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Examining the Role of Green Infrastructure as an Advocate for Regeneration

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The alignment of Green Infrastructure (GI) planning principles with urban regeneration mandates can have a significant impact on the long-term socio-economic and ecological functionality of an area. As a mechanism to address landscape dereliction GI has been promoted as offering a suite of options to revitalize denuded spaces. This can take many forms including tree planting, waterfront redevelopment, the regeneration of former industrial sites, and a rethinking of spaces to make them more ecologically diverse. However, the successes seen in GI-led regeneration need to be considered in terms of the geographical, political, and socio-economic context. The following provides a review of regeneration projects that have integrated GI into development principles, examining whether these have led to positive change. Through a reflection on the scale, focus and location of these projects we discuss the factors that have shaped investment before identifying key factors that influence the inclusion of GI in regeneration works. The paper concludes that we have a growing catalogue of projects that can be used as a "green print" to align GI with regeneration to successfully delivery landscape rehabilitation and socio-economic revitalization.

Keywords: equity, urban development, greenspace, finance, gentrification

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INTRODUCTION

As cities continue to expand and contract, a corresponding impact can be seen in the physical composition of urban landscapes. This can, and should, be considered as both a positive and negative. Formerly underused or undervalued land can be reimagined as multi-functional components of an urban landscape delivering water management, climate change mitigation and socio-economic benefits. However, in many parts of the UK, western Europe and North America, urban, and specifically industrial and infrastructural expansion, has scarred the landscape leaving significant remnants of long-term damage. The industrial heartlands of the Ruhr (Germany), Michigan (USA), and Tyneside (England) all illustrate the ongoing impacts of historical growth at a time when little consideration of landscape conservation was integrated into development.

To address this issue, we identify a change in attitude toward the promotion of landscape aesthetics, functionality and quality located within the evolution of "green infrastructure" (GI) thinking in contemporary planning. Within this this paper GI is defined as the:

> "…natural life support system—an interconnected network of waterways, wetlands, woodlands, wildlife habitats and other natural areas; greenways, parks and other conservation lands; working farms, ranches and forests; and wilderness and other open spaces that support native species, maintain natural ecological processes, sustain air and water resources and contribute to the health and quality of life for…communities and people."
>
> (Benedict and McMahon, 2006:12).

However, GI is not a new concept but one that draws extensively from a range of existing approaches to planning, greenspace, and environmental management. These include but are not limited to *greenways*, *water-based planning*, *landscape ecology*, *sustainable communities* and instills within GI thinking a flexibility to engage with natural and built environments in diverse ways (Matsler et al., 2021). Thus, GI could be viewed as a rearticulation of existing, and in many cases centuries old, approaches to landscape management (Mell, 2010). Within this paper GI planning is framed as addressing, at least in part, the negative legacy of industrial change.

The rise of GI as a "go to approach" for landscape enhancement, a *proxy* for rehabilitation and as an approach to retrofitting in many locations, has recast landscape planning as an opportunity to facilitate socio-economic and ecological regeneration (Mell, 2009). In post-industrial locations this shift in mindset from *economic* to *place-based* development has been critical in promoting investment (Brown and Raymond, 2007). As a consequence, environmentally-led renewal is being maneuvered into the mainstream, as a cost-effective form of investment addressing the negatives of dereliction (Schilling and Logan, 2008). Moreover, reinvesting in landscapes subject to degradation that could be considered to be deprived in terms of their socio-ecologically functionality, has been positioned as an ethical imperative promoting environmental and socio-economic equity (Lovell and Taylor, 2013; Hansen and Pauleit, 2014).

Regeneration is one widely used mechanism facilitating such change. This can be presented in two ways. The first employs GI as a set of principles that can be used to enhance wider regeneration processes, i.e., to add greater ecological functionality to housing or infrastructure development. In this instance GI is a tool aiding development. However, it can also be considered to negatively impact society where it transitions from an aid to renewal to a facilitator of structural change in demographic or physical composition leading to gentrification (Anguelovski et al., 2018). Within the discussions presented in this paper we understand regeneration to be the process of renewal that involves public and/or private investment to facilitate a lasting improvement in the socio-economic and ecological fabric of an area (Hale and Sadler, 2012; Joseph Rowntree Foundation, 2020). In addition, we propose that landscape-led regeneration engages with the renewal and rehabilitation of denuded landscapes, and not explicitly its ecological composition. Thus, we propose a nuanced presentation of GI that aligns the principles of the concept with wider regenerative approaches to improve the quality of life, place, and environment in addition to regeneration activities that are explicitly led by GI design. The former integrates notions of connectivity, access to nature, and multi-functionality alongside a broader consideration of economic, infrastructural, and societal development. Alternatively, the latter uses GI as the catalyst for development *via* the development of projects that anchor investment on landscape rehabilitation. The examples discussed in this paper utilize both articulations of GI to highlight the complexity and complementarity of approaches used to support development.

The paper thus presents regeneration as a programme of works aiming to re-establish value in locations where the primary function of a landscape, i.e., industry or manufacturing, has diminished. It does not present regeneration as a process of ecological restoration as seen in some locations, i.e., China. The focus on developing inclusive places, as noted by Meerow and Newell (2017) and Dempsey et al. (2014), is central to this process and asks whether we should be engaged in regenerative actions if they fundamentally change social structures.

Assessments of regeneration focused on GI investment remain embryonic. In part this reflects the ongoing disciplinary silos of GI research which tends to focus on alternative development and management issues and not specifically on urban renewal. However, there is a need to consider both the short and long-term implications of investment. An understanding of political decision-making, financial support, and the socio-cultural value attached to place are critical in these discussions, as they provide signposts examining how GI can positively shape development (Hoover and Hopton, 2019; Venkataramanan et al., 2020; Zhang et al., 2020). This includes evaluations of greenwashing, "green city" branding and nostalgia for greener environments that may not map effectively on real world planning. Again, this may reflect the alternative approaches to GI-led regeneration compared to urban redevelopment that utilizes GI principles. Both though could be subject to subversions if used to brand a location green and sustainable without effective consideration of development/management needs (Von Döhren and Haase, 2015; Jennings et al., 2021). We also need to appreciate whether this process leads to socio-ecological disservices, and if so how we mitigate these (Hale and Sadler, 2012). In many instances the perceived political need to regenerate to support economic growth undermines the responsiveness of cities to meet local socio-cultural or environmental needs (Adair et al., 2000). However, we consider GI to be a tool of regeneration because it is multi-faceted and facilitates investment *via* the promotion of a positive "vision" for a location. This can unfortunately, in places, lead to a greenwashing of strategic or locally defined objectives. The greening of North American cities to promote greenest city brands are examples of this that may lead to gentrification (Rigolon and Németh, 2018; Nesbitt et al., 2019). It is therefore essential to unpack the political, financial and socio-cultural values embedded within discussions of regeneration if we are to appreciate its utility as a long-term promoter of sustainable development (Couch et al., 2003).

In addition to the socio-economic perspectives linking GI with regeneration there is a corresponding discussion of ecological considerations that need to be made. What form GI

takes is critical to the functionality of a landscape, especially in locations with significant remnants of industrial heritage. The management of environment pollution *via* the use of specific plant species, the effective navigation of water quality improvements *via* sustainable drainage techniques, assessments of soil quality, and the role of street trees or hedges as interceptors of pollutants all need to be discussed. Examples from the USA with regards stormwater management (Burns et al., 2012), street tree species selection in the UK (Hirons and Sjöman, 2019), and the role of soil composition in China (Wang et al., 2018), all illustrate the added value of integrating ecological thinking into urban planning. Where knowledge of ecological functionality is successfully embedded within regeneration efforts there is the potential to develop greater resilience to climatic and societal changes (Hale and Sadler, 2012). Regeneration is therefore not explicitly about ecological restoration but can be used as a catalyst for such thinking when aligned effectively with other development objectives (Otsuka et al., 2021). Thus, although the mainstream regeneration literature does not directly address environmental quality they cannot be divorced if ecosystem functionality is to be promoted.

To consider these questions the following asks whether GI should be considered a force for good, and if not, what examples exist where investment in landscape-led regeneration has led to negative socio-economic or ecological outcomes. To do this we debate a series of examples from Europe, North America, and Asia focusing on the financial, political, and socio-cultural barriers to effective landscape-led regeneration discussing how GI has been positioned within these debates. The paper goes on to ask whether development has transitioned into gentrification and if so, what lessons can be learnt to avoid the negative impacts associated with change. The paper focuses predominately on the socio-economic aspects of GI and regeneration, as these have been discussed most frequently in the literature. This does not mean that ecological considerations are dismissed but are less prominent in current debates. The paper acknowledges though that decisions regarding tree species selection (Galle et al., 2021), the technical aspects of water-sensitive design (Wong, 2015), and the choice of "GI type" are critical to successful regeneration. An emerging literature, especially in China, is visible discussing these issues though it remains small to date (cf. Wang et al., 2018; Yang et al., 2019; Xiao et al., 2021). As such, we focus primarily on the economic, socio-cultural, and political choices made by decision-makers regarding the inclusion of GI in regeneration debates.

To support this discussion, the paper focuses on three distinct types of regeneration that has effectively utilized GI: *linear*, *waterfront* and *landscape-led* investment. These have been selected as they are the most frequently discussed forms of GI reported in the regeneration literature. They also represent examples of developments that have influenced the implementation of GI within other locations, i.e., the projects that mirror the design of the High Line in New York. Furthermore, a significant number of cities bear the scars of former transport infrastructure making these critical locations for landscape-led regeneration (Lindsey, 1999). Waterfront areas offer comparable situations but highlight the additional political dimension of redevelopment used as a precursor for economic development (Hagerman, 2007). As such, the types of regeneration presented can be considered as being at the forefront of redevelopment narratives illustrating the added-value that GI brings to investment discussions. The paper does not though provide a detailed unpacking of the theory of urban regeneration (see Tallon, 2013 and Couch et al., 2003 for further details). Alternatively, it focuses on how landscape-led practice can be discussed alongside it outlining how GI has been used to facilitate effective environmental and urban planning.

To achieve this, we set out a review of GI projects within a broader academic discussion of landscape-led regeneration rather than presenting new empirical findings. This is a purposeful choice, as it illustrates how GI can be utilized to promote a multi-disciplinary approach to urban development that incorporate discussions of scale, multi-functionality, political action, and financing. The paper should not be considered as a systematic review of regeneration and GI but as a scoping exercise. The examples presented are signposts examining the ways in which the socio-economic, ecological, and political framing of GI has been aligned with regeneration practices. The paper concludes that GI should not be considered panacea in regeneration activities, but alternatively as a suite of potential options that address socio-economic and ecological needs collectively. GI is thus presented as complimentary to different spatial planning approaches that can be integrated effectively with discussions of transport, health, and economic uplift. Moreover, we note that responding to local contexts in terms of climate, societal needs, changes in built form, and understandings of GI can provide an evidence base promoting transferable investment opportunities. However, urban planners need to remain reflective of the differences between GI-led approaches and regeneration that includes GI principles, and the alternative outcomes that both can achieve, if they are to caution against accusations, real or otherwise, of using GI to gentrify urban areas.

SITUATING LANDSCAPE IN URBAN DEVELOPMENT DEBATES

The role and value of landscape across the world varies. In some locations, i.e., Australia and Canada, the legacy of cultural place attachment leads discussions of environmental value (Lewis and Sheppard, 2006; Prangnell et al., 2010), whilst in others, i.e., India, change is driven by political and economic growth mandates (Bhan, 2009). In addition, we can identify a nostalgic lens through which landscape is debated in the UK reflecting values that may or may not have been actualized in real time (Matless, 1998). As a consequence, we as planners, need to be cognizant of the interweaving cultural, ecological and economic histories associated with landscape change to examine its meaning in different geographical and political contexts (Lowenthal, 1985). Whilst such a multi-layered approach provides planners, community leaders and landscape professionals with options to explore the meaning of "environment," it can be difficult to align this knowledge with practice (Lynch, 1960; Waldheim, 2016). Furthermore, a significant number of cities only partially engage

with this multi-layered analysis of landscape appreciation within urban planning. This is especially relevant in terms of the ways in which urban ecology is integrated into these discussions, and the increasing value assigned to the functionality of soil, air and water quality, and the livability of a location (Lovell and Taylor, 2013).

Where examples of these myriad appreciations have been successfully aligned we can identify practice that integrates an understanding of personal and communal relationships with the landscape, as working, cultural or experiential places, i.e., the shipyards of Glasgow in Scotland, with the need to meet the socio-economic aspirations of a changing society (Curl et al., 2018). However, this process varies depending on the influence of political, economic, and socio-economic factors linked to the short and long-term needs of a location. As a consequence, we can argue that changes to urban form are dependent on prevailing economic and political actions rather than cultural interpretations of the landscape (Tallon, 2013). We therefore need to consider ways to integrate cultural knowledge more effectively into development to help situate our analysis of urban landscapes.

The ability of decision-makers to engage with this commentary, whilst maintaining a focus on development, is difficult. Some urban areas have been more successful in their management of change, i.e., the wider landscape-led regeneration of the Ruhr in Germany (Zeff, 2018; Reimer and Rusche, 2019), whilst others have moved to rethink their landscapes from alternative economic perspectives, i.e., the use of Yamuna River floodplain in New Delhi (India), at the expense of its ecological functionality (Mell, 2020). In practice this leads to a lack of consistency between cities. As such, there is a growing acknowledgment that the value of landscape within urban planning is variable. Furthermore, we can identify cities that continue to struggle in their responses to population change, climate change and biodiversity loss (Schilling and Logan, 2008; Xiao et al., 2021). In such locations the value of ecological resources within urban development discourses is limited restricting the potential for environmental improvement to act as a catalyst for urban renewal.

Unpacking these complex issues is difficult especially when cities bear the remnants of former development—especially transport infrastructure. Moreover, in areas where industrial decline has been a paramount factor in urban degradation there is a need to re-examine our understanding of the value of these landscapes (Ling et al., 2007). The shift in landscape functionality linked predominately to economic growth illustrates the temporality of value attached to urban form. We can therefore argue that there is a fragility to the links between industrial growth/heritage and environmental management that has come to the fore in the twentieth century, *via* examples from the UK or Europe (Blackman and Thackray, 2007; Ruelle et al., 2013). Within these locations we can identify a transition from "landscape" as a resource used to structure economic growth to a market-led service economy that places limited value on environmental resources (Waldheim, 2016). This invokes the obsolescence noted by Lowenthal (1985) between human associations with nature and their material value. The utility of the landscape as a facilitator of economic development has therefore been challenged, as society has moved away from *working with* the landscape to *utilizing it* for socio-economic, ecological and political reasons (Rydin, 2003; Hall and Tewdwr-Jones, 2010).

Landscape professionals have been tasked with facilitating this transition to examine how best to ensure that "environment" remains an essential component of urban planning. One area where landscape has gained traction in these discussions is *via* the global process of city branding. Evidence presented by Siemens (2011) and the McKinsey Global Institute (2010) illustrates that greener, interactive and attractive cities are regarded as the most livable, and by extension attract greater economic investment. Programming for "livability" *via* the delivery of greener and more connected neighborhoods has been applied in Melbourne (Australia), Singapore, and Vancouver (Canada), facilitating more inclusive forms of urban development (Kear, 2007; Tan et al., 2013; Norton et al., 2015). In many instances this has been centered on newer development but there is the potential for retrofitting of existing infrastructure to aid this process. However, a critical reflection on these approaches suggests that a level of variability is inherent in how "green city" benefits are distributed to a city's population. Moreover, without an appreciation of the political structures of a location and its influence of community engagement or acceptance of development it is difficult to fully understand whether greening activities are delivering what is needed locally. As a consequence, prominent greening projects, i.e., those in New York or Atlanta, could be considered to effectively green their respective city's (and improve their brand externally), but could also be excluding parts of their communities from these benefits depending on how GI is used (Immergluck, 2009; Jo Black and Richards, 2020; Roman et al., 2020). Meaningful consideration is therefore needed to ensure that retrofitting GI accounts for local needs, aspirations, and environmental context before embarking on a wide-ranging programme of greening. Although the economic benefits of urban greening can be seen in increased branding of a city as sustainable, this does not inherently lead to local level improvements. What type of GI, what scale it is developed at, who has access to it, who pays to maintain it, and whether this leads of a cumulative socio-economic and ecological parity all needs to be taken into consideration to help structure regeneration efforts.

However, considerations of the ecological composition of urban form are also needed to assess which species are most appropriate for a specific climate, as well as physical and cultural understandings of nature. For example, Yang et al. (2015) discussed the role of alternative tree species in reducing $PM_{2.5}$ noting that London plane [*Platanus acerifolia* (Aiton) Wild.], silver maple (*Acer saccharinum* L.), and honey locust (*Gleditsia triacanthos* L.) had an above average ability to remove particulates from the urban environments and were used frequently in development. In addition, their study argued that certain species, especially conifer were more effective at removing $PM_{2.5}$ from the atmosphere. However, the "use of conifer species requires choosing the correct gender and matching trees with appropriate sites" (2015:267). The negative health impacts of some allergens associated with the flowers of specific tree species can be reduced

through selective planting (cf. Nowak et al., 2018). The potential drawback of urban greening were also reported by Nowak et al. (2018) who argued that pollutant interception could impact health if pollutants were trapped in close proximity to where people walk, live and recreate. Care is therefore needed to incorporate treescapes that are effective managers of air quality (Hirons and Sjöman, 2019). An appreciation of the links between urban forestry, ecosystem services and disservices is therefore needed if GI is to be effectively used within urban development. Comparable discussions focus on the role of pollinator species, i.e., bumble bees and habitat corridors (Bellamy et al., 2017), the role of GI in addressing urban heat island impacts *via* green walls/roofs implementation depending on species choice (Livesley et al., 2016), and in controlling flooding through the creation of wetlands and woodland (Dixon et al., 2019).

Unfortunately, the successful approaches to landscape-led development visible in some cities are not applicable to all locations. Sustainable urban development requires a bespoke appreciation of the existing landscape and its potential to deliver economic, social, and ecological benefits simultaneously (Austin, 2014; Firehock, 2015). Therefore, following periods of decline cities have needed to rethink the ways in which their landscapes can be used to promote positive links between culture, industry, economic growth, and ecological functionality [see, the Department of Environment Transport the Regions (1999) Urban Renaissance work and Tallon, 2013]. A series of projects, some of which have gained global visibility, including the Coulée verte René-Dumont (*Promenade plantée*) in Paris (France), the *Atlanta BeltLine* in Atlanta (Georgia, USA) or the regeneration of the *Kwun Tong Promenade* in Hong Kong are examples where existing infrastructure has been repurposed as multi-functional GI (Mell, 2016a; Fok and Law, 2018). Each of these projects integrated cultural elements of the former land use to help structure the revised meaning of a site. These projects were also part of a longer-term process of urban redevelopment that required political buy-in, a revised economic understanding of landscape value, and a reflective approach to design respective of former uses.

Although these projects can be considered to have effectively integrated the cultural value of former landscape uses within development this is not a straightforward process in all locations. Issues of temporality, ownership and long-term investment are important considerations that also need to be made. However, such debates often lack an environmental context, and therefore fail to appreciate the added meanings and functions that urban nature in the form of green spaces and waterways hold in rehabilitation efforts (Mathey et al., 2015). Moreover, as the value of urban greening has grown in prominence within planning, we can approach regeneration thinking from a more ecological perspective (Mell, 2009). This potentially facilitates more effective analysis of the complexities of urban ecosystems with regards species selection to avoid health or ecosystem disservices, promote ecological diversity and more adaptive environmental capacity (Von Döhren and Haase, 2015; Hirons and Sjöman, 2019; Lovell et al., 2020). Whether, and if so, how GI can be considered a positive component on urban regeneration remains an under explored area of the academic and practice research. GI planning, and its location within wider urban rehabilitation narratives, does however offer useful insights into how urban nature in the form of parks, community green spaces, canals and waterways, woodlands and public open spaces can be used to regenerate urban areas (Wright, 2011).

DEFINING GI WITHIN DEVELOPMENT DEBATES

The research literature on GI is drawn from a breadth of disciplines including landscape and urban planning, environmental management, hydrology, ecology and more recently engineering and real estate (Koc et al., 2017; Escobedo et al., 2018; Wang and Banzhaf, 2018). Such a diversity of approaches instilled within GI planning has led to myriad definitions, typologies and strategies being used to support its implementation. This has helped establish a flexible basis for discussions of GI, conceptually and in practice, but has also diluted the acceptance of GI because it lacks a universal grounding (Mell, 2014). Although, GI is one of the most recent terms given to planning for sustainable development it is not a new concept. Consequently, there is an ongoing debate within the literature asking whether there is a need for a single definition for GI or if the broader interpretations of GI provide effective signposts for engagement from different stakeholders (Garmendia et al., 2016; Mell and Clement, 2020). These discussions raise questions regarding what GI looks like, for example, are certain types of GI better than others? And what socio-economic or ecological values does GI provide in different geographical locations? (see **Table 1**). This is exacerbated by the disciplinary focus of the research literature, which has debated important, yet siloed discussions of GI as an *ecological* or *socio-economic* approach to planning in some instances (Koc et al., 2017; Jennings et al., 2021; Teixeira et al., 2021).

However, a review of the GI literature promotes the following principles as being fundamental to the concept:

i. The promotion of connectivity between people, place and nature *via* increased access to the landscape;
ii. The establishment of a network of GI elements within a wider spatial network supporting diverse ecological and socio-economic activity;
iii. The utilization of connective landscape elements, i.e., waterways, habitat corridors, and footpaths/cycle routes to facilitate movement within and across urban/rural boundaries;
iv. Support of socio-cultural, ecological and economic benefits *via* investment and maintenance of a variety of GI elements;
v. The creation of spaces that provide multi-functional benefits to people, society, the economy and nature;
vi. The creation of a supportive policy environment that promotes socio-economic and ecological actions in practice;
vii. An appreciation that GI elements can be function at a number of scales;
viii. An awareness of the added economic value that GI can provide at several scales;

TABLE 1 | Common GI typologies (adapted from Mell and Whitten, 2021).

Types of GI	Scale: Site (SI), Street (ST), Neighborhood (NE), City (CI), Landscape (LA)	Benefits	Site/corridor/ network
Street trees	SI, ST, NE, CI	Biodiversity enhancement, habitat creation, climate mitigation/microclimate moderation, interception of rainfall, places for economic development, location of social interaction, communal health and wellbeing	Corridor
Forest	CI, LA	Biodiversity enhancement, habitat creation, climate mitigation/microclimate moderation, economic development opportunities, personal/communal health and wellbeing	Site
Urban woodlands	SI, NE, CI	Biodiversity enhancement, habitat creation, climate mitigation/microclimate moderation, location of social interaction/play, economic development opportunities, personal/communal health and wellbeing	Site
Urban parks	NE, CI	Biodiversity enhancement, habitat creation, climate mitigation/microclimate moderation, interception of rainfall, location of social interaction/play, economic development opportunities, personal/communal health and wellbeing	Site
Pocket parks	SI, NE	Biodiversity enhancement, habitat creation, climate mitigation/microclimate moderation, location of social interaction/play, economic development opportunities, personal/communal health and wellbeing	Site
Private gardens	SI	Biodiversity enhancement, habitat creation, personal health and wellbeing	Site
Public gardens	SI, NE, CI	Biodiversity enhancement, habitat creation, climate mitigation/microclimate moderation, interception of rainfall, location of social interaction/play, economic development opportunities, personal/communal health and wellbeing	Site
Play areas	SI, NE	Location of social interaction/play, economic development opportunities, personal/communal health and wellbeing	Site
Amenity greenspace	SI, NE	Biodiversity enhancement, habitat creation, climate mitigation/microclimate moderation	Site / corridor
River corridors/fronts	NE, CI, LA	Sustainable transport, biodiversity enhancement, habitat creation, climate mitigation/microclimate moderation, location of social interaction/play, economic development opportunities, personal/communal health and wellbeing	Corridor
Lakes/ponds	SI, NE, CI	Biodiversity enhancement, habitat creation, climate mitigation/microclimate moderation, location of social interaction/play, economic development, economic development opportunities, personal/communal health and wellbeing	Site
Sustainable drainage systems (SUDS)	SI, NE	Biodiversity enhancement, habitat creation, climate mitigation/microclimate moderation, interception of rainfall, economic development opportunities, personal/communal health and wellbeing, aesthetic improvements	Site / corridor
Green walls/roofs	SI	Habitat creation, climate change mitigation, flood mitigation, urban cooling, reduced energy costs	Site
Green cycle routes	NE, CI, LA	Sustainable transport, habitat creation	Corridor / network
Infrastructure greening (roadside greening)	NE, CI, LA	Habitat creation, aesthetic greening/screening, flood mitigation, climate change mitigation	Corridor / network
Allotments/urban agriculture	SI, NE, CI	Personal health and wellbeing, climate change mitigation	Site
Formal green belts	CI, LA	Habitat creation, climate change mitigation, sustainable transport, outdoor recreation,	Corridor / network

ix. The values associated with GI elements, functions, and benefits evolve as a landscape (and its socio-economic) needs diversify.

Working with these principles allows different disciplines to apply GI in ways that are responsive to engineered, economic, and socio-ecological needs (Firehock, 2015). It also provides a broad framework that can be applied across geographical locations, whilst being respective of local context. GI as a set of principles, terminology, thematic approaches, or types of investment could also be considered here. This collective understanding of the added-value that GI delivers can be seen as driving the growing number of guidance documents, strategies, toolkits and benchmarks being developed (cf. Harrison et al., 1995; Philadelphia Water Department, 2011; Norton et al., 2015; Calvert et al., 2018). Moreover, this lends itself to a further review of whether GI is being framed as leading investment or is one part of a wider regeneration process.

An appreciation of the *scalar*, *temporal*, *geographic* and *disciplinary* variation of GI is also critical to its successful implementation (Mell and Clement, 2020). However, there is an ongoing debate in the literature examining whether terminological differences are more influential than the four aspects reported by Mell and Clement (2020). The discussions posed by Wang and Banzhaf (2018), Koc et al. (2017), or

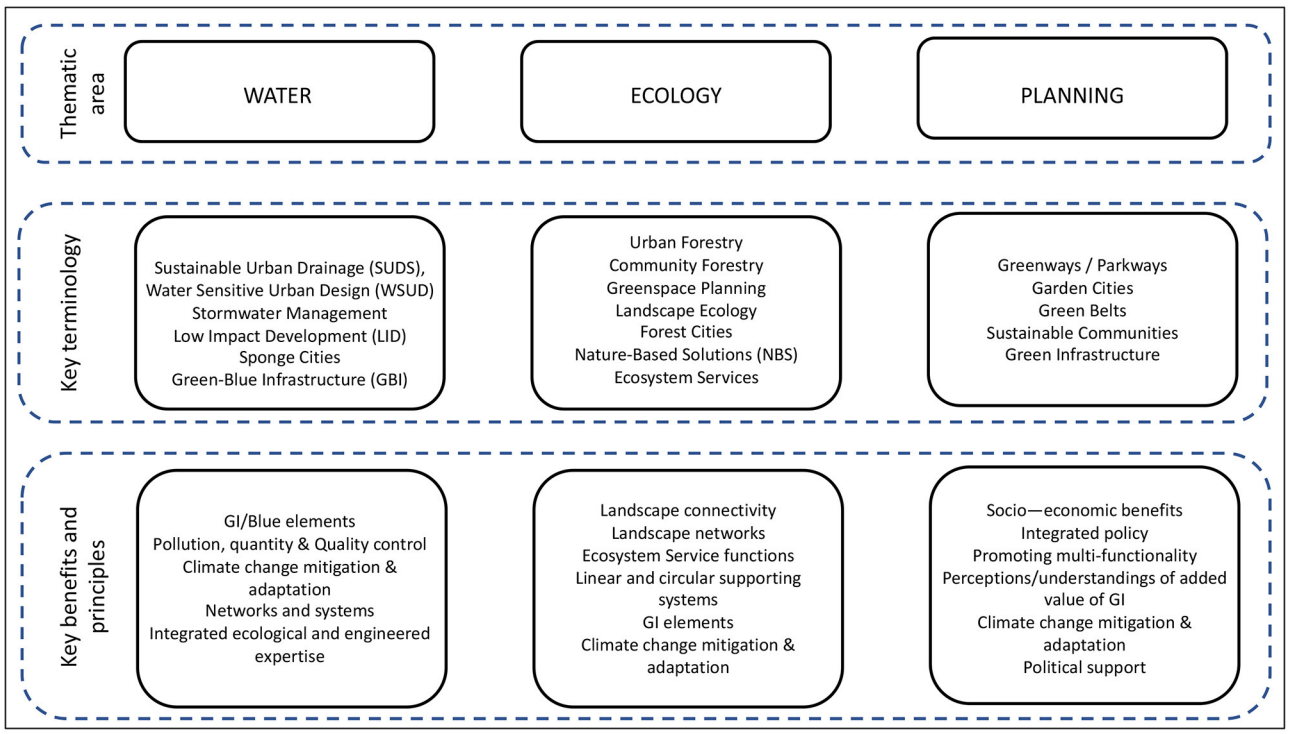

FIGURE 1 | Intersection of GI principles and terminology.

Garmendia et al. (2016) debate the complexity of understanding GI within a broader terminological discussion of urban forestry, ecosystem services and Nature-Based Solutions (NBS). Matsler et al. (2021) offer a contemporary analysis of this discussion drawing on bibliometric, as well as temporal analysis to identify synergies between these alternative framings. Therefore, although the scope of GI use is widening, we can identify a developing examination of GI that bridges the disciplinary, scalar, and importantly temporal and geographical variation. **Figure 1** presents a representation of three of the main principles underpinning GI aligning them with the terminological variation discussed in the literature illustrating the complementarity of its conceptual underpinnings. These discussions have been supported by a groundswell of practitioner, policy-maker and academic engagement promoting the multi-functional value of GI to a wide audience of potential users. The establishment of such a foundation has built upon the work of Benedict and McMahon (2002, 2006) creating a global platform for debate.

The positioning of GI as an adaptable form of landscape and urban management has been prominent in aligning its principles with issues of urban retrofitting and regeneration (Hansen and Pauleit, 2014). The promotion of green walls, green roofs and sustainable drainage have been integral to this process with a wealth of literature examining the variation in technical specifications, infrastructure requirements, and ecological assemblages used within these practices (Carter and Fowler, 2008; Norton et al., 2015; Liberalesso et al., 2020). Research in this area provides greater scope to analyze the ecological aspects of GI and its contribution to urban functionality. Investment in GI that is resilient to climate change, i.e., in terms of tree variety selection to avoid invasive species or negative health pathways (Lovell et al., 2020), the inclusion of vegetation that can act as carbon sinks and are resilient to drought flooding (Maria Raquel et al., 2016), and planting that support soil functionality, as well as water and air quality are key to this process (Dylewski et al., 2019). Environmental specialists, especially landscape ecologists, arborists, and hydrologists, are important actors providing expertise regarding ecosystem enhancement, as well as potential disservices of species selection in this process. Moreover, utilizing ecological perspectives facilitates a greater understanding of landscape connectivity, which can be embedded within decision-making. We can also identify the rehabilitation of derelict land as being equally significant in such situations (Scott et al., 2016). One example is the investment in GI of England's Community Forest network who from 1991 onwards worked extensively to develop a renewed sense of value in post-industrial landscapes, and were pioneers of a "GI approach" to management (Blackman and Thackray, 2007; Mell, 2011). The role of community forestry in the UK mirrors that of conservationist and stormwater management in North America, which has driven forward investment in GI to a broader set of stakeholders (Young et al., 2014; Zuniga-Teran et al., 2020).

The added-value created by England's Community Forest partnerships can be seen in how they generated political support for GI investment. *Via* their project work working with local government, the environment and developments sectors, and

local communities they were able to promote GI interventions that mapped effectively onto prominent health, wellbeing and urban regeneration mandates (Mersey Forest, 2013b; Mell, 2016b). Thus, the rationale for GI was enhanced *via* the reporting of cost-effective landscape enhancement work at the local level. In other locations the politics of GI takes a more critical view of costs/benefits from a capital investment vs. revenue spend perspective. Where the return on investment in terms of property uplift, increased economic spend, as well as improved recreational, sports and tourist facilities are enhanced through GI we can identify a corresponding increase in political support for GI (South Yorkshire Forest Partnership Sheffield City Council, 2012). This, in turn, can be used to market a city or location as greener and more sustainable. However, the establishment of such a positive relationship between GI and political support is a long-term aim for many cities and advocates. To achieve such support robust evidence is needed to support investment and a portfolio of project costs and returns are required to reassure local government and/or developers of the positives of investing in GI (Mell, 2021). Advocates such as England's Community Forests have been catalysts of such evidence sharing but are also aware that this is a long-term process (Mell, 2011).

Investment in GI has thus been proposed as a mechanism to reinstate value in denuded landscapes *via* landscape-led design (Kitchen et al., 2006; Keesstra et al., 2018). Although this has been predominately focused on urban areas there is an value to discussing GI at the landscape scale, especially in terms of managing ecological systems, biodiversity corridors and water catchments (Albert and Von Haaren, 2014; Liquete et al., 2015). The urban focus of the majority of GI planning though can be linked to discussions framing landscape as part of urban debates, as discussed by Waldheim (2016), as well as in the research of Beatley (2000; 2012) and Newman (2010) on green urbanism and biophilia. Moreover, the promotion of ecologically diverse urban areas rejects the simple binary notions of built vs. natural and promotes greater landscape connectivity *via* the implementation of environmental links, hubs and nodes (Thompson, 2012). Common across these discussions is the role played by ecological systems in supporting systems functionality. GI thinking can therefore act as the bridge between traditional regeneration work and a landscape-led approach to urban renewal.

However, a further consideration is needed to assess the potential disservices associated with GI investment. This can take the form of displacement as a result of gentrification and structural changes in local economic conditions (Nesbitt et al., 2018; Rigolon and Németh, 2018), a shift in emphasis on local environmental conditions that fail to meet local needs, i.e., of specific ethnic communities or age groups (CABE Space, 2005; Cleary et al., 2019), and the installation of specific forms of GI that lead to health inequalities or which promote anti-social behavior (Jennings et al., 2019; Roman et al., 2020). All investment in GI therefore needs to be cognizant of the benefits and disservices that may develop because of landscape change. These potential problems though should not limit the discussion of GI intervention in regeneration activities but should be examined to assess who benefits and who loses from change, and how any negative aspects of GI can be mitigated against. This includes looking at the "just green enough" practices' proposed by Curran and Hamilton (2018) and greater engagement with local communities to better understand what GI could have a meaningful influence of local quality of life (Mell, 2016a).

To effectively debate the added value that GI provides in development there is a need to continually reflect on how the use of alternative terminology influences what form investment takes. Thus, an understanding of the various socio-economic and ecological perspectives associated with GI enables advocates from across the built and natural environment to consider issues of diverse form, the complexity of development approaches, and the complimentary offered by different GI synonyms. Within regeneration discussions an acknowledgment of this diversity is critical to the adoption of appropriate forms of GI, especially when dealing with complex ecological contexts, i.e., pollution, to facilitate socio-economic enhancement. To examine this process three types of regeneration project are discussed illustrating the use of connectivity and network principles in redevelopment (*linear corridors*), the promotion of socio-economic benefits associated with politically expedient projects (*waterfronts*), and the creation of multi-functional locations reusing derelict spaces (*landscape-led projects*). Each type of investment is considered within academic and practitioner discussions as an exemplar of good practice linking GI with regeneration. Although other projects could have been debated the spatial configuration and benefits associated with these investments are considered representative of options available in several locations.

LINEAR INFRASTRUCTURE AS REGENERATIVE TOOLS

There is a growing trend in urban regeneration to reactivate former industrial infrastructure into high quality recreational GI that reflects the configuration of infrastructure that previously serviced rail and/or road transit. Located within/across urban areas these infrastructure have been repurposed as "greenways" in the USA, and more recently as linear GI in other parts of the world (Little, 1990). Moreover, former train infrastructure cover extensive areas linking urban centers with suburban areas. It can also be argued that due to their linear nature that these spaces lack the dimensions, i.e., width or spatial extent, needed to be repurposed as housing, commercial or alternative industrial infrastructure. As a consequence, rehabilitation of former transport infrastructure as "GI" offers both a cost effective mechanism to regenerate specific locations and provides opportunities to invest in high quality and accessible green space (Hellmund and Smith, 2006). This is of significant value to cities where repurposing former industrial infrastructure may be considered outside of strategic redevelopment discussions due to the perceived difficulty of its reuse (De Sousa, 2004).

One of the precursors of the current trend in linear greenways was the development of the Coulée verte René-Dumont, also known as the *Promenade Plantée* in Paris (**Figure 2**). Following its closure as a railway service line in 1969 the viaduct was abandoned. In 1979 the City of Paris and SEMAEST (a company of the City of Paris leading localized commercial development

FIGURE 2 | Promenade Plantée, Paris.

activities) worked to develop a regeneration plan for the site, which was completed in 1983. The 4.7 km (2.9 mile) elevated linear park was built on the former Vincennes railway close to the Bastille and Gare de Lyon (Mell, 2016a). Designed by landscape architect Jacques Vergely and architect Philippe Mathieux, the plan aimed to convert the viaduct into an elevated linear park, and was one element of a wider area regeneration process started in the early 1980s, completed in 1986 and inaugurated in 1993 (Heathcott, 2013). Utilizing the first story height of the elevated railway the park dissects residential buildings and connects a series of public spaces and parks including the Parc de Reuilly and Square Charles-Péguy. The compact nature of the site sets it apart from other linear greenways, i.e., those discussed by Lindsey et al. (2001) in Indianapolis and more generally by Little (1990), by making successful use of a geographically restricted area. It also benefits from its modular nature, as the composition of specific sections vary in terms of their aesthetics, species selection, and socio-economic and ecological functions (Gastil, 2013; Heathcott, 2013). It could also be argued that the Promenade Plantée aided the activation of

FIGURE 3 | The High Line, New York.

additional development as proposed by SEMAEST in the area by highlighting a successful reuse of derelict infrastructure.

The High Line in New York is potentially the most visible example of the reuse of linear infrastructure promoting investment in GI (**Figure 3**). Noted as a global reference point of high quality design by Millington (2015) the project can also be considered as an example of neoliberal development that trades public provision of GI for economic development opportunities. This could be viewed as disproportionately benefiting real estate

agents over local communities. The design concept of The High Line repurposed 2.33 km (1.45 mile) of elevated railway infrastructure into a publicly accessible park, although one with permissive access rights. The project was developed by non-profit organizations and received political support from the Mayor of New York, which facilitated additional public and private sector investment. Owned by the City of New York, the park is operated by Friends of the High Line (a non-profit private organization) in partnership with the New York City Department of Parks and Recreation. The High Line was developed in the same time period as the New York Green Infrastructure Plan (New York City Environmental Protection, 2010) highlighting a growing appreciation of the added-value that GI could deliver *via* the reuse of industrial sites or storm water management interventions. This timeframe also illustrates a more nuanced understanding of the evolving economic arguments aligned with ecosystem service functionality supporting GI and their integration into policy and practice (Miller and Montalto, 2019), as identified by the political support from the then Mayor of New York, Michael Bloomberg.

The leveraging of political and financial support allowed The High Line, which opened in 2009, to invest in high quality landscape design that was reflective of the urban and climatic context of New York. The simplicity of its spatial form allowed the designers to use street furniture, specific woods and metals, and climatically responsive plant species to ensure that the site evolved throughout the seasons and over several years. Although considered to have been a successful investment attracting ∼8 million visitors per annum, The High Line has been critiqued as proliferating gentrification in the area. Changes to property prices, the area's demographic profile, and availability of services have been discussed of fundamentally altering the area's socio-cultural fabric (Loughran, 2014). This has raised questions about whether GI should be used to support regeneration efforts if it privileges specific sections of society over others. It could be argued that the failure to ensure local socio-economic contexts were maintained undermines by the positives of The High Line. However, the trade-offs between economic development and local needs places investment in GI in a difficult position. GI provides valuable ecosystems services, feeds into city-scale development targets and supports the economy of the city (McPhearson et al., 2014). However, Millington (2015) and Loughran (2014) in New York, and Immergluck (2009) with regards the Atlanta BeltLine, suggests that investing in linear GI may disproportionately benefit white, middle/upper class residents at the expense of Black Indigenous and People of Color (BIPOC) and lower income communities. It is therefore critical to reflect on the role that GI holds within any investment scenario to mitigate the potential of marginalizing access to all communities (Curran and Hamilton, 2018).

The Camden Highline (London) is one of the most recent attempts to capitalize on the trend of repurposing transport infrastructure as GI. Taking their inspiration directly from the New York Highline (Mell, 2019), the Camden Highline is a collective of four non-profit organizations (focused on business improvement and charitable work), working toward the reuse of existing infrastructure to enhance environmental quality. The proposed 1.2 km route uses rail infrastructure to link Camden in north London with the regeneration work in Kings Cross (Camden Highline, 2021b). One of the key principles of the project's investment in GI is the cost-effectiveness of reuse as a linear greenway compared to either removal or purposing as transport infrastructure. The project aims to promote wider access to green space and provide alternative vistas of the area to a greater number of users. Each of these elements were embedded within the project's promotion of accessibility and within the design competition held in 2020–21 (Camden Highline, 2021a). Moreover, the site will use tree planting, street greening to screen noise and pollution, and a mixture of flora and fauna to create a diverse landscape that changes over the seasons (Mell, 2019).

There are, in addition, a range of additional projects that examine the opportunities for linear GI at a larger scale. These include regional greenway systems such as the New England Greenway system (Ryan et al., 2002), as well as those that emanate from urban cores into suburban and rural areas, i.e., the Copenhagen "Finger Plan" (Caspersen and Olafsson, 2010). It is important to note that in these instances the links being made between investment in GI, strategically linking people with nature, and the use of former industrial infrastructure are central to the effective transition from design to implementation.

WATERFRONT REGENERATION

The alignment of waterfront regeneration with GI has been increasing in number, as cities aim to revitalize former industrial buildings and landscapes. A number of prominent examples can be identified globally including Vancouver, Sydney and Liverpool where investment in river and harbor front developed with significant GI elements (Couch and Karecha, 2006). Moreover, major cities in China and India, i.e., Guangzhou and New Delhi, have also placed an emphasis on riverfront development within their strategic development plans (Jim and Chen, 2007; Nandi, 2014; Mell, 2016a). The use of GI in riverfront areas supports the delivery of a number and socio-economic benefits, for example: property uplift, the relocation of commercial businesses to prime real estate locations, and increased use by local communities and visitors. Riverfronts also act as a *catalyst* for development. Using these locations as physical anchors allows planners to co-locate additional commercial, residential and recreational infrastructure around a waterfront location (Follmann, 2015). However, an awareness is needed to successfully design GI into riverfront developments as a core principle rather than as a secondary consideration. Where this is possible riverfront redevelopments provide an illustration of the added value that GI can deliver in the physical and psychological shaping of place (Mell, 2020). Alternatively where GI is absent, i.e., in large parts of the London docklands development, we can identify a failure by planners, developers and designers to deliver places that are livable, interactive and ecologically functional (Butler, 2007; Brownill and O'Hara, 2015). Consideration is also required regarding the promotion of equitable access to riverfront areas, as well as the potential for gentrification to negatively impact use. Furthermore, as a significant proportion

FIGURE 4 | Sabarmati Riverfront, Ahmedabad.

of riverfront redevelopment projects are government or Public-Private-Partnership led, especially in India and China, there are potential conflicts of interest between the best use of public assets and the promotion of economic returns through redevelopment. This is exacerbated if GI is incorporated within development as a facilitator for commercial gain rather than as public space (Li et al., 2017; Wang and Mell, 2019).

The Sabarmati Riverfront redevelopment in Ahmedabad (Gujarat, India) is one example where such a critical reflection is needed regarding the long-term betterment associated with the project. Spanning a 16 km section of the Sabarmati River the project redeveloped the floodplain *via* a clearance of existing uses and ecology, and a channelization of the area. Aligned with the creation of a concreate promenade (**Figure 4**), the development enabled the city to invest in water control measures supporting more effective water management by combining the project with existing (and new) drainage to/from Ahmedabad's network of lakes (Ahmedabad Urban Development Authority, 2013). Supported by then Chief Minister Narendra Modi, now Prime Minster of India, the project aimed to facilitate economic development *via* the creation of a riverfront investment zone. Strategically this objective was linked to the wider opportunities associated with the New Delhi-Mumbai Industrial Corridor. Due to these links the project was considered to be politically motivated and thus economically supported by the State of Gujarat, which led to additional development funding being allocated to the project (Dutta, 2000). The complexity of funding and the changes in land ownership along the river have been linked to the strategic objectives of the project to align Ahmedabad with wider development agendas in India. The consequence of which has been a critical reflection on the nature of benefits developed locally compared to the disservices associated with displacement and landscape change. The perceived need to locate Ahmedabad within national economic development debates therefore appears to have shaped the project at the expense of local needs (Adhvaryu, 2011; Mathur, 2012).

In action the project utilized several GI approaches to increase the use of the riverfront and its aesthetic quality. First, trees were planted along a significant length of the riverfront providing additional greening to promote rainfall interception and provide shade. In addition, plans to integrate additional GI on the former floodplains are ongoing but subject to change due to modifications to the phased delivery of built infrastructure (Mell, 2016a). The project also invested in two new public parks providing formal green spaces along the river. The combination of these investments provided the project with points of significant GI investment, i.e., Subhash Bridge Riverfront Park, alongside a use of trees throughout the riverfront area. These new interventions provide a significant shift in the urban form, ecological function and aesthetic quality of the area compared to the former floodplain areas (see **Figure 4** and Mell, 2017). However, questions were raised regarding the added-value provided by the project. Commentary from local academic and environmental stakeholders argued that the reconfiguration of the existing ecology (a) sanitized a diverse ecological area and (b) left the area increasingly prone to flooding. In addition, both new parks required an entrance fee thus limiting access for some members of society. The lack of equitable access was noticeable as a high number of public parks in Ahmedabad are free to use, although they have specific opening times (Desai, 2012). It can also be argued that the use of extensive tree planting on an open concrete promenade has limited ecological value due to the lack of water and shade needed for trees to prosper. As a consequence, an ongoing debate exists regarding the added ecological value to society of the project compared to its economic benefits (Mathur, 2012).

As with the Sabarmati Riverfront, The Bund in central Shanghai is located on a river: the western bank of the Huangpu River, an area associated with the historical banking and commercial activity. Over an extended period, the configuration of the adjacent Zhongshan Road has been modified to reflect transport and commercial infrastructure requirements. Consequently, there has been an evolving functionality, accessibility, and utility to The Bund linked to changes in urban form. From the late 1990s onward following significant changes in the layout of Zhongshan Road, The Bund started to take its current form. These changes allowed the project's

FIGURE 5 | The Bund, Shanghai.

FIGURE 6 | Queen Elizabeth Olympic Park.

designers to rethink the ways in which GI could be used to promote interaction with the river and support the recreational aspirations of different user groups (Den Hartog, 2019). The redevelopment of The Bund can also be seen to deliver a range of ecological benefits associated with urban heat island and surface water runoff management, and the development of additional habitats in central Shanghai. Moreover, as noted by the architect Heatherwick (2020:96) the redevelopment of the waterfront and its associated buildings supported their "…focus for the Bund project [that] was to try to invent a new type of place that responded to the history of the city and the layers of cultural influence that have made it so special."

With a length of ∼1.6 km (1-mile), The Bund comprises a modular set of spaces that offer different landscape characteristics along its length (**Figure 5**). At the northern extent of The Bund is Huang Pu Park located at the confluence of the Huangpu River and Suzhou Creek. The Huang Pu Park has a blend of contemporary landscape architecture and public sculpture in the form of the Monument's to the People's Heroes. The combination of street trees, formal planting and shrubbery provide the park with a green aesthetic that counterbalances the dominance of the open plaza of the majority of The Bund. Moving south The Bund opens into a wide promenade located within the clear boundaries of The Huangpu River and Zhongshan Road. This included the removal of the former concrete walls and replacement with more permeable barriers. Periodically along its length clusters of street trees, formal "planters," screening vegetative walls, and street furniture are present. Thus, The Bund has been developed to have a multi-faceted aesthetic quality that enables a substantial number of users to use the site simultaneously without exceeding its capacity. The site is also well-connected to pedestrian access routes into central Shanghai, and extends spatially toward other GI resources, i.e., the park on Renmin Road and Yu Yuan Gardens. Although, the redevelopment of The Bund placed an emphasis on aesthetics it uses GI as a screen for noise, pollution and heat from transport infrastructure, as well as addressing on-street surface water flooding, are also key design features.

GI in Shanghai, and specifically on The Bund, has been used to promote public interactions with high-quality landscapes that has been designed to attract patronage *via* improved access, aesthetics, and multi-functionality. This reflects the wider discussions of GI in Shanghai where it has been used to support improvements in the quality of the built environment, i.e., the greening of transport infrastructure/underpasses. The Bund may be the most visible example utilizing GI, however,

locations including the Riverside Promenade and Lujiazui Park in Pudong and to a lesser extent the Jing'an Sculpture Park and People's Park in central Shanghai have benefitted from the inclusion of high-quality landscape design supporting diverse ecological functionality and added economic value. Development in Shanghai is though subject to extensive political influence in terms of financing, support for development, and land ownership (Wu, 2015). This has led, to some extent, to the inclusion of high-quality investment in GI, as a visual marker of Shanghai's prominence as a world city. It also reflects the links between real estate value and GI that can be seen in other cities in China, as well as in Hong Kong, where investment in GI can increase property prices (Jim and Chen, 2006; Fok and Law, 2018). An understanding of the politics of real estate is therefore an important component of any discussion of GI in Shanghai, and China more widely.

Both of the examples discussed above indicate the potential added-value that investment in riverfront GI can provide. However, we need to be cognizant that the promotion of high quality and accessible public spaces may fundamentally change the socio-cultural and ecological composition of a site. In the case of Ahmedabad, the shift toward economically driven development at the expense of local ecological value has created contestations regarding who the Sabarmati Riverfront is for and questions whether regeneration benefits all citizens equally. The critiques proposed by Mell (2020) and Mathur (2012) suggest that a greater level of thought is needed to ensure that local health, wellbeing, economic and climatic requirements are met and that the current GI resource base is not undermined. Investment in Ahmedabad could also be considered to have directly led to a gentrification of the city's waterfront *via* a process of formalization of access to green space. The redevelopment of The Bund has not been subject to the same level of critical reflection but does illustrate the importance of government support and financing in the delivery of GI. The need to maintain Shanghai's position as a center of global finance enabled developers and the city government to reconsider its public spaces, i.e., the Huangpu River, as a strategic development priority. Thus, as a symbol of China's global political ambitions the design of The Bund reflects both the prestige and innovation associated with the country. This is a political act but is one that has located GI within an international discussion of landscape quality in Shanghai, and China more generally.

LANDSCAPE LED URBAN REHABILITATION/REGENERATION

A significant element in the growth of GI planning has been its links with landscape scale rehabilitation. One example of this process is visible in the UK where England's Community Forests have been at the forefront of GI development, using it as a mechanism to address post-industrial landscape decline around a number of cities, i.e., Leeds and Newcastle (Blackman and Thackray, 2007). The work of England's Community Forests directly challenged the view that landscapes lose their meaning if their productive value associated with industry is lost. Alternatively the Community Forest partnerships, from 1991 onwards, proposed that former industrial sites could be reconfigured as *community assets via* a long-term engagement with urban forestry, waterway restoration, biodiverse planting, and community engagement with nature (Kitchen et al., 2006). England's Community Forests thus acted as a catalyst for positive environmental and socio-economic change, as well as a conduit for knowledge exchange between public, private and community stakeholders.

The process of rehabilitation may appear piecemeal, as "Community Forestry" holds a relatively fluid meaning in terms of physical boundaries, delivery focus and partnership working. Community Forests are not spatially fixed forest entities but geographical areas that predominately map onto local government areas (Coles and Bussey, 2000; Mell, 2011). The fluidity of England's Community Forests is representative of their mandate as revitalizers of denuded space that may be overlooked in other forms of planning. The outcomes of which have including the provision of new parks, woodlands and greenspace located within and across urban/rural areas. These developments have also been aligned with a growing range of public health, ecological and educational activities facilitating community engagement with nature (Mell, 2011, 2016b; Mersey Forest, 2013a). As a consequence, the rehabilitation of landscapes in the north-east of England, Greater Manchester, Merseyside and Yorkshire have led to the reinstatement of socio-cultural and ecological value in these landscapes (Ecotec, 2012; South Yorkshire Forest Partnership Sheffield City Council, 2012). In many instances this takes its reference points from local industrial and ecological history providing the socio-cultural bridge between the landscape and local communities that may have been lost. Examples of this process include the redevelopment of the former Penshaw mining site in Sunderland into Herrington Country Park. This project aimed to re-establish links between local communities and its surrounding landscapes, which had lost its socio-economic value following industrial decline. Investment in landscape-led regeneration was thus seen as a key motivator of a re-engagement with the landscape. Over time this has led to the creation of a form of informal custodianship from the local community who view the park as an extension of their homes and community space.

Post-2010 such work has been restricted due to changes in funding for GI, community forestry and local environmental management due to UK government austerity measures (Mell, 2020). This led to a rethinking of the value attributed to GI by government stakeholders due to the limited availability of funding for local government services. Consequently, the subcontracting of GI projects, programmes and management to England's Community Forests were curtailed. One reaction to this process was a greater emphasis being placed on the generation of collaborative work and multi-partner funding to address the gaps left by funding shortages. In practice this led to several community forest partnerships ceasing to exist, the rebranding of others, and changes in the capacity of each organization to deliver their GI work.

Projects that could be considered to work at the landscape scale, i.e., those that facilitate a significant change in spatial

form and function over an extended area, can combine several the components of linear and waterfront GI already discussed. Through the process of design and planning the connective principles of GI can be integrated to facilitate the creation of multi-functional spaces that meet the needs of a wider range of communities. Historical examples of this process include Central Park in New York, the Olmsted designed Emerald Necklace in Boston and the wider distribution of greenspace in Berlin (Lachmund, 2013), illustrating the added-value that landscape-scale GI can deliver. Moreover, since Benedict and McMahon (2006) outlined their thesis on the principles of GI we have seen a growing engagement with the concept at both a site and a strategic level. In practice GI has provided a suite of design options to address climate change, urban flooding, and inequitable health and wellbeing (Allen III, 2012; Lerner and Allen, 2012; Marcucci and Jordan, 2013). Consequently, working *with* the landscape provides scope for GI advocates to combine ecological knowledge with the socio-economic agendas more effectively.

The Queen Elizabeth Olympic Park in London (**Figure 6**) is potentially one of the most visible landscape-led investments in GI. As a landmark project developed for the London 2012 Olympic Games, GI was central to the design and long-term legacy of the regeneration process. The 250-hectare site combines a range of habitats utilizing a split north-south landscape design that promotes a wilder more "natural" landscape in the north and a formal managed parkland and public plazas in the south (Mell, 2016a). The redevelopment of the site was also conceived to explicitly provide links to the wider regeneration of Stratford incorporating transport, commercial and residential development. The high-profile nature of the project was critical for the successful integration of GI within the area's master planning, as it provided the impetus to engage directly with the delivery of a high-quality and diverse ecological site. This enabled the London Organizing Committee of the Olympic and Paralympic Games (LOCOG) to look beyond the games centring the long-term legacy of Stratford around the success of the park (London Organising Committee for the Olympic Paralympic Games, 2007, 2011). Research by Hoyle and Sant'Anna (2020) discussed the innovation in the ecological composition of the site noting the variation in wildflower meadow species that are responsive to sunshine, i.e., *Echium vulgare* (Viper's bugloss), as well as shady and wet/damp conditions, i.e., *Malva moschata* (Musk mallow) ensuring the site was reactive to its climate. These along with the diverse wetland created on the River Lee integrated a greater resilience to climate change in the site. In addition, the flood mitigation works within the Lee Valley helped address pollution and climate change impacts. The park also providing a free to enter public park to support health, wellbeing and recreation all of which were considered within the design, build and transition from the Olympic site to a new urban neighborhood (Gold and Gold, 2012). However, a series of critiques of the Queen Elizabeth Olympic Park have focused on the negative impacts on the area's demographic and economic profile. To facilitate the creation of the park compulsory purchase orders were issued requiring existing businesses to relocate. Moreover, residential communities were rehoused to other parts of the boroughs of Hackney, Newham, Tower Hamlets and Waltham Forest leading to a change in the demographic profile and tenure of residents on the area (Watt, 2013). Therefore, although the park provides an accessible, multi-functional and high-quality space delivering recreational amenities and ecosystem services questions remain of whether it has been beneficial to all members of society.

The political support for the Olympic Park development was centered on a global understanding of the added-value that the project would deliver economically and ecologically (Davis, 2019). It was delivered as a multi-partner process aimed to improve health and wellbeing, access to nature, address climate change issues, and to support city-wide economic development (Oudes and Stremke, 2020). The magnitude of support thus enabled the designers to plan with confidence for a higher-quality outcome compared to other scenarios, whilst the Olympic Games acted as the catalyst for landscape-led regeneration in London a more long-term process of rehabilitation has taken place in other locations. In Germany, the Ruhr provides examples of GI being used to rethink the impacts of dereliction and promote an alternative set of values for the landscape.

The Landschaftspark Duisburg Nord was a key component of the International Building Exhibition (IBA) Emscher Park project, a regeneration project that ran from 1989 to 1999 and aimed to implement a series of rehabilitation works along the Emscher River. It included new housing, cultural and educational facilities, and the creation of the Landschaftspark Duisburg Nord at the former Thyssen Ironworks in Duisburg-Meiderich. At ∼230 hectares and completed in 2002 the project explicitly aligned the industrial heritage of the area with GI to create a unique visual and amenity-led park landscape. The reuse of the former steelworks provided a *genius loci* for the site blending industrial heritage with a range of plant species to facilitate a more diverse understanding of the site's ecological and historical function (Stilgenbauer, 2005). Furthermore, the site's visual dynamism supports the aesthetic motif developed by landscape architects Latz + Partner providing areas of solitude, adventure, and mystery framed by the industrial remnants. Designing GI around existing infrastructure ensured on site variation with a series of ecological/industrial "zones," i.e., *Sinter Garden*, *Stadtandgarten* and *farmers' gardens*, housing rock gardens, herbaceous perennials and orchards. This provided scope for the provision and/or enhancement of over 700 different plant species including 50 IUCN red list species. Moreover, the site is home to species that grow well in nutrient poor substates, i.e., those associated with industrial reuse, for example silvery cinquefoil (*Potentilla argentea*), small cudweed (*Filago minima*), the common centaury and lesser centaury (*Centaurium erythraea* and *C. pulchella*), as well as species of greater rarity that are non-indigenous to industrial sites, i.e., stinkwort (*Dittrichia graveolens*) or sticky goosefoot (*Chenopodium botrys*). The ability to provide habitats for such a diverse range of ecological species indicates that considerations were made regarding the soils, climate and reuse of industrial space to support a biodiverse landscape (Keil, 2019). Moreover, due to the complexity associated with former industrial uses, i.e., issues of subsidence and pollution, and consideration of water quality

were incorporated to avoid creating adverse environmental conditions in the Emscher River. An additional part of the Landschaftspark Duisburg Nord's success has been the semantic rebranding of "industrial brownfield" as "parkland" (Holden, 1995:42). Within this discussion the transformation of a denuded site into a visibly green and multi-functional park has been key to changing interpretations of its value. The location of the Landschaftspark Duisburg Nord within the wider 800 km^2 regeneration programme of the Ruhr has subsequently been citied as a global example of successful GI-led renewal (Ling et al., 2007). Thus, the project was supported politically by regional and local government who worked with a range of stakeholders to implement the socio-economic and ecological vision set out for the Landschaftspark Duisburg Nord and the wider greening process of the area.

MOVING A GI REGENERATION AGENDA FORWARD

The examples discussed above highlight the variability in how GI has been linked with redevelopment agendas (see **Table 2** for further details). Whilst it should not be argued that GI is the primary catalyst for regeneration it can, and has, been used to elevate the focus, functionality and amenity value of projects, for example in the transformation of the an elevated highway to daylight the Cheonggyecheon stream in Seoul (South Korea) establishing it as a contemporary recreational site (Cho, 2010; Kim and Choe, 2011). Moreover, the breadth of options that investment in GI provides in terms of its utilization of existing linear features, waterfronts or areas of industrial dereliction offers scope for landscape enhancement work to meet myriad socio-economic and ecological issues. Consequently, there is an ongoing discussion linking the added economic, socio-cultural, and political benefits of GI in urban redevelopment practices. Within these debates there is a consideration of the suite of options considered to be "GI" that reflects variation in size, composition, and the functionality of potential investments locating this knowledge in conjunction with an analysis of what resources exist, what can be enhanced and what types of GI can be integrated into a given project. However, there is a less defined literature investigating the ecological alignment of GI with regeneration practices (although ecological considerations are prominent in development debates). Currently, the majority of analysis focuses on considerations of socio-economic and political factors but there is an emerging engagement with discussions of ecological functionality especially those centered on pollution, environmental functionality and disservices (Von Döhren and Haase, 2015; Wang et al., 2018; Roman et al., 2020).

Where GI has been successfully aligned with regeneration agendas, we can identify a series of lessons that support successful investment:

- An understanding of the network and connective capabilities of GI to link single sites with wider landscape resources;
- An appreciation of the complexity of financial and political influences on investment and work with decision-makers, developers and infrastructure providers, and communities to identify how best to utilize different types of GI;
- A need to elevate an appreciation of the benefits and disservices associated with ecological investment regarding species selection, mitigation of climatic variation, impacts of human and environmental health, and fit with local landscape context;
- An ability to link existing heritage assets with an awareness/addressing large-scale issues, i.e., climate change or health inequality;
- Consideration of the long-term legacy of redevelopment and how GI will evolve over time/space;
- An understanding of the complexity of political, stakeholder and financial buy-in needed to deliver GI, and an ability to communicate the added-value of GI to multiple audiences.

In addition, successful GI projects can work at several scales, allowing planners and developers to think more holistically regarding *where* and *what* investment can be made. Practically this enables planners to be more reactive to urban contexts and utilize spaces that may otherwise be left vacant, i.e., in Atlanta with the reuse of railway tracks (Kirkman et al., 2012), due to their spatial configuration. Interventions of this nature can, as a consequence, of their location be considered to visibly modify urban areas and create multi-functional, accessible and connected spaces. The growing number of linear GI corridors projects are examples of the support attributed to the reuse of these denuded spaces. The High Line and The Atlanta BeltLine also illustrate that high-profile regeneration projects can attract significant buy-in from public, private, and community stakeholders providing pathways to delivery. This is especially true of locations where strong civic and private leadership has been used to support innovation GI interventions politically and financially. However, greater reflection on the landscape architecture of these sites also promotes a more detailed understanding of the potential disservices of the ecological choices made during redevelopment, i.e., gentrification (Jennings et al., 2019).

A further benefit of GI is its ability to work effectively with variable environmental conditions. Successful GI projects can retrofit transport infrastructure, former industrial sites, revitalize waterfront areas, and deliver meaningful investment into constrained locations. Whilst other forms of urban development demand pristine sites, i.e., those with no industrial remnants, GI can be implemented in these locations. The rehabilitation of the Olympic Park site *via* extensive washing of the soil to remove pollutants, the reuse of the steel works in the Landschaftspark Duisburg-Nord, and the landscaping of former industrial sites in North-East England are all examples that have utilized derelict spaces to reinforce environmental attachment, functionality and meaning. Moreover, the variability of GI types that can be delivered provides a suite of options that can address water, pollution, and biodiversity needs on a given site, i.e., the ecological variability of species used on the Queen Elizabeth Olympic Park. As such, the use of SUDS, biodiverse planting, as well as play and educational facilities have all been integrated

TABLE 2 | GI/landscape-led redevelopment project characteristics.

Project	Scale and type of GI	Funding (public, private, other)	Features/focus	Visibility/prestige
The High Line, New York	Neighborhood (<2 mile) linear greenway reusing elevated railways tracks.	Private supported by a not-for-profit organization	High quality redevelopment of built infrastructure and investment in seasonal GI.	*High*—The High Line is a global brand and exemplar of landscape/GI inclusive regeneration.
Atlanta BeltLine, Atlanta	City-scale 23-mile greenways reusing former railway infrastructure.	Public-Private partnership with funding being drawn from the City of Atlanta, local taxes, business taxes/payments, private investment. Supported by Atlanta BeltLine Inc.	Circular greenway that passes through all neighborhoods. Redevelopment of railway line into multipurpose paths and cycleways. Additional investment in parks, sustainable drainage, and interpretation signage.	*Medium to High*—The BeltLine is an exemplar of city-scale reinvestment in GI that aligns corporate sponsorship and funding with the provision of public GI infrastructure.
Promenade Plantee, Paris	Neighborhood scale linear greenway located within existing housing.	Publicly funded as part of a wider area regeneration process.	Reuse of existing / redundant railway infrastructure as public open space linked to parks and increased access to the elevated park.	*Medium to Low*—Although known as a precursor to the contemporary trend in elevated greenways it is not viewed with the same prestige as the High Line.
The Bund, Shanghai	City-scale waterfront redevelopment integration GI with public space.	Public and private investment was used to support the regeneration of The Bund linked to the wider economic activities of Shanghai, Pudong and the Lujiazui Financial Zone.	Redesign riverfront promenade that integrates a range of GI in the form of parks, street trees, green screening, and SUDS along its length. GI may not be the primary focus of the project but is a significant factor in its aesthetic quality and functionality.	*High*—The project's location in central Shanghai and vistas make it internationally recognizable.
Sabarmati Riverfront, Ahmedabad	City-scale 16 km riverfront redevelopment.	Publicly funded *via* Gujarat State Government, Ahmedabad city finances, and private investment.	Linear riverfront promenade with associated investment in two riverfront parks, street trees and floodplain clearance to facilitate built infrastructure development.	*High*—The project was supported by now Prime Minister of India and is linked to wider strategic development objectives at the state and national level.
Queen Elizabeth Olympic Park, London	International 250+ hectare public park with range of socio-economic and ecological functions and amenities.	UK government and public financing alongside private investment in wider area regeneration.	Site is split into northern parklands with diverse/evolving landscape and flood mitigation/SUDS and southern public plazas and interactive spaces. Multiple access points, as well as play and sports facilities.	*High*—The association of the development with the 2012 Olympic Games allowed the site to invest an estimated £9 billion on high quality GI and urban infrastructure.
Landschaftspark Duisburg Nord, Ruhr	Nationally important landscape-scale regeneration of 230-hectare site within an internationally significant 800 km^2 GI-led redevelopment programme for the Ruhr.	The redevelopment was financed by a combination of the city of Duisburg, the state of North Rhine-Westphalia, the LEG State Development Company NRW GmbH and the Federal Republic of Germany.	The site combines innovative planting, landscape design, and environmental rehabilitation works with existing industrial infrastructure to provide the site with a unique motif of GI and built environment elements.	*High*—Due to its size and innovative approach to integrating landscape architecture and existing industrial infrastructure the site/area is seen as an exemplar of effective landscape-led regeneration.

The reviewer MW declared a past co-authorship with the author IM to the handling editor.

into regeneration projects that have designed with GI as a core principle.

It is also critical to generate political and financial buy-in when aligning GI with regeneration. Where this has been achieved, i.e., waterfront areas in Shanghai, we can identify clear links between strong political leadership using GI as a tool to aid regeneration (den Hartog, 2021). Moreover, the use of GI as a key design principle, as with The High Line in New York, has been central

to the allocation of funding to deliver innovation. However, generating political and financial backing is a long-term process requiring effective knowledge exchange between GI advocates, planners, designers, and decision-makers. GI should therefore not be considered as a quick fix within regeneration debates but a development option that should be a first principle of design. Moreover, we can identify projects where the engagement of key development stakeholders or businesses, i.e., CNN and Coca-Cola in Atlanta, act as critical advocates for a project creating a stimulus for other stakeholders to engage (Mell, 2016a). The framing of GI as a part of a longer-term and strategic solution to urban renewal could be seen as vital to generating financial support for investment, however, there remains a core need to ensure that development does not adversely impact a local community or lead to a process of greenwashing. The economic arguments associated with of GI should therefore not lead to structural changes in local communities. Alternatively, these communities should be engaged to ensure that GI development services local, as well as city-scale needs.

Furthermore, to effectively use GI within regeneration activities there is a need to consider the timeframe for redevelopment, and how a landscape will evolve ecologically and socio-economically. Those projects that have successful integrated GI, i.e., the Landschaftspark Duisburg-Nord, have considered the project as a long-term commitment in landscape enhancement. Likewise, the ecological design of the Queen Elizabeth Olympic Park in London has been designed to evolve over time, as the site matures, and its environmental and water-based functions become established (Hoyle and Sant'Anna, 2020). Both projects look at regeneration over an extended time horizon providing stakeholders with scope to adapt these sites to address socio-economic and ecological needs. By taking a long-term view they also work to reinstall a cultural value to the landscape that allows communities to reengage with spaces that were formally exclusionary.

CONCLUSIONS

It would be remiss to argue that GI has been an essential component of urban regeneration. However, we can identify a growing consciousness in how GI has been used to address change in landscape quality associated with urban decline and renewal. It is apparent that those cities that have engaged with the principles of GI and applied them within wider discussions of urban regeneration have created more functional, attractive and livable places. However, the inclusion of GI remains subject to complex socio-economic, ecological, and political factors that influence the ways in which landscape is embedded within both strategic and local planning. Finding a balance between landscape rehabilitation and landscape gentrification is not simple, and a more detailed understanding of the added-value of GI, especially its ecological functionality, and its role within a longer-term process of development is needed. Where GI has been successfully integrated into urban renewal projects it provides a level of landscape functionality that is meaningful to all. The impacts of GI on climate change mitigation are also being established within these narratives illustrating a need to consider ecological systems within built environment discussions. Moreover, in most instances GI does not significantly modify the demographic profile of an area and can act as a facilitator of positive change. However, where GI is used to promote economic growth as a primary development objective, we can identify less certainty in the retention of existing socio-cultural or economic structures. Whilst some would argue that change is inevitable within regeneration, it does not necessarily have to be. Working with communities, developers, and decision-makers to identity where and how local landscape knowledge can be integrated into this process can help avoid inappropriate change. This is not always appropriate or indeed acceptable due to the complex socio-economic structure of our cities and the options available for landscape rehabilitation. Therefore, we also need to ask whether we should limit investment in GI if it causes negative socio-cultural change. Many GI advocates would argue that even if GI leads to change that it promotes a significantly positive influence on society, the economy and then long-term ecological functionality and should be promoted. These debates will continue if land values and economic motivations for development are framed as opposites to effective environmental management. GI planning though may go some way to identifying solutions to these *via* the promotion of landscape-led or inclusive regeneration activities.

AUTHOR CONTRIBUTIONS

The author confirms being the sole contributor of this work and has approved it for publication.

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