Regular Paper

Aligning Blue and Green Infrastructure to Sustainable Development: geographical contributions to an ongoing debate

ABSTRACT

Blue and Green Infrastructure (BGI) is increasingly viewed as a promising solution to promoting a shift beyond traditionally engineered "grey" approaches towards more socially and environmentally sustainable infrastructure systems. The specific insights geographical scholarship on how to address issues of processes, scale and place in BGI design, implementation and long-term management would help unlock the potential for BGI to be appropriate and inclusive, as well as support environmentally sound solutions. In this paper we unpack issues of processes for inclusive decision-making to design and implement BGI projects that can advance sustainable development. We present an assessment framework and its application to two case studies that highlight the potential for better alignment of BGI projects to the three pillars of sustainable development and that reveal key research challenges that geographical scholarship could address. We believe that co-produced geographical research in this domain is well-placed to tackle these research challenges.

Keywords: Blue and Green Infrastructure; sustainable development; geography; cities.

1. Introduction

Global challenges linked to climate change, population growth and indeed the breaching of planetary boundaries (Rockström et al., 2009) require a better alignment of infrastructure with the overarching principles of sustainable development in the urban space (henceforth Sustainable Urban Development, SUD) (Parnell et al., 2007; Young et al., 2006; Khosla & Masaud, 2010). Blue and Green Infrastructure (BGI), approaches are increasingly recognised as a key component of SUD. If well planned, they are effective in tackling pressing issues, for instance urban heat islands, as well as providing environmental and health benefits and economic potentials (Nastran et al., 2019). However, there are longstanding issues with these approaches, which relate to unfair distribution of benefits, unequal access and community involvement, untapped economic potential, and gentrification issues (e.g., Anguelovski et al., 2018). We focus on blue and green infrastructure (BGI) as an example of infrastructural intervention at the interface of social, ecological, and technical systems (SETs). There are many definitions of GI and BGI that either stress its role primarily as a technical tool for stormwater management (Jayasooriya & Ng, 2014) or, alternatively, as a planning approach to strategic issues such as meeting the SDGs (Lennon & Scott, 2014). Our focus is on the latter, as we are especially concerned with how BGI projects must benefit local communities and be appropriately integrated with the existing built environment. Therefore, we define BGI as the strategic and creative combination of natural and artificial structures (‘blue’ and ‘green’) intended to tackle specific sustainability goals (Hansen & Pauleit, 2014; Naumann et al., 2011).

BGI allows direct community involvement throughout the design, implementation, and maintenance stages thus representing a laboratory for co-producing solutions that are context-specific and maximise local environmental, social, and economic knowledge (e.g., Lindley et al., 2018; Jones and Somper, 2014). BGI’s potential to provide a multitude of ecosystem services, i.e., the benefits societies derive from healthy ecosystems, from reduction of flood risks to temperature regulation, air quality improvements and enhanced species biodiversity, has been widely acknowledged in the literature (Demuzere et al., 2014; Wolch et al., 2014; Hoang & Fenner, 2016; Raymond et al., 2017; Abhijith & Kumar, 2019). These services provide economic benefits as well as limiting financial losses from environmental disasters (Li et al., 2017; Wang et al., 2017). Meanwhile, among other ecosystem services, scholars have also highlighted BGI’s non-monetisable socio-cultural benefits (e.g., aesthetic, spiritual or cultural values, as well as peace and tranquillity), which may be very highly valued by beneficiary communities themselves (du Toit et al., 2018; Shackleton et al., 2018). Nonetheless when not mindful of local contexts, BGI can lead to greater social inequality, with people from disadvantaged backgrounds being forced to relocate due to BGI-linked gentrification making local land rents rise (“green gentrification”); ending up locked out entirely from enjoying the benefits of improved ecosystem services; or even experiencing ecosystem disservices such as disproportionate pollution burdens (Gould & Tammy, 2017; Haase et al., 2017; Zuniga-Teran & Staddon, 2019;).

Geographers are particularly well-placed to contribute to addressing key challenges in designing inclusive and appropriate BGI as a function of the way that the geographical imagination links a sensitivity to local context (studies of place and place-making) with a well-honed ability to see systemic interconnections (spatial analysis) (Benton-Short et al. 2017).
First, to be sustainable, BGI projects need to follow inclusive and appropriate co-design approaches to design, implementation and management. Geographers can contribute to BGI practice through a better understanding of the stages at which injustices and exclusions are more likely to arise and how they can be redressed. The first step would be to engage in a deeper analysis of the mechanisms behind BGI decision-making: who initiates BGI projects??

How do projects evolve from design to maintenance and to what extent are they truly inclusive? Who are the missing voices and how do decision-making processes create the space for acknowledging cultural values? The scope and constraints of co-produced research and reflections on inclusive approaches within the discipline of geography have been explored in this journal (Holt et al., 2018). These debates can further enrich the application in BGI practice of methodologies such as participatory mapping (e.g., Chambers, 2006), theories of social learning that attempt to go beyond traditional public participation paradigms (e.g., Collins & Ison 2009), and theoretical approaches to the multiple dimensions of environmental (in)justice (e.g., Walker, 2009).

Second, geographers are well-placed to address issues of scale, focussing on developing appropriate BGI solutions within spatial and temporal constraints. Geographical scholarship can address key questions about the temporal and spatial constraints that could hinder BGI's potential for sustainability. Insights from geographical research has looked at the interactions between the ecological and political administrative boundaries and scales (e.g., Sayre, 2005).

Third, Geography is interested in issues of place and place-making, and contributions in this area can be applied to strengthen the social pillar of Sustainable Development in different socio-economic and political contexts. The political, institutional, and regulatory context plays a key role in shaping what BGI projects eventually look like. Geographical scholarship on the relationships between the broader institutional and political context and community interventions, as well as on place-based policies, contributes to enhancing BGI projects (e.g., Pow and Neo (2015) on the relationships between the broader institutional and political context and Chinese green cities programmes, and Hambleton (2015) on the role of city leadership in fostering sustainability and place-based interventions).

This paper contributes to this debate by focussing on *processes* in BGI design and implementation which particularly pose the risks of creating greater social inequality and where we believe geographers can make a powerful contribution. We propose a framework that uses two guiding principles of *appropriateness* and *inclusivity* to operationalise the SUD principles in practice. The framework will highlight Geographers' contribution to BGI practice to enhancing BGI's effectiveness in tackling context-specific issues through maximisation of local knowledge and community involvement from design to maintenance. We then apply the framework to two case studies of BGI in different contexts, selected from a larger database compiled in 2017 as part of Arup's "Resilience Shift" Initiative and we highlight future geographical research opportunities[1]. The two case studies are Firs Farm Wetlands (London, UK) and the Floating Treatment Wetlands (Johannesburg, South Africa). Overall, our findings provide a solid empirical and analytical basis for good practice in designing SETs solutions and processes that directly contribute to the pillars of SUD.

2. Assessment framework: BGI through appropriateness and inclusivity

In work completed in 2018 the authors conducted a review of BGI innovations which included both a desk review and interviews with "City Resilience Managers" appointed as part of the Rockefeller Foundation's "100 Resilient Cities" initiative[2]. From the results of this work we derived a table (Table 1) useful for assessing BGI across the range of "triple bottom line" benefits: environmental, economic and social. As we focus on *processes*, our approach links the recognised characteristics of high-quality BGI (see e.g., Sinnett et al., 2017) to the principles of appropriateness and inclusivity, and we link these to the environmental, economic, and social pillars of sustainable development. Table 1 outlines how it is possible to integrate appropriateness and inclusivity and SUD into BGI planning. In practice this means, firstly, that the process should be informed by local environmental conditions, local knowledge, and the needs of future generations: planners and decision-makers should make sure that funding for the project is sustainable and secured, and that the project develops capacity building and creates job opportunities (appropriateness principle). Secondly, BGI benefits should be fairly distributed. A fair inclusion of all citizens cannot be achieved without deliberate actions on the part of institutions to include disadvantaged groups before, during and after BGI implementation (inclusivity principle).

The appropriateness principle means that BGI projects must be tailored to, and co-produced with, local communities, rather than merely imposed from 'above' or 'outside' because it is seen by external specialists as technically fit for purpose or expedient (Steiner et al., 2013; Roe

[1] More information about the Resilience Shift Initiative is available at: https://www.resilienceshift.org/

[2] More information about the Resilient Cities Network is available at: https://resilientcitiesnetwork.org/

and Mell, 2013). The appropriateness of infrastructure is a pre-condition to both avoiding the failure of BGI and to ensuring that its maintenance is sustainable. It is also a dimension that, if neglected, can exacerbate social exclusion, and even place undue burdens on excluded populations to maintain and manage (Kitchen et al., 2006).

The inclusivity principle aims to include all citizens who might be regarded as at risk because of minority group status through disability, cultural, ethnic, religious, socio-economic and psychological circumstances (definition adapted from Forlin, 2004). It is therefore necessary to entrench public participation processes that do not merely re-inscribe in the newly-greened landscape the inequalities and social-cultural barriers present in the wider society (Collins & Ison, 2009).

The combined effect of appropriateness and inclusivity helps to ensure progress towards stronger social, environmental, and economic sustainability while making sure that negative consequences from opportunistic practices, including poor maintenance, opposition to BGI projects, etc. are avoided (Kuller et al., 2018).

3. Methods

Our paper builds on a larger study conducted in 2018 for Arup's "Resilience Shift" initiative, which involved a systematic review of 64 articles published between 2013-2018, selected to ensure broad geographical coverage and which identified key BGI benefits and challenges; a collection of eight in-depth case studies of BGI projects; and interviews with three City Resilience Managers appointed in cities that were part of the 100 Resilient Cities initiative. We examined key challenges of implementing BGI in cities around the world (Staddon et al., 2017b). The selection of the eight in-depth BGI case studies was undertaken in collaboration with Arcadis (a consultant company that specializes in sustainable urban design and engineering). Selection also entailed a review of projects then underway, as well as a review of applied research projects and SUD approaches carried out as part of the 100 Resilient Cities initiative. The selection criteria highlighted each project's success in tackling one or more of the key challenges identified in the literature (Zuniga-Teran et al., 2018). Here we wanted to juxtapose two relatively well-known BGI cases from different parts of the world to underpin our claims about the need for multidimensional, geographically informed, assessment approaches. We selected Firs Farm Wetlands (London, UK) and the Floating Treatment Wetlands (Johannesburg, South Africa)as they demonstrate BGI's adaptivity and flexibility as they refer to BGI implemented across different scales (small/community site and neighbourhood scale) and in different geographical, socio-economic and political contexts. In the following sections we explore lessons learned and we discuss the strengths and weaknesses in relation to geographical research theories that would enable furthering of the alignment of BGI with SUD.

4. Results: exploring two examples of BGI projects

The two case studies illuminate different aspects of the appropriateness and inclusivity challenges of BGI at different scales (small site and neighbourhood) before turning towards a consideration of the agenda for geographical scholarship in this area. A summary application of the assessment framework to the case studies is provided in Table 2.

4.1 Firs Farm Wetlands, London (UK)

Firs Farm Wetlands, in the London Borough of Enfield, illustrates the huge potential of BGI located in neighborhoods facing environmental and social challenges (Staddon et al., 2017b). An outer suburb of London (UK), at the time of writing Enfield has significant challenges related to homelessness and material deprivation, with 29% of resident workers not earning a living wage (the living wage is set at £7.83/hour) – *eight percentage points higher than the London average* (Trust for London, 2018). Education levels are below the London average, with 45% of adults and 35.8% of 19-year-olds lacking any 'A level' qualifications (which in the UK mark the last stage of state-regulated education, for 16-18-year-olds).

Against the backdrop of fiscal austerity (Lowndes & Pratchett, 2012), which hampered the ability of local authorities to invest in public services, Enfield's local council saw public infrastructure, including green infrastructure, as a way of brokering multiple social, economic, and cultural (as well as economic) benefits for the area (Sitkin, 2018). Started in 2014, skillful redevelopment of the Firs Farm Wetlands has contributed to the achievement of social and economic development aspirations within the framework of the Enfield Local Plan, particularly with respect to the provision of mixed density and mixed cost housing. Addressing the high risk of surface water flooding which, coupled with an over-burdened drainage system, has sometimes had significant community impacts (e.g., displacement from housing, loss of community amenities, etc.) the Firs Farm scheme has been both technically and socially innovative. Here, the project created a series of "integrated wetland habitat cells" capable of storing up to 30,000m^3 of flood water. A wide range of techniques has been used to re-engineer natural water management functions including de-culverting, bioretention channels, integrated constructed wetlands and ponds, and permeable surfaces.

The Firs Farm scheme is a good example of collaborative BGI design that involved many project partners including Enfield Town Council, the Environment Agency, Thames Water, and two NGOs: Sustrans (sustainable transport) and Thames 21 (an urban regional development body). The local community was involved in the design and implementation of the project and has now embraced this newly transformed green space as a well-used community space and an educational resource. Community engagement grew and developed into an established local community group (the Friends of Firs Farm, established in 2014) that continues to raise funds for its maintenance and improvement, including organizing community events such as "Love Your Green Space". A Firs Farm Eco Club provides educational opportunities based on the wetland for young people (for example, pond dipping and nature trail events under the supervision of science teachers). Since 2014, more than 11,000 hours of volunteer time has supported a variety of activities in and around Firs Farm.

Firs Farm also attracted new employment opportunities, especially in the technology, retail and leisure sectors, without yielding community control over either assets. The former Council lead for Regeneration is adamant that success lay in rejecting the choice of private versus public (Sitkin, 2018). Challenging businesses to localize their supply chains was, he admits, easier philosophically than in practice. Many businesses couldn't or wouldn't depart from business models that removed value from Enfield. Others pointed to the lack of appropriate skills in the local labour force. Firs Farm was part of the rejoinder to both challenges, creating a place where local residents could articulate endogenous aspirations and build the skills base necessary to achieve them.

4.2 Floating Treatment Wetlands, Johannesburg (South Africa)

Johannesburg, South Africa, is facing rapid urbanization and population change (OECD, 2012). Here, traditional heavy infrastructure approaches have long failed to address water quality challenges linked to historic pollution from gold mining, wastewater, and industrial activities (Staddon et al., 2017b). Previously implemented BGI projects relied upon urban forests to address these challenges, but the unequal distribution of forest coverage risked aggravating unequal access to BGI benefits between the more affluent northern and the less affluent southern parts of the city (Schäffler and Swilling, 2013). In 2014, an innovative BGI approach involving the creation of artificial constructed floating wetlands, was implemented on an experimental level at a site in central Soweto, southwest Johannesburg. The scheme had also the additional aim of addressing social equality concerns. In Johannesburg, as in other communities, low-income areas often face the biggest water quantity and quality challenges and the introduction of appropriate water treatment methodologies, including BGI, could promote redress of economic and health disparities. The Rockville scheme in Soweto involved rehabilitation of degraded wetlands and the installation of "floating wetlands" (pontoons pre-populated with indigenous grasses and sedges) to enhance attenuation and evapotranspiration of surplus water received during heavy rain events. Works began in the early 2000s to clear generations of fly-tipping and re-nature water flows to keep the wetlands wet. In 2008 the original "Friends of the Park" organization was re-launched as the Thokoza Park Committee, with key stakeholders from local government as well as local residents. The wetland system was further augmented with two floating treatment wetland "islands", each 20m^2 in size and containing 100 indigenous plants with known phyto-remedial properties, in 2016.

Schemes like Rockville also helped create employment because they "are so labour-intensive that [City Parks Department] was able to support the Department of Labour's national call to create green jobs" according to a member of the Committee for Community Development. Regulated harvesting of biomass, especially reeds and brush, supports a local industry in basketry and small furnishings.

These BGI assets are now much used and valued by local residents and have proven more cost effective than traditional "grey" approaches. A rapid survey of local residents conducted following project implementation revealed an appetite for further public engagement and capacity building activities, with the vast majority of respondents (73%) indicating concerns with regards to the quality of water resources in the area. Survey participants also suggested new ways to use the floating treatment wetlands for both educational and restoration purposes. Furthermore, the survey suggested that participants were concerned that poorly managed BGI could lead to increased pressures on the surrounding natural local ecosystem and were willing to contribute time and creativity to protecting and enhancing these local ecosystem assets.

5. Discussion: the contribution of geographical research on sustainable BGI decision-making and practice

Both BGI projects outlined above present different strengths and weaknesses, and a full evaluation of their effectiveness in delivering ecosystem services is beyond the scope of this paper. Yet, the application the framework presented in Table 1 to the two BGI case studies allows for a more systematic analysis of their alignment to the principles of SUD, as well as highlighting the contextual identification of research and practice opportunities stemming from more direct involvement of Geography professionals in BGI practice. BGI studies all too often focus on the physical side of systems design, function, and maintenance, and as a result, the potential contribution of Geographers tends to be underestimated. It is far less common for mainstream BGI practice to emphasise the importance of geographical dimensions. Common sources of guidance for sustainable drainage in the US and in the UK, for example, spend little time on considerations of community-based co-design or governance. Yet it is abundantly clear that BGI as a whole and the elements that comprise it (e.g., permeable pavements, rain gardens, etc.) are fully socio-technical. Our framework contributes to this ongoing debate by positioning inclusivity and appropriateness as key principles that can overcome the current shortcomings of BGI projects and enhance their contribution to sustainable development. We show how appropriateness and inclusivity can be operationalized and integrated within the environmental, economic, and social pillars. The results of this analysis, succinctly presented in Table 2, identify areas that can be further developed to achieve better alignment between the BGI projects and SUD, as well as presenting research opportunities for geographical scholarships.
the Firs Farm Wetlands project represents a model for community organisations meeting the immediate needs of the community, while also shaping its long-term sustainable future. The application of our framework to this case study reveals how it incorporates sensitivity to social sustainability as well as environmental and economic considerations through inclusive co-

design and ownership on the one hand, and through ensuring that the project was appropriate to tackle the challenge faced by the local community (flooding), as well as ensuring appropriate resourcing through involvement of multiple actors in the context of austerity. The examples of floating wetlands in Johannesburg addresses these same dimensions in different ways. However, here challenges remain in terms of wider community involvement and how to use capacity building for maintenance and for the co-development of similar or spin-off projects in this socially and economically hard-pressed community. Moreover, local ownership and institutional support is needed to make sure that the project is appropriately maintained and financially sustainable. Further, our analysis underscores the need to acknowledge and deal with the role of the institutional and regulatory context to foster inclusivity.

BGI projects exist not within hermetically sealed physical systems, but within complex social, cultural, and economic as well as physical systems as presented in Table 2. Our framework demonstrated how Geography, as a field-facing discipline, and as a discipline that is theoretically equipped to tackle sustainability challenges in applied settings, should play a bigger role in BGI practice in ensuring the incorporation of appropriateness and inclusivity with SUD in mind. The framework can enable a stronger integration between BGI practice and Geography scholarship as it speaks to both practitioners and researchers: it can be used by Geography researchers not only to highlight new research opportunities, but also as an evaluation tool of planned or existing BGI projects, thus allowing them to be directly involved in SUD decision-making processes. Moreover, the framework can be used by practitioners as a directly actionable tool to support the design and implementation of BGI projects that contribute to advancing sustainable development more fully.

6. Concluding remarks

This paper aimed at creating a better understanding of the conditions under which its contribution to SUD can be unlocked. The selection of case studies and the subsequent discussion in this paper are not a comprehensive representation of the challenges of implementing BGI. Instead, they highlight how geographical co-produced and applied research could provide the space for addressing some key open theoretical and empirical issues. Across the two cases, further research could be done to evaluate public participation processes against the inclusivity and appropriateness principles, as well as checking the extent to which these were consistent from design to maintenance. This would help inform the design of public participation processes in other BGI projects in an effort to mitigate the risk of negative social outcomes. Pursuing these research and practice opportunities would be instrumental to framing and mainstreaming BGI within broader SUD. Geographical insights address questions about how BGI projects can be designed to be *future facing*, i.e., ready to face future challenges and provide benefits to future as well as current generations; and how they can unlock potential for capacity building, local ownership and flexible funding mechanisms and what principles should decision-makers follow when scaling up a BGI project or transposing it to a different context. This would enable a deeper engagement of BGI practitioners with issues of processes, as well as scale and place and, as a result, encourage a more profound alignment of BGI projects with the three pillars of sustainable development, notably the social pillar.

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