SUSTAINABILITY

SPONGE CITY

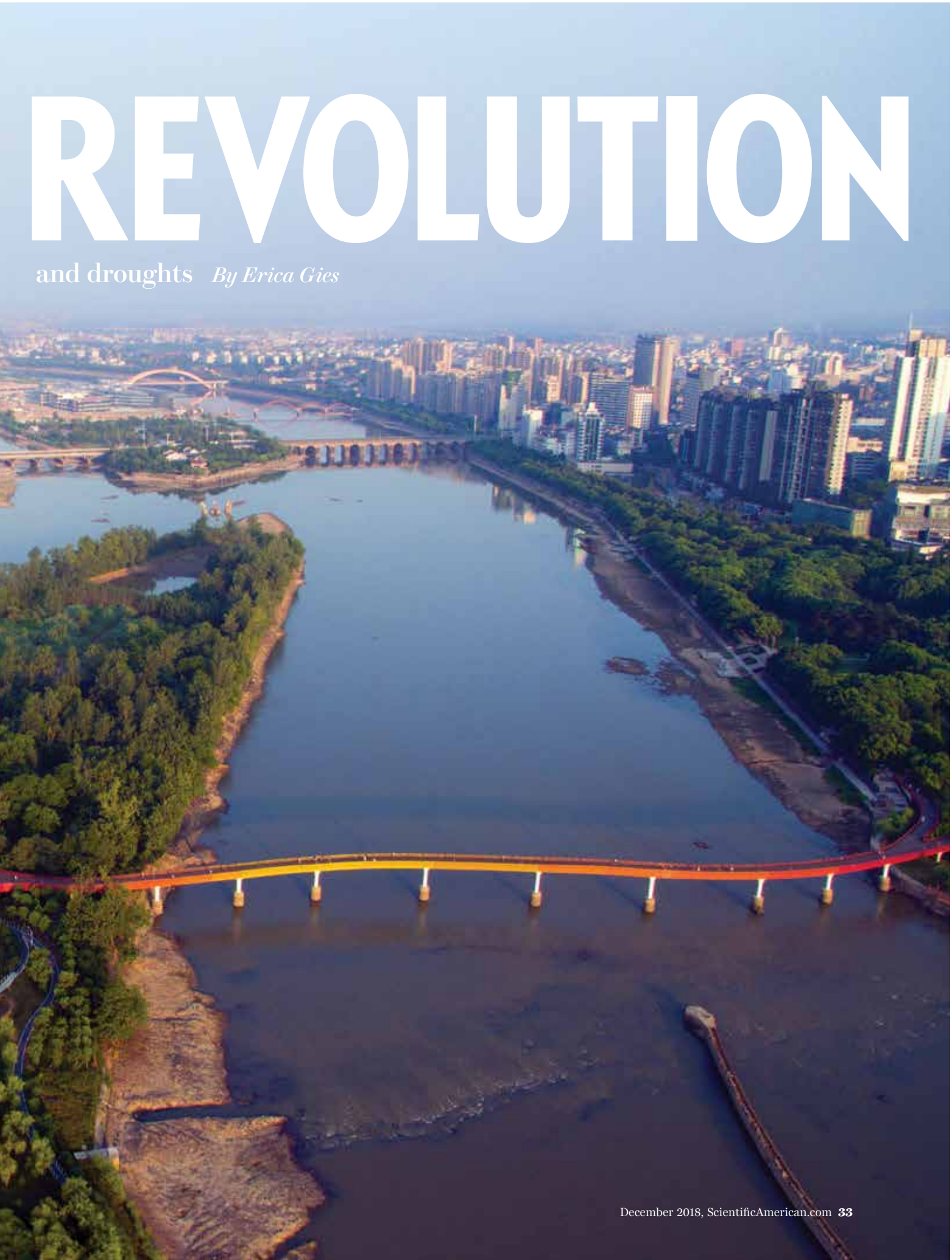
Restoring natural water flows in cities can lessen the impacts of floods

YANWEIZHOU PARK (*center*) **absorbed high river water during a record-setting 2015 monsoon, protecting Jinhua City, China, from flooding.**

REVOLUTION

and droughts

By Erica Gies



Erica Gies writes about science and the environment from Victoria, B.C., and San Francisco. Her work appears in *Nature, bioGraphic, the New York Times,* and elsewhere.

ELEVEN INCHES OF RAIN chucked down on Beijing on July 21, 2012, flooding roads and filling underpasses. Landscape architect Yu Kongjian barely made it home from work. "I was lucky," he says. "I saw many people abandon their cars." As the deluge continued, the city descended into chaos. Beijing's largest storm in more than 60 years killed 79 people, most of them drowned in their vehicles or sucked into underground drains. Damages reached nearly $2 billion.

To Yu, founder of the internationally acclaimed landscape architecture firm Turenscape, the disaster was avoidable, caused by heedless development. He had warned the city government several years earlier, after he led a research team mapping the metropolis's "ecological security pattern," identifying land with high flood risk that should not be developed and used instead to manage stormwater. "The 2012 flood gave us the lesson that ecological security pattern is a life-and-death issue," he says.

A similar story has played out across China. Sixty-two percent of its cities flooded between 2011 and 2014 alone, imposing $100 billion in economic losses, according to the Chinese Ministry of Housing and Urban-Rural Development. The floods are partly the result of stronger storms fueled by climate change. But the harm is mostly self-inflicted: intensive urbanization over the past 30 years has taken over wetlands, felled forests, paved over farms and grasslands, and channeled rivers in concrete straitjackets, leaving stormwater that once filtered into the ground nowhere to go but up.

Urban sprawl is exacerbating water scarcity in China, too. Buildings, streets and parking lots block rain from recharging aquifers. Instead drains and pipes funnel it away—lunacy in a place with water shortages, Yu thinks. Like other cities in China's north, Beijing is pretty dry outside of the summer monsoon season. For decades it has pumped groundwater to supply its growing population and consumption. The city is lowering the water table about a meter a year, causing the ground to sink as well.

Cities worldwide share similar problems because of development and the attempt to control water with "gray" infrastructure—concrete dams, levees, stormwater tanks, pipes and walled rivers whose floodplains are covered with buildings. Experts are recognizing that by breaking the natural water cycle, municipalities are raising the likelihood and severity of flooding, causing disasters from Houston to Chennai, India.

Yu is at the forefront of a global movement of urban planners, water managers, ecologists and engineers who are trying to restore natural water cycles. The work is a kind of un-engineering: giving water space to expand and contract to lessen flooding and slowing it down so it can soak into the ground, thereby preventing shortages later. Practitioners preserve or restore floodplains and wetlands, unearth buried creeks, and create bioswales, retention ponds, sunken parks, green roofs and permeable parking lots. Unlike hardscapes, green infrastructure can also clean water and re-create habitat for wildlife. And it gives urbanites access to nature, increasingly recognized as a pillar of mental health.

Local landscape design projects are popping up everywhere. But Yu and a few other leading practitioners are looking to manage water at a grander scale: an entire city, an entire watershed. Known as green infrastructure in Europe, low-impact development in the U.S. and sponge cities in China, these approaches mimic nature as much as possible, says Tony Wong, an engineer and chief executive of the Cooperative Research Center for Water Sensitive Cities in Melbourne, Australia. The goal is to create water infrastructure that "functions as a living organism," he says.

The sponge cities movement is gaining momentum. In March the United Nations published a report called *Nature-Based Solutions for Water* that advocates the approach. The U.S. Army Corps of Engineers, infamous for its muscular engineering of rivers and wetlands, now has an Engineering with Nature initiative. After centuries of dikes to enclose rivers and low-lying land, the Dutch are onboard, too. Following a near disaster in 1995, when water rose in the Rijn, Maas and Waal rivers, forcing 250,000 people to evacuate, the government created a countrywide program called Room for the River. Instead of only building bigger dams and dikes, Dutch officials increased the capacity of river deltas by asking farmers to agree to let their land flood as necessary.

China, with its rapid growth and centralized government, is pursuing sponge cities on a scale difficult for most countries to even consider. The ambition is impressive. Yet Yu is finding that he still has to overcome a tendency among planners toward one-size-fits-all approaches, which could be disastrous because each location has unique hydrological systems and needs. He is also confronting a penchant among government officials for stronger dams, bigger pipes and larger storage tanks, which symbolize power and progress in modern China.

MR. SPONGE CITY

ON A SPRING DAY in Beijing with a "very high" air pollution rating, I visited Yu at Turenscape's headquarters in the city's Haidian Dis-

IN BRIEF

Floods and droughts are crippling urban areas. Concrete river channels, stormwater tanks and pipes are not keeping up.

An urban-planning approach called sponge cities can more effectively lessen floods, save water for dry spells and reduce water pollution.

Yu Kongjian is leading the way as China reengineers old cities and designs new ones to embrace rather than fight natural water flows.

PRECEDING PAGES: TURENSCAPE

KABAN LAKES in Kazan, Russia, were polluted and flood-prone. Now their redesigned banks absorb and clean urban runoff.

trict. A slim, intense man in his 50s, with sharp eyes and just a bit of gray at the temples, Yu traces his passion to the agricultural commune where he grew up in Zhejiang province southwest of Shanghai. There he observed the Chinese "peasant wisdom" for managing water, practiced for thousands of years. Farmers maintained little ponds and berms to help rainfall infiltrate the ground, storing it for a dry day. The creek next to his village swelled during certain seasons, which no one saw as a threat. "If you have wise ways to deal with flooding, water can be friendly," he says.

Since starting Turenscape in 1998 with his wife and a friend, Yu has built the award-winning company into a landscape architecture empire with 600 employees. The company has more than 640 projects built or underway in 250 Chinese cities and 10 other countries, including a redesign of the Kaban Lake system in Kazan, Russia. Yu is founder and dean of the school of landscape architecture at Peking University and has taught periodically at Harvard University.

For years while Yu was building his firm's portfolio, many Chinese derided his farm-based ideas as backward. Some even called him an American spy—a nod to his Ph.D. from Harvard's Graduate School of Design and his opposition to those big dams. But in recent years sentiment has begun to shift. Various groups in China are building green infrastructure projects, often in partnership with Americans, Australians and Europeans. Yu's influence has been growing in parallel. He lectures regularly at the Ministry of Housing and Urban-Rural Development, and his 2003 book, *Letters to the Leaders of China: Kongjian Yu and the Future of the Chinese City,* is in its 13th printing. Dignitaries ask for his input, such as the Mexican ambassador to China, who is hoping he can solve Mexico City's water problems.

The 2012 Beijing flood was a turning point. Soon afterward, a Turenscape stormwater project in Haerbin won a top U.S. design prize. National Chinese television, CCTV, broadcast a long, high-profile interview with Yu. A government minister told him afterward that President Xi Jinping had seen it. Less than a year later the president stood before China's central urbanization conference and announced his Sponge City initiative, boosting the idea from struggling concept to national goal.

In 2015 the government initiated 16 demonstration projects, each covering at least 10 square kilometers. Today there are 30. The objectives include reducing urban flooding, retaining water for future use, cleaning up polluted water bodies and improving natural ecosystems. By 2020 each project is supposed to retain 70 to 90 percent of the site's average annual rainfall. This past March, Premier Li Keqiang said in his Government Work Report that sponge city construction will be expanded nationwide.

A RIVER RECONSTRUCTED

A WEEK AFTER MEETING YU, I visited one of Turenscape's latest projects, Yongxing River Park, in a Beijing exurb called Daxing. "Before" satellite pictures from three years ago show open land surrounding the river, already straightened and confined by steep concrete walls. "Now" pictures are chock-a-block with buildings. Showing me the park are two of Yu's employees, Geng Ran, who goes by Katie when talking to English speakers, and Zhang Mengyue, a.k.a. Sophie.

The government recognizes that development reduces rain infiltration, Zhang says, so it invited Turenscape to design a park that would enlarge the riverbed to hold more water. The project was nearly completed when I saw it in early April. About four kilometers long and perhaps two city blocks wide, the park follows the river. We stood on a large berm that divides the riverbed into two channels. The river flowed on our right; on our left the channel had big dirt holes of varying depths. During the dry season, the holes will be filled with partially cleaned effluent from a sewage treatment plant. Wetland plants in the pools will further clean the water, Geng says, and filter some of it into aquifers. During the monsoon, the channel will be reserved for flood waters, and the effluent will be treated industrially.

"We say you can't stop the weight of the river," Geng says, "so

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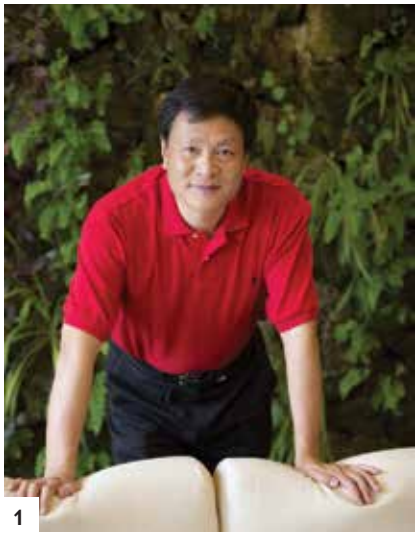
that's why we enhance this river." Turenscape's plan removed concrete along the river and excavated soil to widen the bed. That dirt was then molded into the big berm. The newly exposed, broader riverbanks are dotted with thousands of small sedges planted in closely set rows to hold the earth, reminding me of Georges Seurat's pointillism. Turenscape projects use native plants because they "are adapted to the local environment," Yu says, "and need no supplemental water."

Earlier installations are already demonstrating their efficacy. Yanweizhou Park in Jinhua City, near where Yu grew up, absorbed a 100-year flood in 2015, protecting the city. Shanghai's 14-hectare (34.5-acre) Houtan Park cleans up to 2,400 cubic meters (634,000 gallons) of polluted river water daily, improving the water's quality from grade V (unsuitable for human contact) to grade II (suitable for landscape irrigation) using only biological processes.

To make such projects as effective as possible, they need to connect to other green infrastructure throughout a watershed so all the water can flow in an approximation of its natural path. Across China, whole new cities being built from scratch show what is possible. Turenscape has completed part of the ambitious Wuliji Eco-City in Hubei province. Wuliji's design preserves the natural wetlands for catching and cleaning stormwater on-site. This approach reduced construction costs for underground drainage pipes and conserved habitat for wildlife and vegetation. Buildings have roof gardens and living walls, and pedestrian and bike paths thread through the green space, all of which should enhance quality of life for residents.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FINDING SPACE FOR WATER

IN PLACES ALREADY BUILT, however, making space for water can be difficult. Existing infrastructure often leads to tiny projects, shoehorned between buildings. In Houston, for example, developers limit themselves to building bioswales in new apartment complexes. San Francisco jackhammers bits of sidewalk or roadway medians for plantings.

Reclaiming derelict industrial sites along rivers can result in a more dramatic overhaul. Turenscape oversaw the first phase of such a project in the 1,000-year-old city of Kazan, Russia, which surrounds three oxbow lakes on the Volga River. After the Soviet period, nearly all life had died in the lakes as a result of pollution, and the city was prone to flooding because dams on the river elevated reservoirs above the lakes. The city's seven pumping stations could not keep up when waters rose.

Turenscape's design is reclaiming land for floodwater throughout the 11-square-kilometer watershed, especially along the river and its tributaries. There the city is building linear parks, promenades and bioswales that slow, absorb and clean urban runoff before releasing it into the lakes. Walking and biking routes give people access to the riparian zone and support human-powered transportation throughout the city.

Such extensive redesigns are encouraging Yu to dream beyond sponge cities to Sponge Land. "This is a philosophy for taking care of the continental landscape," he says. "It's time to expand the scale."

Inspired in part by American landscape designer Warren Manning, who created a "Plan for America" a century ago, Yu is working on a landscape master plan for all of China. "That is an incredible vision. No one thinks at that scale and with that political savviness," says Niall Kirkwood, a professor of landscape architecture and technology at the Harvard Graduate School of Design, who has known Yu for many years. Yu's office walls display maps of China that document elevation, watersheds and flood paths, as well as biodiversity, desertification, ecological security, soil erosion and cultural heritage.

Yu can use geographic information system (GIS) and satellite imagery to track China's landscape changes as urbanization spreads, as estuaries and deltas silt up, as water starts to move differently across landscapes and cityscapes. He can isolate priority areas, where projects will have the biggest impact. Kirkwood says this is like applying acupuncture to the human body. Yu "has the understanding that doing a piece of work in one area will have an effect in another area," he says. Yu is "thinking much more holistically" than most landscape architects.

That way of thinking is crucial to successful water management, says Ryan Perkl, head of green infrastructure at Esri, a GIS software company that planners use. In built-up cities, managers can find ways to allow water to flow through infrastructure, he says, with techniques that include permeable pavement and green roofs.

With this principle in mind, Yu has converted his house, a duplex, into a living laboratory. Between the two side-by-side apartments is a living wall Yu built of porous limestone. Water captured from the roof dribbles down its face, from which maidenhair ferns and philodendrons sprout. The green wall cools the two homes enough that they do not need air-conditioning, he says, although he concedes that it gets a bit warm in summer.

Decks off the bedrooms are watered with roof-caught rain, stored in tanks under plant beds. Yu's deck smells great, emanating whiffs of rosemary, lemongrass and Chinese chrysanthemums. It even has a tiny creek in which goldfish swim. His sister lives on the other side. Her deck has terraced beds replete with lettuce and chard. "We collect 52 cubic meters of stormwater [annually], and I grow 32 kilograms of vegetables," Yu says proudly. His efforts reduce runoff and his personal water usage from city sources.

CUSTOM SOLUTIONS NEEDED

FROM YU'S DECK GARDENS to Turenscape's biggest transformations, each design must factor in local climate, soil and hydrogeology.

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YU KONGJIAN (*1*), framed by the "living wall" in his home, has championed China's sponge city projects, including a stormwater park in Qunli (*2*).

If China ignores this specificity, its broad ambition for sponge cities may falter, says Chris Zevenbergen, an expert in urban flood-risk management at the IHE Delft Institute for Water Education in the Netherlands and a visiting professor in Nanjing and Chengdu. The rush to develop cities in the past 20 years did not allow builders time to understand imperfections in design and adjust. That is why so many cities have ongoing problems with floods, he says. Copycat implementation of sponge cities could lead to similar problems. Xi's program has strict deadlines, which may not allow time to monitor performance, adjust if necessary and transfer knowledge. It "takes time to learn and to reflect," Zevenbergen says.

A paper written by Chinese government research institutes last year expressed similar concern about a cookie-cutter approach. It noted that training, long-term data, and new design standards and codes are needed to break the pattern. Yu agrees that "every patient needs a different solution." To provide guidance, the government has formed the Sponge City Technical Scientific Committee, composed of civil engineers, economists and landscape architects, including Yu.

Private investment needed to fully implement the national vision could also undermine sponge cities. Yu worries that companies looking for return on investment will build pipes or dikes—things they can charge for—even though they are anathema to sponge cities' embrace of natural systems.

At Xi's directive, sponge city projects must also attempt to fix another big water issue China faces: pollution. Nutrients, heavy metals, pesticides and microplastics taint surface waters in China, according to Randy Dahlgren, a scientist at the University of California, Davis, who specializes in soil and water chemistry and has worked in Zhejiang province. "If they can get this water to infiltrate into the ground, a huge number of these potential contaminants will be retained within the wetlands systems, buffers, detention basins and bioswales."

Wetlands cannot just be built and forgotten, however. Phosphorus, heavy metals and some nitrogen can accumulate in the plants, but they return to the soil when those plants die. "You really need to be harvesting those plants," Dahlgren says. They can be made into biomass fuels and incinerated, although some pollutants such as metals gather in the ash, which must be disposed of. "It does take active management of wetlands to make them an effective sink for a lot of pollutants," he says. Planners should also be cautious about "trading a surface-water pollution issue for a groundwater pollution issue," where impurities could persist for tens of years to several centuries. This complexity raises the bar for doing sponge cities right. Site-specific modeling based on detailed data is a critical first step.

Sponge city techniques are already reducing pollution in places such as Philadelphia. Like many U.S. cities, its stormwater runs through sewage-treatment plants, which overflow in big storms, pushing untreated sewage into rivers. With its Green City, Clean Waters initiative, the city is reclaiming land along the banks of local creeks and rivers to absorb excessive rainfall and building parks that can flood when necessary. Philadelphia also gives incentives to landowners for creating rain gardens, green roofs, urban farms and porous pavement. These techniques allow stormwater to percolate into the ground, reducing the volume entering the sewage system. Five years in, the city has "greened" 339 hectares, enough to reduce pollution from sewer overflows by more than 5.7 million cubic meters annually.

STATE OF FLUX

NATURAL WATER-MANAGEMENT SYSTEMS are not static or predictable like gray infrastructure: nature is messy. Water rises and falls. Plants sprout, live and die. Mud is exposed. Although these spaces can be beautiful—perhaps more beautiful than, say, a dam—residents might not like what they see. For sponge cities to spread, people will have to accept a dynamic environment.

Yu calls this shift "big feet aesthetics," a counterreference to when Chinese considered the bound, tiny feet of aristocratic women to be beautiful because they were useless, a sign that the women were too rich to work. "Now we need to find big feet attractive," he says. "We need to change our aesthetic to find useful green infrastructure beautiful."

Educators will need a change in perspective as well. Despite the national promotion of sponge cities, China's schools are still training engineers using 20th-century principles, Yu says. "We are fighting so hard to try to get people to think in an ecological way." The hubris of believing that people can control water with concrete will be increasingly exposed as more of those kinds of projects fail, unable to buffer the knock-on impacts from rapid population growth, urban sprawl and climate change. Although sponge cities will likely not protect everyone from these challenges, their advocates think their resilience can temper extremes better than the concrete alternatives. Plus the multiple benefits they bring can make the lives of humans and other species a little healthier and happier. SA

MORE TO EXPLORE

Nature-Based Solutions for Water: UN World Water Development Report 2018. United Nations; March 22, 2018.

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