Green infrastructure as a climate change adaptation policy intervention: Muddying the waters or clearing a path to a more secure future?

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Abstract

As dangerous climate change looms, decision-makers are increasingly realising that societies will need to adapt to this threat as well as mitigate against it. Green infrastructure (GI) is increasingly seen as an ideal climate change adaptation policy response. However, with this research the authors identify a number of crucial knowledge gaps within GI and, consequently, call for caution and for a concerted effort to understand the concept and what it can really deliver. GI has risen to prominence in a range of policy areas in large part due to its perceived ability to produce multiple benefits simultaneously, termed 'multifunctionality'. This characteristic strengthens the political appeal of the policy in question at a time when environmental issues have slipped down political agendas.

Multifunctionality, however, brings its own set of new challenges that should be evaluated fully before the policy is implemented. This research takes important first steps to developing a critical understanding of what is achievable within GI's capacity. It focuses on one of GI's single objectives, namely climate change adaptation, to focus the analysis of how current obstacles in applying GI's multifunctionality could lead to the ineffective delivery of its objective.

By drawing on expert opinion from government officials and representatives from the private, non-government organisation (NGO) and academic sectors, this research questions GI's ability to be effectively 'multifunctional' with an inconsistent definition at its core, deficiencies in its understanding and conflicts within its governance. In light of these observations, the authors then reflect on the judiciousness of applying GI to achieve the other objectives it has also been charged with delivering.

Key words: green infrastructure; climate change adaptation; biodiversity; ecosystem services; multifunctionality; interdisciplinary.

1. Introduction

Central to the preservation of our environmental spaces is the acknowledgement of the environment's role in the maintainence and enhancement of our way of life. Amidst a history of similar concepts failing to communicate our ever more scientific and complex understanding, green infrastructure is a recent environmental policy intervention it is hoped can bridge the divide between scientific robustness and civil society application.

At its most simple, the concept can be defined as *'a network of green features that are interconnected and therefore bring added benefits and are more resilient'* (EEA, 2011, p30) than if they remained isolated. These additional benefits are numerous and include climate change mitigation, climate change adaptation, biodiversity conservation, water management, food provisioning and improving recreational space, to name a few. Possessing this capacity to be multifunctional enhances the concept's political appeal at a time when environmental issues are widely considered to have slipped down political agendas. So far, however, there has been little consideration of what some of the challenges of delivering GI's multifunctionality effectively are, and if the concept is in a position to implement them and maximise its potential.

This research takes a first step in this discussion by critically assessing GI's potential ability to deliver one of its individual benefits – climate change adaptation (CCA) - and in doing so, comment on the state of its ability to deliver numerous benefits simultaneously. Choosing CCA as the lens for this assessment is pertinent given that in their latest report, the international governing research body on climate change, the Intergovernmental Panel on Climate Change (IPCC), predicted that if we continue along our current emissions pathway, global temperatures could rise by as much as 4.8°C by 2100 (IPCC, 2013). A number of influential institutions have echoed this sentiment, suggesting our chances of limiting climate change to the internationally agreed target of 2°C, are becoming increasingly slight (PwC, 2012; IEA, 2012; World Bank, 2012). Also playing into this decision is the waning belief that a meaningful international mitigation agreement can be achieved. Consequently, it is logical, if not essential that academic and political attention now considers measures for adapting societies.

2. Research methodology

At its deductive core this paper tests the hypothesis that GI is a concept that can effectively deliver multifunctionality, by assessing its potential to deliver CCA. However, this is complemented by an inductive component - exploratory observations and discussions are made to theorise what GI can and can't achieve more broadly.

A combination of literature review and desk-based analyses of secondary data - with a strong focus on current policy landscapes and academic literature - along with semi-structured interviews, were utilised in the research methodology. The 'snowball sampling method' (Biernacki and Waldorf, 1981) was prominent in this methodology, in that within each article, a wealth of relevant studies exists in its bibliography that were followed up where appropriate.

Qualitative document analysis (QDA) was used for analysing key policy, academic articles and interview notes. QDA refers to the *'method, procedure and technique for locating, identifying, retrieving and analysing documents for their relevance, significance and meaning'* (Altheide et al., 2008, p128). This involves developing a 'protocol' and testing it on each unit of analysis, e.g. each article, and revising it based on the quality, quantity and likely efficiency of the results (Altheide et al., 2008). The protocol was formed of key words and phrases organised by category and were shaped by the analytical purpose required. In completing this method of analysis, however, there is a threat of bypassing important contexts or paraphrased descriptions. Consequently, where possible, the entire article or report would be reviewed.

The selection of interviewees focused on achieving a sample that reflected the range of perspectives from high level governance institutions responsible for theorising GI and ground level GI practitioners. To achieve this, a list of stakeholder groups relevant to the themes likely to emerge under analysis was drawn up, followed by a long-list of possible interviewees to prepare for the difficulties of capturing interviews.

The names of interviewees have been concealed in Table 1 for confidentiality purposes, but the sector in which they operate is divulged to highlight the breadth of areas captured by this analysis. This is represented by a code assigned to each interviewee. Reference 'A' indicates an EU level government official, 'B' represents a national level

government official, 'C' local/regional level government official and 'D' aspects of civil society including private sector, academia and not-for profits all within the UK.

Table 1: Categorisation of interviewees

Interviewee Reference	Sector	Position/perspective
A1	European Commission Official	Green infrastructure
A2	European Environment Agency Official	Vulnerability of the territorial environment and natural systems
B1	UK Government Official	Adviser on green infrastructure
B2	UK Government Official	Adviser for strategic environmental planning
C1	Local Government Official	Green infrastructure manager
C2	Regional Government Official	Greening team leader
D1	Private Sector	Environment consultant
D2	UK Academic	Sustainable water management
D3	Regional Project Director	Director
D4	Regional Environmental NGO Official	Deputy CEO
D5	UK Academic	EU Project leader

3. Background: The problem with green infrastructure - What is it?

The term green infrastructure is relatively new; however, the concepts that underpin it can be traced back to the beginnings of environmentalism, nature conservation, landscape architecture and planning (Pankhurst, 2010).

The first signs of GI arose when the urban planning and nature conservation/environmental awareness merged for the first time with the Boston 'Emerald Necklace' at the end of the 19th Century, described as a '*complex multi-functional environmental design solution'* which linked areas by green corridors (Engleback, 2009, p24). Planning and conservation were once again brought together in the garden city movement towards the turn of the 20th Century and in the UK's New Town movement after the Second World War.

The evolution of these movements and the lessons learned from them were key factors in the run-up to the first explicit use of the term 'green infrastructure' in the 1980-90s in the US for which the expression was used to emphasise the importance of nature's ecological services (Engleback, 2009). This brief history illustrates that GI is a relatively new concept in name, but not in theory. It also illustrates that GI has always had a multi-disciplinary basis, a factor considered later.

Now, as the broad range of GI's capabilities have become more widely understood, the concept has been adapted and broadened further. In their research, the EEA (2011) identified eight classifications of applications for GI – biodiversity protection, CCA, climate change mitigation, water management, food production, recreational benefits, land values and cultural benefits. These disciplines have each co-opted GI towards their own objectives. Due to such breadth, there is a risk of inconsistency and uncertainty in the understanding of what GI actually is, which could undermine its ability to deliver the objectives of these various proponents.

3.1 Green infrastructure and climate change adaptation

One benefit GI has been charged to deliver, and the focus of this paper, is climate change adaptation. It is through this lens that GI and it's effective multifunctionality will be assessed. GI achieves three main CCA benefits, as identified by the European Environment Agency (2011): mitigating the urban heat island effect; flood risk management; and ecosystem resilience.

Urban heat island effect

When assessing 16 capital cities of Europe, the WWF (2005) found that the mean temperatures of 13 of them had risen by at least 1°C since the 1970s. There are two main reasons for the disproportionate heating of urban areas – most urban buildings are built with impermeable materials, so moisture is not available to help dissipate heat and a significant presence of dark materials serve to collect and trap more of the sun's energy (Gartland, 2008). This poses a significant threat to the functionality of urban ecosystems, the provision of their services, and the safeguarding of human life.

Bowler et al.'s (2010) research observed that urban greening cooled the average park by 0.94°C in the day. Gill et al. (2007) corroborate these findings by stating that,

depending on the emissions scenario, adding 10% more green space to urban areas would reduce maximum surface temperatures by 2.2-2.5°C by the 2080s compared to the 1961-1990 baseline. Pataki et al. (2011, p34) feel that the cooling effects of urban forests *'are likely to be more important than GHG reduction efforts in mitigating the threats of climate change to urban areas*' (Pataki et al., 2011, p34).

Flood risk management

The impermeable nature of most modern urban areas increases the rate and volume of surface water runoff, rendering them most at risk (Mansell, 2003). Coupled with predictions of extreme weather events and winter precipitation being exacerbated by climate change, especially in Northern Europe, the future potential for dangerous flooding seems high.

Again, Gill et al. (2007) attempt to quantify such processes and find that green cover can reduce run-off from urban areas by 4.9% and that tree cover reduces runoff by 5.7%, both from 28mm precipitation events. Brenner-Guillermo (2007 cited by Naumann et al., 2011b) value water flow regulation in urban green space at $15 per hectare per year.

Ecosystem resilience

Ecosystems are expected to tolerate some level of future climate change, as such, resilience is defined as *'the ability of a social or ecological system to absorb disturbances while retaining the same basic structure, ways of functioning, capacity for self-organisation and capacity to adapt to stress and change*' (IPCC, 2007, p86). Ecosystem fragmentation threatens this ability to absorb disturbances. Current geographical patterns of economic development combined with approaches towards environmental protection have rendered nearly 30% of the EU territory moderately to very highly fragmented (Naumann et al., 2011a). Climate change will worsen this level of fragmentation, which in turn degrades the ecosystems that, if healthy, can resist and recover more easily from extreme weather events (EU WG Biodiversity and Climate Change, 2009). GI's ability to increase protected area provision and strategic design, whilst maintaining habitat connectivity, constitutes improved habitat cohesiveness and is likely to increase ecosystem resilience to climate change (Campbell, 2009).

This background review illustrates the contribution GI can make to CCA is significant if fulfilled and that there are overlaps between GI's benefits to CCA and other environmental objectives.

4. Analysis: Uncertainties in understanding and implementing GI

4.1 Scope for convolution: GI's multidisciplinary background

Section 3 gives an insight into GI's multidisciplinary origins that often give ruse to the stance, as adopted by Natural England, that its interdisciplinary nature '*gives GI its strength*' (Pankhurst, 2010, p10). While this is likely to be the case, it also brings unique challenges to practitioners' understanding of GI's components, their priorities and interactions.

To explore the risk of convolution, a policy analysis centring on three concepts fundamental to GI - biodiversity conservation, climate change adaptation and the provision of ecosystem services (ESSs) - has been used below to start bringing clarity to the theoretical structure underlying the umbrella term 'green infrastructure'.

Biodiversity conservation is the primary driver of GI

Due to theoretical commonalities, it can be said that GI is a concept firmly aligned with the 'ecosystem approach' developed by the Convention on Biological Diversity (CBD) COP5. This approach encourages environmental considerations to operate at a landscape scale much like GI. It also strongly emphasises a fully integrative management approach - an attribute integral to GI's broad, multifunctional focus – when describing the ecosystem approach in Decision V/6 as a '*strategy for the integrated management of land, water and living resources*' and goes on to emphasise the need for '*increased intersectoral communication and cooperation at a range of levels*' (CBD, 2000). This level of coherence led the European Commission (2010a, p7) to state that GI may not be a '*direct consequence of the ecosystems approach, [but] it can be said that it is based on this approach*'. Furthermore, at the EU level it is from the EU Biodiversity Strategy to 2020 that a commitment for the Commission to develop a GI strategy was made (EC, 2013).

Ecosystem services is consistently a factor

The ESSs concept was defined in the Millennium Ecosystem Assessment (MEA) and is ever-present in references to the GI concept. The most recent communication from the EC on GI asserts that '*GI requires an integrated view of ecosystem services*' (EC, 2013, p6). To the present day, ESSs has attracted swathes of attention due to its ability to fill the gap in society's understanding of the important role the environment plays in maintaining our existence. In particular, placing a monetary value on ESSs has been earmarked as an effective way to justify policy and persuade decision-makers that conservation and securing ESSs provision is a viable investment option. However, current valuation methodologies are not comprehensive or accurate enough. A statement from interviewee D1 (2012) encapsulates the current state of ESSs valuation assessments aptly; '*there is a lot of good academic work around it, but who was using it? How was it actually affecting planning?*'

Therefore, some see GI to be an extension of the ESSs concept and an opportunity to link further resources to natural capital valuation research and re-energise the sector. So, while the link between the two concepts seems established, how does this relationship coincide with efforts to conserve biodiversity? Also, if the aim is for GI to aid the progress and conceptual uptake of ESSs, does it subsume ESSs? And if not, what are the benefits of their co-existence? Section 5 discusses some of these questions.

Climate change adaptation is becoming increasingly prominent

Climate change considerations are increasingly significant in the application of environmental management tools. Gradually, the focus on CCA within climate change policy has been growing due to the increasingly grave predictions from climate change science. In international discussions and policy, CCA has grown from fleeting references in United Nations Framework Convention on Climate Change (UNFCCC) statements to an agreement at the UNFCCC COP16 that '*adaptation is urgently required*' (UNFCCC, 2010, p5).

The gap between GI and CCA was bridged in 2009 with the EU Adapting to Climate Change White Paper (CEC, 2009, p5), which emphasised GI's '*crucial role in adaptation in providing essential resources for social and economic purposes under extreme climatic conditions'.* From this signal of political intent and predictions of increasingly apparent climate change impacts, it can be assumed GI's convergence to CCA considerations is

likely to accelerate – some see GI as '*one of the most promising opportunities'* for CCA measures (Gill et al., 2007, p131). This acceleration may, in fact, be facilitated by the ecosystem approach flagged earlier, which advocates the use of ecosystem-based approaches to harness the adaptive capabilities of nature, as well as the precautionary approach that action '*may need to be taken even when some cause-and-effect relationships are not yet fully established scientifically*' (CBD, 2000).

Clearly, the biodiversity conservation, ESSs and CCA discplines all see a significant role for GI and have outlined it as such in policy. This may also be the case for the other, arguably more peripheral, disciplines which can also benefit from applying GI. Scope for convolution could emerge when trying to satisy these policy targets simultaneously, when choices have to be made between potential beneficial impacts which *can not* occur simultaneously. An ability to prioritise objectives and impacts, therefore, is essential. Partly this will be determined on a case-by-case basis. But it will also rely in part, on thinking, such as this, around what the foremost underlying goals of GI are.

4.2 Scope for inconsistency: Variable definition content

Presently, the breadth of the GI concept means that '*what constitutes GI varies with each application and is dictated by the priorities and objectives of its user*' (EEA, 2011, p30). This allows discrete conceptual objectives to adjust GI's content and emphases to serve the required purpose. The lack of a static, universal definition is atypical and could result in a lack of consistency in its application and, in turn, a lack of clarity in its comprehension.

To get a sense if this is occurring with GI, 20 definitions from different stakeholders have been compiled to assess the level of consistency in the definition of 'green infrastructure'. Table 2 shows the results of analysing each definition in turn against a set of criteria with regards to GI's perceived i) scale; ii) benefits; and iii) approach.

The definitions selected in Table 2 are designed to cover stakeholders at all scales, from international to regional applications. It is important to note that counts are given to classifications in instances where synonymous terms are used instead of the exact stated terminology.

Table 2: Characterising definitions of green infrastructure

Reference	Classification	Scale				Benefits						Approach			
		Urban	Rural	Site specific	Landscape	Ecological functions	Climate change mitigation	Climate change adaptation	Economic	Ecosystem services	Biodiversity Enhancement	Triple bottom line	Strategic/planning	Conservation	Sustainable development
European Commission (Naumann et al., 2011a)		•	•			•	•	•		•	•				
European Commission (2013)		•	•	•	•					•					
Marco Fritz, EC (cited by EEA, 2011)						•				•	•				
EC GI Workshop (1) (Sundseth and Sylwester, 2009)					•	•							•		
EC GI Workshop (2) (Sundseth and Sylwester, 2009)										•					•
EC GI Workshop (3) (Sundseth and Sylwester, 2009)										•					
EC GI Workshop (4) (Sundseth and Sylwester, 2009)						•				•					
EC GI Workshop (5) (Sundseth and Sylwester, 2009)						•				•			•		
EU Council: Biodiversity Conclusions (EC, 2010b)						•		•		•					
Biodiversity WG Briefing Paper (EEAC, 2009)		•				•									
US EPA (2008)								•							
Natural England (2010)						•				•			•		
Natural England (2011)		•	•		•			•	•		•	•			
Benedict and McMahon (2002)													•	•	
Benedict and McMahon (2006)						•				•			•		
UK PPS 12 (2008)		•	•			•									•
NW GI Guide (2008)		•	•						•	•		•	•		
CABE (2009)												•	•		
UK NEA (2011)		•	•										•		
Landscape Institute (2009)		•	•									•	•		
Total		**8**	**7**	**1**	**3**	**10**	**1**	**4**	**2**	**11**	**3**	**4**	**9**	**1**	**2**

A number of examples can be drawn upon to illustrate important differences in the use and content of GI's definition. Comparing the top two definitions of GI in Table 2, both made by the European Commission (EC) provides an ideal example of this problem. Nearing the completion of this paper, the EC's applied definition of GI appeared to be set on that used by Naumann et al. (2011a; 2011b), which had been referred to in a number of research papers. However, in May 2013 a communication from the EC on GI applies a different definition where GI is defined as;

'*A strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services. It incorporates green spaces (or blue if aquatic ecosystems are concerned) and other physical features in terrestrial (including coastal) and marine areas. On land, GI is present in rural and urban settings*' (EC, 2013, p3).

This definition has different content and emphases of what GI is to that of Naumann et al., as illustrated in Table 2. The earlier definition focuses more on the numerous areas of benefit GI is able to achieve, whereas the 2013 definition is less specific in only mentioning its delivery of ESSs benefits generally, choosing instead to emphasise GI's ability to transcend environmental scales and ecosystem types. In general this latest definition is more broad and flexible than that used for years previously. This may be a beneficial move by the EC, but this change in definition may illustrate that GI remains a working concept that is still being understood and refined.

The fact that more than one definition of GI is sourced from Natural England in the UK and leading GI thinkers in the US, Benedict and McMahon, in Table 2 further corroborates this point. For those already embarking on its implementation, such alterations could mark another setback in the consistency and guidance of GI, and have knock-on effects on practitioners' confidence in the concept's application.

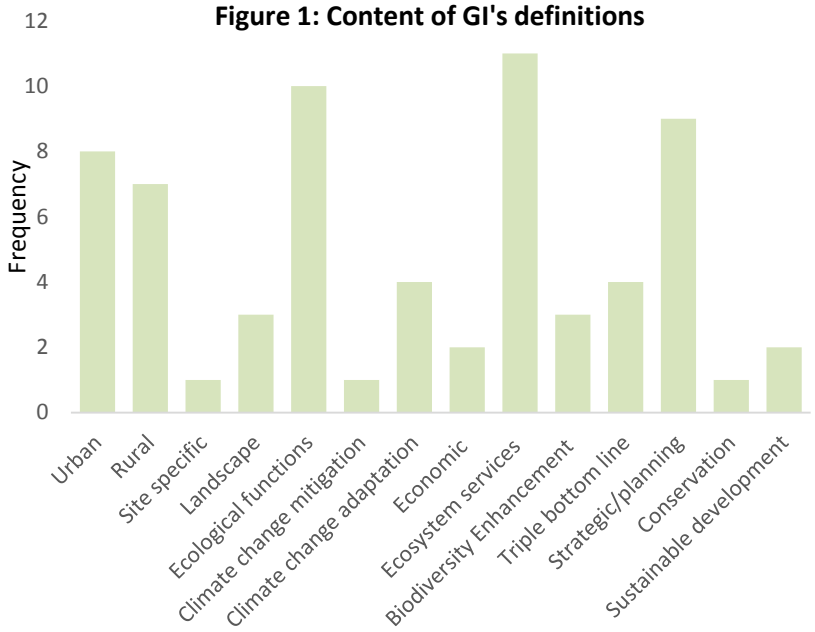
It will always be easy to tweak GI's definition because of the number of facets between which emphasis can vary. For example, the US Environmental Protection Agency (EPA) adopts a highly niche approach to the GI concept, describing GI as:

'An approach to wet weather management that uses soils and vegetation to utilise, enhance and/or mimic the natural hydrological cycle processes of infiltration, evapotranspiration and reuse' (US EPA, 2008).

Restricting GI to a flood management tool is not common, but along with those EC, Natural England and Benedict and McMahon examples, again serve to highlight the level of variability possible when trying to define GI to such a degree that it begs the question: how frequently are references to GI used as a 'shotgun approach' to environmental objectives generally? Compiling the totals from Table 2, as illustrated in Figure 1, gives a clearer insight into the strengths and weaknesses of current GI definitions.

Figure 1 shows a broad range of content features across GI's definitions. Whilst characteristics integral to GI, such as ESSs, ecological functioning and a strategic planning approach appearing more often than others is a sign a consensus exists, whether this is the level of consistency necessary to support widespread and effective implementation of GI is debateable.

Figure 1: Content of GI's definitions



For instance, enhancing biodiversity and ecological functioning is theoretically fundamental to GI as established in Section 3.1. Sundseth and Sylwester (2009, p68) assert that '*almost all agreed*' at the EC workshop 'Towards a Green Infrastructure for Europe' that '*GI needs to maintain and improve ecological functions*' and therefore it should feature in its definition. However, despite being arguably *the* primary driver of GI, enhancing ecological functioning only arises in 50% of the 20 definitions analysed and only 65% of definitions when you include references to biodiversity enhancement, which is almost synonymous. For a requisite aspect of GI, this cannot be considered consistent content representation.

The latest EC communication on GI states that '*a minimum level of consistency [within GI] should be encouraged*' (EC, 2013, p8). While it is difficult to define what a minimum level of consistency would be to aid conceptual clarification and understanding, it would be beneficial if GI's agreed core concepts were more consistently included by stakeholders than currently demonstrated. As the UK National Ecosystem Assessment (2011, p396) suggests, '*developing common terminology…is critical*' to achieving consistent concept application. If a set of default terms that are central to GI could be drawn up and included ubiquitously aross definitions it would make GI more predictable and acccessible for those seeking to utilise the concept. Currently, however, the '*green infrastructure system… requires urgent review*' (UK NEA, 2011, p396) to iron out its fallibilities and achieve this platform to progress.

4.3 An unclear outcome: Poor understanding of GI

What are the implications of the complex theoretical background and potentially unclear concept definition on GI's successful application? Success in this instance is defined by the scale and effectiveness in which GI is applied. This is dependent on two factors: i) whether GI practitioners have the requisite level of understanding to be motivated to choose GI and be able to apply it correctly; and ii) whether the requisite institutional structures and procedures are in place to promote and facilitate its application.

To assess the first of these factors, each interviewee was asked how they deemed the understanding of GI to be of those using the concept on the ground (Figure 2). To keep the analysis at a scale that is manageable this exercise excluded the interviewees from the European Commission and European Environment Agency to focus on GI's UK-level application.

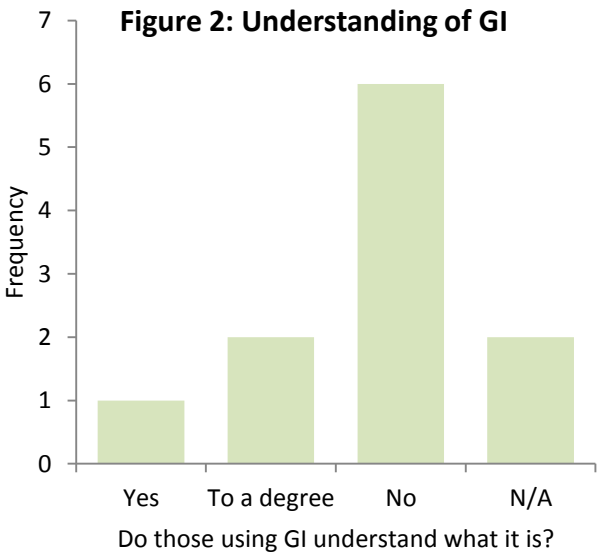


Figure 2 shows that only 1 out of 9 interviewees felt those using the concept fully understand what GI is. Respondees said that people find GI's multifunctionality *'very tricky'* (D3, 2012) and *'confusing'* (B1, 2012). A common misconception which

interviewees referred to themselves or observed of others, is that GI is meant to produce all its multiple benefits simultaneously from each asset: *'the idea behind the multi-functional GI is to use all possible entry points and delivering multiple services from the same space of land',* said interviewee C2 (2012). This implies that by simply administering GI the benefits expected of the concept will result unobstructed. However, this is not necessarily correct (C2 and D5, 2012). This approach is far more likely to result in numerous trade-offs and a non-optimal outcome – as interviewee B2 (2012) states, '*co-benefits [will come] along sub-optimally as opposed to being integral to the design'.* Not regularly enough are the possible trade-offs between GI's discrete objectives considered in detail.

Ideally GI adopts a landscape scale approach that highlights the synergies and trade-offs between its different objectives at each asset allowing the primary driver of that asset to be prioritised. This would result in a strategic approach that achieves the optimal 'net-gain' for that location and, therefore, the network as a whole. Within this ideal, it is the holistic nature of a strategic approach and the need to operate at a landscape scale which are crucial to achieving this outcome. Some interviewees flagged this issue to be a main area of misunderstanding and, as such, showed little indication in their responses that they felt this optimal conceptual implementation is close to fruition, instead blurred by the assumption that *'if you manage the environment better they will deliver all these benefits'* (A1, 2012).

Example: EU Natura 2000 network

The European Commission highlight that *'working with nature's capacity to absorb or control impact…can be a more efficient way of adapting [to climate change] than simply focusing on physical infrastructure'* (CEC, 2009, p5). In practice, improving ecosystem resilience through GI is more difficult than commonly perceived, as explained above. The Natura 2000 network of protected areas, which currently covers 18% of EU territory, is the backbone of Europe's GI. However, some deem it to be merely *'a collection of isolated areas rather than a cohesive network'* (Naumann et al., 2011a, p7). What is correctly being inferred is that increasing protected area provisions is not unequivocally an effective measure to improve GI. GI needs to be implemented with a strategic approach to effectively operate at a landscape scale, bypassing typical distinctions, such as 'urban' or 'rural', to successfully achieve its objectives.

4.4 A change in governance structure?

As well as common theoretical misconceptions, GI has implementational difficulties as a result of a misalignment between current organisational structures and GI's multifunctionality. To hark back to a statement made by interviewee B2 (2012), an environmental management expert, rather than emanating from a strategic, more multi-disciplinary foundation, GI '*is often driven by a disciplinary narrow priority and managed on that basis, with co-benefits coming along sub-optimally as opposed to being integral to the design'*.

There are a few possible reasons for this dearth in strategic GI planning. One is that environmental science is not currently accurate enough; to accurately understand the optimal net-gain of each GI asset ultimately requires the synergies and trade-offs between the likely impacts of application to be quantified. A consensus among researchers about quantifying the environment's services has not yet been reached.

A second reason relates to the institutional structure of environmental governance. The breadth of GI is atypical. GI represents a separation in the usual form of environmental policy interventions, from a single-objective focus to one that seeks to deliver multiple benefits. However, there is no single governing body in the UK responsible for its application. Therefore, GI's successful implementation falls under the remit of those independent institutions who perceive applying GI to be in their interest.

This structure brings with it a number of risks. Larger, overarching organisations for whom GI contributes to achieving their overall objective, such as the Environment Agency, *'struggle with systemic approaches'* because they have been brought up on *'managing problems defined and fixed in discrete disciplinary silos'* (B2, 2012). When tools exceed these parameters, are not strictly defined and cross disciplines it creates unique problems in defining departmental remits and responsibilities, and therefore run the risk of under-investing in its success.

For independent, single objective organisations, a multidisciplinary concept like GI marks an even more competitive landscape for resources than normal. The fact the lack of a formal governing body for GI means the strategic implementation of the concept relies on the cooperation and communication of these independent entities, this is particularly true when it comes to competition for funding. Statements from an

interviewee in charge of a regional GI project testify that the optimal application of GI described earlier '*assumes a rationale*', whereas the reality is '*we do stuff in relation to the easiness of getting money for it*' (C1, 2012). Interviewee D3 says that he *'very rarely'* talks about GI in his work – *'it confuses more than it clarifies'* – but admits he does make applications along the lines of GI because *'it can gain you funding'*. He goes as far as to state *'the main reason I use it (the term GI) is for funding – I can't bite the hand that feeds me!'* (D3, 2012).

Adapting project proposals to cohere with the political trends of the time is nothing out of the ordinary and not unconstructive by its nature. But in the case of GI it appears the high level of competition means any hint of the required level of disciplinary coordination and cooperation is lost. If the scenario is considered whereby a parcel of land is available for development as part of a 'greening' process, each deliverable objective will have an interest group or NGO bidding for that tender in an attempt to contribute towards that purpose. In an unregulated or undirected form, such as that of GI currently with its lack of a governing body, this leads to inefficient green space allocation as a result of competition that is driven as much by societal values, economic constraints and political feasibility as scientific knowledge or strategic considerations (Tear et al., 2005). Interviewee C2 testifies that this process is exacerbated in dense urban areas where the functionality of space is under even greater pressure.

CCA is still an emerging objective and so in this competitive landscape it might be overlooked in favour of more resource-rich, politically-friendly sectors. This has been made even more likely in the UK in light of an announcement that after the release of the National Adaptation Programme, the number of staff at the UK Department for Environment, Food and Rural Affairs (Defra) responsible for CCA projects will be reduced from over 30 to just six (Murray, 2013). Consequently, Defra is expected to shift much of the responsibility for CCA projects onto other departments and industries. This move mirrors exactly the problem with the current structure of GI governance where unclear responsibilities and remits mean there is a significant risk of under-investment as opportunities slip between the cracks due to a lack of holistic oversight.

For CCA, a certain amount of progress, albeit unknown without proper governance, will be achieved indirectly as co-benefits of those more frequently targeted objectives. This

is where GI's multifunctionality complicates the understanding of its contributions to different sectors. For instance, increasing provisions of green space, along with planting hedgerows, rows of trees and introducing a lake, all constitute GI measures that help enhance biodiversity conservation. But they also help achieve basic CCA objectives, not to mention flood management and water quality aims. From the perspective of CCA groups or whom it may concern at Defra, for example, does this contribution count towards their goals, and if so, by how much? Or, alternatively, do you ignore this contribution to purely focus on accountable contributions? This is a grey area that requires guidance for practitioners and is discussed further in Section 5.2.

Generally, practitioners are frustrated by the lack of detail and clarity as to how they are supposed to use GI from the direction given by current policy. A number of the interviewees believed that individual interests and political and societal influences should be nullified through more prescriptive GI policy thereby creating a more level-playing field. Interviewee D3 (2012) describes GI policy as *'a lot of description, not a lot of, 'ok what do I do with it, how do I change my local plan, our core strategy etc. because of it''*. Similarly, Interviewee D4 (2012) says *'there is no high-level indication of priority, what we should be prioritising over others. It makes it very difficult'*.

The primary vehicle to introduce more prescriptive direction into GI in the UK is by integrating it into spatial planning policy. However, the new UK National Planning Policy Framework (NPPF) is deemed *to 'not be the degree necessary, not at all'* (D1, 2012)) leaving uncertainties about how GI is being driven in land use planning.

GI is a concept that requires sectors to cooperate in a discursive policy environment - *'it is the only way to do it'* (C1, 2012) – but GI's multifunctionality seems to uncover age old thematic hierarchies and disciplinary conflicts that prevent this from materialising, seemingly at the greatest cost to immature and emerging disciplines. More prescriptive GI policy has been suggested by our interviewees to help regulate the equality and objectivity of GI projects.

5. Discussion - the climate change adaptation, biodiversity conservation, ecosystem services nexus

So far this paper has pointed to potential problems around defining, understanding, implementing and governing GI that arise chiefly due to a lack of familiarity and experience in dealing with multifunctionality. For the authors, GI's challenges can be resolved to a great extent by creating clearer delineations between those concepts enveloped by GI. This itself comprises two main aspects: i) greater understanding of GI's contribution to the individual disciplinary objectives themselves; and ii) greater understanding of the inter-relationships, synergies and trade-offs between GI's impacts. This second aspect is a result of GI's multifunctionality and so of greater significance to this study. It is considered below in two parts.

5.1 Conceptual inter-relationships

Very few attempts have been made to untangle the theoretical complexity of the interactions between GI and three of its core benefits - biodiversity conservation, ecosystem services (ESSs) and CCA. It is deeply important to understand what makes GI's role unique in relation to these concepts – which has been demonstrated (from the interviews) to be a tripping point for individuals – so that it can be appropriately and effectively applied in line with this unique selling point.

Problematically, these three concepts under GI overlap. CCA and biodiversity conservation appear to have significant commonalities and the same can be said for ESSs and biodiversity conservation. These inter-disciplinary relationships were highlighted in environmental policy most recently with the EU's 2013 communication on GI. It states;

'When appropriate… use GI solutions, because they use biodiversity and ecosystem services as part of an overall adaptation strategy to help people adapt to or mitigate the adverse effects of climate change (EC, 2013, p4).

The first observation that becomes apparent when attempting to untangle this complex nexus is that the likely entry point of GI is ESSs. Interviewees from the private, public and academic sectors (C2, D1 and D2, 2012), along with the EC (2010a) and DG Environment (2012) all purport that at its simplest the primary role of GI is to provide ESSs. For example, the latest European Commission (2013, p3) communication on GI

states that the concept is '*managed to deliver a wide range of ecosystem services*'. However, if this is the case then what unique characteristics do the GI and ESSs concepts have that mean they must exist mutually rather than ESSs be subsumed? Interviewee A1 (2012) goes some way to answering this question in stating that the motivation behind associating the GI and ESSs concepts was the belief that significant biodiversity conservation progress would not be achieved if GI was limited only to the idea of ecological corridors (A1, 2012).

This statement implies that the ESSs concept was needed to help GI achieve biodiversity conservation. Many see ESSs as the most effective way of communicating biodiversity conservation to civil society and policymakers. As the MEA (2005, p1) asserts, *'biodiversity is essential for the functioning of ecosystems that underpin the provisioning of ecosystem services'*. Interviewee A1 (2012), an EC official on GI, stated that the ESSs entry point for EU GI policy was established *on 'the underlying assumption that only healthy ecosystems can guarantee biodiversity conservation'*. At its most simple, therefore, the assessments above hypothesise that the concept of ESSs was established as the primary entry point for GI to aid GI's uptake, but in turn ESSs is itself the tool outlined to ultimately achieve effective biodiversity conservation.

CCA features significantly within this nexus, although its link to an ESSs centre-point is not frequently reported. The UNFCCC (2011, p3) SBSTA asserts that there is a *'growing recognition of the role that healthy ecosystems can play in increasing resilience and helping people to adapt to climate change through the delivery of a range of services'*. The benefits provided to civil society by healthy ecosystems is even greater in a world of more frequent, more intense and more diverse extreme weather events. However, the early stages of understanding this relationship means the wording around this link is generally broad and rarely elaborates more than that CCA benefits arise from *'maintaining and restoring healthy ecosystems services'* (A1, 2012).

This is also partly because of the superior level of understanding between biodiversity's role in producing CCA benefits, compared to that of ESSs' concept. It is widely believed that ecosystems with high levels of biodiversity are more resilient and can serve a number of CCA functions. Indicatively, Recommendation 135 of the Bern Convention (EC, 2008) instils a legally binding agreement for member parties to *'raise awareness of*

the link between biodiversity and climate change and emphasise the large potential for synergies when addressing biodiversity loss and climate change in an integrated manner'.

5.2 Conceptual synergies and trade-offs

The Bern Convention statement above points to the second important consideration in this process of trying to understand the delineations between the concepts in the nexus - what are the synergies between biodiversity conservation, CCA and ESSs; what is the extent of this enhancement; and are their any trade-offs when trying to exploit them? Assessing these questions is also crucial in applying GI. As highlighted in Section 4.1, for GI to achieve the optimal net-gain for the network, the synergies and trade-offs between GI's impacts at each asset must be evaluated. This will ensure GI avoids one type of ecosystem from being poorly represented while others are overly represented, which the Millennium Ecosystem Assessment warns against (MEA, 2005, p70).

Currently, the synergies and trade-offs between GI's benefits represent a knowledge gap that needs to be focused on in great detail. However, based on the understanding of these concepts obtained from the document analysis, literature review and primary analysis conducted for this research, a preliminary evaluation of the relationships between the benefits GI achieves towards biodiversity conservation, ESSs and CCA objectives is provided in Figure 3. This diagram considers each node against all others and explores whether the combination is likely to lead to a positive, complementary relationship or a conflicting outcome. Due to the highly synergistic relationship between most impacts, only the trade-offs have been identified for ease of comprehension.

Figure 3: Potential trade-offs and synergies between biodiversity conservation, ESSs and CCA

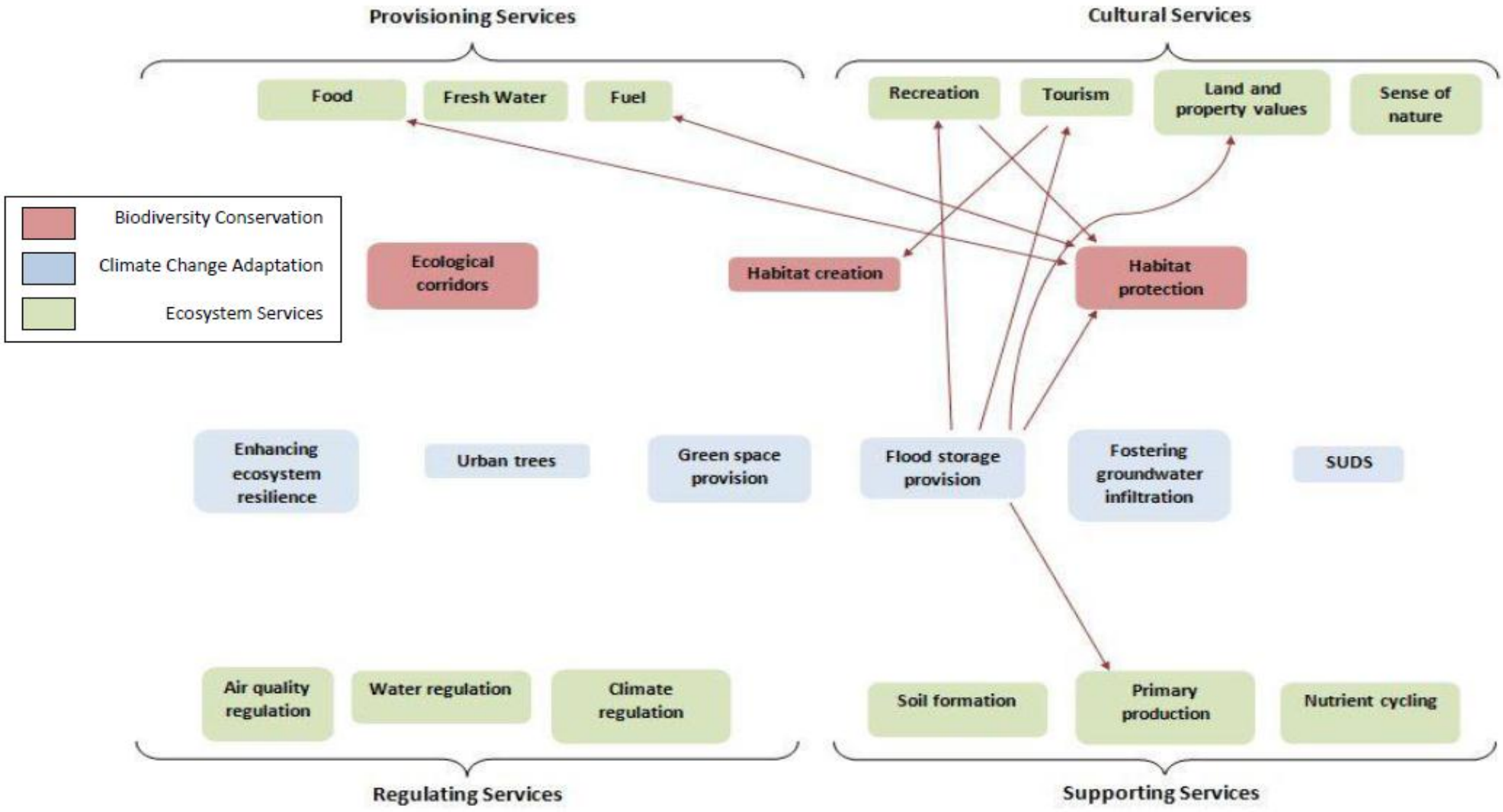
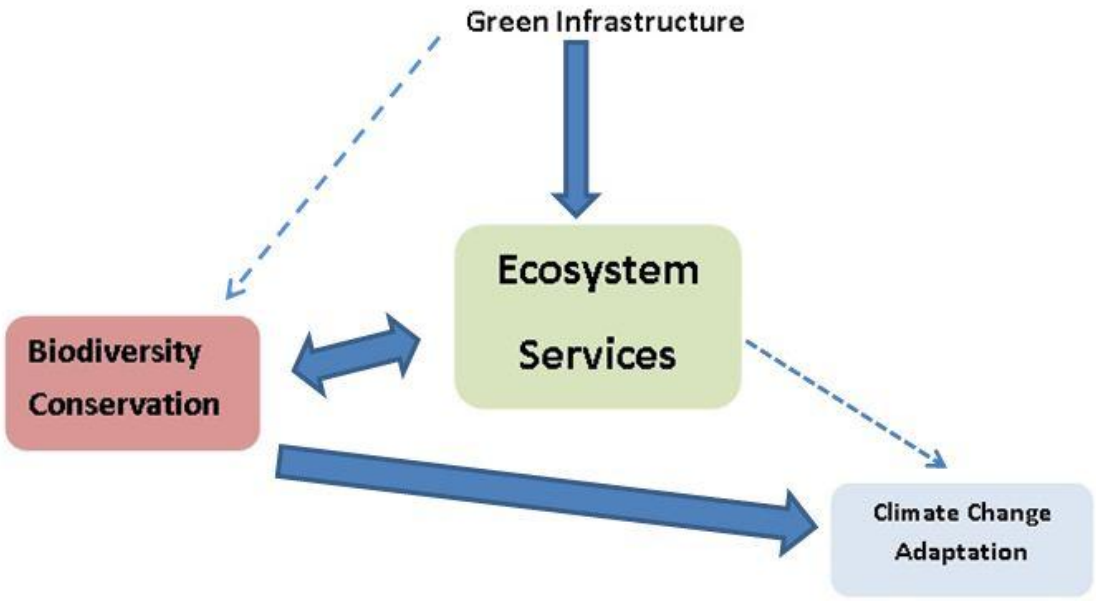


Figure 3 largely supports the theoretical relationships hypothesised between the three concepts in Section 5.1. It illustrates there are strong synergies among the three concepts, highlighting GI's potential for cost-effective, mutually enhancing relationships with regards to these three objectives. Biodiversity conservation and ESSs are highly synergistic meaning having ESSs as the primary entry point of GI will be largely successful in benefiting biodiversity conservation as envisaged by Interviewee A1 (2012). Conflicts that did arise between the two were almost solely against cultural ESSs, which is to be expected given its human focus. Figure 3 also purports there are virtually no trade-offs between biodiversity conservation and CCA benefits meaning GI has the potential for contributing significantly to CCA even when this is not the primary objective for its application. The challenge from there is, how much is that benefit?

5.3 Conceptualising the nexus

Based upon this two-part discussion of the inter-relationships and synergies and trade-offs of these three core concepts, Figure 4 below proposes a conceptual model of their positioning under the umbrella of GI.

Figure 4: Conceptual model showing the relationship between GI, ESSs, CCA and biodiversity



This model considers that GI is a concept whose primary objective is to achieve biodiversity conservation. It does this by utilising the ESSs concept as its main entry point, which although strikingly similar to biodiversity conservation in its ends, is currently more effective in communicating this target. CCA objectives are met by GI

through the significant synergistic effects of biodiversity conservation, and to a lesser extent ESSs. The delivery of these relationships relies on eradicating the current potential failings of GI as discussed throughout this paper, but this discussion illustrates how an improved understanding of the dynamics inherent to GI's multifunctionality could benefit disciplinary communication, cooperation and resource allocation, and contribute to GI delivering its indisputable potential towards climate change adaptation and environmental protection more broadly.

Conclusion: Muddying the waters or clearing a path to a more secure future?

A recent Freedom Of Information request in the UK revealed that the 2013/14 budget for climate change adaptation measures is 41% down on the previous year (Defra, 2014). Within such significant budgetary constraints, the need for cost-effective, strategic and multifunctional adaptation solutions has never been so vital.

This paper has touched upon a number of GI's fallabilities that mean it can not currently be seen to clear a path towards a more secure climatic future. Our analysis has highlighted that questions remain whether practitioners fully understand what GI is, stemming largely from its variable definition; that this makes the concept more unpopular to implement and potentially inconsistent when it is applied; that GI's current governance structures do not discourage disciplinary competition in favour of cooperation; and that a level of understanding around the inter-relationships, trade-offs and synergies between GI's impacts is missing, thereby restricting GI from being a genuinely strategic policy intervention. These are all areas which require concerted research efforts in the future.

Having said that, this research does not suggest that GI is muddying the waters to a more secure climatic future either. If GI continues to be applied in its current state, climate change adaptation benefits will be achieved, predominantly through the synergistic relationships with biodiversity conservation and ESSs efforts described. This contribution marks progress towards a more climate-proofed future but marks also, an opportunity unfulfilled.

GI's multifunctionality characterises environmental policies that will make the most significant contribution in the future by being both politically popular and scientifically robust. It is also this multifunctional ability that at this current moment in time underpins the majority of GI's potential weaknesses. While achieving multiple objectives simultaneously may not be an unprecedented approach, it is clearly one that stakeholders at each level have yet to master.

As with any trial and error policy process, that which GI requires to become more effective will incur opportunity costs. Some may consider that given the rate of global warming and climate change adaptation's resource constraints, investing time and money to improve GI cannot be justified. However, investing in GI's potential to achieve long-term climate resilience benefits to society through working with nature rather than against it, may well outweigh these costs. Who drives GI's progress and improvement from this point, however, is yet to be seen. From the evidence presented in this paper, it is not possible to recommend that all possible beneficiaries of GI invest fully in its future because of the underlying flaws identified. However, perhaps policy areas, such as CCA, that see a return nevertheless, will deem that return to be significant enough to take GI forward.

For practitioners, greater clarity in definition and objectives for GI would help in its implementation and evaluation of effectiveness – whats is it GI is intended to achieve and how do we know if we have achieved the desired outcomes? But for policy makers the fuzziness around GI's definition may continue to serve a useful purpose, since it is sufficiently malleable to be used to support a wide range of objectives. That may mean there is little real incentive from policy makers and politicians to develop the greater clarity in GI's definition and purpose desired by practitioners.

Rather than muddying the waters, therefore, GI has instead revealed, through the questions it poses, previously hidden obstacles preventing it from contributing as effectively as it could to climate change adaptation and therefore ultimately to a more secure future. Dealing with those obstacles requires effective interdiscplinary working and cooperation across disciplines and policy sectors - a perpetual challenge for environmental governance generally and not just for green infrastructure.

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