Response to National Infrastructure Commission: Mainstreaming Green Infrastructure.

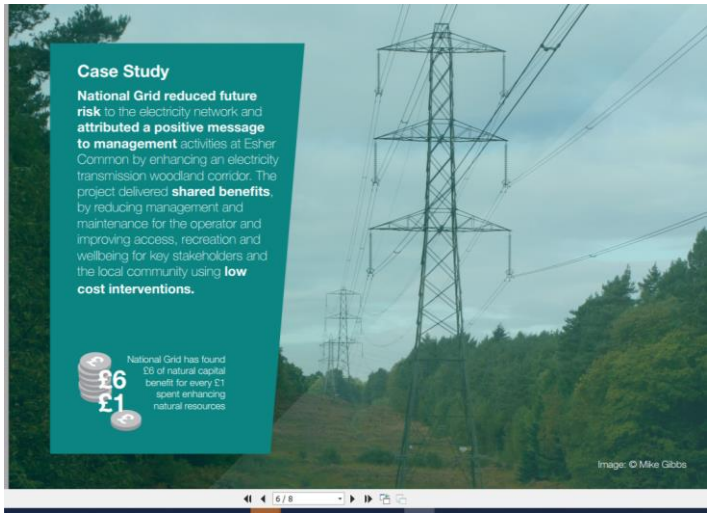
Scope and role of this initial response.

Following initial discussions with NIC a set of key themes with supporting rationale were circulated allowing this briefing paper to be formed. This paper provides a first attempt to (1) identify relevant research work (2) summarise key researcher contributions on each theme. (3) In addition some researchers have identified key themes which were not covered but have emerged from their work and might form useful considerations.

It might be useful given that many researchers here were unable to participate at a busy time in university preparation to arrange a meeting to discuss any specific needs/questions that rise from this briefing paper. Thus it should be seen as an evolving document.

1. **The need to consider place-keeping, social and environmental justice issues in existing national infrastructure developments.**

We are beginning to understand that our most deprived areas often have lack of access to quality greenspace. There are major infrastructure developments in such places with private green space which is not managed to its full potential; e.g. rail corridors; highways; retail developments. These are forgotten opportunity spaces which have potential for improved management for biodiversity and environmental gains and improved/managed access to public which could improve health and well being[1].



This also applies to proposed infrastructure developments and it becomes important that these considerations are built into the design phase at the earliest stage of project proposals rather than added retrospectively as an afterthought. By doing this some important ecosystem service benefits can be secured which have significant and long term economic benefits (preventing costs down the line).

[1] CIRIA Developing green infrastructure along linear assets https://www.ciria.org/Resources/Free_publications/Green_infrastructure_along_liner_assets_scoping_study_p1.aspx

2. **Infrastructure depends significantly on nature as an input:** For example, the scale of flood defences required might be dependent on natural flood management elsewhere in a water catchment.

This theme champions taking a systems within systems perspective (see Leach et al 2019[2]: ICASP 2020), set within the landscape(s) and ecosystems they are impacting on. From research on Urban Living in Birmingham, all too often development interventions are identified, designed and planned in separate silos meaning that rarely is there any join up or holistic diagnosis (Leach et al 2019).

Thus, important synergies are missed. Drawing upon separate ADEPT and NERC workshops[3] held by Scott in 2020 concerns were expressed about how this fracturing is evident in the planning system itself. Thus we have national infrastructure planning, town and country planning, environmental land management (agri environment and forestry, building regulations and utility planning all operating over the same places and spaces and all engaged in placemaking strategies but under separate governance frameworks and roles which actively prevent joined up solutions.

Crucially, this silo mentality misses the cumulative impacts of how for example investment in nature based solutions (e.g. tree planting) in one part of a catchment might mitigate flooding elsewhere and also help shape safer development. It also fails to capture the cumulative negative impacts of developments. This highlights that accounting for cumulative development is still a major weakness in current planning policy and practice (Scott et al 2014)[4].

For example it has been estimated that peatland rewetting has significant potential to reduce peak flows in river catchments (Alott et al 2019)[5] . The ONS have also published the natural capital value of peatlands which identify multiple benefits; (1) supply over a quarter of the UK's drinking water, valued at £888 million in 2016.(2) Estimated time spent for recreation on peatlands in 2016 is 180 million hours valued at £274 million (3) Publicly funded research on Peatlands estimated to be £882,796 in 2018.(4) The net benefits, in terms of climate change emissions alone, of restoring 55% of peatlands to near natural condition are estimated to have a present value of approximately £45billion to £51 billion. However only 22% peatlands are in a near natural or rewetted condition, consequently the Centre for Ecology and Hydrology (CEH) estimated peatlands emitting around 23,100 kt CO2e yr-1 greenhouse gas (GHG) in total.

There is a need therefore to look at the systems within systems[6]; hence the need identified above for closer alignment across the different planning systems within the planning system. Here taking account of the cumulative impact of development and interventions is a key challenge. Without such work perverse outcomes can all too easily occur.

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[2] Leach et al 2019 https://www.sciencedirect.com/science/article/pii/S0264275118303093

[3] ADEPT https://mainstreaminggreeninfrastructure.com/outputs-page.php?what-does-good-strategic-planning-for-nature-conservation-look-like- and NERC workshops https://mainstreaminggreeninfrastructure.com/outputs-page.php?strategic-planning-for-nature-conservation

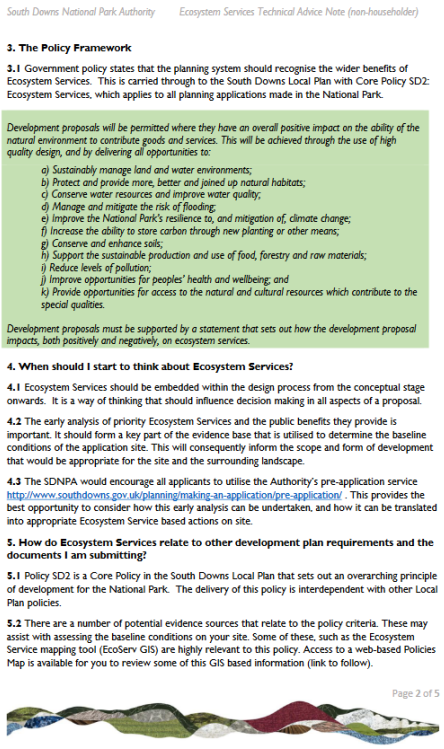
[4] Scott et al 2014 https://www.researchgate.net/publication/263696003_Evaluating_the_cumulative_impact_problem_in_spatial_planning_A_case_study_of_wind_turbines_in_Aberdeenshire_UK

[5] Alott et al 2019 https://research.bangor.ac.uk/portal/files/27930383/Allott_et_al_2019_IUCN_COI_Peatlands_and_NFM_FULL_REPORT.pdf

[6] Systems within systems challenges are holistically and exploratively diagnosed through an open process that does not focus upon a specific problem, issue, or system. This is rarely found in research or practice (Leach et al 2019)

To counter this risk involves a process objective to get all key stakeholder interests together at the outset to map existing developments and interventions and then to understand where the best places are for planned development(s) and their impacts. Here within the environmental lens the current state of natural capital/ecosystem service provision within an area can be used strategically to identify ecosystem service opportunity areas (Rode et al 2016)[7]. A practical application of this is within Bridgend which improves strategic planning for housing, employment and recreation[8]

Here good development depends on a good ecosystem services/natural capital mapping baseline. The South Downs National Park also provides a good case study using ecosystem service mapping as a baseline to discuss ecosystem service enhancement in any development application in a positive manner (Scott et al 2018)[9]. To work however the evidence base is backed up by a strong high level policy which must be met by all development in the park. This provides an important lesson for linking evidence with policy to achieve good outcomes[10].



South Downs National Park Authority *Ecosystem Services Technical Advice Note (non-householder)*

3. The Policy Framework

3.1 Government policy states that the planning system should recognise the wider benefits of Ecosystem Services. This is carried through to the South Downs Local Plan with Core Policy SD2: Ecosystem Services, which applies to all planning applications made in the National Park.

Development proposals will be permitted where they have an overall positive impact on the ability of the natural environment to contribute goods and services. This will be achieved through the use of high quality design, and by delivering all opportunities to:

a) Sustainably manage land and water environments;
b) Protect and provide more, better and joined up natural habitats;
c) Conserve water resources and improve water quality;
d) Manage and mitigate the risk of flooding;
e) Improve the National Park's resilience to, and mitigation of, climate change;
f) Increase the ability to store carbon through new planting or other means;
g) Conserve and enhance soils;
h) Support the sustainable production and use of food, forestry and raw materials;
i) Reduce levels of pollution;
j) Improve opportunities for peoples' health and wellbeing; and
k) Provide opportunities for access to the natural and cultural resources which contribute to the special qualities.

Development proposals must be supported by a statement that sets out how the development proposal impacts, both positively and negatively, on ecosystem services.

4. When should I start to think about Ecosystem Services?

4.1 Ecosystem Services should be embedded within the design process from the conceptual stage onwards. It is a way of thinking that should influence decision making in all aspects of a proposal.

4.2 The early analysis of priority Ecosystem Services and the public benefits they provide is important. It should form a key part of the evidence base that is utilised to determine the baseline conditions of the application site. This will consequently inform the scope and form of development that would be appropriate for the site and the surrounding landscape.

4.3 The SDNPA would encourage all applicants to utilise the Authority's pre-application service http://www.southdowns.gov.uk/planning/making-an-application/pre-application/ . This provides the best opportunity to consider how this early analysis can be undertaken, and how it can be translated into appropriate Ecosystem Service based actions on site.

5. How do Ecosystem Services relate to other development plan requirements and the documents I am submitting?

5.1 Policy SD2 is a Core Policy in the South Downs Local Plan that sets out an overarching principle of development for the National Park. The delivery of this policy is interdependent with other Local Plan policies.

5.2 There are a number of potential evidence sources that relate to the policy criteria. These may assist with assessing the baseline conditions on your site. Some of these, such as the Ecosystem Service mapping tool (EcoServ GIS) are highly relevant to this policy. Access to a web-based Policies Map is available for you to review some of this GIS based information (link to follow).

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Postance et al 2020[11] reveal through an innovative risk assessment methodology how 34% of Scotland road infrastructure is susceptible to land slip; thus highlighting the need for improved ability to plan and mitigate for extreme weather events. Increasing transport network resilience, requires the identification of the critical network segments which if disrupted would incur

[7] Rode et al 2016 https://www.sciencedirect.com/science/article/pii/S161713811630053X
[8] SCANN in Bridgend (2012) https://www.envsys.co.uk/wp-content/uploads/2015/02/A-Practical-application-of-SCCAN-in-Bridgend1.pdf
[9] Scott et al 2018 https://www.sciencedirect.com/science/article/pii/S0264837716306421
[10] South Downs National Park Authority https://www.southdowns.gov.uk/wp-content/uploads/2018/04/Core-07-Ecosystem-Services-Technical-Advice-Note-non-householder.pdf
[11] Postance et al 2020 https://iopscience.iop.org/article/10.1088/1748-9326/aa5555

undesirable or unacceptable socio-economic impacts. The results indicate that at least 152 road segments are susceptible to landslides (£35k -80k each day of closure). This suggests that infrastructure planning needs to use greater risk assessment tools to build in resilience rather than retrofit. In risk analysis, it is recognized that hazards can often combine to worsen their joint impact, but impact data for a rail network show that hazards can also tend to be mutually exclusive at seasonal timescales. So we need to champion a broader view of risk from compound hazards as illustrated in the diagram below (Hillier et al 2020)[12].

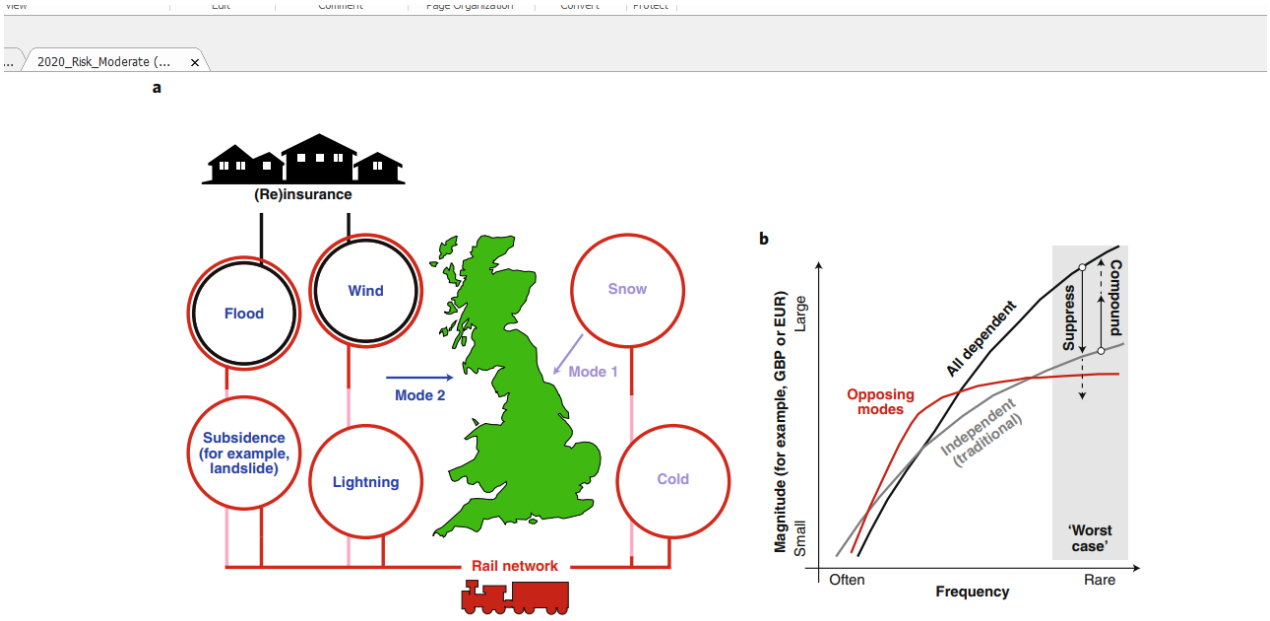

Fig. 1 | Illustration of plausible effects when the activity of hazard(s) switches between climatologically controlled modes of behaviour, based on Great Britain. a, Impact-centric[1,3] conceptualization of the multi-hazard system. Two hazard modes, each associated with a dominant wind direction (blue arrows), drive six hazards (circles). Rail infrastructure (red) is exposed to all six hazards, while (re)insurance (black) is primarily concerned with only two hazards in Mode 2. **b**, Losses in terms of magnitude and frequency, with rare 'worst cases' on the right-hand side (grey band). A conventional view that does not consider dependencies (grey) might underestimate risk if two hazards (for example, flood and wind) compound. However, where exposed assets are subject to hazards driven by two opposing modes (red), compounding effects are suppressed, so care is needed to avoid overestimating risk. Solid arrows represent effect magnitudes seen within the Network Rail loss data (Fig. 2 and Box 1), with dashed lines indicating plausible stronger effects.

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3. **Infrastructure creates harmful impacts on nature which are significant relative to other impacts:** Infrastructure's land footprint is small relative to agriculture for example, but the systemic nature of ecosystems means that some impacts may nonetheless be significant. We are keen understand whether infrastructure's specific impacts, viewed in a holistic context, are important relative to other causes of natural capital degradation.

According to recent report on Biodiversity loss from the EU the key drivers for loss are (1 Changes in land use (e.g. deforestation, intensive mono-culture, urbanisation) (2) Direct exploitation such as hunting and over-fishing (3) Climate change (4) Pollution (5) Invasive alien species[13]. This reinforces

[12] Hiller et al 2020 https://www.nature.com/articles/s41558-020-0832-y

[13] EU Parliament 2020 https://www.europarl.europa.eu/news/en/headlines/society/20200109STO69929/biodiversity-loss-what-is-causing-it-and-why-is-it-a-concern

the need for understanding the synergies between the different parts of the planning system and its sub systems. It is dangerous to try and separate out infrastructure to identify its single impact when the need for infrastructure development is caused through the operation of these factors. The current exploitation of the Amazon rain forest illuminates this link. Here a native ecosystem is destroyed by increased agriculture and forestry for markets. This activity leads to new roads and transport links to further open up the area.

So this theme raises legitimate issues about how effectively the planning system supports getting the right development in the right place. Here the role of the mitigation hierarchy is crucial yet not always observed[14]. In major projects EIA/SEA is the key mechanism for assessment of impacts but few EIAS contain a natural capital assessment or indeed even ecosystem services assessment (Baker et al 2013[15]; Turnpenny et al 2014[16]). However the requirement for developers to assess reasonable alternatives to their plan/project provides a means to for Nature Based solutions/ecosystem services to feature more prominently with potential to encourage environmentally-friendly solutions to meet economic/social development needs. Within this context, contractors and planners can build 'win-win' solutions, which not only meet their development needs, but also maintain or benefit the quality of affected ecosystems and habitats. However, the extent to which NBS are considered or adopted as an alternative to the originally proposed grey-dominant plans is unknown and remains an important research priority.[17].

Tools such as the Natural Capital Planning Tool[18] can help developers understand the impacts of their development on key ecosystem services thus providing a mechanism to deliver better and more connected GI solutions. This tool has been developed within Natural England's EcoMetric tool but is not yet in the public domain.

Using the example of the Black Country Garden City the NCPT was used to assess the impact of two proposals. The Sandwell one illustrated here was for 100 dwellings on a greenfield site (4.5ha). The NCPT assessment indicated negative impacts on almost all ecosystem services. This was not surprising because no new Natural Capital (greenspace) was proposed as part of the initial plan and 'grey infrastructure' would replace existing greenspace. Because the existing Natural Capital is not performing ecosystem services to a great extent, there is significant potential to improve the performance of the design which is also indicated by the maximum possible scores in the left-handed column which indicate the ecosystem services potential for the site. Thus rather than framing as negative impact we can start to work with developers to achieve positive impacts thus helping to make green infrastructure work harder. It is

[14] CBSI (2015) A cross-sector guide for implementing the Mitigation Hierarchy http://www.csbi.org.uk/wp-content/uploads/2017/10/Mitigation-Hierarchy-Executive-summary-and-Overview.pdf

[15] Baker et al 2013 https://www.sciencedirect.com/science/article/abs/pii/S0195925512000996

[16] Turnpenny et al 2014 https://ueaeprints.uea.ac.uk/id/eprint/50300/1/EPC_the_challenge_of_embedding_an_ESA_in_PA.Turnpenny_et_al.2014.pdf

[17] Naturvation (2018) https://naturvation.eu/sites/default/files/result/files/naturvation_nature-based_solutions_in_european_and_national_policy_frameworks.pdf p19 (Davis, M.; Abhold, K.; Mederake, L.; Knoblauch, D. (2018): Nature-based solutions in European and national policy frameworks. Deliverable 1.5, NATURVATION. Horizon 2020 Grant Agreement No 730243, European Commission, 50 pp

[18] Natural Capital Planning Tool http://ncptool.com/

important to realise however that the net gains or losses in each ecosystem services should not be reduced to a single impact score as ecosystem services are not transferable[19].

Initial Sandwell Masterplan

Source: Based on data provided by Sandwell MBC; digitalised by CEEP

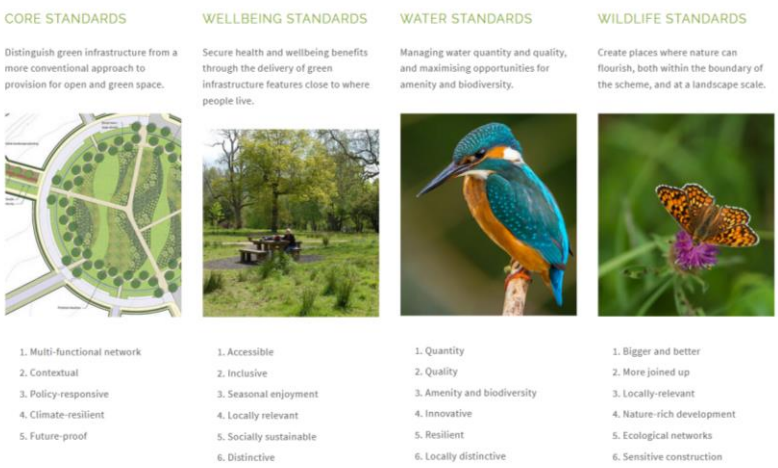
NCPT findings for Sandwell case study

Development Impact Score Average Per-Hectare			
Ecosystem Services Impact Scores	Max Possible	Adjusted Scores	Min Possible
1. Harvested Products	+0.04	+0.01	+0.00
2. Biodiversity	+3.77	-1.04	-1.23
3. Aesthetic Values	+0.36	-2.89	-4.64
4. Recreation	+3.01	-1.96	-1.99
5. Water Quality Regulation	+0.47	-0.88	-1.83
6. Flood Risk Regulation	+7.62	-0.20	-0.38
7. Air Quality Regulation	+5.51	+0.30	-2.49
8. Local Climate Regulation	+4.05	-0.94	-1.81
9. Global Climate Regulation	+4.52	-0.24	-0.48
10. Soil Contamination		+0.00	
Development Impact Score	+29.34	-7.83	-14.84

In looking at quality there is also a useful qualitative tool to help with improving green infrastructure in infrastructure developments, Building with Nature is the first UK benchmark for green infrastructure[20]. Building with Nature is a voluntary approach that enables developers to go beyond current statutory requirements to create places that really deliver for people and wildlife. It brings together guidance and good practice to recognise high quality green infrastructure at all stages of the development process including policy, planning, design, delivery, and long-term management and maintenance. It comprises 23 standards and involves a developer working with an assessor to ensure the development meets the requirements. It is not metric based and is context based involving multiple evidence sources and a strong process where the environmental components of a scheme are embedded at the design stage for maximum impact.

[19] See also Holzinger et al 2019 https://mainstreaminggreeninfrastructure.com/reports/Oliver%20Holzinger%20Natural%20Capital%20Planing%20Toolkit%20for%20measuring%20net%20gains.pdf

[20] Building with Nature https://www.buildingwithnature.org.uk/



The framework of standards is divided into four themes: core, wellbeing, water and wildlife. There are three levels of accreditation:

Design - high quality green infrastructure demonstrated at the planning and design stage of development;
Good - high quality green infrastructure, delivering benefits within the boundary of the scheme;
Excellent - exemplary quality green infrastructure, delivering benefits within and beyond the boundary of the scheme.

Meeting these standards help developers think carefully about how to work more effectively with nature as an asset moving away from simple metric box ticking. It becomes more about developing a story about your development. This can be highly effective and has produced exemplar developments.

The EU funded IGNITION[21] project helps tackle a variety of urban climate-related challenges including flooding, drought and heat waves as well as improving air quality, biodiversity, productivity, health and well-being. Evidence of the performance and potential economic, environmental and social benefits of installing green infrastructure is central to the development of robust business case for investment in nature-based solutions. The IGNITION evidence base currently covers the multiple-benefits of green walls, street trees, urban green space, green roofs and sustainable drainage systems (SuDS).

Using the example of urban green space (an extract captured below), 317 evidence items were assesed from 163 different data sources. 24% related to health and wel being; 13% carbon and 10% land and property benefits; 3% noise and biodivrsity and 2% local economic bene fits.

[21] IGNITION https://www.greatermanchester-ca.gov.uk/what-we-do/environment/natural-environment/ignition/

Benefit	Description	Summary findings	Unit
Air quality	NO_2 removal	2.6%*	% reduction in ambient concentration of NO^2 50m inside a park
	Particulate matter (PM_{10})	9.1%*	% reduction in ambient concentration of PM_{10} 50m inside a park
		1.45*	PM_{10} captured g m^2 yr.
Carbon	Carbon sequestration	0.2 [Rng. 0.09 - 0.41]	Avg. carbon sequestered kg yr. m^2
	Above ground carbon storage	1.01 [Rng. 0.1 – 3.16]	Avg. carbon stored kg m^2
	Below ground carbon storage	5.9 [Rng. 1.4 – 7.7]	Avg. carbon stored kg m^2
Water quantity	Runoff	6.8 [Rng. 6 – 8]	Avg. runoff from green spaces l m^2 for per 10mm rainfall event
		3.36 [Rng. 0.6-4.8]	Avg. runoff from green spaces l m^2 for per hour 40mm rainfall event
	Infiltration rate	30% [Rng. 18 - 35%]	Avg. % annual rainfall retained or infiltrated
Water quality	All pollutants	85%*	% reduction in all pollutant concentrations
	Suspended sediments	42 - 100% [Midpoint 71%]	% reduction in total suspended sediment concentrations
	Phosphorous	22 – 95% [Midpoint 58.5%]	% reduction in total soluble phosphorous concentrations
	Nitrates	31 - 100% [Midpoint 65.5%]	% reduction in total soluble nitrate concentrations
Temperature	Air temperature	2.7°C [Rng. 0.5 - 7°C]	Avg. air temperature reductions daytime °C
	Night-time temperature	1.2°C	Avg. air temperature reductions night-time °C
Energy use	Annual cooling savings	15.4 [Rng. 9.7 - 24.7]	kWh per day (data from non-UK studies)
		10-17% [Midpoint 13.5%]	% seasonal cooling-energy savings per day
Health and well-being	Mental health	Not possible to summarise	Not possible to summarise
	Physical health	Not possible to summarise	Not possible to summarise
Noise attenuation	Sound reduction	4	Decibels reduction per m2
Land and property value	Direct or close proximity to a park or green space	9.5% [Rng 2.6 - 20%)	Avg. % uplift in property value
	Between 100-600m from a green space or park	3.1% [Rng. 0.5 - 8%]	Avg. % uplift in property value

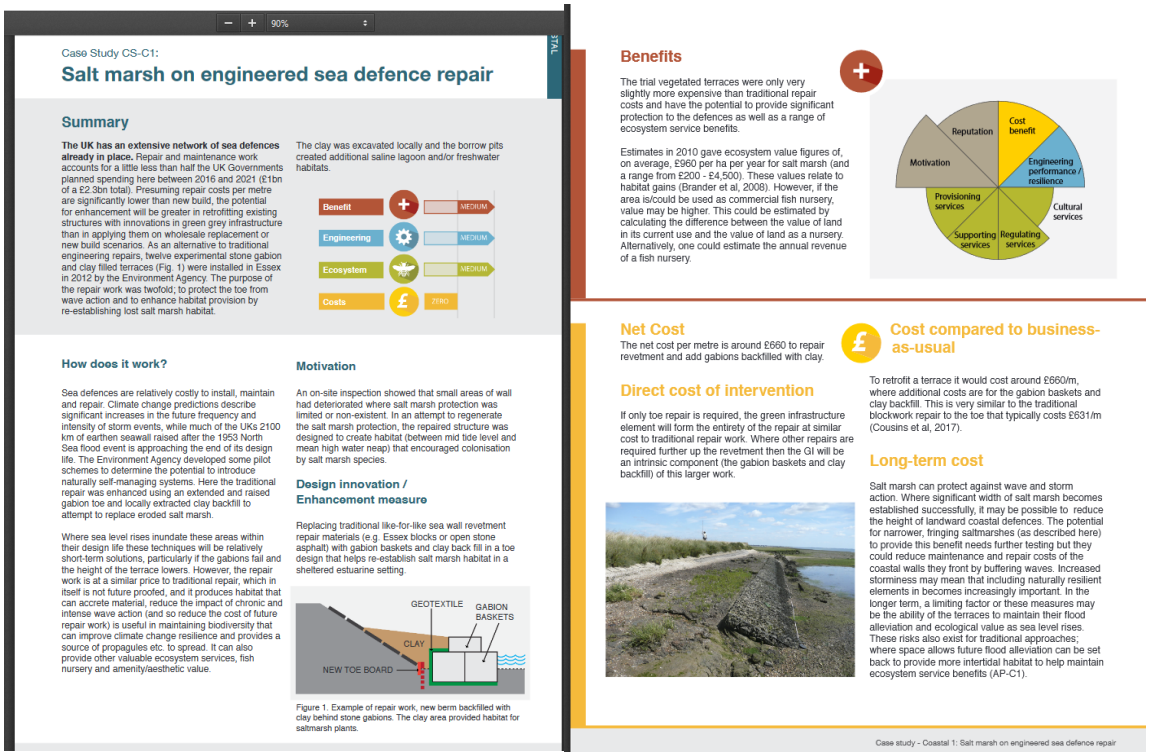
4. **In respect of any of the above three interdependencies, there are mitigation/improvement options (whether for active project sponsors or passive asset owners) which are potentially cost-effective relative to other natural capital improvement**: For example, we are interested in the costs and benefits of mitigation/improvement options (e.g. green infrastructure) relative to other natural capital interventions (e.g. subsiding environmental land management).

In terms of addressing this theme explicitly there is a dearth of research on this. This also begs the question of what green infrastructure is and isn't (Scott et al 2019) [22]. The green network will by definition normally include both urban and rural settings which then blurs the boundary between improving green infrastructure and subsiding env land management as they become part of the same system.

Larissa Naylor has done some useful work identifying the opportunities, economic costs, wider benefits and risks of approaches to construction and development that seek to green elements of grey infrastructure[23]. The example below from the appendices is one of several case studies which demonstrate value of GI solutions for a range of different types of development.

[22] Scott et al 2019 https://mainstreaminggreeninfrastructure.com/project-page.php?understanding-our-growing-environmental-vocabulary-in-england

[23] Naylor http://eprints.gla.ac.uk/150672/37/150672Full.pdf



Case Study CS-C1:

Salt marsh on engineered sea defence repair

Summary

The UK has an extensive network of sea defences already in place. Repair and maintenance work accounts for a little less than half the UK Governments planned spending here between 2016 and 2021 (£1bn of a £2.3bn total). Presuming repair costs per metre are significantly lower than new build, the potential for enhancement will be greater in retrofitting existing structures with innovations in green grey infrastructure than in applying them on wholesale replacement or new build scenarios. As an alternative to traditional engineering repairs, twelve experimental stone gabion and clay filled terraces (Fig. 1) were installed in Essex in 2012 by the Environment Agency. The purpose of the repair work was twofold; to protect the toe from wave action and to enhance habitat provision by re-establishing lost salt marsh habitat.

The clay was excavated locally and the borrow pits created additional saline lagoon and/or freshwater habitats.

Benefit MEDIUM
Engineering MEDIUM
Ecosystem MEDIUM
Costs ZERO

How does it work?

Sea defences are relatively costly to install, maintain and repair. Climate change predictions describe significant increases in the future frequency and intensity of storm events, while much of the UKs 2100 km of earthen seawall raised after the 1953 North Sea flood event is approaching the end of its design life. The Environment Agency developed some pilot schemes to determine the potential to introduce naturally self-managing systems. Here the traditional repair was enhanced using an extended and raised gabion toe and locally extracted clay backfill to attempt to replace eroded salt marsh.

Where sea level rises inundate these areas within their design life these techniques will be relatively short-term solutions, particularly if the gabions fail and the height of the terrace lowers. However, the repair work is at a similar price to traditional repair, which in itself is not future proofed, and it produces habitat that can accrete material, reduce the impact of chronic and intense wave action (and so reduce the cost of future repair work) is useful in maintaining biodiversity that can improve climate change resilience and provides a source of propagules etc. to spread. It can also provide other valuable ecosystem services, fish nursery and amenity/aesthetic value.

Motivation

An on-site inspection showed that small areas of wall had deteriorated where salt marsh protection was limited or non-existent. In an attempt to regenerate the salt marsh protection, the repaired structure was designed to create habitat (between mid tide level and mean high water neap) that encouraged colonisation by salt marsh species.

Design innovation / Enhancement measure

Replacing traditional like-for-like sea wall revetment repair materials (e.g. Essex blocks or open stone asphalt) with gabion baskets and clay back fill in a toe design that helps re-establish salt marsh habitat in a sheltered estuarine setting.

GEOTEXTILE
GABION BASKETS
CLAY
NEW TOE BOARD

Figure 1. Example of repair work, new berm backfilled with clay behind stone gabions. The clay area provided habitat for saltmarsh plants.

Benefits

The trial vegetated terraces were only very slightly more expensive than traditional repair costs and have the potential to provide significant protection to the defences as well as a range of ecosystem service benefits.

Estimates in 2010 gave ecosystem value figures of, on average, £960 per ha per year for salt marsh (and a range from £200 - £4,500). These values relate to habitat gains (Brander et al, 2008). However, if the area is/could be used as commercial fish nursery, value may be higher. This could be estimated by calculating the difference between the value of land in its current use and the value of land as a nursery. Alternatively, one could estimate the annual revenue of a fish nursery.

Reputation
Cost benefit
Motivation
Engineering performance / resilience
Provisioning services
Cultural services
Supporting services
Regulating services

Net Cost

The net cost per metre is around £660 to repair revetment and add gabions backfilled with clay.

Direct cost of intervention

If only toe repair is required, the green infrastructure element will form the entirety of the repair at similar cost to traditional repair work. Where other repairs are required further up the revetment then the GI will be an intrinsic component (the gabion baskets and clay backfill) of this larger work.

Cost compared to business-as-usual

To retrofit a terrace it would cost around £660/m, where additional costs are for the gabion baskets and clay backfill. This is very similar to the traditional blockwork repair to the toe that typically costs £631/m (Cousins et al, 2017).

Long-term cost

Salt marsh can protect against wave and storm action. Where significant width of salt marsh becomes established successfully, it may be possible to reduce the height of landward coastal defences. The potential for narrower, fringing saltmarshes (as described here) to provide this benefit needs further testing but they could reduce maintenance and repair costs of the coastal walls they front by buffering waves. Increased storminess may mean that including naturally resilient elements in becomes increasingly important. In the longer term, a limiting factor or these measures may be the ability of the terraces to maintain their flood alleviation and ecological value as sea level rises. These risks also exist for traditional approaches; where space allows future flood alleviation can be set back to provide more intertidal habitat to help maintain ecosystem service benefits (AP-C1).

Case study - Coastal 1: Salt marsh on engineered sea defence repair

5. **There are structural issues preventing infrastructure operators/owners from taking forward cost-effective natural capital measures on a significant scale.**

Perhaps the biggest issue here is the conceptual one where the environment is still framed within many infrastructure developments as a constraint to be overcome rather than as an asset. The development manuals and training still focus on hard engineering options with nature based solutions not seen as viable or meeting existing standards; a computer says no syndrome.

Across the literature whilst there is a lot of work undertaking natural capital assessments of environmental assets there is no consistent approach to quantifying the impact of GBI investments on Ecosystem Services and Natural Capital. As the Naturvation project exposed the extent to which NBS and GBI are considered or adopted as alternatives to originally proposed grey-dominant plans is unknown and remains a research priority.

When making a case for development developers will follow the Treasury green book where the business and strategic case are separated. Unfortunately, there is no clear guidance on what constitutes “robust” and “appropriate” valuation evidence to include within the measured impact of GBI investments on Ecosystem Services and Natural Capital in the Economic Case which weakens its impact when compared with other consistent economic data. There is a wider issue that in this area

there are no clear examples of what good looks like. It is disappointing that the report on the Defra Pioneer projects is still not in the public domain as this would have some useful messages[24].

There are important opportunity spaces. For example, biodiversity net gain is being mandated for development in the forthcoming Environment Bill, but at the time of writing, major infrastructure projects would be exempt from this requirement. This requires a greater culture of trying to "build back greener and to integrate biodiversity, climate and health and well being standards into all developments. Whilst emergent schemes like Building with Nature can do this it is not mandatory and increased regulation is important in securing change as long as there are incentives to do this. It is unclear why national infrastructure developments should be exempted from having to secure the 10% net gain but it is clear that major schemes like HS2 involve the loss of irreplaceable habitats and therefore would never be able legitimately to claim net gain. This does raise a key question of how developments that are allowed to go ahead as they are in the national interest as to how environmental gains are qualified and quantified.

In addition, net gain policies of infrastructure owners may be ineffective if restrictions on where they can place environmental improvements result in piecemeal and unconnected habitats, which are ecologically fragile and are highly unlikely to improve biodiversity.

Key Players and Projects that can help feed this strand of work include[25]

Larissa Naylor Larissa.Naylor@glasgow.ac.uk key author of greening the grey NERC project
Harriet Bulkeley h.a.bulkeley@durham.ac.ukPI of Naturvation[26]
John Hillier J.Hillier@lboro.ac.uk NERC KE fellow Risk
Andrew Brown A.Brown@lubs.leeds.ac.uk Lead ICASP project[27].
Alison Smith alison.smith@eci.ox.ac.uk Lead EcoMetric project

[24] Defra Pioneers an interim 2018 report is here http://sciencesearch.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=20084 Defra have established four "Pioneer" projects to aid in the development of the 25 year Plan: a catchment Pioneer in Cumbria; an urban Pioneer in the Greater Manchester area; a landscape Pioneer in North Devon; and a marine Pioneer across two sites, one in East Anglia and another component in Devon. These projects are intended to act as test-beds to develop methods for natural capital assessments that could be scaled up and applied at the national level.

[25] Important point to note that given deadline and imminent preparation for university teaching I have not been able to have proper conversations with these and key reports are still not I the public domain. It may be useful to have a virtual meeting later in the year.

[26] Key work yet to come on stepping stones which feeds into this document but not yet published.

[27] Key work on barriers to nature via Treasury Green Book and review of tools. Report currently being finalised.