New Civil Engineer | Examines

Nature-based solutions + digital technology

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From supposition to certainty

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This *Examines* is being published on the eve of the COP30 UN Climate Change Conference in Brazil in November 2025, at a time when – if global warming is left unchecked, disruptive change will be imposed on societies, economies, and families. That's the message of COP30 President Ambassador André Corrêa do Lago, who advocates for "changing by choice" through shaping an alternative vision designed by human intervention. That call to action implicitly positions proactive human intervention as the appropriate response to the climate crisis, in terms of both climate change adaptation and mitigation.

Nature-based solutions (NbS) have a pivotal role to play in that intervention. These are solutions that are designed with nature to restore ecosystems, reverse biodiversity loss, manage water and tackle the negative effects of climate change on both infrastructure and society.

Encompassing a wide range of measures including sustainable urban drainage systems (SuDS), rain gardens or green roofs to manage stormwater runoff, NbS support climate adaptation strategies by using natural processes and ecosystems to adjust to the effects of climate change. They are also key to climate change mitigation, reducing greenhouse gas emissions and storing CO_2 while also supporting flood prevention and biodiversity protection.

While NbS are not mandated in the UK, the Environment Act 2021 sets legally binding environmental targets, such as a 10% increase in biodiversity for developments in England, and government policies are designed to encourage NbS for achieving the ultimate target of net zero emissions by 2050. It's a trend echoed across many markets globally, with cities and smaller urbanised localities increasingly recognising the need for NbS as a sustainable way to build resilient communities and infrastructure while supporting biodiversity.

Financial institutions and investors are also increasingly focused on investing in NbS, because they promise long-term value creation by mitigating financial risks from climate change and nature loss, as well as offering the potential to create new revenue streams.

Given this growing momentum, it's little wonder that those planning, designing and managing infrastructure are increasingly tasked with incorporating NbS – wherever possible – into the design of infrastructure schemes. Yet despite this growing demand, delivery has met challenges: from understanding when and where to implement them, to a lack of integrated approaches to financing, limited evidence of effectiveness and blockers to scaling up small, localised interventions to cover entire catchments and systems.

Digital tools including AI can help address many of these challenges. Data from satellite imagery, drones and sensors can capture nature insights on – for example – a city-wide scale. Powered by machine learning, these tools can analyse urban areas, enabling the development of "sponge cities" that can absorb water.

Other benefits include the analysis of factors such as where CO_2 is sequestered or where flood zones are located within a catchment.

Measures such as earth observation can provide a rich data resource about the biodiversity of an infrastructure scheme's site before work begins, enabling biodiversity to be a key consideration of a project from the outset, often resulting in marked efficiencies.

As well as accelerating the analysis of data, machine learning and AI also enable data to be processed from a vast range of sources, identifying trends that inform more effective resource allocation and project management and expediting real-time monitoring and data analysis to support decision-making and tailored investment.

This *Examines* explores the emergence of digital tools that are enabling the capture and analysis of data at an unprecedented scale to support NbS. With the integration of digital technology and AI to support better design, implementation and evaluation of NbS, their positive impact and contribution to climate resilience and a more sustainable future have the potential to be dramatically upscaled. **E**

Complex problems, natural solutions

Nature-based solutions (NbS) are recognised as a key enabler in tackling environmental, social and economic problems, so how might their wider uptake and viability be secured? Sotiris Kanaris reports.

"We are facing a global crisis. We are totally dependent upon the natural world. It supplies us with every oxygen-laden breath we take and every mouthful of food we eat. But we are currently damaging it so profoundly that many of its natural systems are now on the verge of breakdown," wrote Sir David Attenborough in the foreword of HM Treasury's The Economics of Biodiversity: The Dasgupta Review published in 2021.

Apart from the importance of nature for the population's health and wellbeing, the review points out the relationship between ecology and economics, with the latter described by Attenborough as "a discipline that shapes decisions of the utmost consequence."

"The report clearly states that nature fundamentally underpins and encompasses our economy," says Arup UKIMEA Nature Leader Tom Butterworth, highlighting why actions to protect and restore nature are so vital. He also points to Green Finance Institute findings that nature degradation could cause a 12% loss to UK's GDP, "which is larger than the global financial crisis and the impact of the Covid19 pandemic."

"The Dasgupta Review highlighted a substantial underinvestment in natural capital and biodiversity, and also that environmental services – the functions that nature provides – are in serious decline," says leading nature recovery marketplace Entrade Managing Director Guy Thompson. "A problem author Partha Dasgupta discovered was that those services are valued at zero."

These factors have contributed to the biodiversity crisis the world is now experiencing. Institution of Civil Engineers (ICE) President Jim Hall says nature-based solutions (NbS) are important in tackling this crisis. "We can't reverse biodiversity loss just through conservation and protected areas, we need to provide new space and habitats for nature to restore some of what has been lost through human development, and NbS do that," says Hall.

NbS encompass any intervention that deploys nature's own systems as a design guide to solve a particular issue – for example a rain garden that collects rainwater from roofs and driveways, allowing it to soak into the ground and be absorbed by plants as a solution to surface water flooding.

"There are ways in which nature-based solutions can either substitute or complement more traditional engineering solutions," Hall notes.

He emphasises that they can offer a wide range of benefits beyond solving the specific problem they were implemented for. "They sequester carbon, provide more liveable and attractive places for people to enjoy, enhance resilience, improve water quality and help the cooling of urban areas."

ON THE RISE

NbS is not a new idea," Butterworth says, emphasising that the concept has existed for a long time under different terminology. "We've been talking about green and blue infrastructure in our cities for an age now, NbS gained a lot of traction in terms of the language and the audience that it landed with."

> **12%**
> **The loss possible to the UK's GDP caused by nature degradation**

"Some enthusiasts haven't necessarily been using the terminology of NbS or natural flood management, but they've long been recognising engineering with nature," Hall comments. He says there is now an understanding of this type of engineering which has led to the wider adoption of NbS.

He gives the example of the increased use of NbS by the Environment Agency.

"There are people in the Environment Agency who were always enthusiastic about natural flood management and there was an era of pilot schemes around the country. Now it has become much more mainstream, with an emphasis on looking at natural flood management first."

He also notes that the Environment Agency recently reviewed the latest research on natural flood management and updated the 'Working with natural processes evidence directory'. "This should help people use NbS more often to support flood and coastal resilience alongside nature recovery."

Thompson believes the emergence of integrated teams within the engineering sector has also played its part in the uptake of NbS. "There are large teams of landscape architects, ecologists, environmental economists and water specialists looking at nature-based solutions within organisations like Arup, which not that long ago, would have comprised almost exclusively of engineers and architects.

So we have different mindsets coming together to find integrated solutions."

Butterworth adds: "It is about bringing the green and grey together, working and co-designing with nature, that's where we see the best solutions for people, nature and clients."

REGULATION

Regulation has also been a factor behind the increased popularity of NbS. Hall points to nutrient neutrality – a planning policy that requires new housing developments to have no net increase in nutrient pollution (nitrogen and phosphorus) into protected river or wetland sites – and Biodiversity Net Gain (BNG). BNG is a policy in England, part of the Environment Act 2021, that mandates developments must deliver a measurable 10% increase in natural habitat compared to its pre-development state.

Butterworth is a strong advocate of BNG. He is the technical lead author of an International Organization for Standardization (ISO) standard on BNG.

On the link between NbS and BNG, Butterworth explains: "When we look to nature, in other words NbS, to help us solve a specific, identified problem, it is likely that biodiversity will benefit. BNG policy does not require us to look for solutions to a specific problem, but it does ensure that we're not losing biodiversity from a development – and that we're putting back more than we're impacting. If designed and delivered well, BNG-related activations can deliver other benefits as well, for example reduced flood risk. In this way, BNG can become a useful lever for increasing the uptake of NbS."

"We still need further regulation," says Hall, calling for the implementation of Schedule 3 of the Flood and Water Management Act 2010, which mandates the installation of SuDS in new developments in England.

Thompson says there needs to be a move away from what he describes as the current "input/output based regulation."

"Regulation tends to be focused on the protection of assets at the expense of the enhancement of those assets, and the very narrow prescription of very specific inputs and outputs that are required from regulated entities such as water companies. For example, water companies have been prescribed by regulators to invest in very specific end-of-pipe inputs to deliver very narrow outputs, often focused on water quality improvements. What NbS do in contrast, is provide a range of environmental benefits beyond that water quality improvement."

He adds that investment at scale in NbS is hindered by the current lack of coherence between environmental regulation, existing public funding mechanisms like the Environmental Land Management scheme for farmers, and incentives for private investment, such as the water industry national environment programme. "This creates barriers that substantially increase the cost of developing and aggregating NbS. What is lacking is the scale, certainty and liquidity that would enable the private sector to step in and play its part."

UNLOCKING INVESTMENT

Thompson believes there should be a shift towards "outcome-based environmental regulation", as demonstrated by the Frontier Economics' Outcome-based Environmental Regulation report for Wessex Water published in November 2021.

The report explained how outcome-based environmental regulation can be crucial for the UK Government's 25 Year Environment Plan (25YEP) goals to be achieved. "Where regulation needs to significantly pivot from where it's been, is the mechanisms to incentivise the delivery of those environmental improvement goals on the ground, and in particular, the integrated delivery of those goals and the cross-sectoral collaboration that needs to take place," Thompson explains.

If this shift takes place, there will be a much greater uptake of NbS because "financial institutions and investors are in fact interested in investing in these solutions and nature markets", he

Regulation such as policy relating to housing developments is a factor behind growing interest in NbS

Digital technologies have the potential to increase understanding of large scale natural systems such as mangroves, which support wave attenuation and coastal protection

emphasises. "We need to find better ways of monetising and valuing these to reflect the benefits provided by nature. Nature markets are emerging as part of the response."

Thompson explains that nature recovery markets or "nature markets" like Entrade, work by allocating resources to activities that provide the maximum environmental, social and economic benefits. "Those nature-based activities are funded by the payments for the environmental benefits they deliver, such as clean water, carbon sequestration, and so on. Nature markets offer incentives for land holders and farmers to play their part in nature recovery."

Butterworth notes that alongside this, coordinating the delivery of a service with the actions from multiple landowners presents challenges about shared responsibility.

"This means that market solutions to NbS are vital, but it needs to be a coordinated market that is delivering constant NbS across the landscape. For example, one green roof will not mitigate the flood risk in a city area, but 10 will. The question is, in a market driven system, how do we get every organisation managing those buildings to coordinate this so that we all reap the collective benefit?"

Commenting more generally about the potential for greater investment in NbS, Hall says the industry needs to get better at making a multiple benefit case to clients. "We are talking about solutions that don't just do one thing, they do many good things, so we've got to get better at explaining that.

"Market solutions to NbS are vital but it needs to be a coordinated market that is delivering constant NbS across the landscape"

TOM BUTTERWORTH, ARUP UKIMEA NATURE LEADER

"There's the appetite, but we've identified knowledge gaps, evidence gaps, technological gaps within the industry. Those need to be filled so we can get better at persuading clients as well as the public, what these solutions are going to do, what they're not going to do under what circumstances and timescales, and what's to be done to ensure they continue to do that."

ROLE OF TECHNOLOGY

"I think that technology is central, because these are systems that need to be constantly monitored and to some extent adapted through time. So that lends itself to using technology for sensing, for interpreting that sensing data, possibly for digital twins, and then for guiding asset management system control interventions," says Hall.

He specifies that in some instances the level of monitoring to date has been "unsatisfactory", citing it as a factor hindering SuDS adoption. He says monitoring and interpretation of data is important to enable intervention at the right time in the right way.

"In terms of the evidence base, we could be in a much better position than we are," says Hall. "For example, in my research group in Oxford, we looked at the role of mangroves in wave attenuation and coastal protection. There's some pretty good science out there, but being able to predict both what the effect of mangroves on coastal storm surges might be, and how mangroves might alter coastal geomorphology, is very difficult. So, there's still a lot to learn in terms of the evidence base, and there's a lot to do in terms of monitoring systems."

Butterworth says technology is critical for NbS projects. "We're using AI to identify the habitats and models to assess the services provided. We have great tools that allow us to model what NbS can do and map habitats."

"But, we need to develop the ability to assess the benefits over time and then use that data to inform the management of a given site, in order to ensure the services carry on being provided and the benefits are felt by the communities." **E**

New frontiers

Early engagement and the fine-tuning of digital tech and AI promise new efficiencies in abating the impacts of climate change, writes **Thomas Johnson.**

The thought of digital technology and artificial intelligence (AI) playing a role in harnessing the benefits of nature might seem extraordinary. But this isn't science fiction. Organisations across the world are using innovative digital methods to identify where biodiversity net gain (BNG) goals can be met, supported by nature-based solutions (NbS) such as Sustainable Drainage Systems (SuDS).

EARLY ENGAGEMENT

Arup Global Digital Nature Leader Damien McCloud notes that while NbS have the potential to play a key role in solving societal problems, from creating community amenity to alleviating flood risk, designing and locating NbS for infrastructure projects can be a difficult and drawn-out process.

As McCloud explains, to date, major infrastructure projects have typically deferred engaging with ecological concerns in their programmes, adding mitigation measures into late-stage designs.

However, this looks set to change. Increasingly, digital models, earth observation data, machine learning algorithms and AI are being used in unison to allow teams to assess and integrate natural assets from the outset of a project, altering how they are being conceived and delivered.

"Using these tools enables an environment-led approach, which essentially identifies where NbS can be used and how nature, habitats and so on can affect design," says McCloud. "It's becoming something that's considered upfront," he says.

This contrasts with conventional thinking about major infrastructure projects, "which have traditionally waited for the ecology surveys to be done, when it suddenly becomes a consideration," he says.

The data now available is not only allowing opportunities to be identified earlier but the pace at which the tools analyse data, allows an unprecedented array of options to be considered.

Arup UKIMEA Managing Director Tom Wilcock notes: "Traditionally, you need to be pretty certain you know what you're going to do to invest time doing the relevant analysis. These models are enabling us to interrogate many options early in a project and make different decisions based on insight, not just our gut and our experience," he adds.

Where ecologists once had to rely almost entirely on field surveys, digital tools allow users to, for instance, digitise an entire catchment and attach real-world attributes to each pixel. The details behind those attributes might include land use, vegetation type, carbon sequestration potential, flood attenuation capacity and more.

Such attributes also enable organisations to simulate "What if?" scenarios. "As an example, we can model what happens if we change arable land to meadow, to immediately see the predicted effect on carbon uptake or stormwater runoff in the catchment," McCloud explains.

GROWING UPTAKE

A key tool in this context is Arup's mapping and modelling tool package NatureInsight, created in collaboration with Scalgo.

"Sitting on Scalgo's web-based environmental platform, NatureInsight pixelates an entire catchment project area and maps the most suitable nature-based solution opportunities, based on the different land types, terrain and hydrological flow dynamics," McCloud explains. "Each pixel uses a host of underlying datasets to identify the range of nature-based solutions available in a pixel alongside the various environmental benefits they can deliver, enabling informative decision-making to be applied to NbS business case development.

"One of the key things that advances in data and now in AI have enabled, is the ability to think about multiple scales simultaneously, from the very large scale to the very small scale," says Wilcock.

The availability of useful datasets, an increase in affordable top-end computational power and the accessibility of the digital tools in question are causing dramatic shifts in thinking, he says.

"There's a pattern we're seeing generally in this space, and this is that you need less and less specialist knowledge for the technology piece," Wilcock notes. "But what you do need is the domain expertise to really understand what you're looking at and therefore to make decisions on the back of the data.

"It's moved from needing research-level skills to get to the point of having insight, to the tools actually serving up insight so that experts in catchment management and other areas can then make decisions and scenario plan."

While civil engineering and construction firms have increasingly embedded an expectation that their employees will innovate with digital tools and data models, clients are also taking this approach more seriously within their own organisations and with their contractors.

> **"These models are enabling us to interrogate many options early in a project and make different decisions based on insight, not just our gut and our experience"**
> TOM WILCOCK, ARUP UKIMEA MANAGING DIRECTOR

"We've seen a shift in the client landscape and it's not just in the bids they're putting forward, it's in their organisations as well," says Wilcock.

"We are increasingly seeing large infrastructure providers who have data and chief digital officers who are thinking about what the next two or three decades of their organisation are going to look like, and how data and digital technology play a part."

GEOSPATIAL INSIGHTS

A major change in the industry has been the unlocking of geospatial data, as well as factoring machine learning models into the mix to understand it.

"A fundamental foundational shift technologically has been with geospatial data and its availability," Wilcock explains.

"On top of that, with the increase in computational power and advances in machine learning over the last decade, frankly, this is also not all that new, but it has enabled us to classify imagery around a whole range of parameters, including land usage."

This year, the UK Space Agency assumed the role of chair of the Committee on Earth Observation Satellites. The committee, which is comprised of global space and meteorological agencies, is responsible for coordinating observation of the Earth from space.

In chairing the committee, the UK Space Agency has selected 'Unlocking Earth Observation for Society' as its headline theme for the year. The aim is to drive an increased uptake and use of Earth Observation (EO) data – information about the Earth's surface, oceans, and atmosphere collected by sensors, primarily from remote sensing platforms like satellites, drones, and aircraft – to improve public services and address environmental and climate challenges.

Earth observation is not a new concept, but changes over the past few years have transformed it from a specialist data discipline into a broadly accessible resource. The availability of open datasets, notably the US Landsat series and the European Sentinel constellation, McCloud and Wilcock explain, combined with free analysis libraries and cloud computing, mean that anyone with modest computing skills can extract value from it at scale.

"You don't need software per se to do it now, you just need some Python data libraries and to be able to code," McCloud says.

He points out that the timing is critical. Pressure on biodiversity and the urgency of climate-related risks have created an environment where nature-based measures are not just attractive, but necessary, and Earth Observation data allows them to be well thought out.

"It has transformed the industry. Earth observation has really been a solution waiting for a problem for many years. This is just one of those great serendipitous moments where it can have a role to play in terms of the pressure on nature and the biodiversity crisis.

"People know how to extract the value out of that data better than they've ever done, and nature-based solutions are just right for that."

DATA CHALLENGES

While increased access to data has been revolutionary for biodiversity and NbS, there are also challenges associated with it.

"I think there are a couple that we see," Wilcock says. "One is poorly organised or unstructured data and that can be a result of legacy approaches in an industry that historically wasn't that organised around data."

The second, in Wilcock's eyes, relates to the fact that the planning and delivery of projects can entail many different organisations throughout a project's lifecycle.

"The data at different parts of that cycle resides in different

Data collected via remote sensing platforms such as drones is increasingly deployed to address environmental and climate challenges

Evolving technologies enable datasets to identify a wide range of nature-based solutions and related benefits at the level of a single pixel

organisations. The parties who might plan and then design the project are often different from those who might construct it who are then different again from those who might operate it and own it," Wilcock explains.

"We tend to find that we haven't got joined-up life cycle data for assets and that means we can miss opportunities to think about how to optimise existing assets, extend their life, but also how to learn from the way the last asset was formed when you design the next one."

Data overload is recognised as a challenge for many sectors, leading to operational inefficiencies, poor decision-making, missed opportunities, and increased costs. However, Wilcock notes: "There's a bigger challenge than having too much data, and that is that data is not necessarily accessible at the right point in time to those who could generate value from it. That's an area where collaboration across organisations is really important."

An example of success in such collaboration is a set of interconnected digital twins of the energy network that the National Energy System Operator (NESO) is building, he says. These are needed due to changes to the way energy is produced and consumed as the UK moves towards more renewable energy sources.

"We're moving away from a small number of large power stations with predictable generation curves towards power being generated when the sun shines and the wind blows," says Wilcock. "To marry that with shifts in demand, particularly for electricity, you need a sophisticated way of sharing data across different organisations."

"There's quite a lot of nervousness around AI, especially amongst practitioners in ecology. I think everyone recognises this but also wants to push forward and unlock the benefits"
LUCY COLLINS, AI4NATURE SPOKESPERSON

UNCHARTED TERRITORY

Collaboration may be one accelerator of success, but it's a safe assumption that no commentary on the use of digital tools in 2025 would be complete without mentioning AI. McCloud and Wilcock agree that AI and machine learning – the area of AI that enables machines to learn from data and improve without programming – have dramatically accelerated digital capabilities.

For example, advances in image classification now enable automated identification of land uses, habitats and other features from satellite or aerial imagery, allowing sites to have their habitat mapped quickly and early on in a project and then monitored moving forward.

And large language models and generative AI have begun to complement geospatial machine learning. When infrastructure projects involve hundreds of stakeholders and decades of documentation, tools that can interrogate project records in natural language within the project's documentation provide an easily searchable knowledge bank for project teams.

Organisations dedicated to fostering the responsible use of AI for the good of nature are beginning to form. One of these is the AI4Nature Alliance.

AI4Nature spokesperson Lucy Collins acknowledges that for many, this is uncharted territory - but one that could offer significant rewards.

"There's quite a lot of nervousness around AI, especially amongst practitioners in ecology," says Collins. "I think everyone recognises this but also wants to push forward and unlock the benefits."

She explains that the alliance was created to bring together industry, academia, technology, ecology and government, with the shared goal of exploring and accelerating the role AI can play in nature restoration and enhancement.

That mission includes supporting the development of "clear standards, ethical frameworks and best practices for how AI is applied in biodiversity monitoring, assessment and long-term planning."

"It's all about building trust," Collins adds. "With technology in general - and AI in particular - trust is a major challenge. If we want people to understand and adopt AI in their work, we need to make it explainable, transparent, and easy to trust. That's where we're focused." E

Systemic change

System-wide ecologies are being planned and supported via digitally designed nature-based solutions (NbS), writes **Tom Pashby**.

"Climate change is dire. Sea levels are rising, increasing the risk of erosion, flooding, and extreme storms in coastal regions around the world. Heat waves are occurring with greater frequency, fanning the flames of wildfires, putting stress on wildlife habitats, and driving droughts that threaten crops and water security."

This statement from the World Wildlife Fund (WWF) paints a cataclysmic picture of a climate-degraded natural environment. Yet at the same time, WWF also notes that nature has a positive role to play in helping mitigate the problem.

"Evidence increasingly suggests that nature-based solutions (NbS) – natural systems or processes used to help achieve societal goals – could contribute mightily to minimising climate change and its effects," it states.

CONSIDERED CO-DESIGN

WWF's stated hope is timely. Delivering NbS is already an ambition for some forward-thinking developers in the UK and abroad. BNG helps deliver NbS by mandating habitat creation and enhancement, which in turn supports broader environmental benefits like carbon sequestration, flood mitigation, and improved ecosystems.

Following the Environment Act 2021, mandatory BNG in England came into effect for major developments on 12 February 2024, and for small sites on 2 April 2024. Proposals indicate it will be required for infrastructure schemes from the middle of 2026.

The overarching aim of these changes is to ensure that habitats for wildlife are left in a better state than they were before any development. Schemes will be increasingly focused on delivering BNG through effective deployment of sustainable urban drainage systems (SuDS), new woodlands, green roofs and other NbS across a range of environments.

Arup UKIMEA Nature Leader Tom Butterworth indicates that growing demand for NbS will necessitate greater understanding of how to implement them effectively. And he cautions against their ineffective deployment.

For example, he is a strong advocate for design solutions that incorporate mainstream NbS concepts like tree planting. However, he also notes that this approach needs the right conditions to be successful.

He points to a problem which has blighted some tree planting along the grass verges of motorways across England. Young trees are planted onto south facing slopes and then we have a very dry Spring, and swathes of them end up dying.

By contrast, he refers to examples such as a woodland creation scheme where the density of tree planting has been decreased to allow scrub to come through. By providing more space "the scrub will protect those trees and create the environment that those trees actually need to grow", he says.

"Trees don't naturally just pop up on a grassland very often. If you leave grasslands, first scrub grows through. The trees tend to have a better chance where bramble scrub, blackthorn and hawthorn are growing, and then the trees grow through the scrub. This mirrors natural processes for woodland creation."

Allowing the natural process to take place means that the trees that do grow will be more resilient to issues such as high heat in summer, he says.

"Rather than saying 'We've got to plant species A, B and C trees here,' why don't we plant native tree seeds and see what comes through the scrub? What comes through will be resilient to the soil type and conditions in a particular area."

"This is about designing with nature. This is about co-design. Instead of being completely prescriptive and planting 20% oak, 15% beech, and 4% something else, for example, let's work with the natural systems and start to bring in thinking that creates that relationship between design and what nature's already doing.

"These woodlands can be considered NbS at scale, he adds. If grown in the right place, they can help manage water, decreasing flood risk or improving water quality, as well as sequestering carbon."

Butterworth shares another example of an NbS concept. Green roofs can be delivered much more effectively when designed with a broader view of the natural world and the changes we can expect to see due to climate breakdown.

Green roofs are likely to be increasingly important in cities adapting to climate change, he says, with the roofs likely "to be very dry environments," that will be particularly exposed to the impacts of climate breakdown.

"We probably need to be thinking completely differently about the planting that we're putting in," he says.

He cites a notable UK example of this thinking: as part of a strategy to plant resilient species and improve biodiversity, The Royal Botanic Gardens in Kew is conducting research

Singapore deploys rain gardens and wetlands to support stormwater management and nature-rich urban spaces

> **"Traditionally, the built environment has had a predominantly negative impact on climate and nature. If we design with nature, we can reverse the trend and have the urban built environment contribute positively to support the 1.5 degrees Celsius target and cities' net zero ambitions**
>
> DIMA ZOGHEIB, ARUP DIRECTOR – LANDSCAPE ARCHITECTURE EXPERIENCE

to identify climate-resilient tree species for future planting. The research harnesses localised climate models to identify vulnerabilities in Kew's plant collections. It also assesses the potential of globally sourced seeds for planting.

The UK's cities of the future could look very different to now, he says. "We probably need to be thinking about planting the species types that are in Barcelona, for example, or the Mediterranean areas. Otherwise, all we're doing is creating an ecosystem that isn't viable into the long term."

95%
The percentage of a building's impact that occurs offsite

ENHANCING URBANISATION

Valuable change can emerge from the implementation of NbS, particularly at a system-wide scale.

This can be especially impactful in the context of flood prevention and water management or storage, which both carry weight in a climate change affected world.

Arup Digital Water Leader Vikki Williams points to Singapore, which is recognised globally for an urban water management strategy that works particularly well because of how it interacts with nature.

"Singapore should be a really poor place from a water perspective, but it has systematically invested in a really good way to allow the system to work."

The country's use of green infrastructure such as rain gardens and wetlands enables both the management of stormwater and the creation of nature-rich urban spaces. The approach entails "systematically reusing water" as part of "a completely integrated water management solution."

Arup Director – Landscape Architecture Experience Dima Zogheib concurs, citing Singapore as "a great example" of effective NbS implementation. She notes that Singapore is often referred to as a "city in a garden", reflecting its commitment to integrating nature into the urban environment. Cities like Singapore exemplify the concept of nature-positive cities.

"Traditionally, the built environment has had a predominantly negative impact on climate and nature. If we design with nature, we can reverse the trend and have the urban built environment contribute positively to support the 1.5 degrees Celsius target and cities' net zero ambitions. The narrative on cities and climate is strong; we have only started to realise that nature is the third big component. At a building level, research conducted by Arup with WBCSD on nature-positive buildings found that 95% of a building's impact is offsite (embodied - remote impacts occurring within the supply chain of construction materials) and only 5% of nature loss is within the site boundary.

Meanwhile In Thimphu, the capital of Bhutan, people live in close proximity to nature, she says.

"In Thimphu, a few years ago, headlines emerged when a tiger was spotted strolling through a city neighbourhood" she says. "And the reason the tiger came is because Thimphu is a city built within and in harmony with nature."

"We have to strike a balance," she says. Rather than viewing this as a threat, it is a reflection of Thimphu's relationship with nature, a consequence of the delicate balance we must strike between development and nature. "With sensible design," she says, people can live in harmony with nature.

"Without digital tools, it would be almost impossible to build these approaches into our solutions as a company doing large infrastructure projects

TOM BUTTERWORTH, ARUP UKIMEA NATURE LEADER

Tirana's plan to plant 2M trees by 2030 was supported by Arup's Terrain tool to identify different land use types, help plan and design the forest and quantify benefits

MEASURING CHANGE

Increased uptake of well implemented NbS is clearly desirable and ensuring that happens is a worthy ambition. Digital tools such as Arup's Terrain have a role to play, by enabling the "quantification of the benefits of NbS," Zogheib says. She believes digital technologies have worked well in places where there is "limited data or limited information."

She adds that technology can help with scenario-planning for various climate pathways and can help create evidence-based green infrastructure and landscape strategies for the future.

She cites Arup's work with the Municipality of Tirana and the European Bank for Reconstruction and Development (EBRD) to develop the Tirana Orbital Forest, a plan to plant two million trees by 2030, creating a green belt on the periphery of Tirana, Albania. Given the limited availability of data, the work was supported by Arup's Terrain tool to identify different land use types, help plan and design the forest and quantify environmental and climate resilience benefits.

"We used digital technology to help us quantify climate resilience benefits – in terms of both heat and flooding," she notes.

And importantly, understanding and measuring the benefits are essential to the ability to attracting funding for NbS.

"Quantification is critical to be able to make the case for funders and investors to finance NbS," she says.

While using energy- and carbon-intensive digital tools might seem anathema to those interested in trying to address climate and biodiversity crises, Butterworth believes their astute deployment can make a critical difference.

"If we're going to do this co-design, if we're going to work with our landscapes in this way, we need to be able to understand the benefits that these landscapes provide," he says.

"We need to be able to measure them, and we need to work with nature to co-create places that will improve those services. Then we need to be able to monitor that over time, so that if for whatever reason, one piece of land stops providing that service, we can jump in and do something about it before it becomes an issue.

"All of that can only be done with digital tools, for example remote sensing satellite data to understand habitats and how they're changing. The frequency of updates that we've got now allows us to show change regularly."

And he also points to useful markers for measuring biodiversity benefits from NbS, for example Environmental DNA or eDNA, the genetic material organisms shed into their environment. Samples of eDNA can be analysed to identify the species present in an ecosystem without needing to directly observe, capture, or tag them.

Another marker might emerge through measuring bioacoustics – the sounds produced by or affecting living organisms.

There are also tools that support climate prediction, which can be used for "mapping out what's coming, what that's going to look like in the future, and starting to think, 'How do we create the space for nature within that to make sure that it can provide the benefits that we need?'"

"Without digital tools, it would be almost impossible to build these approaches into our solutions as a company doing large infrastructure projects," Butterworth concludes. E

2M
The amount of trees planned to be planted to develop the Tirana Orbital Forest

Compelling storytelling

Real-world deployment shows organisations' evolving understanding of their natural assets and how to optimise them, writes **Robert Hakimian**.

With awareness growing of the need to maintain and augment nature alongside infrastructure, clients are recognising the need to hone their understanding of natural assets and how best to use them in their projects.

At a company level, there are requirements to collect data for environmental, social and governance (ESG) purposes or, in the EU, to comply with the Corporate Sustainability Reporting Directive (CSRD). On a project level, the UK has implemented the world-leading biodiversity net gain (BNG) mandate, which requires schemes to restore the nature they remove with an extra 10% on top.

To implement and deploy BNG and nature-based solutions (NbS) accurately and effectively, especially over a large area, datasets and digital tools are required.

"One of the things we say a lot is 'you can't monitor what you can't measure'," says Arup Global Digital Nature Leader Damien McCloud. "How do we use digital tools and datasets to understand how we got to where we are? How do we then check multiple scenarios within a project area to ensure that we get the best solution for nature and for the project? And then how do we monitor that effect going forward?"

To that end, Arup has developed a series of tools and utilities using open-source data and machine learning that can help its clients build in the best way for the natural environment, implementing NbS in the most effective manner for local conditions.

"We're making it as easy as possible," McCloud says. "But also, we're making sure we get the best outcomes and that we understand as much as possible, so every project improves upon the last one."

These tools are not intended to replace or undermine on-site ecological surveys but to present a high level of certainty of what will be found once on site. This then allows the on-site surveys to be more "focused", according to McCloud. "We're maximising their value," he adds.

Machine learning and artificial intelligence (AI) are being used to help the industry understand what the environmental requirements of its projects are, while also helping to implement the solutions in the right way.

"It's about storytelling," McCloud says. "How would you tell the story of the value of nature to your client who might not have considered it? If it's a civil engineer who's always put a concrete tank under an area, how do you articulate the value of creating a wetland to solve the same problem?

"I think the industry as a whole has a challenge in terms of storytelling and that's one of the things that we're focused on."

80%
The amount of time saved in reaching the best solution for a project by using NatureInsight

LAND USE ANALYSIS

One way in which Arup has been doing this is taking satellite imagery on a city-wide scale and – via machine learning – analysing the urban typologies from that data. This is valuable information for understanding how to turn a city into a "sponge city" that can absorb water across its natural assets to mitigate against flooding.

Arup has created an AI and land use analysis tool to analyse the satellite imagery and detect different urban elements – including water, green space or impermeable space – to understand the land cover. There is also historic data from older satellite images that can be analysed to understand how the city has changed over the last decade or so.

The result is an understanding of city's permeability or "sponginess." Different layers can be superimposed over the imagery to see the different urban typologies in detail or simply to assess where it is permeable or impermeable, for example. Other data, for example relating to transport networks, can then be overlaid to give more depth and understanding to the picture of the city.

"It just gives a flavour and then you're able to look at different solutions and where interventions need to be," McCloud says. "It allows you to have that picture very early on in the project and that allows you to understand the areas of risk, and what needs to be done."

Arup has used this method to compare the sponginess of 10 major urban centres around the globe: Auckland, London, Montreal, Mumbai, Nairobi, New York, Shanghai, Singapore, Sydney and Toronto.

Of these, it found that Auckland is the spongiest, at 35%, as it has 50% blue-green areas and its soil types are <60% sand and 10-20% clay. At the other end is Sydney, which is only 18% spongy as it has just 24% blue-green space and its soils are >60% sand and 10-30% clay, making for moderately high run-off potential.

"This flags aspects that need to be considered and what the possible interventions are, whether it's around physical interventions or policy," McCloud says. "That's when the water team, cities team and landscape architects would design accordingly to meet whatever the cities require, because every city wants to approach the problem in a different way."

NATUREINSIGHT

Another tool that uses data and AI to optimise nature is Arup's NatureInsight, created with web-based environmental platform Scalgo, which can help clients map and model flood resilience and NbS on a catchment-wide basis.

NatureInsight builds on the data found through analysing satellite imagery and helps to determine factors such as where carbon is sequestered or where flood zones are located. It maps the whole of a catchment at 250m² pixels and, based on information from multiple datasets such as land cover and topography, determines the intervention opportunities. These could be tree planting, floodplain reconnection or soil management among numerous others. Each pixel on the map is coloured to show which would work best in that 250m² area.

NatureInsight can then tell the user how a chosen intervention would affect factors such as biodiversity measure, carbon sequestration or other metrics that must be adhered to on projects. In this way, an organisation can show what it already has in terms of natural assets and what it could achieve.

"It's a way of starting to go into the weeds of a catchment and scenario checking, all driven by different datasets – some of it satellite data, some of it Ordnance Survey data or other relevant datasets. A full rules base and set of expertise sits behind it to ensure we are asking and addressing the questions that need to be asked," McCloud says.

On a catchment scale, NatureInsight can tell the user the total area of mitigation strategy, the potential number of habitat units created, the cost of implementing a strategy, the water storage capacity and more.

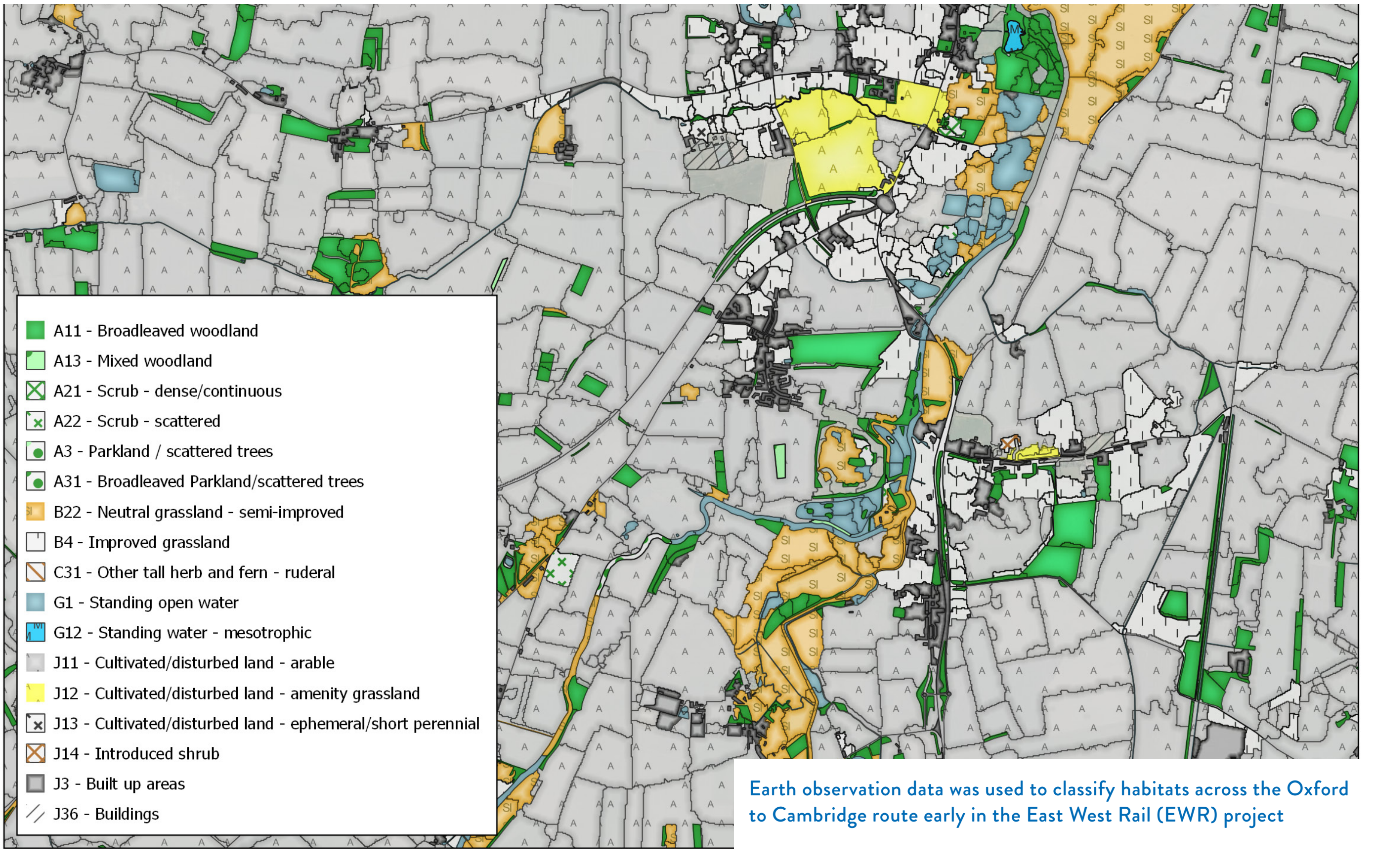
Of interest to flood specialists is how quickly an area reaches peak flow during rainfall and NatureInsight can calculate this – both for the current environment and after landscape changes are made.

"It's about knowing where you can make certain interventions to bring the peak of that graph down, especially in areas of high population for example," McCloud says. "You can quickly start to plan and scenario check, leading you to make the best choice for the project."

NatureInsight has been put into practice in drawing up the South Warwickshire Local Plan, via which the local authority wanted to update its planning policy to address the climate and biodiversity crises.

The tool can provide the authority with a baseline for ecosystem services across the district and estimate the potential additional benefits achieved through the application of NbS. This in turn informs South Warwickshire when it is making development decisions, ensuring it is doing the right thing in terms of its net zero and BNG strategies.

The tool can also be used at a project level. For example, at Haworth train station, the local authority sought NbS to alleviate flooding. It was determined that five upstream watersheds could be introduced, but this was in a tight urban area. NatureInsight proposed optimal locations for them by opportunity mapping and modelling simulations to explore the impact of different potential positions. It considered factors such as outflow pipe diameter and offtake conditions before presenting the best solution.



Earth observation data was used to classify habitats across the Oxford to Cambridge route early in the East West Rail (EWR) project

> Data that would be great to train these models on to get a better understanding of nature is just sat there gathering dust, not doing anything, when it could be adding value to the industry as a whole, making it cheaper to bid and getting better outcomes for nature
>
> DAMIEN MCCLOUD, ARUP DIGITAL NATURE LEADER

Arup has found that the tool can speed up the time taken to reach the best solution for a project by as much as 80%.

"The interface looks like a geographic information system [GIS] package and that's about making it as simple to use as possible," McCloud says.

85%
The level of consistent accuracy of Arup's models

SUPPORTING BIODIVERSITY WITH EARTH OBSERVATION

Arup has also used its Earth observation expertise to understand biodiversity at different scales, including on an infrastructure network scale or a county-wide scale.

An example comes from East West Rail (EWR), where Earth observation data was used to classify habitats across the entire Oxford to Cambridge route early in the project. Similar to the examples of working out a city's sponginess, the team again used machine learning to interpret habitat data from the satellite imagery – though it was done at a 10m resolution for this project and used UK Habitat Classification (UKHAb) level 3, known as Broad Habitats, which provides a general understanding of habitat types within a broader ecosystem, such as neutral grassland, coniferous woodland, or cropland. This enabled Arup to map the baseline biodiversity and assign habitat distinctiveness, condition and strategic significance to all pre- and post-construction habitat types.

"We were significantly quicker [than standard ecological surveys], captured more data and did it more accurately," McCloud says. "And the benefit is the consistency. We know our models are consistently 85% accurate, whereas an ecologist might be 85% accurate but the next ecologist might be 85% accurate on different things."

Arup had its method approved for technical soundness by the joint Nature Conservancy Council, which enabled the findings to be valid for use in the EWR development consent order (DCO) application.

McCloud says this process provides so much data about biodiversity on the site before anyone even steps out onto it, that "there's no reason not to include nature in the design considerations," especially as it can have an impact on a project's cost.

"Projects have to mitigate the loss of natural habitats with a 10% improvement due to England's Biodiversity Net Gain legislation. This means improvements on site or offsetting elsewhere, all of which have a cost to the programme." he says. "So, understanding it can have a big effect on the cost of a project, or even the route you choose. It's about understanding as many issues as possible up front."

In the case of EWR, the model was able to generate project data up front that impacted the scheme's route choice, a significant change from other major projects that have done ecological surveys once the route is determined.

Again, the system is designed to be accessible and easy to use, with detail to show each little parcel of land – boxed in by hedgerows, roads, railways or otherwise – colour coded to display the type of habitat found within it.

On a county-wide scale, Arup's model has been used by Worcestershire County Council for its habitat inventory.

McCloud says the team used Earth observation data, which it was able to provide cost-effectively and with a greater level of detail on the different land covers than had previously been available. Arup ecologists were only required to attend areas of "low confidence, while for most places the algorithm had furnished "high accuracy and understanding," he says.

UNTAPPED POTENTIAL

McCloud adds that models like Arup's could be improved if more of the data collected by on-site ecologists on, for example, major road and rail projects, were made freely available. "There's a load of ecology surveys that have been verified and offer good data that could be great to train people's models," he says. "[For now] it's stuck with companies who procured the services or in Government for major Infrastructure schemes such as HS2, which means we can't use it.

"These datasets would be great to train these models on, or just to get a better understanding of nature are just sat there gathering dust, not doing anything, when it could be adding value to the industry as a whole, making it cheaper to bid and getting better outcomes for nature. That's one of the things that I'm driving in my current role: how do we release it?

"If you open that up, I believe you change the quality of the models almost overnight, because everybody's got the data to train them on. It would position the UK at the forefront of nature modelling in the world." E

Scaling Nature as a Service (NaaS)

Digital tools, data and AI can radically expand the uptake of future NbS.

Given the changing climate's interactions with the built environment and nature's ability to mitigate or leverage those interactions, it's no surprise that infrastructure specialists can be seen as the "engineers of nature", in ICE President Jim Hall's words.

Civil engineers and infrastructure clients are increasingly looking at NbS as an input across projects of all scales. It's a radical shift away from hard engineered interventions towards the integration of nature and biodiversity as key design constraints.

Incorporating NbS early into projects is the optimal approach, reducing the need for large upfront investments in new infrastructure and leading to lower maintenance costs over the long run. It also enables multi-pronged solutions to be envisaged early – for example those that encompass a range of outcomes, from flood alleviation to drought prevention, enhanced biodiversity and improved community amenity.

To date, NbS' adoption has been hampered by a lack of evidence on their long-term efficacy and scalability, along with a perception that they are difficult to implement, and other blockers such as insufficient financing.

Digital technology offers the key to implementing NbS, capturing and utilising standardised, large-scale data for monitoring performance, scaling up, data streamlining and stakeholder engagement, making it easier to manage complex, interconnected systems.

Digital tools – coupled with specialist expertise from organisations such as Arup – can be utilised for a wide range of tasks, from land use analysis to identify optimal placement of NbS and to address urban heat islands.

By combining data analytics, machine learning, and AI with satellite imagery, these tools help assess environmental risks and plan sustainable developments. Through data-driven insights, they also ensure schemes build a stronger business case for investments in nature positive projects.

And as digital tools increasingly enable the identification of optimal solutions, as well as facilitating the delivery of NbS at scale and supporting the benchmarking of their performance, it's possible to envisage a longer-term ambition: the widespread, even nationwide, adoption of these approaches.

An optimal future should be defined by the broader uptake of climate-resilient, nature-rich infrastructure, with the potential to drive transformative outcomes – and to realise this vision, data and digital solutions must be at the core. Their deployment can support a vision for "nature as a service" in which the benefits of nature, such as clean air, water, food and climate regulation are delivered and viewed as essential services, vital to economies, wellbeing and the environment. **E**

ARUP DIGITAL TOOLS

Terrain: Terrain utilises machine learning and data analytics on satellite imagery to understand land use, identify risks and opportunities, and test future scenarios for sustainable land planning. Such tools support risk analysis as well as unearthing insights at the early stages of a project, ensuring a more sustainable and outcome-led design approach.

NatureInsight: NatureInsight's mapping and data analysis capabilities identify optimal sites for nature-based interventions, assess their costs and benefits, and provide insights for decision-makers. The tool also analyses potential locations for flood protection measures and helps prioritise interventions by evaluating their cost-effectiveness.

WeatherShift: WeatherShift uses climate projection data to collate data that supports building and infrastructure design, helping to assess their long-term performance against potential future weather impacts.

UHeat: UHeat identifies the materials and urban areas contributing to urban heat, enabling better integration of green spaces and cooling solutions. It does this by employing machine learning to analyse satellite imagery and identify the causes of urban heat islands, allowing for the modelling of effective mitigation strategies using green infrastructure.

New Civil Engineer

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