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Management innovation – the forgotten component in maximising the value of urban nature-based solutions

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Abstract Nature-based solutions (NBS) enable the ecosystem service benefits associated with natural landscapes to be embedded into the built environment, simultaneously providing environmental, social, and economic benefits. This represents a mechanism for renaturing cities that can address many of the interrelated challenges associated with urbanisation and climate change. If NBS can be delivered effectively on city-wide scales, it presents an opportunity for the development of sustainable, resilient and liveable cities. Examples of innovation in relation to designing and delivering NBS are emerging globally. However, the legacy of management plans, an essential element of NBS that typically underpins the long-term success of these high-profile initiatives, is often overlooked or under-planned. Careful consideration of the technical, financing and governance aspects of NBS management can be critical to determining whether an NBS is able to: deliver the multifunctional benefits for which it was designed; adapt to changing needs and environmental conditions; and avoid becoming a liability to those communities it was designed to benefit. Here we present a series of case studies demonstrating how innovation in NBS management can secure and maximise the long-term success of NBS and avoid the legacy of neglected or poorly managed 'green wash'.

Keywords: Nature-based Solutions, legacy, management, innovation

Introduction

Valuing nature – ecosystem services

Nature is a hugely beneficial asset to human society, providing us with a vital earth support system that creates the oxygen we breathe, cleans the water we drink and provides the food we eat. In the last few decades, we have termed these benefits "Ecosystem Services" (ES). ES are defined as the benefits provided by ecosystems that contribute to making human life both possible and worth living (UK NEA, 2012). These services can be at the global, landscape or at the local scale. While most proponents of the ES approach tend to think of whole organisms or ecosystems as providing ecosystem services, or ES as direct products, for example food and wood, the definition is extremely broad. At the global scale Constanza et al., (2014) estimated that in 2011 we received $125 trillion of benefits from nature, compared to a global GDP of $75 trillion per year. Worryingly, they also estimated that between 1997 and 2011, $4-20 trillion per year of these benefits were being lost through land use change.

At the landscape scale there are numerous examples of ecosystem service provision being enhanced to benefit cities. For example, for the last decade the Forest Research, UK, have been engaging in a project to restore upland forests to decrease upland water flow, promoting woody debris build-up in streams and thus reducing the amount of water flowing down to the lower catchments, where urban areas typically lay (Nisbet et al., 2015). In Portland, Oregon, USA, large sections of upland riparian habitat has been purchased by the municipality in order to conserve wildlife and prevent development, reducing downstream flooding (The City of Portland Environmental Services, 2020).

At a local scale, trees provide an enormous range of ecosystem services within cities. The surface area of a single mature tree is very large; For example, a densely leaved tree such as the small-leaved lime (*Tilia cordata*), could have something like 100m^2 of leaf surface area, while occupying only a fraction of this in realised crown space (Trowbridge and Bassuk, 2004). This surface area traps particulates from the atmosphere (Nowak et al., 2006) and stores water droplets in rain events (so called "interception". See: Wang et al., (2008)). In the London i-Tree Eco Project (Rogers et al., 2015) it was estimated that London's urban forest removes 1700 tonnes of air pollutants and 2.7 million m^3, equalling £70 million is value.

Ecosystem services approach – benefits and trade-offs

The popularity of the ecosystem services concept has been driven by the fact that a large range of ecosystem services are able to be quantified, monetised and therefore compared to services offered by grey infrastructure. As such, this enables an architect to justify the inclusion of vegetation not only because of its aesthetic benefit but also because it is a long-term investment that will, for example, reduce the energy costs of the building (Nowak et al., 2017). Tree officers and parks managers, whose budgets are reducing over time are now able to balance their books, demonstrating the monetary value that is being gained from ecosystems, as well as the costs involved in their installation and maintenance. While proponents of ES see it as a necessary tool to ringfence ecosystems in a strongly capitalist society, others have argued that some non-market benefits such as the social, cultural and resilience values of ecosystems cannot be adequately evaluated using monetary metrics, and continue to be missed as hidden externalities (Gomez-Baggathun et al., 2011, 2013; Chan et al., 2012). This can lead to a focus on solutions that provide single or a narrow range of ecosystem services, with those that are difficult to value being overlooked. Nature-based solutions have emerged as a new framework for the delivery of ecosystem services that has shown to address some of these pitfalls.

Nature-based solutions – an emerging model for ecosystem service delivery

A nature-based solution approach promotes the maintenance, enhancement, and restoration of biodiversity and ecosystems as a means to address environmental, economic and societal challenges simultaneously (Kabisch et al., 2016). Having emerged relatively recently, nature-based solutions are still evolving as a concept. The European Commission has developed and driven this priority area, defining them as "actions which are inspired by, supported by or copied from nature. Many nature-based solutions result in multiple co-benefits for health, the economy, society and the environment, and thus they can represent more efficient and cost-effective solutions than more traditional approaches." (European Commission 2015). This is not, however, a universally adopted definition and alternative descriptions have been proposed. The International Union for the Conservation of

Nature has defined nature-based solutions as "actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits" (Cohen-Shacham et al., 2019).

Whilst there is yet to be a consensus on an exact definition, the principles behind the definition are clear. The nature-based solutions concept is intended to build on ecosystem services and ecological engineering approaches and offer an integrative and more holistic method for addressing ecological/environmental degradation and societal challenges, whilst delivering economic benefits and building resilience in the face of climate change (Nesshöver et al,2017; Cohen-Shacham et al., 2019). As such, nature-based solutions represent an umbrella concept that incorporates ecosystem-based approaches (e.g. ecosystem services, green infrastructure) and goes beyond them in terms of its more explicit focus on addressing social and economic challenges and alignment with policy agendas (Cohen-Shachem et al., 2019).

Why are nature-based solutions important?

With an urgent need to deliver on global sustainability challenges, and predictions that this need will be exacerbated by climate change, nature-based solutions represent potentially cost-effective sustainable solutions that work in harmony with nature rather than exploiting it (European Commission 2015). This is particularly the case in urban areas, where biodiversity has largely been excluded at the expense of grey infrastructure engineered solutions. Research has identified the potential for nature-based solutions to address a broad range of urban challenges such as biodiversity conservation (Connop et al., 2016), stormwater management (Haase, 2015), carbon capture (Davies et al., 2011), improving health and social cohesion (Kabisch et al., 2017; Rutt & Gulsrud, 2016) and generating economic growth (Gore et al., 2013). Nature-based solutions have the potential to deliver more co-benefits than predominantly hard-engineered infrastructure (Raymond et al., 2017), they are generally more adaptive to changing conditions (Reguero et al., 2018) and therefore more resilient to climate change. Perhaps most critically, their development is also more likely to involve local communities in a co-creation/co-production process. This facilitates a stronger focus on social benefits and stronger links to community ownership and stewardship of implemented nature-based solutions (Frantzeskaki, 2019). Nature-based solutions can directly contribute to the delivery of Sustainable Development Goals (United Nations, 2015; Cohen-Shachem et al., 2019) and there is growing evidence it is a cost-effective alternative to traditional approaches (Reguero et al., 2018).

Three phases of nature-based solution implementation: planning, delivery, and legacy

To position Europe as a global leader in nature-based solutions delivery, the European Commission Horizon 2020 programme has funded a series of research innovation actions to generate a more comprehensive evidence-base and develop a framework for effective and more widespread implementation and upscaling of nature-based solutions (European Commission, 2015). The Connecting Nature project represents one of the consortia funded through these innovation actions. The project brings together industry, local authorities, local communities, NGOs and researchers to create a community of cities that fosters peer-to-peer learning and capacity building in the field of nature-based solutions. A key objective for the project is to facilitate cities in scaling-up and scaling-out innovative nature-based solution pilots, so that they can be implemented on a city-wide scale and become the mainstream good practice approach to creating green, healthy and resilient cities.

The consensus emerging from the Horizon 2020 nature-based solution projects is that there are key phases in the implementation of nature-based solutions. Whilst there is agreement over the differentiation between design and delivery phases (Somarakis et al. 2019), different approaches have been adopted when it comes to categorising the ongoing management of nature-based solutions. Some projects include this as part of the delivery phase (Somarakis et al. 2019), however the Connecting Nature project categorises three key phases associated with the implementation of nature-based solutions: planning, delivery and legacy (Connop et al. 2019). In relation to this categorisation, the planning stage examines amongst other things the challenges and policy priorities the city faces, the type/design of nature-based solution that could address these needs, considers benefits/co-benefits/trade-offs, and funding and the range of stakeholder involvement needed for effective delivery. The delivery stage involves the implementation of the nature-based solution, including securing the necessary funding, ensuring that benefits and co-benefits are not lost during implementation, minimising impacts, and dealing with trade-offs if they arise. The legacy phase is concerned with management, maintenance and monitoring of the nature-based solution after delivery, to evaluate whether expected benefits are being sustained and if the scheme has the flexibility to adapt to change over time and/or to future demands. The framework in Figure 1 illustrates the role of legacy management in the sustaining the delivery of nature-based solutions benefits.

(suggested position for Figure 1)

Legacy – the forgotten component

During the process of exploring the barriers and drivers for nature-based solutions with Connecting Nature cities, it was evident that the majority of resources were typically devoted to the planning and delivery phases of nature-based solution implementation. Conversely, the legacy phase received limited consideration and resources in comparison. Indeed, the legacy phase was repeatedly identified as a key barrier to wider adoption of the nature-based solutions approach. In particular, lack of technical experience in monitoring and evaluation, and problems with governance and funding for long-term management/maintenance were identified as key challenges. For many pre-existing nature-based solutions projects, the legacy phase was almost entirely overlooked. This not only impacts the capacity of the nature-based solution to deliver benefits, but also means that most cities have not generated an evidence-base to demonstrate that multifunctional benefits of adopting a nature-based solutions approach, thereby impeding its mainstreaming and upscaling at a policymaker/decision-maker level.

This lack of focus on legacy phase management is also mirrored across nature-based solution case studies presented in emerging online databases. Whilst a plethora of nature-based solution good practice examples are emerging online (Nature4Cities 2019; Naturvation 2019), there is a tendency for these to focus on technical design, governance and funding at the project planning and delivery stage, but with limited reference to technical performance, financing and governance during the legacy phase.

The importance of legacy planning

Ignoring or under-resourcing the legacy phase of nature-based solution implementation brings with it risks, not just for the project itself, but for nature-based solution implementation in general. Nature-based solutions are typically implemented to deliver a number of targeted benefits and a range of associated co-benefits. For these to be sustainable beyond the delivery phase, there is a need to ensure that the nature-based solution is appropriately evaluated, managed and funded (Frantzeskaki et al. 2019; Somarakis et al. 2019). Without this approach, ecological, environmental, social and/or economic benefits can be lost. Appropriate consideration of legacy management is also necessary to ensure that the nature-based solution is flexible enough to adapt to changing external conditions and future demands. Such changing demands can mean that merely attempting to retain the status-quo of the original conditions at the time of delivery can be an ineffective strategy for delivering long-term benefits.

When legacy is not effectively considered or resourced, the nature-based solution can become a white elephant (or even a liability) for the communities that it is intended to benefit (Figure 2). Under such a scenario, it is often perceived to have 'failed'. A prevalence of perceived 'failed' nature-based solutions can act as a barrier to the rollout of further nature-based solutions (a drawback identified during Connecting Nature workshops with city practitioners). With nature-based solutions still an emerging concept, there remains scepticism regarding their performance compared to more established, traditional approaches. Schemes that are perceived to have failed or under-performed can therefore reinforce such scepticism and jeopardise further adoption of nature-based solutions. It is thus critical to ensure that the legacy phase is given equal consideration and resourcing as the planning and delivery phases of nature-based solution implementation.

(suggested position for Figure 2)

Case studies

The following case studies demonstrate how innovation and forward-thinking in relation to ongoing management can secure and maximise the long-term legacy of nature-based solutions, preventing pioneering projects from becoming neglected or poorly maintained 'green wash'.

Nature-based solution legacy: technical – the Queen Elizabeth Olympic Park

For many NBS projects the design focus is on technical performance, with this linked to the delivery of environmental, social and economic benefits. However, for the technical design to sustain the desired level of performance in the long-term, an appropriate management legacy is crucial, otherwise ecosystem service delivery can diminish over time (Cohen-Shachem et al, 2019). The following case study illustrates that even when the technical design has resulted in pioneering and multifunctional nature-based solutions, inappropriate habitat management

can potentially compromise a key ecosystem service benefit, in this case biodiversity and nature conservation, a primary target of the technical design.

London's Queen Elizabeth Olympic Park (QEOP) was built for the 2012 Olympic Games and has since been transformed into one of the largest urban parks in western Europe. A fundamental aspiration was to break the mould of traditional park design, and create a landscape that was multifunctional, inclusive and sustainable. A key aspect of the technical design of the QEOP was that it would make a significant contribution to nature conservation and the environment, as well as promoting and delivering core objectives such as social equality, healthy lifestyles, employment opportunities and economic growth. Biodiversity was considered to play a key role in achieving all of this, and therefore enhancing biodiversity was a top priority for the park (LLDC, 2013). To achieve this, around 100 hectares of natural and semi-natural habitats have been created, including wetlands, wildflower meadows and biodiverse brownfield habitat, as well as formal parks, recreational green spaces and green roofs (ODA 2008). The habitat design for the QEOP was intended to set new standards and be an exemplar in the delivery and management of wildlife-rich habitats within a high-profile urban park (Figure 3).

(suggested position for Figure 3)

As part of the exemplar approach, a Biodiversity Action Plan (BAP) was developed for the Park, and part of its function was to provide a long-term monitoring tool for evaluating whether ongoing management was delivering the biodiversity aspirations of the technical design. Ecological surveys measure and monitor biodiversity across the Park, including a number of specific 'target' species and groups. These surveys have provided evidence of just how vital appropriate ongoing management practices were to sustaining the ecological legacy of this innovative urban greenspace. In particular, the results of invertebrate surveys of wildflower meadows and a biosolar green roof in the Park identified that the meadows were being managed in a uniform way, that was potentially detrimental to species and faunal groups that the technical design was intended to benefit.

Through the BAP monitoring, it was identified that standard maintenance actions for meadows was to cut and clear all vegetation at the same time towards the end of the main flowering period. Whilst some form of mowing/cutting is necessary to encourage flower diversity in meadows, such a blanket, essentially generic management approach caused a catastrophic loss of above-ground plant resources for a whole range of biodiversity, including some of the park's target species. This is because countless species, including some pollinators, rely on resources within these meadows beyond just the pollen and nectar offered by flowers. For instance, for a broad range of fauna, winter seed-bearing flowerheads provide food, thick grass tussocks are used for nesting, and seed heads and stems for overwintering. And, indeed, the results of the BAP monitoring surveys indicated there was a negative impact on biodiversity from this management approach, with dramatic declines in invertebrate species richness recorded in areas subjected to a blanket cut. Species Quality Index scores (an indicator of site quality) followed a similar trend, except in one meadow that was left uncut and on the green roof, which was never cut but 'naturally' disturbed by summer drought.

The focus on managing wildflower meadows to provide pollen and nectar resources for bees/pollinators, and the pressure to 'tidy up' public pollinator havens appears to have made this approach standard practice, not just in the QEOP. In terms of the QEOP BAP, the outcomes of this practice were contradictory to the habitat requirements of several of their target species, as well as a broad array of other biodiversity. From the monitoring results, it was clear that innovative management was needed if the biodiversity aspirations for this urban greenspace exemplar were to be sustained.

'Mosaic management' represents one such innovative approach. Inspired by the patchy, sporadic and localised disturbances that occur on 'open mosaic habitat on previously developed land' (OMH) – a highly biodiverse urban habitat – mosaic management is the antidote to prevalent regimented, blanket and intensive habitat management practices. Instead mosaic uses a patchwork and rotational approach, where for wildflower meadows, section are cut but some sections are left uncut, and these are rotated on an annual or biennial basis. Uncut areas provide a continuity of resources, critical for the successful completion of the complex lifecycles of many insects. Meadow swards can be cut to different heights in different sections, increasing structural heterogeneity, and if undertaken creatively, can create patterns and frames for uncut areas. This not only provides visual interest but ensures that areas look cared for. In terms of co-benefits, mosaic management can be more cost-effective and reduce greenhouse gas emissions as overall less cutting is needed annually than typical intensive management techniques.

After implementation of this mosaic management the results were extremely positive. Species richness had increased by over 30% and four times as many nationally rare species were recorded. Whilst species richness in all the meadows surveyed that year had shown an increase, those that had been subjected to the standard blanket management had no change in the number of rare species. Without a replicated experimental set up, it is difficult to confidently determine causation of this increase in rare species. But the fact that the number of rare species did not increase as dramatically in the other meadows suggests that this management approach could be an important factor and an effective driver for increasing nature conservation value of urban wildflower meadows.

This case study highlights that 'locked in' habitat management practices based on custom and aesthetics must be transformed to meet the long-term technical aspirations of such innovatively designed nature-based solutions. It also illustrates the importance of evaluation of the technical legacy to ensure that the original intended benefits and co-benefits of nature-based solutions are sustained in perpetuity.

Nature-based solutions legacy: governance – the Barking Riverside Community Interest Company

Nature-based solutions affect a broad range of stakeholders and facilitating multi-stakeholder participation in projects can ensure the generation of multiple benefits (Ershad Sarabi et al., 2019; Nesshöver et al., 2017). Engaging communities in understanding the function and delivering the management of nature-based solutions can be crucial to its long-term success (Frantzeskaki et al. 2019). Without this involvement, citizens can misunderstand and undervalue nature-based solutions, potentially resulting in its misuse or neglect. Ultimately, this can compromise its multifunctionality, with nature-based solutions being perceived as a liability by the very community it was intended to benefit. Moving away from traditional, top-down, public-sector-led legacy management, and actively involving local people in the governance of nature-based solutions can foster knowledge-sharing and greater acceptance of this approach (Ershad Sarabi et al., 2019). Through active participation in the stewardship of nature-based solutions, local communities can develop a sense of ownership and empowerment, which not only engenders feelings of belonging and place, but offers an innovative mechanism to secure the successful and sustainable long-term management legacy of nature-based solution projects. The following case study illustrates how a new housing development has developed an innovative governance model to involve the local community in the management legacy of their local nature-based solution assets.

Barking Riverside, in the London Borough of Barking and Dagenham, is a 180 hectare brownfield site that is being transformed into a new sustainable community and will be one of the largest new housing developments in London. On completion it will comprise approximately 10,800 new housing units, along with seven schools, sport facilities, a health and community hub and around 40% of the site will be dedicated green space and parkland. The vision for Barking Riverside is that it will be an exemplar of sustainable and resilient urban design and provide a healthy and well-connected community. Much of the innovation of the development resides in the way its ecological, cultural and industrial heritage have been interwoven into the design to make a positive contribution to local ecosystem service provision and climate change mitigation. Located on the riverfront, the site was historically part of the floodplains of the River Thames, until the landscape was industrialised and for several decades was occupied by a coal-fired power station. When this was decommissioned, the site transformed once more into richly biodiverse, post-industrial brownfield site.

In recognition of this heritage and the associated ecosystems service value of the pre-development site, a green infrastructure masterplan was established to ensure that biodiversity and sustainability were core to the design for the Barking Riverside development. This included state-of-the-art nature-based solution features such as biodiverse green roofs designed specifically for locally important biodiversity, as well as multifunctional Sustainable Drainage Systems (SuDS) that not only provided flood risk mitigation, but also offered important habitat resources for wildlife and attractive recreational spaces that would contribute to the health and wellbeing of the local community. These features were integrated into the heart of the new neighbourhoods, to bolster sustainability and resilience and provide opportunities for residents to experience nature where they live (Figure 4).

To encourage residents to understand and engage with the design, management and maintenance of the local green and social assets within the development, the Barking Riverside Community Interest Company (CIC) was set up in 2009. A CIC is a form of social enterprise that has an overriding community purpose and has a formal legal status in the UK. An essential part of a CIC governance structure is the concept of "asset lock", whereby all assets have to be held for the benefit of the community and any surplus proceeds used for community purposes. For Barking Riverside, this innovative governance model included key stakeholders involved in the development and served to empower local residents, through self-management, to support and create a sustainable community -

socially, environmentally, economically and also institutionally. As well as responsibility for control and management of the community and nature-based solution assets of the Barking Riverside development, the CIC will also function as an interface between new and existing communities, providing information and community services for incoming residents.

(suggested position for Figure 4)

The Barking Riverside CIC was formally constituted through its governing document with powers to hold and manage the community social and green assets and to invest in community cohesion, social enterprise activities, and local infrastructure according to the needs and wishes of local residents and businesses. The CIC is currently funded from the proceeds of ground-rents and is expected to become self-financing when sufficient residential units have been constructed. Initially the CIC was established in partnership with the local authority – the London Borough of Barking and Dagenham, and the development company Barking Riverside Limited, with two directors from each organisation represented on the CIC board. This institutional representation on the CIC board enabled residents to learn how such boards were run and to become familiar with the responsibilities and range and scope of activities open to the CIC. Once the CIC has built capacity amongst residents in terms of developing the required management and business skills, it will become an entirely community-led venture that manages assets for the benefits of all and upskills local people to improve their employment opportunities and prosperity.

Involving a resident group has already provided a way for the Barking Riverside CIC to effectively connect and relate to their local environment. As such, residents are now actively suggesting activities they would like to have at Barking Riverside and identifying opportunities for new nature-based solutions to be delivered through the CIC. For instance, a new garden has been created at one of the schools where children can grow food and foster contact with nature. The Barking Riverside CIC offers an innovative governance model for holding and managing community assets at this neighbourhood scale and represents a sustainable and resilient method for delivering the legacy of long-term nature-based solution benefits through community-engaged management and stewardship.

Nature-based solution legacy: finance – Glasgow SuDS adoption

Ensuring that a financial legacy is in place is critical to the long-term functioning of nature-based solutions. Without this, the sustainable delivery of benefits and co-benefits cannot be guaranteed (Smorakis et al. 2019). Various opportunities exist in relation to sourcing the finance required for legacy management (e.g. payments for ecosystem services, adoption into local authority management duties, entrepreneurship associated with the nature-based solution that re-invests back into management, etc) (Vandermeulen et al. 2012; Smorakis et al. 2019), with strategies typically based on the type and scale of the nature-based solution. However, compared to finance for planning and delivery, legacy financing is often under-estimated, or even overlooked completely (personal communications, Connecting Nature cities). Even under the lowest-cost scenario (for instance, a voluntary/community group taking responsibility for maintenance), long-term funding will be required for management operations such as: maintenance equipment purchase/servicing, repairing damage, replacing plants, irrigation, expert input on evaluation/re-design. Without financial planning for these whole life costs, it is unlikely the implemented nature-based solution will sustain its targeted performance. Moreover, this leaves little or no financial capacity for adaptation of the nature-based solution to changing demands and/or in relation to a changing climate. Under such scenarios, not only does this risk the nature-based solution become a liability, if it is perceived to have failed, it can also represent a barrier to future roll-out of nature-based solutions.

Innovative approaches to securing the economic legacy necessary to ensure the sustainability of nature-based solutions are emerging. One such example is provided by the adoption of SuDS nature-based solutions in Glasgow. Glasgow is a city situated on the River Clyde in Scotland's West Central Lowlands (UK). It has a population of approximately 615,000 people. With a strong industrial heritage, the city has a history of population and industrial expansion and contraction. Currently, in a post-industrial phase, Glasgow is focused largely around tertiary sector industries such as financial and business services, communications, biosciences, creative industries, healthcare, higher education, retail and tourism. Whilst the city hosts booming areas of regeneration, a matrix of luscious green parks, grand buildings and many attractions, it also contains areas of deprivation and a high proportion of vacant and derelict land.

Like many cities of its era, it faces myriad challenges associated with its ageing infrastructure and changing demographics. A key challenge currently faced is its ageing stormwater infrastructure, a problem that is being exacerbated by climate change and is expected to worsen. Consequently, dealing with flood management and urban

water has become a strategic priority for the city. Glasgow has embraced a nature-based solution approach to urban design, most recently through the development of a city-wide Open Space Strategy, and through embedding green infrastructure principles into the City Development Plan. A nature-based solution approach is also reflected in the establishment of the Metropolitan Glasgow Strategic Drainage Partnership (MGSDP) which focuses on the delivery of the national Flood Risk Management Act locally through the delivery of Sustainable Drainage Systems (SuDS) solutions.

SuDS represents a departure from the traditional way of managing stormwater using grey infrastructure pipes that rapidly convey water offsite to an underground sewer network. Instead SuDS mimic a more natural catchment approach and offer an alternative to using heavily engineered grey infrastructure that is proving to be costly and unsustainable in the face of ever-increasing demands on its capacity. By storing stormwater on site, allowing it to infiltrate into the ground, and/or releasing it more gradually, it is possible to reduce the demand on the sewer network, recharge groundwater tables, and improve water quality before it enters the sewer system. By using a nature-based solution approach to SuDS, it is also possible to provide a broad array of additional benefits including supporting biodiversity, providing relief from heat stress, providing green recreational and play spaces, improving air quality, and making more attractive living and work spaces (Woods Ballard et al. 2015).

Glasgow's Local Flood Risk Management Plan requires developers and engineers to produce Flood Risk Assessments and Drainage Impact Assessments for any development that will impact infiltration and drainage. The MGSDP requires, where possible, a SuDS approach to deal with these predicted impacts from new development. Responsibility for the management and treatment of water is shared between the Local Authority and the water company (Scottish Water). Originally, there was a consensus between the two partners that the management of SuDS delivered on private property was the responsibility of the individual. However, it very quickly became apparent that, under such a scenario, management was not carried out and that SuDS ceased to be effective: permeable paving blocked up with silt and was no longer permeable, overgrown swales no longer had the same storage and conveyance capacity, and detention basins filled with fly-tipping and rubbish. In response to this, it was recognised that SuDS management needed to be transferred to an organisation that would look after it in perpetuity. As an example of innovation in collaborative management of nature-based solutions, a Memorandum of Understanding was developed between Scottish Water and the Local Authority Highways Department to adopt all SuDS schemes implemented in Glasgow managing stormwater draining from public roads and/or the curtilage of housing or dwellings (land immediately surrounding it, including any closely associated buildings and structures). Such adoption is dependent upon the implemented SuDS being approved by local authority assessment and following Scottish Water design principles. Once adopted, however, a financial legacy is assured that will enable the SuDS systems (including nature-based solution SuDS) to be managed effectively and appropriately, securing the legacy of the scheme (Figure 5).

(suggested position for Figure 5)

The Memorandum of Understanding determines that Scottish Water will take responsibility for below ground aspects of the SuDS and the Local Authority will take responsibility for the above ground aspects. In urban areas, this can mean that the burden of management falls upon the Local Authority, as the majority of maintenance is litter removal and vegetation management. However, Whole Life Cost Analysis (Pittner and Allerton 2004) was used as a foundation for this memorandum and this includes the cost of replacement of the asset if it is no longer functioning. This replacement responsibility falls upon Scottish Water and, as such, it was determined that the burden of cost would be split equally between the two partners. Such an approach was found to be cost-effective for both partners as, due to the division of responsibility for aspects of water treatment, conveyance, and management in relation to roads and curtilage, the alternative would be that each partner would have to look after an entire sewer pipe system in isolation. It is cheaper to look after half a system than a whole system and, as such, represents value for money for both partners and a mechanism to provide wider benefits.

This approach represents an excellent example of collaborative working for a combined goal, and an innovative example of ensuring that legacy finance is in place to secure sustainable functioning of nature-based solutions in perpetuity even when developed on private land.

Concluding summary

These case studies detail some emerging innovative approaches for ensuring a sustainable legacy to nature-based solution implementation. Such approaches are vital if nature-based solutions are to be effective in delivering on their design aspirations, and if barriers to more widespread rollout across our cities and rural landscapes are to be broken down. It has been suggested by other researchers that assessing diverse case studies is an important tool for operationalizing nature-based solutions, demonstrating their value and their effectiveness and highlighting knowledge gaps and potential challenges (Kabisch et al., 2016; Cohen-Shacham et al., 2019). In order to raise awareness of the importance of the legacy phase, it is essential that good practice is captured and shared on databases showcasing nature-based solution projects globally. Only by recognising the importance of the legacy phase, will the long-term performance of nature-based solutions be secured, a critical step if nature-based solutions are to be considered a viable and reliable approach to tackling socio-environmental and economic challenges.

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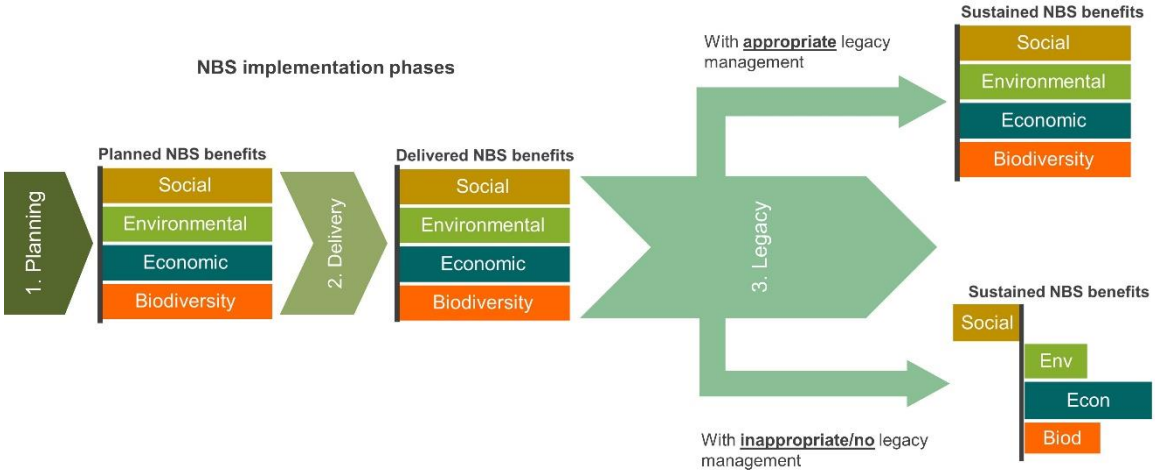

Figure 1. Framework depicting an example of the role of legacy management in relation to the sustainable delivery of nature-based solution benefits. The framework comprises the three phases of nature-based solution implementation: Planning, delivery and legacy.

Figure 2. Example of a nature-based solution with inadequate legacy management. The legacy of this stormwater management ditch was not considered in relation to appropriate management. As such, it is seen as a negative feature of the area and is used for dumping of trash. © Stuart Connop

Figure 3. An area of the Queen Elizabeth Olympic Park, London UK, managed specifically to support biodiversity. © Stuart Connop

Figure 4. An example of nature-based solutions within the public realm of the Barking Riverside development. The management of this amenity, biodiversity, and stormwater management area will be taken over by the Community Interest Company. © Stuart Connop

Figure 5. An example of a well-adopted Sustainable Drainage System (SuDS). Consideration for the SuDS legacy means that it is well-managed and considered to be a valuable asset by the local community.