exploring the global implications of the pervasive phenomenon of the “Urban Heat Island” and other heat-producing paved and de-vegetated surfaces around the globe. We then explore various general, non-urban land conservation priorities (intact forests, wilderness areas, large old trees, and habitat corridors), and finish with a sampling of stories of real communities restoring their local ecosystems.

Adaptation and Urban Resilience

The industrialization that has built today’s splendid high-tech cities isolated us from the land and water sources of the materials fueling this progress. Our cities scarcely reveal that the oxygen we breathe, the food we eat, the purification of waters, and to some extent the bucolic weather patterns we have long relished have been gifts from the ensemble of living creatures on Earth

[1] We refer to carbon in soils and biomass, etc. by weight of carbon; atmospheric carbon may be referred to by weight of carbon *or* by weight of CO_2, a frequent source of confusion.
[2] Ppm is a volume measurement, 1 ppm is approximately equal to 2 gigatons carbon by weight - and yes, this can be confusing too. Moving 1 ppm CO2 from the atmosphere results in 2 Gt carbon added to soils or other carbon sink.

interacting in the form of ecosystems. We urbanites have managed in this brief past couple of centuries – a small fraction of human history - to harbor an illusion of independence from nature.

With their hard, gray and angled surfaces, ravenous appetites, and continuous toxic waste streams, cities in general surrendered themselves as ecological sacrifice zones. Against a foe so powerful as the drive for industrial development, there was never much hope for nature's cause in a city. Yet to those of us with the means, cities are treasure troves of excitement, intrigue, social interaction, pleasure, and comfort, and it has perhaps been worth the sacrifice.

Yet if the wholesale exchange of ecosystem services for techno-industrial services was largely affordable in the 20th century, the growing likelihood of suffering or dying from climate-change-induced extreme weather makes this bargain harder to swallow. We've reached a time of reckoning. Cities of the world are now on the front lines of increasingly severe hurricanes, floods, fires, heat waves, and sea-level rise, and are thus bearing witness to our inextricable ties to nature.

As home to more than half of humanity, though, cities are uniquely positioned to drive the transition needed to salvage civilization and life in general from real-time ecological collapse. As aggregators of consumption and waste production, cities have plenty of slack to tighten. As population centers, they have the most at stake. As weavers of diverse cultures bursting with talent and creativity, cities have the people power to discover effective solutions. And as localized political bodies, cities have the potential to be cohesive enough to make key policy changes that favor adaptation and resilience to climate change.

Many effective ways to enhance urban resilience are known. They are described in various schools of thought – ecological engineering, industrial ecology, green infrastructure, sponge cities, biophilia, reconciliation ecology, and urban ecology, for example, which all generally aim to bolster ecosystem services in and around human habitation. Methods involve restoring original ecosystems (such as wetlands, forest, prairie, floodplains, mangrove forests, river delta systems and oyster reefs) adjacent to cities, and creating ecologically functional green spaces within cities, such as vegetated roofs and walls, or wooded parks. The ecosystem services these features deliver are meant to replace or fortify industrial infrastructure serving similar purposes. Here are a few examples:

- Forested watersheds purify water for downstream consumers. For example, New York City compensates upstream watershed communities for protecting riparian forests and reducing agricultural runoff. These watershed investments totalling $1.5 billion over 10 years pale in comparison to the alternative of building a $6-billion dollar filtration system requiring additional annual operating and maintenance costs [Postel & Thompson 2005]. Globally, "restoring upland forests and watersheds could save water utilities in the world's 534 largest cities an estimated $890 million each year and is critical for regulating water flows and managing the future's more extreme floods" [Global Commission on Adaptation 2019: 31].

- Salt marshes and coastal wetlands trap sediment to allow for coastal elevation rise in the face of sea-level rise, while also lowering erosion rates, and reducing wave strength in storms. "Properties behind a marsh, on average, save 16% in flood losses every year compared to properties where marshes have been lost," according to a study of a coastal community in New Jersey hit by Hurricane Sandy in 2012 [Narayan 2017: 9463]. Coastal wetlands can even work in concert with nature friendly, grass-covered levees further inland by protecting the levees from wave damage [Cheong 2013].
- An oyster reef can reduce up to 95% of wave height; trap sediment allowing the shoreline to rise as sea level rises; protect shorelines from erosion; improve water quality through filtration; and support breeding ground for economically valued species, such as blue crab, red drums, flounder and spotted sea trout [Cheong 2013]. By contrast, sea-walls, which can also protect coastal cities from wave action, have the negative side effects of eroding neighboring shoreline and damaging surrounding ecosystems.
- A single full-grown tree has the cooling power of 10 air conditioning units [Kleerekoper 2012], and a patch of woods in a city can make even a broiling summer day feel fairly pleasant. Wooded areas of Washington DC are 17F degrees cooler than areas of the city with no trees on a hot summer day [NOAA 2018]. "For cities, an annual investment of $100 million in urban tree planting could create enough shade to cut average temperatures by 1°C for 77 million people around the world" [Global Commission on Adaptation 2019: 31].
- Green walls and green roofs cool buildings through shading, evapotranspiration and insulation (the soil layer of a green roof insulates the building), thus significantly reducing buildings' energy demands. Green walls have been shown to lower adjacent air temperatures by 0.2C to 3C [Kleerekoper 2012, Cameron 2014].

These methods are immediately relevant as cities continue to grow: two thirds of humanity is projected to reside in cities by 2050 [Collas 2017]. Population growth and aging infrastructure require ongoing renovation and new construction. For example, the number of houses in the US grew by 1.2 million between 2017 and 2018 [US Census 2019]. Globally, an estimated 60% of the built environment will be new or replaced by 2050 [Ahern 2014].

Individual buildings and houses are not necessarily designed, however, with climate risk in mind. The American Institute of Architects has recently created a new standard that a building must be designed to withstand environmental conditions over its entire design life. That means that if an architect today takes on the design of a commercial building whose estimated life is 80 years, it must be designed for the expected climatic conditions of 2100. For example, if climate-projection maps show a likelihood of flooding in a particular location, then a new building site should be considered; if high winds are a projected risk then special attention should be paid to roof design. However, architects are not required to consider climate projections and in many cases rely solely on building codes, which are based on historical data sometimes decades old [The American Institute of Architects 2019].

In the rush to grow and in the absence of an ecologically informed planning and design framework, new construction often increases a city's vulnerability to severe weather and puts people in harm's way who might otherwise have been better protected. "In several coastal U.S. states, for example, the highest rates of home construction since 2010 have occurred in flood-prone areas" [Global Commission on Adaptation 2019: 39]. Tragically, "cities are building over floodplains, forests, and wetlands that could have absorbed stormwater or offered respite and precious water during heat waves and droughts" [Global Commission on Adaptation 2019: 39]. Globally, some cities lack even basic floodplain maps.

Tragically, "cities are building over floodplains, forests, and wetlands that could have absorbed stormwater or offered respite and precious water during heat waves and droughts" [Global Commission on Adaptation 2019: 39]**. Globally, some cities lack even basic floodplain maps.**

Why, when information grows daily about climate risk as well as effective methods to enhance resilience, is it too often not taken into account? The answer to this question certainly involves complex political, cultural and economic analyses. Yet more superficially, a barrier may simply be that ecology and climate are not well integrated into mainstream planning and engineering, and that various types of expertise are too often siloed, resulting in insights from urban ecology being "often overlooked in engineering, planning, and policy for any sort of urban future." Likewise, "the technical and built aspects of cities are central to the very fabric of urban systems and, perhaps unintentionally, are often overlooked or ignored in social-ecological studies" [McPhearson 2016: 11].

Even climate-focused institutions tend to unnecessarily separate mitigation and adaptation objectives, rather than thinking holistically through how solutions could be multifunctional and mutually reinforcing. This current lack of integration results in suboptimal outcomes and scarce resources being inefficiently spent. By contrast,

> With a synergetic approach, AFOLU [agriculture, forests, and other land use] projects would be designed to combine adaptation and mitigation in a way that project

> components interact with each other to generate additional climate benefits compared to projects in which adaptation and mitigation are separated. Mainstreaming climate compatible development (i.e., adaptation, mitigation, and development) may avoid that projects respond to adaptation and mitigation urgencies separately [Kongsager 2016: 279].

Similarly, urban ecologists argue for holistic and collaborative approaches to development in the face of climate breakdown. Multidisciplinary teams must work together

> to facilitate understanding of how both green and grey infrastructure can be linked - and in the future, deeply integrated - to deal with urban challenges and meet the needs of urban residents [McPhearson 2016: 11].

In addition to greater inter-sectoral collaboration, a large body of generalized and transferable knowledge in urban ecology is still needed, given the relative newness of this field, for planners to more easily incorporate new perspectives into their work. Given the urgent need for ecologically informed development, however, Ahern et al. [2014] argue that urban planners could forgo future research results by taking an ‘adaptive design’ approach. This would involve working in multidisciplinary teams that “learn by doing,” and incorporate low-risk, experimental design features into urban development plans, monitor results, make adjustments, and share what they learn.

> Professionals, planners and designers need to make decisions in response to approval and development schedules. However, the “traditional” professional timeframe mandates an “imperative to act” that relies on readily available, existing knowledge and established best practices – typically without the opportunity to conduct new research. This imperative tends to favor decisions based on existing knowledge, and to inhibit innovation. The challenge of providing ecosystem services for urban sustainability planning and design will rely on emerging urban planning and design theory and new knowledge in design and engineering. Transdisciplinarity, implying the co-production of knowledge by scientists, planning professionals and urban dwellers, is a key to realize the potential of this planning approach [Ahern 2014: 255].

Further stressing the urgency to mainstream ecological principles into development planning and engineering, Mitch and Jorgenson [2003: 372] state: “The idea of nature conservation is so important that it needs to become a goal of engineering, not just one of its possible outcomes.” These authors argue that any engineering plans that omit ecological considerations have no place in today’s ecologically devastated world.

> **“The idea of nature conservation is so important that it needs to become a goal of engineering, not just one of its possible outcomes”** [Mitch and Jorgenson 2003: 372]**.**

> We build solid waste facilities and water pollution control systems and atmospheric emissions of the greenhouse gas methane result. We use industrial wastewater treatment methods to remove heavy metals from a factory and then must dispose of metal-rich sludge. We burn sludge and solid wastes and we create air pollution problems. We are moving materials around in a shell game—if it is not under one shell, it is under another [Mitsch & Jorgenson 2003: 374].

The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services reiterates this observation of the shortcomings of strictly human-built infrastructure and technology to deal with grave environmental problems.

> People have created substitutes for some other contributions of nature, but many of them are imperfect or financially prohibitive. For example, high-quality drinking water can be realized either through ecosystems that filter pollutants or through human-engineered water treatment facilities. Similarly, coastal flooding from storm surges can be reduced either by coastal mangroves or by dikes and seawalls. In both cases, however, built infrastructure can be extremely expensive, incur high future costs and fail to provide synergistic benefits such as nursery habitats for edible fish or recreational opportunities. More generally, human-made replacements often do not provide the full range of benefits provided by nature [Diaz 2019: 13].

A great irony, as Carl Sagan once observed, is that as deeply divided as humanity is along nationality, political and class lines, not to mention professional specialization, the earth’s climate and ecosystems are deeply intertwined. What happens in Las Vegas or any other city does not stay in that city, but ripples out over the region and the globe. Likewise, how we manage landscapes upstream of and around a city significantly affects how badly battered it will be by the next big storm passing over it.

What the articles summarized below illustrate is that working with nature to boost ecosystem services to cities is eminently practical. Not only are ecological climate-change adaptation approaches highly effective as a protective buffer against severe weather; they also deliver several co-benefits - not the least which is mitigating the city's impact on the rest of the planet by creating desperately needed wildlife habitat (at least for insects, birds and other small animals) and sequestering greenhouse gases. Urban green space also improves human health and wellbeing by reducing air pollution and providing islands of beauty and tranquility.

What's exciting about the urban ecology opportunity is that more than half of us are perfectly situated to help shift the tide toward more ecologically coherent cities. Through collective action in shared spaces like schoolyards, churchyards or parks, even people without land of their own can restore ecosystems. Proponents for a "citizen science" model of grassroots engagement in conservation efforts [Francis & Lorimer 2011] note that urban areas have key advantages: (1) a large population base potentially available for training, implementation, monitoring and knowledge sharing related to ecosystem restoration; (2) concentrations of university and professional scientists with expertise to offer in grassroots and collaborative projects; and (3) high visibility of ecological urban adaptation efforts to generate enthusiasm and raise public awareness.

Francis and Lorimer [2011] further observe, however, that "motivation for conservation remains a major obstacle" and that "the biodiversity that emerges [from urban ecology efforts] is likely to be in untidy, unexpected and non-traditional forms" [Francis & Lorimer 2011: 1435] and that the management of expectations is therefore important. Perhaps, though, as the stakes continue to rise and to become clearer and more alarming to more and more people, the knowledge base already established on how to work with nature to better protect cities from climate change will be just enough to kick-start a paradigm shift in urban planning and development.

> **More generally, human-made replacements often do not provide the full range of benefits provided by nature** [Diaz 2019: 13].

Compilation of article summaries on adaptation and urban resilience

Global change and the ecology of cities, Grimm et al. 2008

Whereas just 10 percent of people lived in cities in 1900, now more than half the global population is urban and that proportion continues to grow. Cities occupy less than 3% of the

Earth’s land surface, but generate 78% of global CO2 emissions and consume 76% of wood used for industrial purposes.

> Urban dwellers depend on the productive and assimilative capacities of ecosystems well beyond their city boundaries — “ecological footprints” tens to hundreds of times the area occupied by a city — to produce the flows of energy, material goods, and nonmaterial services (including waste absorption) that sustain human well-being and quality of life [Grimm 2008: 756].

The social and environmental costs of building and servicing the world’s wealthiest cities since the colonial period to the present has been enormous:

> Although exacerbated by recent globalization trends, centuries ago the demands of European consumers led to deforestation of colonial lands and, more recently, demand for beef from countries of the Western Hemisphere has transformed New World tropical rainforests into grazing land [Grimm 2008: 756].

Because cities so radically transform landscapes, creating new and less functional ecosystems in the process, they were “shunned” by ecologists during the 20th Century, “with the result that ecological knowledge contributed little to solving urban environmental problems” [Grimm 2008: 756]. However, even though cities contribute disproportionately to the current ecological crisis, they are by the same token increasingly seen as a necessary part of the solution, both in terms of mitigating their effects, and withstanding and adapting to severe weather.

The field of “urban ecology” seeks to better understand the processes and patterns of urban ecosystems, with an eye toward boosting the ecosystem services within and around cities upon which urban dwellers depend. An observable pattern is the cycling of resources through a city. “The concept of urban metabolism analogizes a city to an organism that takes in food and other required resources and releases wastes to the environment” [Grimm 2008: 757]. Unlike natural ecosystems, though, which constantly recycle resources, urban ecosystems notoriously recycle little to nothing, and are therefore reliant on fresh extraction for the provision of new resources, while letting waste products accumulate as pollution.

Through an urban ecology lens, this discrepancy between natural and urban resource metabolism is duly noted and practical solutions proposed:

> Cities are hot spots of accumulation of N [nitrogen], P [phosphorus], and metals and, consequently, harbor a pool of material resources. Could high-nutrient, treated wastewater substitute for commercial N fertilizers to supply crops and lawns with nitrogen, for example? [Grimm 2008: 757]

Similarly,

> A small (but growing) proportion of the copper extracted globally is recycled, yet increasing the reuse and recycling of copper and other metals would do much to stem the rapid rise in demand from sources increasingly difficult to extract. Such reuse also would alleviate problems of metal accumulation in soils [Grimm 2008: 757].

Another tendency of urban ecosystems is to generate surplus heat, creating an urban heat island (UHI), due to reduced vegetation cover (thus, reduced cooling effects of evapotranspiration) and increased surface area absorbing solar energy (buildings, roads, etc.). This UHI effect in turn increases the use of air conditioning by 3-8% in the US, the additional energy use for which represents a positive feedback, which increases global warming. By contrast, increasing vegetation cover in cities reduces the UHI effect, while also removing greenhouse gases from the atmosphere, thus representing a negative feedback, which reduces global warming.

Another area of analysis in urban ecology involves water management (including channelization of streams and sewers, for example). The design of urban water systems is typically devoid of the ecosystem service provided by the waterways that urban systems replace, making cities vulnerable to flooding, drought and excessive pollution.

> Among the most important modifications that affect streams in urban areas is increased impervious cover, which changes hydrology and funnels accumulated pollutants from buildings, roadways, and parking lots into streams [Grimm 2008: 759].

Yet,

> Successful, ecologically based designs of novel urban aquatic ecosystems are becoming more common and exemplify stream-floodplain protection, retrofitting of neighborhood stormwater flow paths, and use of low-impact stormwater/water capture systems as creative solutions to urban stormwater management [Grimm 2008: 759].

Advancing urban ecology toward a science of cities, McPhearson et al. 2016

The study of urban ecology has grown rapidly over the past couple of decades as the planet becomes increasingly more urbanized. The field started as the study of ecology within the green spaces of cities, and has since evolved into a multidisciplinary approach to understanding the city itself as an ecosystem with interacting social, ecological and technical components.

> A variety of social processes contribute to vulnerability to heat, including variation in social capital and legacies of disinvestment, which can affect vulnerability to heat waves. Furthermore, differences in intra-urban surface temperature can be as large or larger than urban-rural temperature differences, and a number of social-ecological-technical infrastructure interactions have been found to determine climate outcomes in cities. For instance, the dense distribution of tall buildings influences the spatial pattern of solar radiation intensity and duration and so influences air temperatures.[3] The highly heterogeneous distribution of vegetation in cities is a primary determinant of heat exposure, which is often greater for poor, elderly, and minority segments of the population, who are often less able to cope [McPhearson 2016: 9].

With an ultimate aim of fostering resilience among the world's ever-growing cities, urban ecologists envision a transdisciplinary, participatory "ecology for cities" approach that integrates research and practice. Such collaboration could result in the beneficial integration of gray and green urban infrastructure.

> Traditional risk-avoiding engineering designs for infrastructure design focus on hard, resistant elements such as increased-diameter sewage pipes for stormwater management or tanks to store sewage. In contrast, more flexible, diverse, and ecologically based elements include green infrastructure such as parks, permeable pavement, swales or retention basins, or agricultural and vacant land sites in urban areas. Urban infrastructure therefore mediates the relationships between human activities and ecosystem processes and may exacerbate or mitigate human impact depending on how it is developed [McPhearson 2016: 11].

How to make a city climate-proof, Kleerekoper, van Esch & Salcedo 2012

"The geometry, spacing and orientation of buildings and outdoor spaces" [Kleerekoper 2012: 30], as well as the prevalence of hard surfaces and reduced amount of vegetation, strongly modify the micro-climate of urban areas compared to rural surroundings. Characterized by an increase in temperature, a phenomenon referred to as urban heat island [UHI] effect has multiple causes. This includes, for example:

- Absorption of short-wave radiation from the sun in low albedo (low-reflection/high-absorption) materials
- Absorption and re-emission of longwave radiation by pollution
- Heat released through combustion from traffic, heating and industries

[3] See "Heat Planet," for further explanation of heat dynamics of cities.

- Reduction of wind speed and obstruction of sky view by buildings, resulting in lowered heat loss from street “canyons”
- Decreased evaporation due to a surfeit of impermeable surfaces

An increase in global temperature combined with UHI may have serious health implications including death. The heatwave of 2006 resulted in about a thousand heat-related deaths in the Netherlands and was rated fifth-worst natural disaster of that year. Cities can reduce the UHI effect with adaptive measures that combine vegetation, water, built form and material.

“**Vegetation** cools the environment actively by evapotranspiration and passively by shading surrounding surfaces that otherwise would have absorbed short-wave radiation” [Kleerekoper 2102:]. Such methods include expanding urban forests/parks, street trees, private gardens, and green walls or roofs. “Vegetation has an average cooling effect of 1 – 4.7C that spreads 100 – 1,000m into an urban area, but is highly dependent on the amount of water the plant or tree has available” [Kleerekoper 2012:]

Water cools by evaporation, or by transporting heat out of the city as does a river or stream. The cooling effect of water ranges from 1 - 3^0C to a distance of 30 - 35m, with stagnant water cooling the least and flowing and dispersed water (like a fountain) cooling the most. Water also cools through permeable pavement and water storage infrastructure that makes it available to trees for transpiration.

The **built form** of cities increases the UHI effect by reducing heat loss when tall buildings block the release of long-wave radiation back up toward the sky, while also blocking wind ventilation. While city form is hard to change, any new development can opt to reduce the height to width ratio of streets to allow better ventilation and heat loss. Slanted roofs also increase ventilation.

Lastly, the choice of building **materials** affects the UHI effect. Permeable materials facilitate evaporation and light/white (high albedo) materials reflect short-wave solar radiation, thus cooling the city. By contrast, “waterproof” and dark materials reduce evaporation and absorb short-wave radiation, thus contributing to the UHI effect. A simulation model for Sacramento, CA, showed a 1 – 4C drop in temperature from a city-wide increase in albedo (such as through white rooftops) from 25 to 40%.

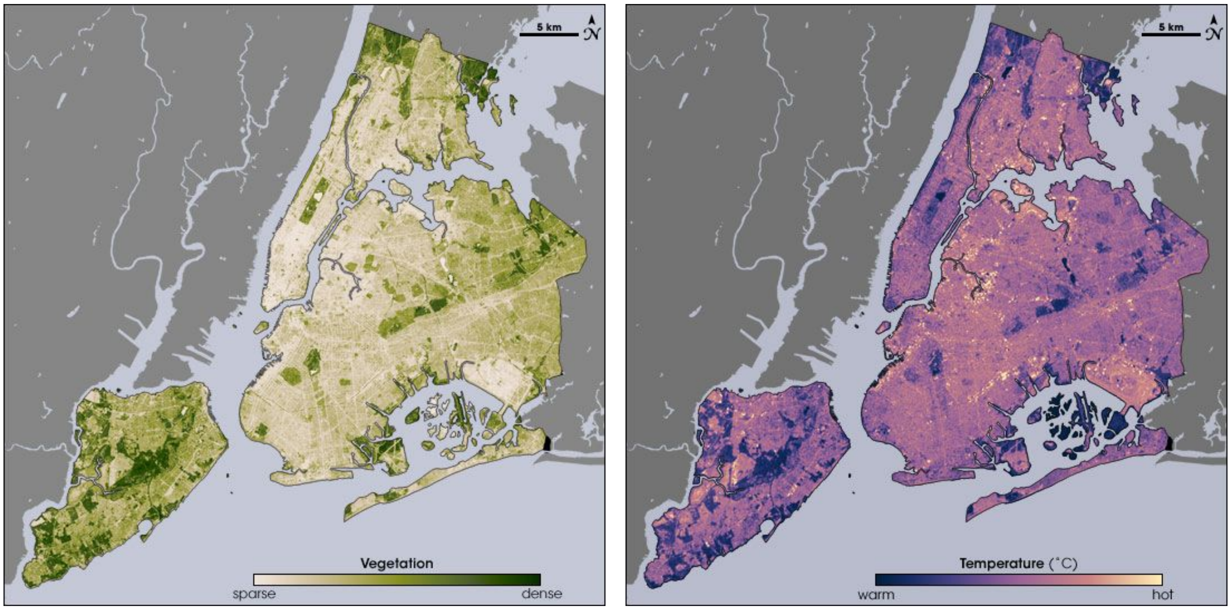
Despite the existence of a substantial body of knowledge on the causes of and solutions to the UHI effect, the transfer of this knowledge to city planners is often lacking. Due to differences in aim, focus, and expression among the various actors in the city planning process, as well as the theoretical (rather than practical) nature of scientific studies discussing the UHI effect, communication about UHI-reduction design solutions can be a challenge. Furthermore, quantification is often lacking in terms of heat accumulation for a given area, maximum acceptable levels of heat, and the quantity of needed measures to reduce UHI (number of trees or square meters of green space, for example) .

However, certain cities like Stuttgart have developed spatial parameters in urban planning guidelines with respect to climate change. In California a cool-roof material with low thermal admittance has been introduced in the Building Energy Efficiency Standard regulation of the state. The city of Portland is creating a reference guide of pavement options for low-use traffic zones. The greening policy in Chicago and Edinburgh involves increasing the number of street trees, as well as species heterogeneity to ensure resistance to vegetal disease (given that species diversity limits pest infestation).

Mitigating New York City's heat island with urban forestry, living roofs and light surfaces, Rosenzweig et al. 2006

Urban heat islands are created when solar energy is absorbed by non-reflective, impervious, and often rather dark surfaces, such as asphalt, stone, metal, and concrete, which are ubiquitous in cities. Exacerbating this solar energy absorption effect are abundant amounts of heat released from vehicles, factories and air conditioners, for example, as well as pollutants trapped in the lower troposphere that slow down the cooling of rising air.

In New York City, where this study was conducted, the "summertime nocturnal heat island averages 7.2ºF (4ºC). This means that during the summer months the daily minimum temperature in the city is on average 7.2ºF (4ºC) warmer than surrounding suburban and rural areas" [Rosenzweig 2006: 1]. The authors tested the cooling effects of tree plantings, living rooftops and high albedo (light colored) surfaces, and found that curbside tree plantings were the most effective form of cooling per unit area, followed by living rooftops. High albedo (light/white) surfaces were the least effective at cooling per unit area, but were the most effective overall "because 64% of New York City's surface area could be redeveloped from dark, impervious surfaces to lighter high-albedo surfaces" [Rosenzweig 2006: 3], whereas only 17% of the city's surface could be planted with new street trees.



A vegetation map (left) and a temperature map (right) of NYC, captured in August 2002, show vegetated areas are cooler. Maps by Robert Simmon.

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The interaction of rivers and urban form in mitigating the Urban Heat Island effect: a UK case study, Hathaway & Sharples 2012

Like vegetative and light or reflective surfaces, water bodies have a cooling effect on cities, reducing the Urban Heat Island effect. The average temperature at the river in this study was 1C less than at a reference point elsewhere in the city. Furthermore, the form of the landscape on the banks of an urban river can either propagate (increase) or diminish the cooling effects of the river. This study found that vegetated river banks increased the cooling effect of the river by a difference of 2C compared to river banks covered in hard engineering materials (concrete/asphalt), while opening river banks (rather than enclosing them with buildings or walls) permitted significant cooling effects to be felt up to a distance of 30 meters from the river.

> Overall, the results indicate that high levels of vegetation next to the river increase the cooling on the bank, that opening up the streets to the river increases the propagation of cooling and that the surface nature of the surrounding materials [e.g. vegetation versus concrete] can have a more significant effect on the air temperatures than the presence of the river [Hathaway & Sharples 2012: 20].

[4] Maps (above) retrieved from NASA: https://earthobservatory.nasa.gov/features/GreenRoof/greenroof2.php.

> **Overall, the results indicate that high levels of vegetation next to the river increase the cooling on the bank, that opening up the streets to the river increases the propagation of cooling and that the surface nature of the surrounding materials [e.g. vegetation versus concrete] can have a more significant effect on the air temperatures than the presence of the river** [Hathaway & Sharples 2012: 20].

Urban development, land sharing and land sparing: the importance of considering restoration, Collas et al. 2017

With 66% of the world's population predicted to live in cities by 2050, the challenge of reconciling urban growth with biodiversity conservation demands attention.

> Although the environment is altered by urbanization, there is potential for cities to support a great deal of biodiversity [Collas 2017: 1866].

This study shows that urban growth and biodiversity enhancement are compatible by increasing housing density (in order to reduce total surface area of development) while restoring ecosystems on remaining green space through woodlot plantings. The study was conducted in Cambridge, England, whose population is expected to grow by 22% between 2011 and 2031, and where "current green space supports relatively few trees" [Collas 2017: 54]. Green space could be maximized and restored to woodlots while additional high-density housing could accommodate the expected population growth.

Furthermore, only 2% of green space (i.e. ≥30 ha) is needed for conversion to woodlot to increase the native tree population size in Cambridge while also increasing high-density housing. This is compared to an alternative growth scenario, where new development is low-density and inhabitants are expected to plant trees in their relatively large yards, while no city-led green space ecosystem restoration occurs.

In conclusion, the authors offer this:

> For other cities in the UK and across Europe, which have generally long been cleared of natural habitat, restoration in parallel with the expansion of higher density housing would appear to offer greatest scope for accommodating population growth at least cost to

> nature. This would require policy and economic incentives to directly link high-intensity human land-use to large-scale restoration [Collas 2017: 1871].

Promoting and preserving biodiversity in the urban forest, Alvey 2006

Given the dangerous, precipitous global decline in biodiversity, coupled with rapid urbanization, cities have a key role to play in protecting biodiversity. In fact, cities already do harbor a large share of biodiversity. This may be due to the fact that cities are often situated in places of large inherent biodiversity (along rivers, for example), and/or because of large numbers of introduced species and landscape heterogeneity in cities. Furthermore, surrounding agricultural areas are often simplified landscapes with limited biodiversity while many forests are degraded, and thus less biodiverse, due to timber harvest regimes, roads, etc. Thus, contrary to what might be assumed, rural areas are not necessarily more biodiverse than cities.

The author stresses the importance of managing cities to increase biodiversity. This process should begin with a city-wide tree inventory to identify tree species, locations and health. Management should focus on increasing biodiversity among street trees, and in parks, woodlots, abandoned lots, and back/front yards, while also fostering public awareness and appreciation for ecological principles. Planting efforts should prioritize native species, which are better adapted to local conditions, are non-invasive, and whose protection contributes to global biodiversity conservation. (While great numbers of introduced species may increase local biodiversity, it has a homogenizing effect on global biodiversity.) Furthermore, natural regeneration of parks and woodlots should be encouraged through less intensive management, whereby seeds of native (or at least non-invasive) species are allowed to germinate and establish where they fall, instead of being fastidiously mowed or weeded.

A new vision for New Orleans and the Mississippi delta: applying ecological economics and ecological engineering, Costanza, Mitsch & Day 2006

> What happened in New Orleans [during Hurricane Katrina], while a terrible “natural” disaster, was also the cumulative result of excessive and inappropriate management of the Mississippi River and delta, inadequate emergency preparation, a failure to act in time on plans to restore the wetlands and storm protection levees, and the expansion of the city into increasingly vulnerable areas [Costanza, Mitsch & Day 2006: 467].

Mismanagement here refers to damming, leveeing and canal dredging of the Mississippi River Delta, resulting in a significant loss of wetlands and the erosion of barrier islands over the past 100-plus years. Coastal marshes and barrier islands depend on regular inputs of sediments deposited by the river, which has been isolated from the delta plain and unable to thus nourish it. Two thirds of the river empties directly into the depths of the Gulf of Mexico, while one third empties into shallow waters, where it nourishes wetlands via the Atchafalaya, the river's single remaining distributary (other distributaries having been closed off).

Damage from Hurricane Katrina was exacerbated by its prior loss of wetlands. Expansive coastal wetlands protect coastal communities from hurricanes by "decreasing the area of open water (fetch) for wind to form waves, increasing drag on water motion and hence the amplitude of a storm surge, reducing direct wind effect on the water surface, and directly absorbing wave energy" [Costanza, Mitsch & Day 2006: 468].

For the rebuilding of New Orleans after the hurricane, the authors recommended several core principles aimed at social and ecological resilience. Among their recommendations, they advise that areas of the city currently below sea level (by as much as 5 meters in some parts) not be rebuilt, but, rather, be restored to wetland. This would allow for temporary water storage within the city, water filtration, and biodiversity protection. They also suggest the reopening of distributaries and the controlled breaching of certain levees to allow the river to resume its ancient task of distributing sediment over a greater expanse of coastal marshes, allowing these marshes to gradually rise in step with sea level rise.

Eco-engineering urban infrastructure for marine and coastal biodiversity: which interventions have the greatest ecological benefit? Strain et al. 2017

While the majority of people on Earth live in cities, the majority (60%) of the world's largest cities are located within 100 kilometers of a coast. The pollution and urban infrastructure (such as marinas, sea walls, or oil/gas platforms) emanating from cities greatly stresses coastal marine habitats. Coastal infrastructure tends to be vertical and smooth, offering little or nothing in the way of habitat niches or physical protection for various marine organisms. An eco-engineering approach to improve habitat quality and increase biodiversity is the addition of textural features, such as ledges, small holes, basins or crevices to the hard surfaces of urban marine infrastructure.

> As predicted, overall microhabitat-enhancing interventions had a positive effect on the abundance and number of species across the studies. Nevertheless, the magnitude of their effects varied considerably, from zero to highly positive according to the type of intervention, the target taxa, and tidal elevation [Strain 2017: 434].

In the intertidal[5], interventions that provided moisture and shade had the greatest effect on the richness of sessile[6] and mobile organisms, while water-retaining features had the greatest effect on the richness of fish. In contrast, in the subtidal[7], small-scale depressions which provide refuge to new recruits from predators and other environmental stressors such as waves, had higher abundances of sessile organisms while elevated structures had higher numbers and abundances of fish. The taxa that responded most positively to eco-engineering in the intertidal were those whose body size most closely matched the dimensions of the resulting intervention [Strain 2017: 426].

Coastal adaptation with ecological engineering, Cheong et al. 2013

Because of the multiple threats and uncertainties of a changing climate, protecting coastal areas simply by building new seawalls (or some other such inflexible, single-tactic approach) is unlikely to be the most effective option. Instead, combined coastal adaptation strategies to allow for a dynamic response to multiple stressors are increasingly preferred. Climate scientists and coastal managers are mainstreaming inclusion of climate change into an Integrated Coastal Zone Management framework, aimed at promoting the activities of the different coastal sectors by coordinating government agencies and private participation.

Contrary to a “regret-risking option,” a no- or low-regret option is adopted to generate a net social benefit irrespective of the future outcome of climate change. Revamping early warning systems, preventing land reclamation, improving housing and transportation, capacity development in education, poverty reduction, and efforts to build resilient ecosystems are examples of a low- or no-regret options.

Traditional engineering, while sometimes protective of coastal communities, has undesired effects, such as eroding non-target, neighboring coastline and destroying adjacent ecosystems. By contrast, eco-engineering tools emphasize positive interactions among species that boost ecosystem productivity and stability, and therefore the strength of the ecosystem to withstand and buffer heavy storms, thus protecting coastal communities.

For example, sea-grasses planted with clams at their roots grow faster and in turn increase total fixed carbon. Oyster reefs attenuate up to 95% of wave height, control turbidity by removing algae, bacteria, and suspended organic matter, improve water quality through their filtration capacity, and enable seafood supply and thus job creation and recreation. Oyster reefs also

[5] The intertidal refers to the area between the low and high tide marks.
[6] Attached in place.
[7] Shallow area below/beyond the low-tide mark.

support breeding ground for economically valued species, such as blue crab, red drums, flounder and spotted sea trout.

In mangroves, transplants planted in close proximity rather than the traditional spread pattern allows for a shared benefit of positive interaction that enhances plant growth and biodiversity. Restored mangrove ecosystems alleviate the impact of moderate tsunami waves, while the roots trap sediment and elevate the land surface, allowing for adaptation to sea-level rise. Intact mangrove also provides local employment as well as breeding grounds for fish.

Marshes dampen wave actions and reduce shoreline erosion, increase fish production, and are compatible with levee designs on the marshes' landward edges that are nature-friendly. In the Netherlands, for instance, levees built to prevent flooding during storms were covered with thick grass to maintain their integrity, while the seaward marshes reduce the levees' exposure to wave action; grasses were then grazed by sheep to provide milk and meat for consumption.

The synergy of ecology and engineering is key to addressing uncertainties related to climate-induced stressors. The combination of traditional and eco-engineering approaches coupled with the evaluation to measure the effectiveness of eco-engineered structures facilitate better decision making and prioritization of options.

Where we stand: climate action, The American Institute of Architects (AIA) 2019b

Noting that 40% of carbon emissions in the US come from the construction (including sourcing of materials) and operation (heating, cooling, lighting) of buildings and houses, the AIA pledges to achieve zero-carbon construction and operation of all new buildings, and retrofitting of existing buildings to reduce their energy use and increase their resilience to severe weather. They will achieve these goals through education, policy advocacy, calling for zero-carbon building codes, and advocating for the reuse of historic buildings rather than new construction.

Living Building Challenge Standard, June 2019

The construction and operation of buildings and houses is a major source of pollution and ecosystem destruction around the world. In light of this, the Living Building Challenge invites people to reimagine the built environment as a source of social and ecological regeneration.

> Nothing less than a sea change in building, infrastructure and community design is required. Indeed, this focus needs to be the great work of our generation. We must remake our cities, towns, neighborhoods, homes and offices, and all the spaces and

> infrastructure in between. This is part of the necessary process of reinventing our relationship with the natural world and each other—reestablishing ourselves as not separate from, but part of nature, “because the living environment is what really sustains us” (E.O. Wilson) [International Living Future Institute 2019: 8].

To that end the Living Building Challenge invites us to collaborate in building houses and buildings - or adapting existing ones - to have a positive, rather than simply less-negative, impact on the social and ecological systems where they are situated. The initiative runs educational and certification programs with several high standards, including, for example:

- Projects must be observant of and responsive to the local ecological and social context of the sites, and onsite landscaping must seek to emulate local ecosystem function.
- Access to locally grown food should be assured through onsite production and/or connection to local farms.
- The site must ensure adequate habitat for local species.
- Living Building Challenge designers must find ways to encourage pedestrian, bike and public transport options, while discouraging individual car travel.
- Water should be harvested and wastewater treated onsite using living or natural/non-chemical systems.
- Buildings/houses should supply their own energy on site (not through combustion), monitor their energy use, and minimize use through conservation.
- Construction materials should be salvaged or sustainably and transparently sourced, and non-toxic.
- In the interest of human wellbeing and social equity designs should allow natural light, beauty and comfort in the interior of the building, while the exterior must be accessible and welcoming to all members of the public, regardless of socioeconomic status.

Adapt now: a global call for leadership on climate resilience, Global Commission on Adaptation, September 2019

This report, led by Ban Ki Moon (UN), Bill Gates (Bill & Melinda Gates Foundation) and Kristalina Georgieva (World Bank), calls on decision makers worldwide to facilitate coordinated action to help communities adapt to climate change. Importantly, the report makes the case for nature-based adaptation approaches, which inherently help mitigation efforts as well. Adaptation measures are much cheaper than recovery and rebuilding: every $1 invested in adaption yields $2-10 (or more by some estimates) in avoided losses and other economic benefits (such as improved crop yields), as well as social and environmental benefits.

Despite a clear global imperative for rapid adaptation planning and action to be taken at local, regional and national levels, action is desperately lagging. The report cites four reasons for inaction: (1) broad failure to internalize climate change risk in everyday decision making; (2) human tendency to prioritize short-term planning at the expense of long-term goals; (3) lack of cross-sector collaboration, which leads to fragmentation of responsibility; and (4) lack of power/voice among those most affected by climate change.

The report succinctly articulates the value of working with nature to adapt to climate change, while highlighting the extent to which this vital information is neglected.

> We can already see the immense opportunity of using nature to increase societal resilience in landscapes ranging from uplands to the ocean. Restoring upland forests and watersheds could save water utilities in the world's 534 largest cities an estimated $890 million each year and is critical for regulating water flows and managing the future's more extreme floods. Meanwhile, lakes, marshes, and river floodplains both slow the release of floodwater and filter out sediment. The Netherlands has harnessed these capabilities with a Room for the River strategy that increases capacity of rivers and their floodplains to hold floodwaters, reducing damage and loss of life.
>
> Ecosystem restoration also is a powerful tool for feeding the hungry, cooling sweltering cities, and protecting communities. One striking example is farmer-led reforestation in the Maradi and Zinder regions of Niger, which has boosted crop yields, improved soil fertility, and lifted communities out of poverty. Tree cover has soared ten-fold and the daily time spent gathering firewood—a task that mainly falls to women—has dropped from 3 hours to 30 minutes. For cities, an annual investment of $100 million in urban tree planting could create enough shade to cut average temperatures by 1°C for 77 million people around the world. Restoring the mangrove forests that offer protections from rising seas and storm surges is two to five times cheaper than building engineered structures like underwater breakwaters, while also storing carbon and improving water quality and local fisheries.
>
> Yet despite the powerful case for working with nature to reduce climate risks, the world has barely begun to realize this potential. Few governments have adopted these approaches widely, even though many cite natural solutions in their NDCs. And only 3 percent of nearly 2,000 companies reported using natural ecosystems as part of their climate adaptation strategies. The barriers include lack of awareness of the critical role of natural assets in underpinning social and economic resilience and lack of accessible funds to invest in nature-based solutions. In addition, the piecemeal way adaptation is often planned and executed undervalues or ignores the many benefits of working with nature.

> Humanity faces a stark choice: We can harness nature-based solutions to mitigate climate change and to better adapt—or we can continue with business as usual and lose the essential and myriad services nature provides [Global Commission on Climate Adaptation 2019: 31].

To encourage adoption of nature-based adaptation strategies, the report recommends three steps: (1) raise the level of understanding of the value of nature for climate adaptation; (2) embed nature-based solutions into adaptation planning and policy; and (3) increase investment into nature-based solutions. Indeed, it is precisely the aim of Biodiversity for a Livable Climate and its compendium series to elevate the level of understanding and appreciation for nature-based adaptation and mitigation solutions to the climate crisis.

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Humanity faces a stark choice: We can harness nature-based solutions to mitigate climate change and to better adapt—or we can continue with business as usual and lose the essential and myriad services nature provides [Global Commission on Climate Adaptation 2019: 31].

Heat Planet: Biodiversity, the Solar Interface and Climate Disruption

By Christopher A. Haines, Biodiversity for a Livable Climate

Christopher Haines is a seasoned architect licensed in both MA and NY who applies expertise in regenerative architectural design, healthy materials, preservation, renovation and specification writing to small commercial and urban projects. He has spoken for years at US and international forums as well as formally teaching sustainability and environmental management to undergraduate and graduate students. Christopher has been deeply involved in the Living Building Challenge and is certified as a Living Building Challenge consultant.

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The year of 1979 was a critical one for the science of greenhouse gases and climate change. In April, the Jasons, a "mysterious coterie of elite scientists" [Rich 2019:15] published a report "The Long-Term Impact of Atmospheric Carbon Dioxide on Climate." This report was subsequently reviewed by a National Academy of Science team commissioned by the Carter Administration and led by Jule Charney of Massachusetts Institute of Technology.

With the publication of the "Charney Report," "Carbon Dioxide and Climate: A Scientific Assessment," in July of 1979, the science of greenhouse gases as the sole cause of climate disruption was codified and canonized. Climate modeling was later made more sophisticated by the Intergovernmental Panel on Climate Change (IPCC), but the basic structure was not changed. We are thus the recipients of sophisticated modeling of a very complex system based on a single variable with secondary inputs.

We have spent the last 40 years so focused on the "pot lid" being the cause of the pot boiling over that we have failed to consider the possibility of turning down the stove. Climatologists all agree that the atmosphere is warmed by infrared rays radiated from the earth's surface. Greenhouse gases are so named because they perform like a greenhouse, trapping that heat. But the 'science' seems to have overlooked where the heat comes from.

Sunshine is utilized differently depending on the interface it strikes. Living plant tissues promote photosynthesis and transpiration of water, causing cooling, while inanimate materials merely convert solar energy into heat. Everyone knows that walking barefoot on a summer day through a forest or across a meadow, desert or parking lot provide very different thermal experiences, particularly for your feet.

In walking across the desert and parking lot your feet experience sensible heat, the heat you can measure with a thermometer. In walking through the forest you experience latent heat, which is the heat required to convert water into vapor. Since considerable heat energy is spent converting liquid water into vapor (590 calories per gram), that heat does not increase the temperature. This is also the cooling mechanism of sweating. The evaporation of water increases humidity, and is thus experienced as sensible cooling. It's worth noting that it takes only 80 calories to melt a gram of ice, which illustrates how powerful a cooling agent is the transfer of heat to water vapor (heat of vaporization). These experiences acknowledge different materials in different environments, generating very different temperatures.

Photo of square and adjacent park in Třeboň, Czech Republic, taken with a thermal camera; the dark parts are significantly cooler at 15°C (59°F) compared to the light parts, over 30° C (86°F). Photo retrieved from Kravčík, M. et al., 2007, Water for the Recovery of the Climate - A New Water Paradigm.

Climatologists monitor reflectivity of land surfaces ("albedo") as a guide to their thermal characteristics. Trees and forests have a reflectivity of between 5% and 20% for different species, and NASA uses an average of 14% for its Earth model. This turns out to be almost exactly the same as brick, concrete or urban areas overall. The question is what happens to the energy that is <u>not</u> reflected. Schneider and Sagan [2005] document energy balances for forests with 15% of energy reflected, 18% turned into heat, 1% turned into biomass and 66% used for transpiration. Yet for brick, concrete or urban areas, the roughly 85% of energy not reflected is turned wholly into heat. *Thus albedo is an inaccurate description of the heat generating characteristics of a land surface.*

Urban heat islands have been known since Luke Howard published his two-volume thesis on the Climate of London in 1818 and 1820. While we have focused on greenhouse gases that have risen 30.85% from 1800 to 2000, urban land area has increased 3345% and urban population has increased 3836% in the same timeframe.[8] And that is just the footprint. The solar interface - that is, the surface area of urban buildings that the sun strikes - could easily be ten or more times the footprint, even recognizing that some of the buildings' surfaces remain in shade.

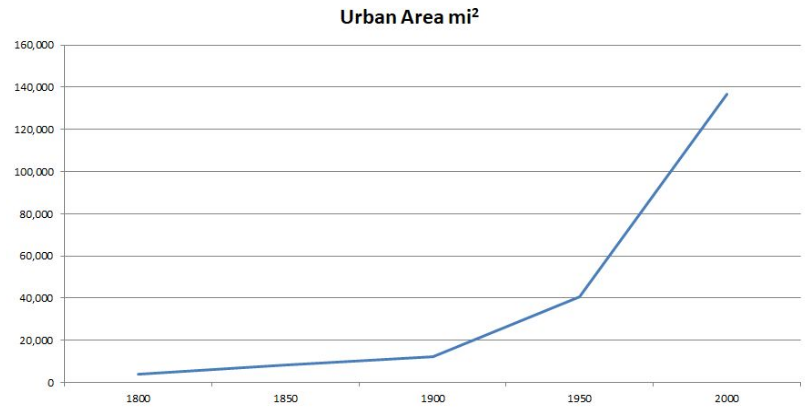
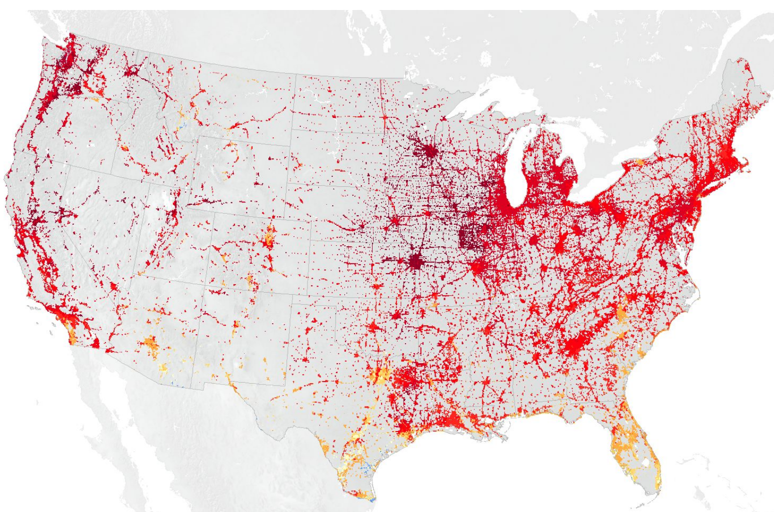


Chart drafted by Christopher Haines, using data retrieved from https://ourworldindata.org.

While the physics of urban heat islands were discovered in urban centers where the phenomenon is concentrated, what is critical to recognize is that the same physics apply everywhere. We define urban heat islands as urban centers that are warmer than non-urban areas some distance away. But the sun shines on non-urban areas as well, and *any inanimate object - bare soil, a building, or a road - generates heat from insolation*. Those non-urban areas are thus warmer than they would otherwise be, and we are underestimating the temperature rise of urban areas because we have no "zero zone" to measure against.


NASA research modeling US cities and surrounding areas found that the impervious surfaces of urban and suburban areas, as well as the highways connecting them, had an average summer temperature difference of 1.9C compared to surrounding rural lands.

The destruction of biodiversity in any form that reduces leaf surface area, reduces the evapo-transpiration of water, the cooling it produces and the rain it promotes. It also reduces the biomass growth that increases sequestration. Thus biodiversity destruction directly causes a loss of cooling but is also the precursor to the generation of heat from bare ground, deforestation, aridification, open pit mining, mountaintop removal, roadways or the construction of buildings and urban centers. We

[8] Figures calculated by author based on data retrieved from: https://ourworldindata.org/urbanization
* US map (above) showing concentrations of impervious surfaces retrieved from: https://earthobservatory.nasa.gov/images/86440/vegetation-limits-city-warming-effects

must therefore recognize that the destruction of biodiversity causes double damage. Is it relevant to note that the IPCC has spent much of its correspondence in the last few decades admitting that it has underestimated the rate at which warming was occurring? Is this because it has failed to account for the rising temperature of the ‘stove’?

In other words, we have created what is effectively a global heat island, caused by solar energy generating sensible heat from the inanimate materials it strikes. Greenhouse gases exacerbate the problem by increasing the percentage of heat trapped, thus increasing the warming effect, but they do not cause the creation of sensible heat from solar energy.

The science of reducing urban heat islands has been known for decades, so we know what has to be done, although we surely need to dig deeper. With this perspective we open a world of opportunities to resolve our current predicament at the level of root causes.

Bare soil in agriculture does not produce as much heat as a roadway or a building, but there is a lot more of it. If all agriculture were converted to regenerative methods, such as practiced by Gabe Brown [2018], we might find that, globally, we have increased cooling and reduced heat generation sufficiently. Even short of a full transition to ecological/regenerative agriculture, a change in practices as simple as reducing fallow (bare) land in the Canadian prairie provinces produced significant improvements in temperature, rainfall, humidity and cooling [Vick 2016].

None of this diminishes the importance of reducing greenhouse gas emissions. However, it means that many other options to reverse climate disruption exist and several of the ones we have focused on may be less effective than others we have not yet considered, or even counterproductive. Perhaps some new balance between ecological regeneration and a reduction in greenhouse emissions will be found that would take us out of the danger zone.

The Heat Planet hypothesis provides a far more hopeful future where climate solutions are largely local and where impacts can be felt almost immediately.
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Land Management and Conservation

A spatial overview of the global importance of Indigenous lands for conservation, Garnett et al. 2018

Indigenous people make up less than 5% of the global population, but their lands encompass 37% of the planet’s remaining natural lands and (partially overlapping with natural lands) 40% of Earth’s protected area, much of this in sparsely inhabited places. Like everyone, indigenous people have multiple interests (economic, political, cultural), which don't necessarily always support conservation interests. However, "Indigenous Peoples often express deep spiritual and cultural ties to their land and contend that local ecosystems reflect millennia of their stewardship" [Garnett 2018: 369]. Indeed, "Countless Indigenous management institutions have already proven to be remarkably persistent and resilient, suggesting that such governance forms can shape sustainable human landscape relationships in many places" [Garnett 2018: 370].

Thus, the authors argue for indigenous voices to be prominent in land-use decision-making processes at global and local levels. "There is already good evidence that recognition of the practices, institutions and rights of Indigenous Peoples in global environmental governance is essential if we are to develop and achieve the next generation of global biodiversity targets" [Garnett 2018: 372].

> In total, Indigenous Peoples influence land management across at least 28.1% of the land area.
>
> About 7.8 million km2 (20.7%) of Indigenous Peoples' lands are within protected areas, encompassing at least 40% of the global protected area with the proportion of Indigenous land in protected areas significantly higher than the proportion of other lands that are protected. The relationship between Indigenous Peoples and conserved areas varies in nature. While some protected areas (as defined by states and/or the International Union for Conservation of Nature (IUCN)) are under the governance of Indigenous Peoples themselves, others are governed by state authorities with varying degrees of respect for the presence of Indigenous Peoples. This respect ranges from collaborative governance where Indigenous Peoples are consulted on decisions, to de facto management and use of protected areas by Indigenous Peoples despite threats of eviction [Garnett 2018: 370].
>
> Around half of the global terrestrial environment can be classified as human-dominated. Using this as a measure of human influence, we estimated that Indigenous Peoples' lands account for 37% of all remaining natural lands across the Earth. A higher proportion (67%) of Indigenous Peoples' lands was classified as natural compared with 44% of other lands. Even though no global data are available on other anthropogenic pressures such as grazing, burning, hunting or fishing, the drivers assessed by the Human Footprint (which range from roads, access, population density and different agricultural land use activity) are suitable surrogates. Consistent with this, most parts of the planet managed and/or owned by Indigenous Peoples have low intensity land uses: less than 3.8 million km2 (10.2%) of the world's urban areas, villages and non-remote croplands are on Indigenous Peoples' lands, whereas, in contrast, they encompass 24.9 million km2 (65.7%) of the remotest and least inhabited anthromes. Many of these

> remote Indigenous areas are nevertheless under pressure from intensive development [Garnett 2018: 370].

Wilderness areas halve the extinction risk of terrestrial biodiversity, DiMarco et al. 2019

> We found that wilderness areas act as a buffer against extinction risk. The global probability of species extinction in non-wilderness communities is over twice as high as that of species in wilderness communities. The buffering effect that wilderness has on extinction risk was found in every biogeographical realm, but was higher for realms with larger remaining extents of wilderness such as the Palaearctic[9] [Di Marco 2019: 26].
>
> The remaining intact ecosystems of Earth—which are increasingly seen as essential for providing ecosystem services on which humanity relies and maintaining the bio-cultural connections of indigenous communities—have been neglected in efforts to conserve biodiversity. This is largely due to a belief that these areas are less vulnerable to threatening processes and less rich in threatened biodiversity, thereby having lower conservation value [Di Marco 2019: 585].

However,

> These areas are important because they host highly unique biological communities and/or represent the majority of remaining natural habitats for biological communities that have suffered high levels of habitat loss elsewhere [Di Marco 2019: 585].

Ongoing accumulation of plant diversity through habitat connectivity in an 18-year experiment, Damschen et al. 2019

This long-term experiment measured the difference in colonization and extinction rates of connected habitat fragments versus isolated fragments. The connected fragments were linked by a narrow (150m by 25m) strip of habitat. These habitat corridors increased the biodiversity of connected fragments by 14% after 18 years compared to their isolated counterparts.

> In a large and well-replicated habitat fragmentation experiment, we find that annual colonization rates for 239 plant species in connected fragments are 5% higher and annual extinction rates 2% lower than in unconnected fragments. This has resulted in a

[9] The Palaearctic is the largest of Earth's eight biogeographic regions; it encompasses Europe, North Africa, and Asia north of the Himalayas (https://en.wikipedia.org/wiki/Palearctic_realm).

> steady, non-asymptotic increase in diversity, with nearly 14% more species in connected fragments after almost two decades. Our results show that the full biodiversity value of connectivity is much greater than previously estimated, cannot be effectively evaluated at short time scales, and can be maximized by connecting habitat sooner rather than later [Damschen 2019: 1479].

The authors note that 70% of the world's forest area is within 1 km of an edge - meaning Earth's forests are very fragmented. They stress that connecting habitat fragments is critical to the success of habitat and biodiversity conservation.

> Conservation plans that ignore connectivity, such as plans that focus solely on habitat area, will leave unrealized the substantial, complementary, and persistent gains in biodiversity attributable specifically to landscape connectivity [Damschen 2019: 1480].

Plant phylogenetic diversity stabilizes large-scale ecosystem productivity, Mazzochini et al. 2019

> Phylogenetic[10] measures of diversity contain information on evolutionary divergences amongst species, thus representing the diversity of phylogenetically conserved traits related to resource use, acquisition and storage. Thereby, distantly related species are expected to respond differently to changing environmental conditions. These functional traits can be general traits related to the fast–slow growth rate spectrum, such as specific leaf area and wood density, and also physiological traits triggering plant responses to climatic fluctuations, such as flowering and leafing phenologies[11]. [Mazzochini 2019: 1431].

This study shows that (phylogenetic) plant diversity helps to stabilize ecosystem productivity - even at the landscape scale. Previous experiments have shown that plant diversity increases the stability of ecosystem productivity in small patches of vegetation where plant interaction boosts overall productivity, as does difference in response to environmental fluctuations among different species. The present study increases the scale of observation to the landscape level, and finds that biodiversity increases ecosystem stability due to varied or "asynchronous responses of distantly related species during environmental fluctuations" [Mazzochini 2019: 1431].

> Our results expand by several orders of magnitude the spatial scale of evidence that high biodiversity strengthens the resistance of key ecosystem features to climatic

[10] Phylogeny refers to the evolutionary history of related groups of organisms.
[11] Phenology refers to periodic biological phenomena (such as migration or flowering) that are correlated with climatic conditions.

> fluctuations. Specifically, we show that the positive relationship between phylogenetic diversity and stability reported in local experiments can also be observed at larger spatial extents and grain sizes using available biodiversity databases and modelling techniques. As we expected, in the analyses at the landscape resolution, phylogenetic diversity correlates with vegetation productivity stability mainly due to a reduction in productivity variability across the years, and not by increasing average productivity, which was mostly driven by climatic variables [Mazzochini 2019: 1435].

Rate of tree carbon accumulation increases continuously with tree size, Stephenson et al. 2014

The growth rate of trees – and thus their accumulation of carbon – increases continuously with tree size. Even though the leaves of smaller, younger trees are more efficient (more productive per unit area of leaf surface), larger trees have more total leaf surface area and thereby grow at a faster rate than their smaller counterparts. “For example, in our western USA old-growth forest plots, trees > 100cm in diameter comprised 6% of trees, yet contributed 33% of the annual forest mass growth” [Stephenson 2014: 92].

Since trees use atmospheric carbon to grow, the more they grow, the more carbon they sequester. “Thus, large, old trees do not act simply as senescent carbon reservoirs but actively fix large amounts of carbon compared to smaller trees” [Stephenson 2014: 90].

Europe’s forest management did not mitigate climate warming, Naudts et al. 2016

Despite their total area having increased by 10% since 1750, European forests have failed to achieve a net removal of CO2 from the atmosphere because of how they’ve been managed over that time. Eighty-five percent of Europe’s once largely unmanaged forest has been subjected to tree species conversion, wood extraction via thinning and harvesting, and litter raking, resulting in a large overall loss of carbon from biomass and soil.

> Putting 417,000 km2 of previously unmanaged forest into production is estimated to have released 3.5 Pg of carbon to the atmosphere, because the carbon stock in living biomass, coarse woody debris, litter, and soil was simulated to be, respectively, 24, 43, 8, and 6% lower in managed forests compared with unmanaged forests [Naudts 2016: 598].

The sweeping change in Europe’s forest species from broad leaf trees to conifers represents a shift to a production-oriented approach to forestry undertaken to satisfy demands of a population that quadrupled between 1750 and 2010.

> Whereas deforestation between 1750 and 1850 mainly replaced broadleaved forests with agricultural land, afforestation from 1850 onward was often with coniferous species. Broadleaved forests were also directly converted to coniferous forests, resulting in a total increase of 633,000 km2 in conifers at the expense of broadleaved forests (decreasing by 436,000 km2). For centuries, foresters have favored a handful of commercially successful tree species (Scots pine, Norway spruce, and beech) and, in doing so, are largely responsible for the current distribution of conifers and broadleaved species in Europe [Naudts 2016: 598].

The authors note that many other parts of the world have followed a similar path,

> Wood extraction occurs in 64 to 72% of the 26.5 to 29.4 million km2 of global forest area, and substantial species changes have occurred in China (216,000 km2), Brazil (71,000 km2), Chile (24,000 km2), New Zealand (18,000 km2), and South Africa (17,000 km2) [Naudts 2016: 599].

This global trend has resulted in limiting the ability of many managed forests to sequester carbon, compared to their wild or better-managed counterparts.

> Hence, any climate framework that includes land management as a pathway for climate mitigation should not only account for land-cover changes but also should equally address changes in forest management, because not all forest management contributes to climate change mitigation [Naudts 2016: 599].

The exceptional value of intact forest ecosystems, Watson et al. 2018

Forests currently cover a quarter of Earth’s terrestrial surface, although at least 82% of that remaining forest is degraded by human activity. While a handful of international accords rightly encourage forest conservation and reforestation to limit global warming, these agreements fail to prioritize protection specifically of intact forests, or forests that are free from human activities “known to cause physical changes in a forest that lead to declines in ecological function” [Watson 2018: 1].

The authors argue for the protection of all forests, including degraded ones, as well as reforestation, to stem global ecological collapse, while here they particularly emphasize the exceptional value of intact forests. They present these key arguments:

- **Carbon sequestration and storage**. "Intact forests store more carbon than logged, degraded or planted forests in ecologically comparable locations. Industrial logging and conversion of forest to cropland causes heavy erosion and contributes to the loss of belowground carbon" [Watson 2018: 3].
- **Local climate.** "Intact tropical forests are critical for rain generation because air that passes over these forests produces at least twice as much rain as air that passes over degraded or non-forest areas" [Watson 2018: 4]. By contrast, deforestation and forest degradation can increase the frequency of hot, dry days, leading to drought.
- **Biodiversity.** Forested ecosystems support the majority of global terrestrial biodiversity, and "beyond outright forest clearance, forest degradation from logging is the most pervasive threat facing species inhabiting intact forests" [Watson 2018: 4]. "For example, a recent global analysis of nearly 20,000 vertebrate species showed that even minimal initial deforestation within an intact landscape had severe consequences for vertebrate biodiversity in a given region, emphasizing the special value of intact forests in minimizing extinction risk" [Watson 2018: 5].
- **Indigenous peoples.** "Industrial-scale degradation of intact forest erodes the material basis for the livelihoods of indigenous forest peoples, depleting wildlife and other resources. It also renders traditional resource management strategies ineffective, and undermines the value of traditional knowledge and authority" [Watson 2018: 5], ultimately driving indigenous peoples off their land.
- **Human health.** "Forested ecosystems are major sources of many medicinal compounds that supply millions of people with medicines worldwide" [Watson 2018: 6]. Forest degradation results in the decline or loss of medically relevant species, while also directly harming human health through increased wildfire severity and spread of disease.
- **Forest resilience.** Forest degradation reduces the resilience of forests to climate change, leading to even greater ultimate loss of ecosystem function.

The authors warn that intact forests could soon disappear unless action is taken to protect them, which must necessarily start with greater recognition of their value compared to degraded forests.

> There are still significant tracts of forest that are free from the damaging impacts of large-scale human activities. These intact forests typically provide more environmental and social values than forests that have been degraded by human activities. Despite these values, it is possible to envisage, within the current century, a world with few or no significant remaining intact forests. Humanity may be left with only degraded, damaged forests, in need of costly and sometimes unfeasible restoration, open to a cascade of further threats and lacking the resilience needed to weather the stresses of climate change. The practical tools required to address this challenge are generally well understood and include well-located and managed protected areas, indigenous

> territories that exemplify sound stewardship, regulatory controls and responsible behavior by logging, mining, and agricultural companies and consumers, and targeted restoration. Currently these tools are insufficiently applied, and inadequately supported by governance, policy and financial arrangements designed to incentivize conservation. Losing the remaining intact forests would exacerbate climate change effects through huge carbon emissions and the decline of a crucial, under-appreciated carbon sink. It would also result in the extinction of many species, harm communities worldwide by disrupting regional weather and hydrology, and devastate the cultures of many indigenous communities. Increased awareness of the scale and urgency of this problem is a necessary precondition for more effective conservation efforts across a wide range of spatial scales [Watson 2018: 8].

Addressing change mitigation and adaptation together: a global assessment of agriculture and forestry projects, Kongsager, Locatelli & Chazarin 2019

In climate policy and financing, the goals of adaptation (helping communities and ecosystems adapt to the effects of climate change) and mitigation (reducing carbon emissions and increasing carbon sinks) are often separate. This is because “adaptation and mitigation are driven by different interests and political economies, with distinct international donors and national institutions. These differences are reflected in the guidelines and requirements that climate change project developers have to follow” [Kongsager 2019: 279].

This present study, however, found that many climate change projects do or could address adaptation and mitigation jointly.

> PDDs [Project Design Documents] integrating adaptation and mitigation shared several common features. They recognized ecosystems as providers of multiple services for both mitigation (carbon) and adaptation (watershed protection, forest products for livelihood diversification or safety nets, mangrove protection against storms and waves, microclimate regulation in agricultural fields) [Kongsager 2019: 278].

Ninety percent of mitigation projects mentioned adaptation goals while 30% of adaptation projects had mitigation goals. The authors speculate on the reason for this discrepancy:

> There appears to be an intrinsic value in integrating adaptation into mitigation projects even without incentives provided by funders, because of reduced climatic risks and increased sustainability, as mentioned by a few project developers … By contrast, there is no clear rationale for a project developer to integrate mitigation into adaptation

> projects, beyond the perspective of receiving additional support from mitigation funding by selling carbon credits [Kongsager 2019: 279].

The authors recommend adjusting the institutional framework to encourage deeper, better coordinated integration of mitigation and adaptation goals into climate-related projects.

> With a synergetic approach, AFOLU [agriculture, forests, and other land use] projects would be designed to combine adaptation and mitigation in a way that project components interact with each other to generate additional climate benefits compared to projects in which adaptation and mitigation are separated. Mainstreaming climate compatible development (i.e., adaptation, mitigation, and development) may avoid that projects respond to adaptation and mitigation urgencies separately. Scarce resources could be more efficiently spent, for instance, by not establishing separate institutions and processes to support adaptation and mitigation, and by avoiding conflicting policies, because a current major challenge in integrating adaptation and mitigation is the institutional complexity [Kongsager 2019: 279].

Blessed Unrest

In continuation of the "blessed unrest" section of Compendium V3N1, the following sketches illustrate how people throughout the world are coming to recognise the enormous value of intact ecosystems, and are doing their part to protect and restore. Adopting Paul Hawken's terminology and characterization of "blessed unrest" as a spontaneous, decentralized global social movement, we here present a diverse series of vignettes of everyday heroes. May such stories light the fire for new heroes to perpetually emerge in defense of all life on Earth.

Sri Lanka wields mangroves, its tsunami shield, against climate change, summarized from Mongabay News, September 2019

https://news.mongabay.com/2019/09/sri-lanka-wields-mangroves-its-tsunami-shield-against-climate-change/?n3wsletter&utm_source=Mongabay+Newsletter&utm_campaign=a1cff7d467-Newsletter_2019_09_26&utm_medium=email&utm_term=0_940652e1f4-a1cff7d467-77145713

Sri Lanka is home to 82 lagoons and estuaries and is among the top five countries that will be impacted by climate risk. Thilakaratne De Silva, a 63-year old local fisherman, saw the Tsunami of December 2004 sweep off half his home village. He was among the first to join hands with other community members on a coastal natural buffer initiative of replanting the mangroves. In the aftermath of the tsunami, it became apparent that those who lived behind a thick buffer of mangrove forest were better shielded from the destructive waves.

The government and NGOs initiated the mangrove replanting, as well as implementing regulations aimed at curbing mangrove clearing, coral reef destruction and sand excavation. But after the Government and NGOs moved on, it's been the local community's engagement and consistency that is ensuring the success of a green belt along the south coast.

The critical goal now is to sustain the positive conservation effort already in place. Sustainable use enables gathering of edible mangrove varieties and collecting twigs and branches rather than cutting down trees and shrubs, according to Sarathchandra de Silva, an international agency worker involved in the replanting program.

Sugunawathi, a 51-year-old villager says that they are mindful of not cutting mangrove for fuelwood, though the burning efficiency of mangrove is preferred to forest wood, gas or kerosene. The frequency and extent to which communities access mangrove forest has much to do with poverty and lack of livelihood. However, growing tourism employs more rural men, creating livelihoods and boosting mangrove appreciation by the local community. A local NGO has sought to incentivize women because of their influence on children and the community on the need for the sustainable use of mangroves. The Galle success is now a model for replication, which inspires authorities to want to boost coastal buffer owning to the resilient nature of mangrove forest in climate risk, with an addition of 10,000 hectares to the existing 15,670 hectares already in place.

For one Indonesian village, mangrove restoration has been all upside, summarized from Mongabay News, September 2019

https://news.mongabay.com/2019/09/for-one-indonesian-village-mangrove-restoration-has-been-all-upside/?n3wsletter&utm_source=Mongabay+Newsletter&utm_campaign=a1cff7d467-Newsletter_2019_09_26&utm_medium=email&utm_term=0_940652e1f4-a1cff7d467-77145713

Demand for firewood in recent years led to the depletion of the mangrove forest in the Indonesia village of Paremas. For years the people's occupations were agriculture and fishing. Depleted fish stock, poor irrigation and challenges associated with land ownership drove most of the men to work overseas in order to raise money to care for their loved ones, while some women went abroad to work as domestic servants. The women who stayed home have depended on their husbands' remittances in addition to collecting fish and other sea life in pools.

However, about 10 years ago, the local government and environmental NGOs emphasized the significance of restoring the mangrove. With the help of the locals, everyone got to work

replanting Paremas mangrove forest, which in turn now cushions the effect of tidal waves, limits coastal flooding, saves arable land from coastal erosion, reduces plastic and garbage deposit on the beach, and increases biodiversity. With the availability of crabs, vegetables and fruits, the women started making crab crackers, as well as cakes made from the flour of mangrove fruits, creating a source of income for the women to support their families. “There are many benefits now,” says Hanieti, a resident mother, “even the mosquitoes are gone.”

Coastal recovery: bringing a damaged wetland back to life, summarized from Yale Environment 360, May 2019

https://e360.yale.edu/features/the-science-and-art-of-restoring-a-damaged-wetland

“It was a stink hole,” says Al Rizzo, the refuge manager of Prime Hook National Wildlife Refuge in Delaware Bay. Humans had messed with hydrology in an ill-conceived project aimed to convert salt marsh into a large open freshwater impoundment system to attract migrating waterfowl among others. Lines of dunes and tidal gates were constructed to barricade the inflow of salt water. However, severe storms, including Hurricane Sandy, tore open gaps in dune lines, inundating the re-engineered system with salt water, killing fresh-water marsh grass, and turning a healthy riparian forest into a wasteland of dead trees.

In order to reverse the damage of this unnatural disaster, government agencies and conservation groups used the Hurricane Sandy Disaster Relief Fund to embark on a $38 million attempt to restore 4000 acres of damaged wetland. Engineering with nature is how Rizzo and Bart Wilson, restoration project manager, describe their approach, in which they are taking cues from nature to create a more resilient ecosystem. The objective is to allow the system to adjust itself and to work based on normal coastal dynamics.

Relying on existing data, extensive hydrodynamic modeling was applied to find out what actually works. The refuge was found to have no elevation problem but rather a plumbing challenge. Work started with closing up the breaches by reconstructing the beach and dunes. The restored dunes are now 10ft high, allowing for overwash to dissipate storm and wave power. Sediments produced were cast onto the banks creating sand flats that are being colonized naturally by native grass. A neural network of channels was opened on historic waterways to let the tide flow back in and out. The result is a healthy tidal marsh with meandering channels, lush salt-tolerant grasses and mudflats that attract rich diversity of fish and birdlife. The Prime Hook is becoming a model for wetland restoration globally.

Indian temple restores sacred forest stream flow

Sacred forests/groves are not uncommon in India, especially in the biodiverse Western Ghats mountain range. These groves are community-protected patches of forest ranging in size from less than a hectare to several hundred hectares, and they are often believed to house gods [Ormsby & Bhagwat 2010]. A particular temple in the Western Ghats just outside the small town of Meenangadi in the state of Kerala owns 30 acres of forested hillside regarded as sacred.

In a clearing at the bottom of these hills, the people of the temple erected a shrine over a small stream flowing from their forest. Eventually, they built an elegant structure around the shrine with an opening in the roof to allow rain to wash onto the shrine. Praying involves touching the sacred stream water.

Photo by Hannah Lewis

A few decades ago, however, in need of revenue, the temple cut a few acres at the uphill edge of their 30-acre plot and sold the wood. Following the loss of this portion of forest came a decline in the flow of the stream connecting the remaining sacred forest with the shrine. During the seasonally dry months of March and April, the stream had begun to run dry.

Photo by Hannah Lewis

Concerned, temple officials went to the mayor in search of a solution to the drying of their stream. Town officials connected the temple with Kerala's forestry department, whose mission includes increasing "the inflow of water to the reservoirs by improving the tree cover / forest cover over catchment areas," "managing forests in such a way that it protects and enriches the social and cultural values of the state," "protection and expansion of mangroves, sacred groves and other highly sensitive ecosystem," and taking "Kerala to greater heights in the matter of biodiversity conservation," among other goals [Kerala Forests and Wildlife Department website].

Given a mission such as this, the forest department knew what to do. They agreed to help by reforesting the clear-cut uphill edge of the sacred forest. Using only indigenous species, they planted some 89 different varieties of trees and shrubs, including medicinal varieties, on 1.6 hectares. This project was completed about five years ago.

On an afternoon in late January this year, as a Paradise Flycatcher darted in and out from the edge of the sacred grove to drink and bathe a few meters upstream of the shrine, a trained ear could hear another couple of dozen different bird species calling from the surrounding forest. Temple staff members said they have indeed seen more birds now that the cleared forest has been replanted. And the stream no longer runs dry, not even in March and April.

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