Institution: University of Sheffield		
Unit of Assessment: C-13 Architecture, Built Environment and Planning		
Title of case study: New vegetation layers enable climate-change adapted urban landscapes previously considered impossible		
Period when the underpinning research was undertaken: 2003–2020		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s): Nigel Dunnett	**Role(s) (e.g. job title):** Professor of Planting Design and Vegetation Technology	**Period(s) employed by submitting HEI:** 1996–present
Period when the claimed impact occurred: 2016–2020		
Is this case study continued from a case study submitted in 2014? N		

1. Summary of the impact (indicative maximum 100 words)

A sustained programme of experimental research addressed the key technical barriers to widespread and transformative urban greening in high-density urban developments, as an essential component of climate-change resilience in cities. The research developed a suite of New Vegetation Layers (NVLs) which have changed perceptions of the acceptability of 'nature in cities', and as a result have enabled delivery of ecosystem service benefits in places previously considered impossible due to perceived excessive resource requirements. NVLs have been applied in flagship inner-city climate-change adaptation urban greening schemes in the UK and abroad, resulting in job creation, inward investment, reductions in emissions and improved user experience.

2. Underpinning research (indicative maximum 500 words)

The context. The widespread and transformational application of effective Green Infrastructure (GI: networks of multi-functional green spaces and features) is widely recognised as an essential component in meeting the impacts of climate-change and extreme weather events. These impacts are magnified in high-density urban development because of the overwhelming dominance of hard impermeable surfaces, resulting in increased risk of surface water flooding, enhanced heat island effect, poor air and water quality, impoverished biodiversity, and lack of human contact with nature. While the benefits of 'nature-based solutions' to address these issues are well known, there has been a failure to implement GI in high-density development as mainstream practice, due to cost, aesthetics, ease of implementation and maintenance, and widespread perceptions that ecological function can only be delivered through use of native plant species. These barriers are exacerbated by the need to retrospectively incorporate green space into dense urban environments, and the lack of space for conventional green space and gardens. Previous research had focused on ecological function only, limiting understanding of these other key barriers.

The research. The New Vegetation Layer (NVL) research programme commenced in 2003 by Dunnett as a sustained attempt to overcome the above key barriers to GI application. It is unique and significant in its focus on a) visual appeal and aesthetics, b) ease of implementation, establishment and maintenance, c) demonstrating ecological function, and d) a toolkit of solutions suitable for use across a range of high-density urban applications. NVLs are plant

mixes for use in engineered features in challenging environments to promote and enable stormwater attenuation and infiltration, water conservation, for microclimate modification, and to promote biodiversity in applications such as green roofs and 'landscapes above structure', rain gardens and vegetated sustainable drainage systems (SuDS), all of which can be retrofitted into existing urban contexts.

The research comprised an ongoing plant testing and selection programme that identified suitable plant species for use in NVLs for green roofs and vegetated SuDS systems under the hostile conditions found in these environments: thin layers of growing medium and limited water supply for green roofs (R1), and repeated cyclical flooding for SuDS contexts (R2). In all cases, experimental microcosms (small-scale versions of the real-world systems) were constructed, and plants were subjected to variables (such as irrigation frequency, depth of growing medium, competitive pressure) under controlled conditions. Additional distinctive aspects of this research are the recording of the visual quality and performance of NVLs (R3), and their resistance to weed invasion (R4), both of which are crucial for their uptake in practice. The research has been highly collaborative, engaging with stakeholders throughout.

Because the research has taken an aesthetically-driven approach it has been crucial to demonstrate that NVLs have high ecological benefit as well as high visual quality. The research identified that NVL vegetation out-performs the standard recommended short-turf vegetation of bioswales and other vegetated SuDS in terms of stormwater attenuation (R5), and, for the first time, showed that vegetation composition, diversity and structure affect green roof hydrological performance (R6).

3. References to the research (indicative maximum of six references)

R1. Dunnett, N., Nagase, A., & Hallam, A. (2008). The dynamics of planted and colonising species on a green roof over six growing seasons 2001–2006: influence of substrate depth. *Urban Ecosystems*, *11*(4), 373–384. https://doi.org/10.1007/s11252-007-0042-7

R2. Yuan, J., & Dunnett, N. (2018). Plant selection for rain gardens: Response to simulated cyclical flooding of 15 perennial species. *Urban Forestry & Urban Greening*, *35*, 57–65. https://doi.org/10.1016/j.ufug.2018.08.005

R3. Nagase, A., Dunnett, N., & Choi, M.-S. (2017). Investigation of plant growth and flower performance on a semi-extensive green roof. *Urban Forestry & Urban Greening*, *23*, 61–73. https://doi.org/10.1016/j.ufug.2017.01.013

R4. Nagase, A., Dunnett, N., & Choi, M.-S. (2013). Investigation of weed phenology in an establishing semi-extensive green roof. *Ecological Engineering*, *58*, 156–164. https://doi.org/10.1016/j.ecoleng.2013.06.007

R5. Yuan, J., Dunnett, N., & Stovin, V. (2017). The influence of vegetation on rain garden hydrological performance. *Urban Water Journal*, *14*(10), 1083–1089. https://doi.org/10.1080/1573062x.2017.1363251

R6. Nagase, A., & Dunnett, N. (2010). Drought tolerance in different vegetation types for extensive green roofs: Effects of watering and diversity. *Landscape* and *Urban Planning*, *97*(4), 318–327. https://doi.org/10.1016/j.landurbplan.2010.07.005

Grant

GRID: Green Roof Infrastructure Development, (£820,000) ERDF, 2006-2009, in partnership with Sheffield City Council, and Green Roof Systems, £1.2 million.

4. Details of the impact (indicative maximum 750 words)

Over 15 years, a coordinated strategy targeted local authorities, planners, architects and designers, and the public, informing them of the benefits and practical implementation of NVLs.

Pathways to impact included: a) organising, hosting, and coordinating the first and second Green Roof conferences in the UK; b) extensive programme of external talks and CPD events to national and international non-academic audiences and end-user groups; c) articles in trade and industry media; and d) delivery of five demonstration gardens between 2011 and 2017 at the Royal Horticultural Society Chelsea Flower Show (the world's premier garden and landscape show).

A crucial element of raising awareness was the delivery of accessible demonstration projects that show NVLs in practice to wide audiences. Dunnett has directly influencing real-world outcomes, policy, and practice through consultancy activity, and is regularly part of international design competition teams as the horticulturist applying the NVL method.

The NVL 'Low-Input, High-Impact' approach has widened the interest in, and uptake of, diverse and naturalistic green infrastructure with high public appeal, in urban contexts in the UK and beyond where such applications would previously have been thought impossible. It has broken down previous cost and logistical barriers to the implementation of ecological greening, widened the scope for its application, and has led to changes in policy and practice at national and international level (S1). Specifically, it has been fundamental to the delivery of the UK's two largest inner-city climate-change adaptation flagship projects (Sheffield Grey to Green and The Barbican Podium), which have themselves spurred similar projects in other locations in the UK and Australia.

Flagship Project 1: Sheffield Grey to Green (G2G, 2016-2020)

This is the UK's largest retrofit Sustainable Drainage Scheme, and the UK's largest inner city 'green street', transforming 1.3 km of redundant highways into vegetated areas for flood prevention, with 20,000 pedestrian users per day. The initiative is a key part of the city's strategy to prevent a repetition of the devastating floods of 2007 that claimed two lives and caused damage to the value of £30 million. Dunnett worked with Sheffield City Council (SCC) to apply NVLs as the basis for the whole scheme (Phase 1 completed 2016, Phase 2 completed 2020). SCC invested £5.8 million to introduce the NVL approach that guarantees ecological function with high visual quality and cost-effective simple maintenance (S2): "*The result has been a spectacular transformation, which has changed the way the area is perceived and enjoyed by local people. It attracted new investment, and considerable interest from cities around the world*" (Simon Ogden, Head of City Regeneration, Sheffield City Council, S3). Key outcomes include surface water management and flood prevention, visual amenity, biodiversity, cleaner air (a reduction of 230 tonnes of CO2 is attributed to G2G), the creation of an environment that attracted £1 million inward investment and due to greater public footfall created 540 jobs (S2). User surveys of Grey to Green show high public approval and demand for more urban greening

of this type in the city (98% of users wishing to see more planting of this type) and 16% of all users diverting their previous journeys purely to experience the G2G NVLs (S4).

Grey to Green Phase 1 was the winner of the 2016 CEEQUAL 'most outstanding project' Award (the evidence-based sustainability awards scheme for civil engineering, infrastructure, landscaping and public realm projects) and the judges commented: "*The result is a striking planting scheme that is very different to anything the Council has ever done before and it is believed to be unique in a UK City Centre setting*" (S5).

Flagship Project 2: City of London Corporation Public Realm and The Barbican (2016-2020)

The Barbican Centre is the UK's largest climate-change adapted urban landscape, covering an area of 1.2 hectares. It is Europe's largest arts and cultural complex with 1.5 million visitors each year, with a significant residential community of 4,000 people. It is managed by the City of London Corporation (CLC), which provides local government services for the City of London.

In 2014 Dunnett presented NVLs to planning officers from across all London Boroughs. Following this, he was asked by the CLC to propose a method to transform the public landscape of The Barbican Centre as part of a competitive process to refurbish its landscape. His proposal replaced energy-, water-, and labour-intensive traditional green areas of lawns, shrubs, and seasonal bedding plants with extensive areas of diverse NVLs. The NVL method was chosen, as it met their goals of creating a low-maintenance and colourful landscape with increased biodiversity which was well-adapted to climate change (S6). Compared to the previous landscape, annual irrigation water use has been reduced by 70%, maintenance time has been reduced by 40%, and extensive user surveys (of both residents and visitors) demonstrate high approval for the new NVL landscape compared to the previous situation (S7). In 2019, as a direct result of The Barbican experience, the CLC has implemented a new climate-change adaptation policy for its street plantings. This replaced irrigated systems with non-irrigated plantings using NVLs, and changed the growing medium specifications (S7). Sites transformed in 2019 and 2020 include Cheapside and St. Pauls, Artizan Street, St. Brides Street, The Monument, and the street frontage of the Goldman Sachs Head Offices, Plumtree Court. These changes eliminated previous unsustainable seasonal bedding schemes, promoting longevity, conserving water, all of which achieve significant cost savings alongside increased biodiversity support.

In 2018, the project was recognised by the Landscape Institute's (UK professional body for Landscape Architects) winning their national award for Planting Design and their Fellows' Award for Creating Healthy Spaces. The Landscape Institute remarked that "*This well-researched scheme delivers a breath of fresh air to this urban podium landscape' and 'represents a new benchmark for the future of urban planning*" (S8). The Barbican NVL approach has inspired other transformations of prestigious sites in London. Dunnett was invited by Grosvenor Great Britain and Ireland to apply the concept 'to ensure that the plants we are using are low-input, high-impact to create a landscape that is dynamic, diverse, and tuned to nature' across new areas of sustainable greening in Grosvenor Square (S9).

In 2016 Dunnett became the Royal Horticultural Society's (RHS) ambassador for the 'Greening Great Britain' campaign, promoting transformational urban greening through media appearances, articles and features in the RHS Journal 'The Garden' (circulation 450,000, UK's largest circulation horticulture journal). He delivered the 'Greening Great Britain' garden at the 2017 RHS Chelsea Flower Show, showcasing NVLs and The Barbican project, and

communicating the planting concepts to 150,000 show visitors and a TV audience of 3 million viewers (S10).

[Text removed for publication] Dunnett to applied the NVL concept as the basis for the pioneering roof garden on the first hospital building in the world with full outdoor life support for intensive care patients. The key aspect of NVLs in this context were their strongly natural character (important for well-being) combined with high aesthetic quality, and ease of maintenance, to create the sense of patients being surrounded by a vibrant and beautiful meadow (S11).

International Flagship: Melbourne Arts Precinct

In 2019, Dunnett was the horticulturist in the winning design team for the re-development of Melbourne's Arts Precinct, Australia (development delayed due to pandemic restrictions and will now start 2021) (S12). Based on the Barbican NVLs, 18,000m^2 of new public greenspace will create an estimated 10,000 new jobs during construction, and is expected to draw an additional 3 million people to the area each year. This is the biggest cultural infrastructure project ever undertaken in Australia (S13).

5. Sources to corroborate the impact (indicative maximum of 10 references)

S1. Testimonial, President of The Landscape Institute 2018-2020.

S2. Sheffield City Region Mayoral Combined Authority and Local Enterprise Partnership Local Growth Fund: Mid-Term Evaluation December 2020.

S3. Sheffield City Council 'Sheffield's Grey to Green Corridor' Film, September 2020.

S4. PhD Thesis, Adrien L'Homme, University of Sheffield. 2018.' Urban naturalistic meadows to promote cultural and regulating ecosystem services'. Pages 41, 43.

S5. CEEQUAL Case Studies, Grey to Green Phase 1.

S6. Barbican Landscape Review, *Daily Telegraph*, 11th October 11 2015.

S7. Testimonial, Open Spaces, City Parks and Gardens, City of London Corporation.

S8. Landscape Institute Awards 2018. Pages 62-63 & 86-87.

S9. Testimonial, Senior Development Manager, Grosvenor Great Britain and Ireland.

S10. BBC Film Chelsea Flower Show Feature 'The Barbican', 25th May 2017.

S11. [Text removed for publication]

S12. Testimonial, Hassel Studio.

S13. Victoria Government website.