Using a Conceptual Site Model for Assessing the Sustainability of Brownfield Regeneration for a Soft Reuse: A Case Study of Port Sunlight River Park (U.K.)

Authors

Xiaonuo Li [a,b], Paul Bardos [a,c *], Andrew B. Cundy [d], Marie K. Harder [e,f], Kieron J. Doick [g], Jenny Norrman [h], Sarah Williams [i], Weiping Chen [b]

[a] School of Environment and Technology, University of Brighton, Brighton BN2 4GJ, U.K.

[b] State Key Laboratory of Urban and Regional Ecology, Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, Beijing 100085, China.

[c] r3 environmental technology ltd, Reading RG6 6DW, U.K.

[d] School of Ocean and Earth Science, University of Southampton, Southampton SO14 3ZH, U.K.

[e] Department of Environmental Science and Engineering, Fudan University, Shanghai 200433, China

[f] School of Computing, Engineering and Mathematics, University of Brighton, Brighton BN2 4GJ, U.K.

[g] Centre for Sustainable Forestry and Climate Change, Forest Research, Farnham GU10 4LH, U.K.

[h] Department of Architecture and Civil Engineering, Division of Geology and Geotechnics, Chalmers University of Technology, Goteborg SE-412 96, Sweden

[i] The Land Trust, Warrington WA3 7GB, U.K.

---

[*] Corresponding author at: r3 environmental technology ltd, Reading RG6 6DW, U.K.
E-mail addresses: xnli@rcees.ac.cn (X.N. Li). paul@r3environmental.co.uk (P. Bardos). A.Cundy@soton.ac.uk (A.B. Cundy). m.k.harder@brighton.ac.uk (M.K. Harder). kieron.doick@forestry.gsi.gov.uk (K.J. Doick). jenny.norrman@chalmers.se (J. Norrman). SarahWilliams@thelandtrust.org.uk (S. Williams). wpchen@rcees.ac.cn (W.P. Chen).

Abstract

Brownfield regeneration to soft reuse such as recreation and amenity has become increasingly common due to the demand for the potential environmental, social and economic benefits that it can deliver. This has led in turn to an increased demand for improved tools to support decision-making for this style of regeneration: tools which are simple to use, based on robust scientific principles and preferably which can ultimately link to quantitative or semi-quantitative cost-benefit analyses. This work presents an approach to assessing and comparing different scenarios for brownfield regeneration to soft reuse and other end-points. A "sustainability linkages" approach, based on sustainability assessment criteria produced by the UK Sustainable Remediation Forum (SuRF-UK), is developed and used in a refined qualitative sustainability assessment, and applied to develop a conceptual site model of sustainability, for a specific case study site (Port Sunlight River Park, U.K., a public leisure park established and maintained on a capped and managed former landfill site). Ranking, on an *ex post* basis, highlighted the clear sustainability advantages that the establishment of the Port Sunlight River Park has compared with a hypothetical non-development scenario. The conceptual site model provides a clearer basis for understanding cause and effect for benefits and disbenefits and a rationale for grouping individual effects based on their ease of valuation, providing a road map for cost-benefit assessments by (1) being able to match specific linkages to the most appropriate means of valuation, and (2) transparently connecting the sustainability assessment and cost benefit assessment processes.

Keywords: SuRF-UK guidance; sustainability linkage; qualitative sustainability assessment;

overall benefits

1 Introduction

The worldwide diversity of pollutants and contaminated sites, coupled with a scarcity of available land in urban spatial planning, has led to an increasing political significance for re-use of brownfield land to achieve sustainable land management. The importance of integrating brownfield regeneration strategies into land and urban planning is now a vital part of sustainable land use patterns and reducing the consumption of green field land by urban sprawl (HOMBRE, 2014). Brownfield regeneration can be for hard reuse (e.g. housing or infrastructure developments), soft reuse (e.g. green space or biomass production), or a combined approach. Soft reuse has historically tended to be overlooked (Bardos et al., 2015). However, responding to the sustainable development vision, there is a broad agreement among stakeholders that soft reuse of brownfield can bring major environmental, societal and economic benefits (Bardos et al., 2011 and 2016a; Cundy et al., 2016; Moffat, 2015). Indeed, it is becoming increasingly popular in a number of countries such as the US, UK, mainland European countries and China (BenDor et al., 2011; Bardos et al., 2016b; Schädler et al., 2012). There are now examples of brownfield generation for recreation and amenity in several countries, at sites ranging in scale and complexity from small urban parkland sites, to larger former mining sites and complex former industrial areas, such as:

- A mixed-use community, the London Olympics venue redevelopment as an example of a complex former industrial area, UK (DCMS, 2010).
- Urban green space, the Betteshanger Country Park on a former spoil tip in Kent, UK (Cundy et al., 2013).
- A public park, Gas Works Park on the site of the former Seattle Gas Light Company

gasification plant in Seattle, US.

- An integrated cultural district, Museum Folkwang of the regeneration of Ruhr industrial region in Essen, Germany (Heidenreich, 2015).
- An entertainment complex, Cool Docks transformed from derelict warehouses in Shanghai, China.

In order to gain support for soft reuse, it is important to not just illustrate sustainability in the redevelopment process, but also to understand how it can create value for stakeholders. Therefore, there has been a growing interest in valuing wider sustainability benefits by applying qualitative, semi-quantitative and quantitative methods including multi-criteria decision analysis (MCDA) (Rosén et al., 2015), life-cycle assessment (EEA, 2014; Favara et al., 2011), and cost benefit analysis (Söderqvist et al., 2015). A number of sustainable remediation appraisal frameworks have recommended a tiered application of such methodologies to assess the sustainability of remedial options and help stakeholders form a disciplined risk management strategy (CL: AIRE, 2011; Holland et al., 2011; HOMBRE; ISO, 2017; NICOLE, 2010; SuRF-US, 2009), and a number of tools have been developed to support application of these approaches in stakeholder decision making (e.g. Cappuyns, 2013 and 2016; Huysegoms and Cappuyns, 2017). As Smith and Kerrison (2013) suggested, the ideal sustainable remediation decision support tools should be quick and easy to use while requiring minimal input yet directing robust management decisions. Recently developed approaches include the UK Sustainable Remediation Forum (SuRF-UK) guidance and EU HOMBRE project Brownfield Opportunity Matrix - BOM (Beumer et al., 2014; Bardos et al., 2016b; CL: AIRE, 2011; HOMBRE; Menger et al., 2012).

Within the UK, the SuRF-UK guidance now forms part of the general remediation / restoration guidance and is accepted and endorsed by UK regulators and cited in UK regulatory publications. It has also been used as a basis for sustainable remediation frameworks in a number of other countries (Rizzo et al., 2016), and was one of the drivers for the recent ISO standard on Sustainable Remediation (ISO, 2017; Nathanail et al., 2017). Clearly, optimizing the management of brownfield land for sustainability purposes necessitates some form of sustainability assessment, and in the UK the general approach to setting out sustainability assessment (its preparation and definition) and also for qualitative assessments has been set out in a series of SuRF-UK guidance downloads (CL:AIRE, 2010, 2011 and 2014). These are now used routinely by the UK brownfields / contaminated land sector.

The work reported here develops the SuRF-UK guidance to provide an improved approach to assessing and comparing the sustainability of brownfield restoration scenarios for a soft re-use, by integrating the use of sustainability linkages both in analysing standard guidance categories (in this case the SuRF-UK guidance categories) and for constructing an effective conceptual site model. The use of sustainability linkages, and the concept of Conceptual Site Models of Sustainability (first proposed by the European HOMBRE Project (Bardos et al., 2016b; Menger et al., 2013) allows a more refined and enhanced SuRF-UK analysis for the sustainability assessment. We illustrate this approach by analysing two scenarios for a given site, first without and then with the sustainability linkages.

Following framing of the sustainability assessment to determine its objectives, scope, boundaries and methodology, a sustainability assessment comparing two scenarios for a case study site, a public leisure park (Port Sunlight River Park (PSRP), U.K.) established and maintained on a previous landfill site, is presented using the methodology provided by SuRF-UK. This is then expanded and refined through the development of sustainability linkages and a conceptual site model for sustainability, to describe individual sustainability effects at the site in a way that might better support their valuation or even monetisation. The advantages and limitations of these approaches are then assessed, particularly with respect to "monetising" the sustainability benefits of land redevelopment and regeneration projects.

2 Method

2.1 Method outline

The sustainability assessment carried out is retrospective in nature (i.e. *ex post*), but its purpose was also to understand how useful it might be for a project or site manager in deciding approaches to planned or prospective projects in the future. It applied the prevailing UK sustainability assessment guidance for the UK (Bardos et al., 2016a; CL:AIRE, 2010, 2011 and 2014), which is typically used *ex ante* for option appraisal.

This work also investigated the use of "sustainability linkages" and a conceptual site model for sustainability (Bardos et al., 2016b) to refine the SuRF-UK assessment carried out, and potentially describe individual sustainability effects in a way that might better support their valuation or even monetisation. It was also anticipated that any possible improvements from the use of a conceptual site model of sustainability for the case study might also inform development of the *ex ante* tool.

Hence the work reported here consisted of four stages:

- Framing the sustainability assessment to determine its objectives, scope, boundaries and methodology
- "Method A" sustainability assessment comparing the two scenarios was carried out using the methodology provided by SuRF-UK, including an MS Excel template, downloadable from www.claire.co.uk/surfuk, originally produced by AECOM. This spreadsheet records simple rankings (e.g. in this case 1 = best 2 = worst) across 15 broad categories of sustainability criteria, five for each element of sustainability (environment, economy and society), shown in Table 1. These are then simply aggregated (summed) to provide overall rankings for each element of sustainability, and sustainability overall. The assessment is supported by a checklist of possible individual indicators / criteria that can be used to guide the broader category-based assessment (CL:AIRE, 2011). This approach is referred to as "Method A" in this paper.
- "Method B" sustainability assessment comparing the two scenarios was carried out in a greater level of detail by dividing the broad categories in Table 1 into individual sustainability linkages, based on the individual considerations in the Annex 1 guidance checklist (CL:AIRE, 2011). These were used both as the basis of a conceptual site model of sustainability, and also to review and amend the broad category rankings used in the spreadsheet. This was done by applying the same ranking approach to the individual linkages within each category, and then reporting a mean ranking to the spreadsheet. This approach is referred to as "Method B" in this

paper.

- Individual sustainability linkages were combined as a network diagram to produce an overall conceptual model for sustainability considerations. One possible application of such a model might be to provide a road map for cost-benefit assessments by (1) being able to match specific linkages to the most appropriate means of valuation, and (2) transparently connecting the sustainability assessment and cost benefit assessment processes.

Table 1 The overarching categories in the SuRF-UK sustainability assessment guidance, for each element of sustainability (CL:AIRE, 2011)

Environment	Social	Economic
Emissions to air	Human health & safety	Direct economic costs & benefits
Soil and ground conditions	Ethics & equity	Indirect economic costs & benefits
Groundwater & surface water	Neighbourhoods & locality	Employment & employment capital
Ecology	Communities & community involvement	Induced economic costs & benefits
Natural resources & waste	Uncertainty & evidence	Project lifespan & flexibility

2.2 Case Study Site description, and timing of study

Port Sunlight River Park is a 28-hectare park near Birkenhead in Wirral, Merseyside, U.K. (Figure 1)[1] It is located on a former landfill site (see *Supplementary Information Figure*) which infilled the former Bromborough Dock between 1991 and 2006 (the Land Trust, 2015a and 2015b). The landfill was capped and covered by the waste management company (Biffa Waste Management) and leachate and gas management systems were put in place. The site

[1] https://thelandtrust.org.uk/space/port-sunlight-river-park/?doing_wp_cron=1523454123.0293600559234619140625

was passed over to the Land Trust on a 99 year lease and, after planning and design, was created as a riverside park in 2013 and opened to the public in 2014. The waste management company remains responsible for ongoing management and monitoring of the capping, landfill gas and leachate treatment.

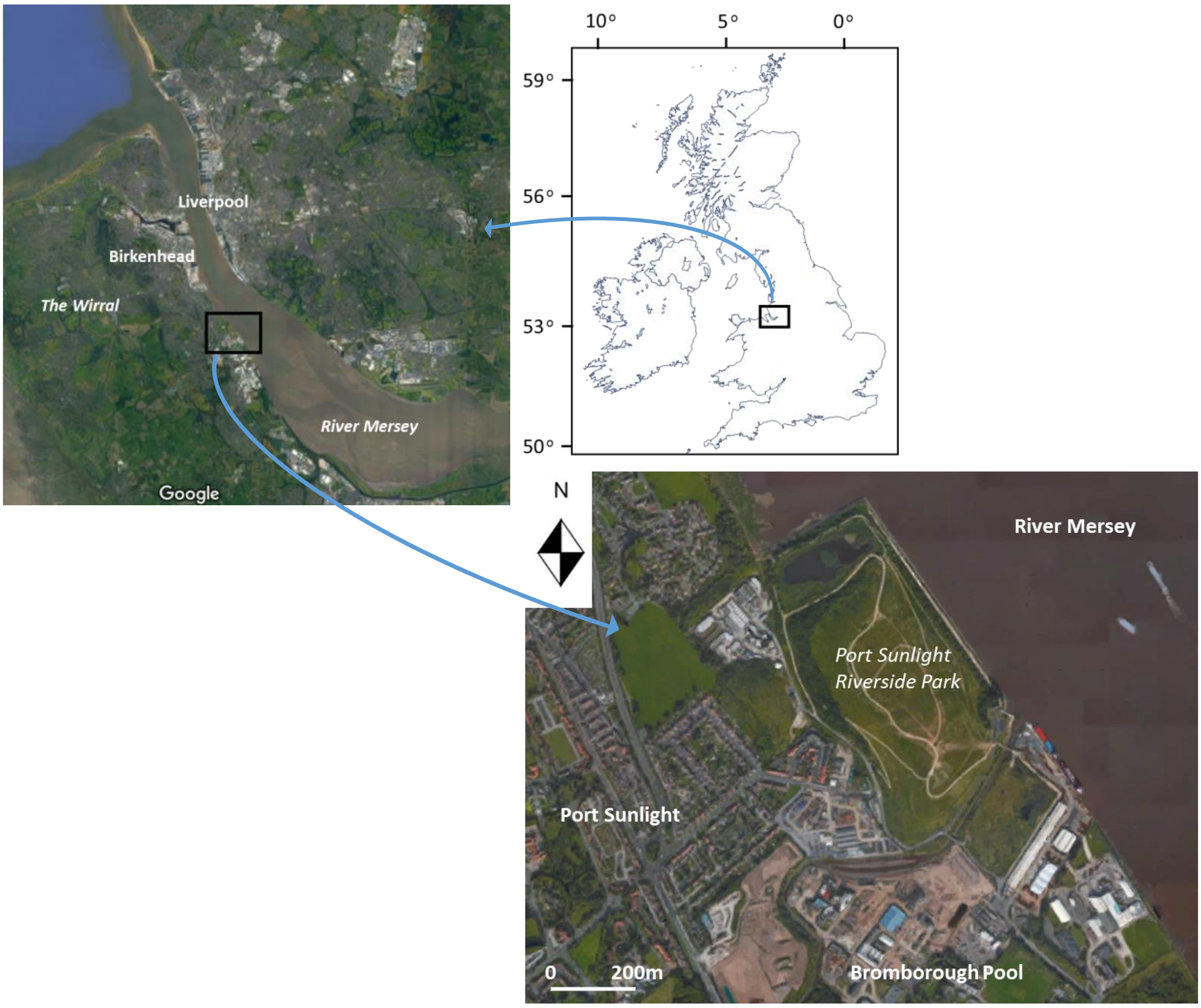


Figure 1 Case study site: Port Sunlight River Park, Wirral, Merseyside, U.K. Aerial photographic imagery Copyright 2017 Google. Map data Copyright 2017 Google.

The condition of the site prior to the establishment of the parkland was of rough cover, very limited public access and a significant amount of debris on the surface (see

Supplementary Information Figure). Its waterfront location, interrupted footways, and the size of the site had a significant detrimental landscape impact. The Land Trust secured a £3.4 million investment for a transformation project encompassing park creation and ongoing management, and established a partnership with the local charity, Autism Together, who manages the park on a day to day basis and leads local community engagement and involvement with the park.

The completed park provides visitors with a scenic waterfront and a variety of walks whilst a section of wetland to the north of the site, along with the adjacent River Mersey mud flats, is already a protected site for water birds. The qualitative sustainability assessment was carried out in 2016. The aim of the sustainability assessment was to understand the economic, environmental and social benefits/disbenefits of transforming the former landfill into a public open space, managed long term.

The sustainability assessment therefore compared two intervention scenarios:

(1) Establishment of Port Sunlight River Park (i.e. The transformation from a restored landfill site to park and long term management, including construction of roads, paths, landscaping, drainage and car parking; but excluding existing landfill management measures);

(2) A hypothetical "no intervention" baseline, (i.e. which assumed that the site continued as a former landfill site being managed with all the appropriate planning condition and regulatory requirements following landfill closure).

The existing landfill management measures such as capping and gas/leachate management) are common to both scenarios, and so are excluded from the comparative assessment.

A large range of stakeholders have interests in this site and project (Table 2). This listing is not exhaustive as there are additional community interest groups with ambitions for the PSRP, and there are also opportunities for new or co-development of adjacent sites to provide additional amenity facilities now that PSRP has been established. In addition, other potential interested parties are local property owners who may have received beneficial impact, such as improvement in property values, or detriments such as from poor parking by visitors.

This paper reports on the provisional sustainability assessment outcomes derived from consultation with three "core" stakeholders (with the broadest understanding of the park development and outcomes, grey-shaded in Table 2), and does not include perspectives from the wider stakeholder listed in Table 2, except for (primarily technical) information available in documents, such as site restoration reports.

Table 2 Potential stakeholders at the Port Sunlight River Park case study site, and their roles in the SuRF-UK sustainability assessments undertaken in this paper. Grey highlighting shows the three "core" stakeholders consulted during framing and execution of the sustainability assessment.

Potential stakeholders	Role
University of Brighton (UoB)	Sustainability assessors.
Land Trust (corporate)	Broad perspectives of Land Trust sustainability interests and wider evidence base, access to past reports and site records.
Land Trust (restoration project manager)	Managed the operational work and interests and discussions with other stakeholders over the restoration project (e.g. contractors, adjoining premises).
Autism Together (Charity – park users and park management)	Autism Together provide the on site management of the PSRP, and also represent one of its major users from the community.
Forestry Commission	Assisted in developing the project concept and securing funding. Technical contributor to Land Trust restoration thinking.
Biffa	Manage the containment and capping of the site, and its leachate and gas management systems.
Environment Agency	Waste management regulator, water body regulator.
Wirral Council	Local planning authority, environmental health.
Port Sunlight Village Trust	Conservation and historical context of the Port Sunlight legacy.
Friends of PSRP	Community interest group initiated by the Land Trust who support the PSRP.
United Utilities (WWTP)	Have a water treatment facility that adjoin the site and an interest through their rights to shared access for a roadway on site.
Unilever	Unilever is the landowner of the area of edges of the River Mersey and the River Dibbin and the Land Trust has a long lease on this land, which forms part of the PSRP site.
Essar Oil Limited (pipeline)	Manages a high pressure oil pipeline that crosses the north-eastern segment of the site.
Wirral Wildlife Trust	Community group / charity for local conservation and local nature reserves, they keep records of wildlife in the PSRP and guide walks open to the public.
Gillespies / WSP	The main site restoration contractors for the development of the PSRP (design and implementation).
SUSTRANS (Charity)	Use of the site for a cycle hub to help adults and children learn to ride.

2.3 Framing the sustainability assessment

A SuRF-UK sustainability assessment follows three broad stages: Preparation, Definition, Execution (Figure 2). The preparation and definition stages provide the 'framing' for the third, execution stage, thus:

(1) The preparation stage sets out the rationale for the assessment, the project or site being considered, the scenarios being compared, any opportunities and constraints that may apply, who will be consulted and when, and how the assessment will be reported and communicated.

(2) The definition stage summarizes and formats the preparation work as a series of objectives for the assessment, and then goes further to set careful boundaries for the work, how the comparison will be made, and how uncertainties will be dealt with.

(3) The execution stage applies the framing developed to a sustainability assessment. The framing is specific to each site / project. The assessment is based on comparison of different options across a range of sustainability considerations, which are then aggregated, for example to provide overall rankings for each of the three elements of sustainability (environmental, economic, social) or sustainability as a whole. In this study, a simple ranking was used for the assessment: 1= good compared to the other scenario, or 2= poor compared to the other scenario. Where no clear difference was evident the rankings for both were assigned to 1.

In this study the framing was developed during a meeting at the Land Trust’s Head Office (which then went on to carry out a ranking). Both the framing and execution were made on the basis of open discussion between the “core” stakeholders: University of Brighton (UoB); Land Trust (Corporate Communications and Fundraising Officer); Land Trust (the restoration project manager) and Autism Together (Charity – park users and park management) and in accordance with the Land Trust’s wishes. These initial conclusions were followed up by dialogue (e-mail and telephone) to reach the endpoints described in this paper.

This output should be seen as a provisional assessment that would then need to be refined in consultation with the wider stakeholder interests listed in Table 2. Although the assessment is provisional in that not all of the stakeholders listed in Table 2 have been engaged with, its outcomes do allow a comparison between Method A and Method B and to make an provisional conceptual site model of sustainability.

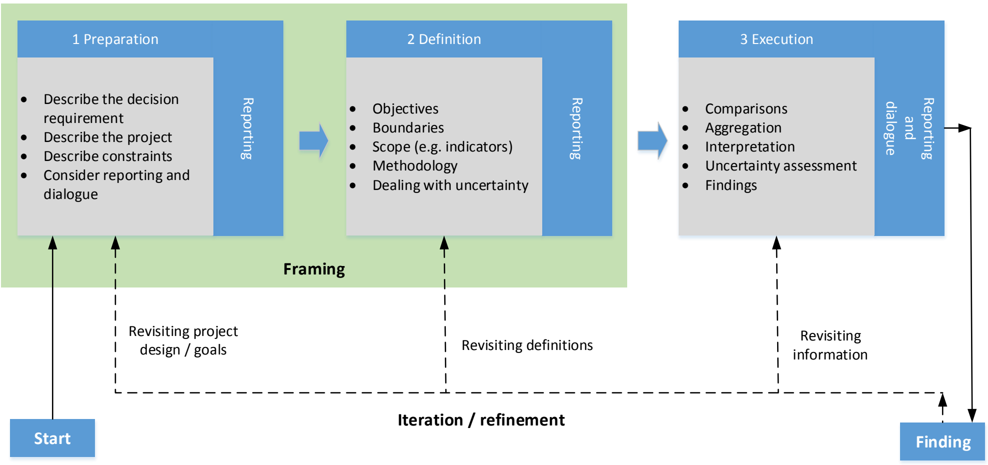


Figure 2 A schematic overview of the SuRF-UK approach to sustainability assessment (CL:AIRE, 2014)

2.4 Development of the sustainability linkages

The HOMBRE concept collates individual sustainability effects as "sustainability linkages", analogous to the way in which potential "contaminant or pollutant linkages" are identified for contaminated site risk assessment and management best practice (Cheng et al., 2017; Environment Agency, 2009; Nathanail, 2005). A "sustainability linkage" describes the connection between a cause (a pressure or a change), something that might be affected (i.e. a receptor) and the mechanism by which a pressure or change affects a receptor (see Figure 3). It is consistent with the Driving Forces – Pressure – State of the DPSIR model which is widely used in environmental policy development (Smeets and Weterings, 1999). A sustainability effect requires all three components to be in place. Individual linkages can be collated and combined to provide an overall conceptual model which also has the benefit of identifying and hence reducing unintentional duplications of sustainability criteria (Bardos et al., 2016a).

For example, in Figure 3 a potential sustainability pressure or driver might be the numbers of visitors coming to the park, where previously few people visited the site as a former landfill. A number of mechanisms may deliver consequences to different receptors. For example, one might envisage an increase in road traffic in the locality which might have some negative consequences for the local community through different processes (vehicle emissions, inconvenience from congestion, road safety). But increased visitor numbers might also bring benefits for instance in terms of pride of place and more money spent locally. The linkages assist in making these individual cause and effect chains explicit, in a way that different management options can be more readily compared, and different linkages can be more explicitly valued.

The use of sustainability linkages also facilitates the generation of an overall conceptual model created by combining linkages in a single network diagram, for instance as is practiced in contaminated land risk assessment (Nathanail and Bardos, 2004).

Visitors to the Port Sunlight River Park	1) Increased road traffic generates greater exhaust emissions affecting local air quality 2) Increased road traffic generates greater congestion 3) Increased road traffic causes greater road safety concerns 4) Increased sense of pride / place	1) Local community
	5) Increased economic activity in local shops and businesses	2) Local business

Figure 3 A sustainability linkage, and five possible examples (not exhaustive) for the Port Sunlight River Park case study site.

Initial identification of the sustainability linkages was made in discussion between the stakeholders at the face to face meeting while working through the SuRF-UK "Annex 1" guidance checklist. This was conducted as a comprehensive discussion of what were perceived as being the individual effects and how these could be summarised in terms of pressure/change --> mechanism --> and receptor. A useful additional outcome of this discussion was the identification of redundancies or duplications, for example where effects on air quality might be double counted within the broad environmental headline "emissions to air" and the broad societal headline "neighbourhoods and locality".

2.5 Development of the conceptual site model for sustainability (network diagram)

A network diagram was constructed by listing each discrete linkage in a table of three columns: pressure/change; mechanism; receptor, and sorting these by each category so that three lists of discrete pressures, mechanisms and receptors were apparent. These individual items were transferred to a diagram and interconnecting arrows used to show the linkages. In this way each discrete element only needed to be named once.

3 Results

3.1 Framing the sustainability assessment

3.1.1 Preparation

Table 3 provides a summary of the Preparation Stage of the framing process.

Table 3 Summary of the Preparation Stage for the Port Sunlight River Park Sustainability Assessment Framing (see text for further discussion)

Element	Description	
Decision Requirements	To understand the relative sustainability of the transformation scenario of a former landfill site into a public park compared with a "no intervention" baseline scenario where the site continued as a managed former landfill planning condition and regulatory requirements following landfill closure. This is a retrospective assessment, and so encompasses some information which would not have been apparent *ex ante*. However, the assessment applies the same methodology.	
Project/site Description	Comparative sustainability assessment of the development of the PSRP on the former Bromborough Dock Landfill Site (see Section 2.2) compared with the baseline scenario.	
Project Opportunities and Constraints	Opportunities	• No significant soil or water contamination issues identified during site investigation; • Bird populations protected and connected with an adjacent RAMSAR site; • Access to the river, due to available land between the site and the river; • Capping and drainage will be maintained by external contractor; • Management of the site by a local charity, also creating opportunities for sheltered employment.
	Constraints	• On-site leachate and gas management plant constrains park design; • Heavy infrastructure cannot be placed on top of the landfill due to settlement issues and a buried oil pipeline; • Existing soil cover over landfill is of poor quality and has high pH; • Site topography (steep slope and uneven ground) limits path width, access for users with mobility difficulties, and maintenance tasks; • The access road is externally owned which put constraints on site access.
Reporting and dialogue	Dialogue	16 stakeholder groups were identified (Table 2) and all are candidates to provide additional information and perspectives. However, this provisional sustainability

		assessment is based on the views of a more limited group, with the intention of further consultation and discussion at some point in the future to improve the robustness of the sustainability assessment in any subsequent iterations.
	Reporting	The following outputs are/were planned: • A technical report for Land Trust; • A briefing summary for wider stakeholders and any other interested individual to be produced by Land Trust; • Additionally, academic papers from the research team (mentioned here for the sake of completeness).

3.1.2 Definition

Table 4 provides a summary of the outcomes of the Definition Stage, i.e. the definitions of objectives, boundaries, scope and approaches to methodology and uncertainty agreed by the “core” stakeholder group. All 15 of the overarching SuRF-UK sustainability categories were accepted as forming the scope of the sustainability assessment. However, not all of the individual detailed considerations within each category of the SuRF Annex 1 guidance were considered relevant for the sustainability assessment by the “core” group. In addition, some effects of potential interest, for example potential public health benefits from access to green space were felt to be missing. The scope was therefore refined from the original checklist (in line with SuRF-UK’s guidance which recognises that scope is site/project specific). For Method A these considerations informed a *single* ranking process made for each headline category.

The process of reviewing which individual considerations to consider was critical to Method B, which aggregated rankings from individual linkages. The underlying assumption was a conservative one: that if there is no *valid* reason to discard it, the criterion should remain. Overall there are 73 specific suggestions in the SuRF-UK “Annex 1” checklist. 25 of these were considered not relevant for the PSRP sustainability assessment, and the rationale for discarding them was recorded. For example, the checklist identifies within the headline category for “emissions to air” four broad types of effects: climate change, acid rain related emissions, ground air quality and ozone depleting substances. Of these only one was felt relevant for PSRP: climate change emissions. Acid rain emissions or emissions of ozone depleting substances were not thought likely to take place at any significant scale for either options, and ground air quality impacts were considered as being covered by the considerations of “neighbourhood and locality” in the PSRP context. However, the discussion also concluded that there were different effects under “climate change” that should be separated out to better differentiate between the options being compared (PSRP and baseline):

- The effect on atmosphere (receptor) from vehicle and machine emissions,
- The effect on atmosphere as landfill capping degrades potentially allowing escape of methane / carbon dioxide, which would be affected by the soil and vegetative cover maintained on the site,
- The mitigation of greenhouse gas release through sequestration into soil over the landfill cap, which would also be affected by the soil and vegetative cover maintained on the site.

Two linkages were added: one was “human health benefits” under social category of human health and safety, the other was “development of sustainable transport opportunities” under social category of neighbourhoods and locality.

The 50 individual sustainability effects identified by this discussion informed the broad category rankings recorded for “Method A”. They also went forward for subsequent elaboration as sustainability linkages for "Method B" and the conceptual site model. The process of agreeing which sustainability effects were to be considered/discarded, are summarised in *Supplementary Information 1* of this paper.

Table 4 Summary of the Definition Stage for the Port Sunlight River Park Sustainability Assessment Framing (see text for further discussion)

Element	Description	
Objectives	The objectives of the sustainability assessment to be carried out were agreed as: • To provide a qualitative understanding of the sustainability gains of the PSRP establishment on Bromborough Dock Landfill compared with a baseline, "no intervention" strategy. • To investigate how a more detailed sustainability assessment based on sustainability linkages ("Method B") might affect sustainability outcomes from the SuRF-UK method ("Method A"). • To develop a conceptual site model using sustainability linkages and examine its potential usefulness in valuing or monetising the qualitative sustainability assessment. • To provide an opening or provisional sustainability assessment for development in consultation with a wider stakeholder group.	
Boundaries	System	The operations and activities for i) no development, or ii) ongoing management of the defined public park, both excluding ongoing capping, gas and leachate management typical of basic landfill site maintenance. This includes operations that might take place off site, for example the disposal of wastes to a different landfill site.
	Life Cycle	The consumption of resources by site management and restoration activities, such as materials for footpaths, maintenance of equipment, energy etc, deterioration of capital equipment but excluding the existing cap and gas and leachate management systems.
	Distance	• Local effects o Onsite effects: those within the park border, including the surface of the former landfill, lake, car parking, visitor centre, oil pipelines and drainage. o Offsite effects: local and wider effects affecting the adjacent features, including residential dwellings, the RAMSAR / wetland intertidal areas, the water, gas and leachate treatment plants, land surrounding the park and local environment (i.e. within circa five miles of the PSRP). • Wider: effects occurring that are not solely proximal.
	Time	• Short term (temporary) effects are those related to restoration / management activities. • Long term (permanent) effects, those persisting after the restoration work is completed.
Scope	All 15 SuRF-UK overarching indicator categories were considered. The Annex 1 guidance checklist was used to identify individual criteria.	
Methodology	• SuRF-UK guidance to provide sustainability criteria to be comparatively ranked in the two scenarios, analysed in the generic approach in Method A). • A conceptual site model would be developed to depict all single linkages in Method A), and all	

	sustainability linkages in Method B). • In future work: Valuation methods would be used to estimate the wide overall benefits at a quantitative level. These might be able to be identified and applied by making use of the sustainability linkages developed in Method B). • "Method A" and "Method B" as described above.	
Uncertainties	Definitional uncertainty	This uncertainty describes where there might be disagreement or uncertainty lack of clarity on what should be considered within the assessment framing, e.g. objective, scope and boundary. The focus group meeting achieved a clear and agreed definition for the sustainability assessment.
	Informational uncertainty	This uncertainty describes where there might be insufficient, outdated or unavailable information affecting the identification of individual sustainability linkages and quantitative valuation. The sustainability assessment process identified a number of informational uncertainties, which while not considered to affect the overall *qualitative* rankings, would have an impact on any subsequent semi-quantitative (scoring/weighting) assessment, or quantitative (valuation based) assessment.
	Methodological uncertainty	This uncertainty describes where there might be disagreement among stakeholders on how the sustainability assessment should be carried out. No such disagreement was evident for the *provisional* qualitative sustainability assessment reported here.
	Stakeholder uncertainty	The reliability of sustainability assessment is improved by the engagement of stakeholders, where a greater breadth of stakeholder types and opinions are considered (CL:AIRE, 2010). The assessment reported here is a provisional outcome from a small stakeholder grouping. Were wider consultation to take place Land Trust's preference would be for targeted meetings with individual stakeholders focusing on the sustainability considerations of greatest interest to the, using the provisional sustainability assessment and its framing as a starting point.

3.2 Qualitative SuRF-UK sustainability assessment: "Method A" and "Method B"

Table 5 shows the rankings that the "core" stakeholders agreed for each of the 15 overarching SuRF-UK categories, using "Method A". It also shows (in brackets) how these changed when the mean rankings for each overarching category found by "Method B" were substituted. Each ranking was based on a discussion of the available evidence and the different stakeholder meetings at the meeting at Land Trust HQ, and minor changes made subsequently as a result of further e-mail / telephone discussions. These changes might be triggered because of an apparent inconsistency or because of information contained in a site report / document reviewed subsequent to the meeting. A record of the rationale (and supporting evidence) for each headline category ranking was recorded in the "Method A" spreadsheet template, which is available as Supplementary Information 2 to this paper.

The individual rankings determined under "Method B" which were averaged for inclusion in Table 5, along with their rationale, are included in Supplementary Information 3 to this paper. "Method A" rankings were either 1 or 2. "Method B" rankings were either 1 or 2 or one decimal value between them.

Table 5 Ranking results for the two scenarios (Establishment of the Port Sunlight River Park, and a No Intervention Baseline) using the overarching categories from the SuRF-UK sustainability assessment guidance. Rankings are shown from Method A and Method B (in brackets).

Assessment criteria	**Scenario Establishment of PRSP**	**Scenario 2 No intervention baseline**
Environmental		
Emissions to air	2 (1.33)	1 (1.67)
Soil and ground conditions	1 (1)	2 (1.8)
Groundwater and surface water	1 (1)	2 (2)
Ecology	1 (1.2))	2 (1.8)
Natural resources and waste	1 (1.4)	2 (1.6)
Environmental Total	*6 (5.9)*	*9 (8.9)*
Economic		
Direct economic costs and benefits	2 (1.5)	1 (1.5)
Indirect economic costs and benefits	1 (1)	2 (2)
Employment and employment capital	1 (1)	2 (2)
Induced[2] economic costs and benefits	1 (1)	2 (2)
Project lifespan and flexibility	1 (1)	2 (1.7)
Economic Total	*6 (5.5)*	*9 (9.2)*
Social		
Human health and safety	1 (1.3)	2 (1.5)
Ethics and equality	1 (1)	2 (2)

[2] This SuRF-UK term essentially describes a gearing effect of a project encouraging wider economic activity / investment

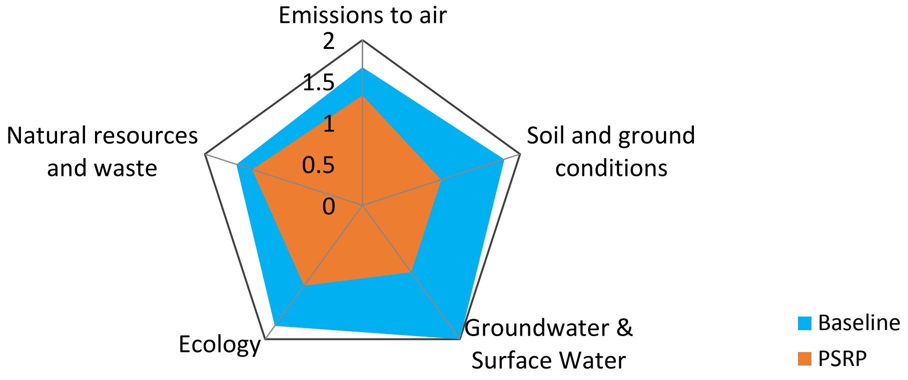
Neighbourhoods and locality	1 (1.2)	2 (1.8)
Communities and community involvement	1 (1)	2 (2)
Uncertainty and evidence	1 (1)	2 (2)
Social Total	*5 (5.5)*	*10 (9.3)*

The overall message from application of both “Method A” and “Method B” is that the establishment of the PSRP is more sustainable (shown by the lower Environmental, Economic and Social total ranking values, Table 5) than the baseline scenario (i.e. leaving the area as a capped and managed but otherwise unimproved landfill site would have been (the baseline). The pattern for the three main elements of sustainability: environmental, economic and social is the same, i.e. that the PSRP establishment was more sustainable, with only slight differences in summed rankings between Method A and Method B.

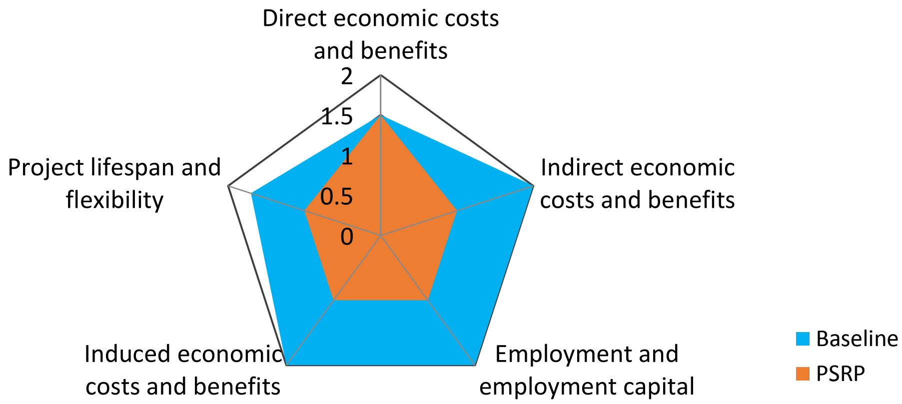
However, the detail of the individual category rankings differ between the single rankings of Method A and the averaged rankings across sustainability linkages of Method B. The pattern of the 15 overarching (headline) categories is different between the two methods. For “Method A” 13 of the 15 categories indicated that the establishment of the park was more sustainable, with the “emissions to air” and “direct costs and benefits” categories being a lower ranking for the park than the baseline. However for “Method B” the establishment of the park was ranked as more or equally sustainable for all 15 headline categories. The averaged ranking for “direct costs and benefits” was the same for the two scenarios; and for “emissions to air” the averaged ranking was slightly better for the PSRP scenario.

In addition, the difference in averaged ranking, than the Method A ranking, was <1 for a further 7 categories. These averaged rankings reflect the greater resolution of considering effects as individual sustainability linkages rather than attempting a single overall ranking for each broad headline category. The use of sustainability linkages as a discipline ensured closer scrutiny of the comparison process and what effects exactly were being compared.

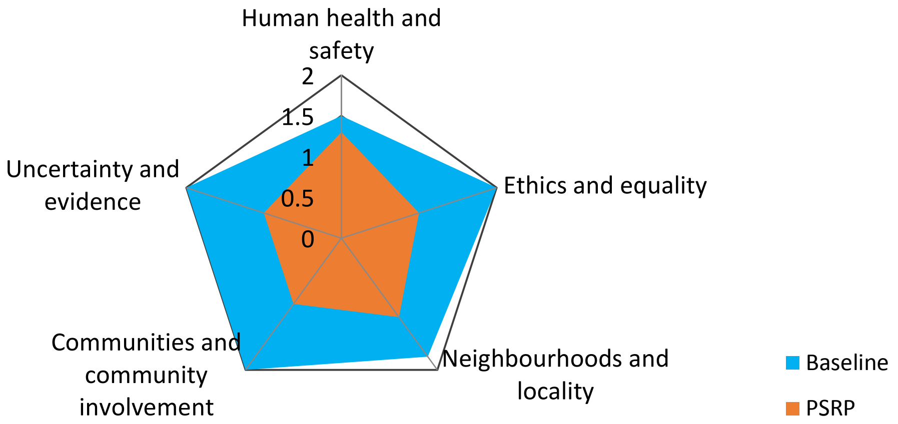
While this qualitative sustainability assessment does not deliver a monetised valuation of sustainability, it does provide a very useful snapshot of the sustainability benefits of the PSRP establishment, especially when viewed visually as radar plots, as shown in Figure 4a, 4b and 4c.



(a) Environmental



(b) Economic



(c) Social

Figure 4 Radar plots of rankings across the three elements of sustainability for SuRF-UK headline categories for the two scenarios using "Method B". A smaller area indicates a lower overall ranking = "more sustainable" The relative sizes of the two areas indicate how close the rankings were.

Had there been significant uncertainties in the qualitative assessment, these could have been examined using a simple form of sensitivity analysis. This sensitivity analysis would have been to examine the effect on the rankings of the uncertainties on the outcome of the qualitative sustainability assessment, for example:

- If some stakeholders preferred a different definition of the sustainability assessment (e.g. boundaries, scope).
- If stakeholders disagreed about the evidence or rationale for a particular indicator/criterion ranking, the effect of changing the ranking order for that particular criterion.

However, at least at this provisional stage there were no differences in opinion on framing or ranking. There does remain an uncertainty because the sustainability assessment is based on relatively few stakeholders (as previously mentioned).

3.3 Conceptual site model of sustainability

A network was constructed using all the sustainability linkages to provide a conceptual site model for sustainability, as shown in Figure 5. This describes both the delivery of the project and the ongoing use and maintenance of the park. The diagram is organised across three columns: pressures / changes (left-hand column in pink), mechanisms by which a pressure or change might affect a specific receptor (middle column), and receptors (right column in red). The mechanisms are coloured depending on whether they are considered deleterious as (gray) or beneficial (white). Linkages are shown as arrows, colour-coded to environmental, economic and social elements of sustainability, using green, yellow and blue respectively. In total, 30 pressures, 31 mechanisms and 6 receptors encapsulated the 50 linkages identified.

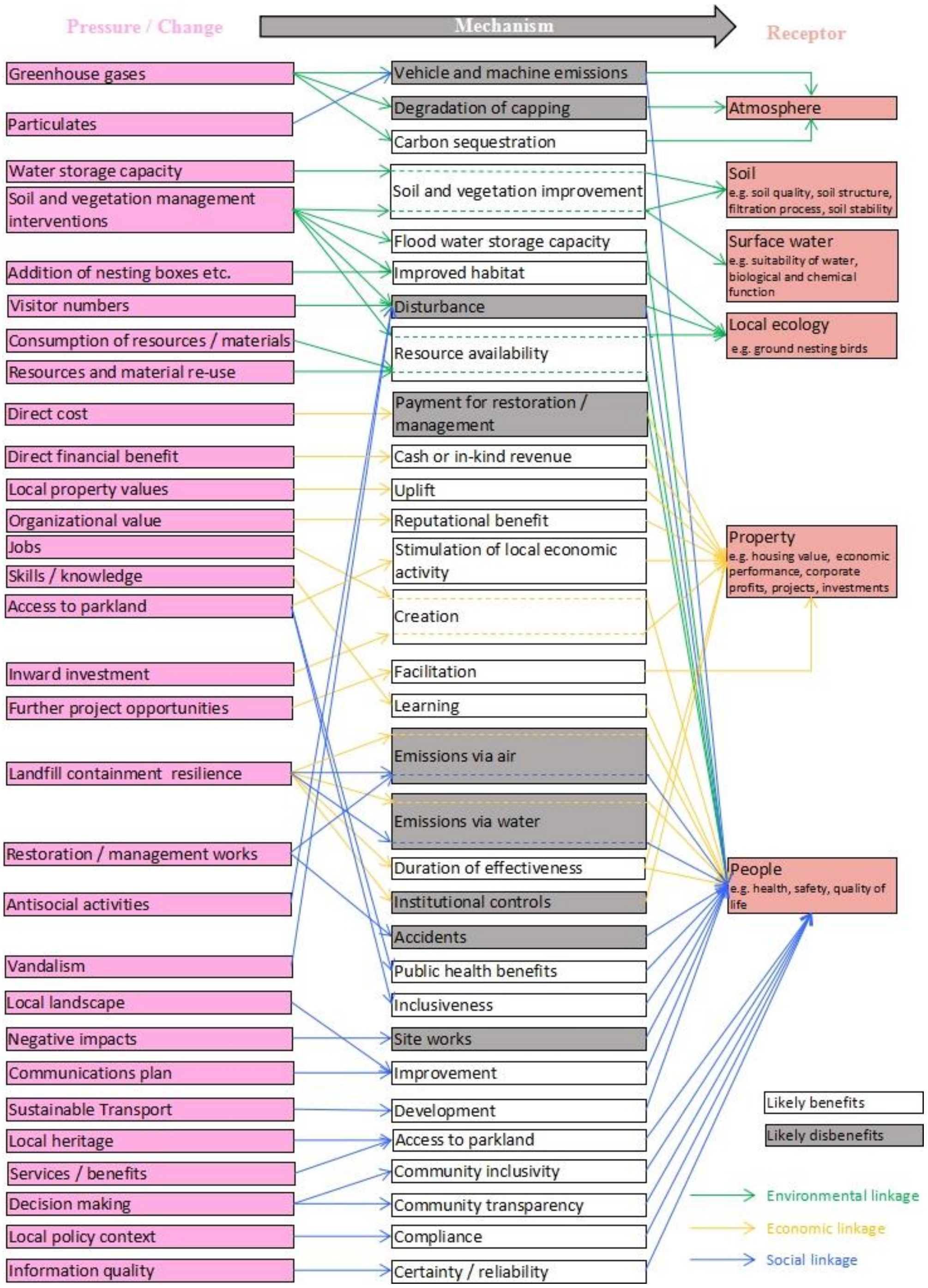


Figure 5 A conceptual site model for sustainability (network diagram) for the Port Sunlight River Park (see text for further discussion).

4 Discussion

Integration of sustainability principles and metrics in contaminated land remediation projects is becoming increasingly important worldwide (Rizzo et al., 2016). Several standards and guidance documents have been developed to describe or codify approaches to "sustainable remediation" and the more narrowly defined "green remediation", which focuses on environmental aspects only (ASTM, 2013a and 2013b; CL:AIRE, 2010 and 2014; ITRC, 2011a and 2011b; ISO, 2017; SURF-US, 2009; US EPA, 2008). The use of a range of individual "sustainability" criteria to define scope is common to all of these approaches, and the SuRF-UK framework methodology is broadly consistent with all of these methods and explicitly consistent with ISO 18504:2017. While there are some regional differences, the use of qualitative approaches is likely to be dominant on grounds of cost, simplicity and ease of communication (compared with quantitative or semi-quantitative approaches (Bardos et al., 2016a). Conceptual site models of sustainability present the logical flow from one step to the next, as such they are a form of logic-chain model (Millar et al., 2001). Logic chains have been used to understand success in the context of brownfield regeneration to a soft-end use (Doick et al., 2009), namely to understand what a regeneration project must achieve in order to meet its stated aims and objectives and to describe monitoring and evaluation required to demonstrate such achievements. While application of logic-chains in this context have, so far, only been applied post-hoc, their description and commonality with conceptual site models of sustainability implies logic-chains could be added to this framework in order to extend its remit beyond *ex ante* appraisal, to include project success evaluation. Alternatively, the conceptual site model for sustainability framework could be used directly to inform monitoring protocols, and the potential of such an application should be the focus of future research.

The qualitative assessment used here, based on either the broad SuRF-UK headline categories or specific linkages, has shown clear sustainability advantages that the establishment of PSRP has over a baseline of having left the site under its previous management regime. This assessment has been carried out on an *ex post* basis. This may have provided a stronger ranking for the PSRP establishment than would have been the case for an *ex ante* comparative sustainability assessment because a number of outcomes of the park's establishment were clearly evident, which might have been more conjectural *ex ante*. These include in particular economic and social factors like the facilitation of further development projects centred on an adjacent site, the widening involvement by other charities and the expanding use of the site for training and education purposes.

This paper's findings are consistent with previously reported work which also suggests that qualitative sustainability assessment can be an effective basis for decision making, avoiding the cost and effort of more intensive semi-quantitative and quantitative approaches (Harclerode et al., 2016; Ridsdale and Noble, 2016; Smith and Kerrison, 2013). Moreover, the use of sustainability linkages (Method B) in this case study was found to facilitate the sustainability assessment for the PSRP site discussion, and in our view provide a more nuanced assessment than the broader headline category approach of "Method A".

One of the wishes of the Land Trust was to be able to monetise the sustainability benefits of their PSRP project, in a way that could be replicated across their existing projects, and to support the planning of new projects. Cost benefit analysis tools are regularly used to assess the value of built developments versus their costs in the brownfields sector. However, their usefulness for soft re-use of brownfields is limited because of the way in which they value externalities such as landscape benefits or health benefits. Available valuation tools have significant technical limitations for some externalities, they can have poor levels of acceptance for some stakeholders; and often they lack transparency in approach, use and assumptions, especially for non-expert practitioners (Ackerman, 2008; Atkinson and Mourato, 2008; Cellini and Kee, 2010; Haninger et al., 2015; Linn, 2013).

The suggestion of this project was that the sustainability linkages could be used to assist a more robust valuation by: (1) ensuring that any cost benefit assessment was consistent with a conceptual model of sustainability, rather than being based on a different set of premises; and (2) providing a better and more targeted valuation approach. This suggestion is rather simple and divides the sustainability linkages that comprise the conceptual model into three groups as shown in Figure 6:

- Some linkages relate to planned or anticipated cost or return – allowing a direct financial model to be applied.
- Some linkages relate to wider effects (i.e. externalities) that can be readily and broadly agreed as being linked to effects that are economically tangible and so more readily valued, for example, value uplift in surrounding properties. A recent study carried out for the Land Trust provides economic valuations for property value uplift and local business benefits (Cárdenas Giraldo et al., 2017).
- Some linkages relate to wider effects (i.e. externalities) that at least one stakeholder considers economically intangible, i.e. not easy to value in a reliable way, for

example the value of an improved landscape or a public health benefit.

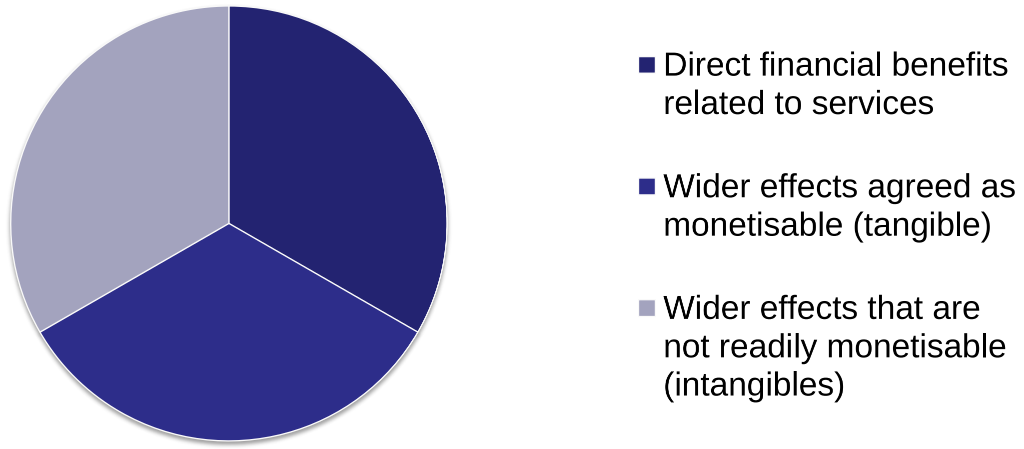


Figure 6 Classifying sustainability linkages by ease of monetisation (note that this figure is purely illustrative and not quantitative)

This categorisation may support stakeholders of different types finding agreement on where monetary valuations can be readily deployed, and those where disagreements between them are likely.

Cost-benefit analysis (CBA) strives to monetise all costs and benefit items. There are arguments for complementing a CBA with other types of assessments (see e.g. Söderqvist et al., 2015) since there may be other ethics that are relevant (e.g. rights-base and duty-based) for societal decision-making. Thus, valuation or assessment of effects of interventions from a sustainability perspective should also include other types of methods than monetary valuation. Moreover, there are well known limitations of quantification techniques used in CBA (Bardos et al., 2016a) that mean that an overarching approach based on monetisation of all factors may of limited persuasiveness for some stakeholders. On the other hand investment decisions, whether by public or private sector organisations are made on the basis of some form or return on investment, whether in directly financial terms, or some form of wider notional returns via CBA. Consequently, the Land Trust, needs to makes its investment cases in monetary terms both in order to demonstrate “value for money” of its existing projects and to give confidence in its ability to deliver “returns” for future projects.

There are different ways forward from this conundrum. (1) The “investor” (funder) simply takes the view that for all its shortcomings they will continue to base their decisions on CBA, which will mean that some stakeholders might feel what is valuable to them is not properly represented. (2) The investment decision could be based on a combined approach, in which the CBA is based on the direct return and wider effects (externalities) agreed as monetisable (or possible to monetise in terms of time and money) by all or most of the stakeholders involved with the site, and an alternative approach to valuation is taken for what are perceived to be intangibles. Such an approach recognises that economic valuation may not be founded on the same ethical basis as considerations of social or environmental values (Söderqvist et al., 2015). (3) The cost benefit appraisal for “investors” could be closely aligned to a qualitative sustainability conceptual model. This approach recognises that ”investors” have a specific need for an overarching monetisation to provide a defensible rationale for their investment decision. However, the transparency and rigour of this CBA could be considerably enhanced by aligning it with a qualitative conceptual site model of sustainability which is more broadly accepted by the wider project stakeholders. Furthermore, the model can be used to find the most appropriate matches between quantification tools and specific sustainability linkages, rather than using a single “one size fits all" approach to monetisation. A benefit of this transparency is that it can support the elaboration of alternative valuation viewpoints by different stakeholder interests, which perhaps allows for a range of estimates of benefit (or detriment) to be considered in decision making.

This third option might be particularly useful for bodies like the Land Trust that both need to attract public and private sector investors or funders, but also be able to show with some rigour that they have both made a robust monetisation, and one that can be queried by their different audiences and stakeholders. The next phase of work we plan is a review of different quantitative valuation techniques to identify those that are most appropriate for the different sustainability linkages identified in the PSRP conceptual site model of sustainability.

Our hope is that this might provide more effective valuation by applying the tools that best fit each particular linkage, and also a more transparent approach because the cost benefits assessment or valuation framework will be consistent with the (qualitative) sustainability assessment.

A possible direction of travel might be to aim for finding consensus on which sustainability linkages are generally considered as important by stakeholders. For those that are seen as less tangible, whether a benefit or a detriment, instead of attempting a direct valuation it might be easier to cost the delivery of an equivalent benefit by an alternative means, or similarly for avoiding a detriment. This is analogous to some forms of determination of payments for ecosystem services (Salzman et al., 2018) albeit on a more localised scale, and across all three elements of sustainability (environmental, economic and social).

5 Conclusions

The qualitative sustainability assessment used here, based on either the broad SuRF-UK headline categories (Method A) or specific sustainability linkages (Method B), has shown clear sustainability advantages that the establishment of the Port Sunlight River Park has over a baseline of having left the site under its previous management regime. This paper's findings are consistent with previously reported work that suggests that qualitative sustainability assessment can be an effective basis for decision making, avoiding the cost and effort of more intensive semi-quantitative and quantitative approaches. The use of sustainability linkages (Method B) in this case study was found to facilitate the sustainability assessment for the site discussion, and provides a more nuanced assessment than the broader headline category approach of "Method A". While direct monetisation of sustainability benefits was not possible, the conceptual site model based on sustainability linkages provides a clearer basis for understanding cause and effect for benefits and disbenefits and a rationale for grouping individual effects based on their ease of valuation. This potentially provides a road map for cost-benefit assessments by (1) being able to match specific linkages to the most appropriate means of valuation, and (2) transparently connecting the sustainability assessment and cost benefit assessment processes.

Acknowledgments

This work was supported by National Key R&D Program of China (grant number 2017YFC0505702). We gratefully acknowledge the support of the University of Brighton, the Land Trust, Research Center for Eco-Environmental Sciences, CAS and University of

Chinese Academy of Sciences, as well, the technical support from r3 environmental technology ltd. We also thank Autism Together, and the assistance freely given by Sarah Williams, Euan Hall, Anne Litherland, Alison Whitehead, Sarah Palgrave-Neath from the Land Trust and Autism Together.

This report has greatly benefited from the inputs of a number of technical reviewers: Emily Connors (Office for National Statistics); Steven Broekx (VITO); Lars Rosen (Chalmers University of Technology).

References

Ackermann F., 2008. Critique of Cost-Benefit Analysis, and Alternative Approaches to Decision-Making. A report to Friends of the Earth England, Wales and Northern Ireland. Available at: www.foe.co.uk/resource/reports/policy_appraisal.pdf (accessed 26/2/2018)

American Society for Testing and Materials (ASTM), 2013a. ASTM E2876-13, Standard guide for integrating sustainable objectives into cleanup. Astm Int., West Conshohocken, PA. Available at: www.astm.org (accessed 26/2/2018)

American Society for Testing and Materials (ASTM), 2013b. ASTM E2893-13, Standard guide for greener cleanups. Astm Int., West Conshohocken, PA. Available at: www.astm.org (accessed 26/2/2018)

Atkinson G., Mourato S., 2008. Environmental cost-benefit analysis. Annual review of Environment and Resources, 33: 317-344.

Bardos P., Bone B., Boyle R., Ellis D., Evans F., Harries N.D., Smith J.W.N., 2011. Applying Sustainable Development Principles to Contaminated Land Management Using the SuRF-UK Framework. Remediation Journal, 21(2): 77-100. DOI: 10.1002/rem.20283

Bardos P., Bone B.D., Boyle R., Evans F., Harries N.D., Howard T., Smith J.W.N., 2016a. The rationale for simple approaches for sustainability assessment and management in contaminated land practice. Science of The Total Environment, 563-564: 755-768. DOI: 10.1016/j.scitotenv.2015.12.001.

Bardos P., Jones S., Stephenson I., Menger P., Beumer V., Neonato F., Maring L., Ferber U., Track T., Wendler K., 2016b. Optimising value from the soft reuse of brownfield sites. Science of The Total Environment, 563–564: 769-782. DOI: 10.1016/j.scitotenv.2015.12.002.

Bardos P., Stephenson I., Menger P., Beumer V., 2015. Maximising the value-proposition for soft reuse of brownfields. AquaConsSoil 2015, Session 2.3 - Redevelopment of brownfields 1. Available at:

http://www.zerobrownfields.eu/HombreMainGallery/Docs/Bardos%20Session%202.3%20ACS%202015%20v2%20Hombre%20web%20site.pdf (accessed 7/7/2016)

BenDor T.K., Metcalf S.S., Paich M., 2011. The Dynamics of Brownfield Redevelopment. Sustainability, 3: 914-936. DOI: 10.3390/su3060914.

Beumer V., Bardos P., Menger P., 2014. HOMBRE D 5.2: Decision support system on soft reuses. HOMBRE Deliverable D 5-2. Deltares. Available at: http://www.zerobrownfields.eu/HombreTrainingGallery/HOMBRE_D5.2_final.pdf (accessed 7/7/2016)

Cappuyns V., 2013. Environmental impacts of soil remediation activities: quantitative and qualitative tools applied on three case studies. Journal of Cleaner Production, 52: 145-154. DOI: 10.1016/j.jclepro.2013.03.023.

Cappuyns V., 2016. Inclusion of social indicators in decision support tools for the selection of sustainable site remediation options. Journal of Environmental Management, 184(Part 1): 45-56. DOI: 10.1016/j.jenvman.2016.07.035.

Cárdenas Giraldo J.A., Ryan L., Prutthisathaporn M., Joshi N., Sato Y., 2018. Evidence of economic impact of Port Sunlight River Park. Alliance Manchester Business School, Master of Business Administration. Available at: https://thelandtrust.org.uk/wp-content/uploads/2018/02/Manchester-Business-School-MBA-Consultancy-project-Final-report.pdf (accessed 14/5/2018)

Cellini S.R., Kee J.E., 2010. Cost-Effectiveness and Cost-Benefit Analysis, in (Eds. Wholey J.S., Hatry H.P. and Newcomer K.E.) Handbook of Practical Program Evaluation, 3rd Edition, Wiley, pp 493-530. ISBN: 978-0-470-52247-9.

Cheng Y., Tang Y.T., Nathanail C.P., 2017. Determination of the potential implementation impact of 2016 ministry of environmental protection generic assessment criteria for potentially contaminated sites in China. Environmental Geochemistry and Health, 1-19. DOI: 10.1007/s10653-017-9953-2.

Contaminated Land: Applications in Real Environments (CL:AIRE), 2011. The SuRF-UK indicator set for sustainable remediation assessment. ISBN: 978-1-905046-1292-5. Available at: http://www.claire.co.uk/index.php?option=com_content&view=article&id=748:annex-1-surf-uk-indicator-set-for-sustainable-remediation&catid=966&Itemid=78 (accessed 7/7/2016)

Contaminated Land: Applications in Real Environments (CL:AIRE), 2010. A Framework for Assessing the Sustainability of Soil and Groundwater Remediation. Available at: http://www.claire.co.uk/projects-and-initiatives/surf-uk/20-framework-and-guidance/89-framework-document (accessed 24/4/2016)

Contaminated Land: Applications in Real Environments (CL:AIRE), 2014. The SuRF-UK Bulletin 4. Available at: www.claire.co.uk/surfuk. (accessed 26/2/2018)

Cundy A.B., Bardos R.P., Church A., Puschenreiter M., Friesl-Hanl W., Mueller I., Neu S., Mench M., Witters N., Vangronsveld J., 2013. Developing principles of sustainability and stakeholder engagement for “gentle” remediation approaches: the European context. Journal of Environmental Management, 129, 283-291.

Cundy A.B., Bardos R.P., Puschenreiter M., Mench M., Bert V., Friesl-Hanl W., Müller I., Li X.N., Weyens N., Witters N., Vangronsveld J., 2016. Brownfields to green fields: Realising wider benefits from practical contaminant phytomanagement strategies. Journal of Environmental Management, 184(Part 1): 67-77. DOI:10.1016/j.jenvman.2016.03.028.

Department for Culture, Media and Sport (DCMS), 2010. Plans for the legacy from the 2012 Olympic and

Paralympic games. Available at: https://www.gov.uk/government/publications/plans-for-the-legacy-from-the-2012-olympic-and-paralympic-games (accessed 20/9/2018)

Doick K.J., Sellers G., Castan-Broto V., Silverthorne T., 2009. Understanding success in the context of brownfield greening projects: success criteria and acceptable standards for urban greenspaces. Urban Forestry and Urban Greening, 8 (3): 163-178. DOI: 10.1016/j.ufug.2009.05.002

Environment Agency, 2009. Updated Technical Background to the CLEA Model. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/291014/scho0508bnqw-e-e.pdf (accessed 26/2/2018)

European Environment Agency (EEA), 2014. Study on land recycling. Available at: http://www.eea.europa.eu/publications/land-recycling-in-europe (accessed 30/6/2016)

Favara P.J., Krieger T.M., Boughton B., Fisher A.S., Bhargava M., 2011. Guidance for performing footprint analyses and life-cycle assessments for the remediation industry. Remediation, 21 (3): 39-79. DOI: 10.1002/rem.20289.

Haninger K., Ma L., Timmins C., 2015. The value of brownfield remediation. NBER Working Paper No.20296. pp 1-50. Available at: http://www.nber.org/papers/w20296.pdf (accessed 8/3/2016)

Harclerode M.A., Macbeth T.W., Miller M.E., Gurr C.J., Myers T.S., 2016. Early decision framework for integrating sustainable risk management for complex remediation sites: Drivers, barriers, and performance metrics. Journal of Environmental Management, 184 (1): 57-66. DOI: 10.1016/j.jenvman.2016.07.087.

Heidenreich M., 2015. The New Museum Folkwang in Essen. A Contribution to the Cultural and Economic Regeneration of the Ruhr Area? European Planning Studies, 23, 1529-1547.

Holistic Management of Brownfield Regeneration (HOMBRE), 2014. HOMBRE's Role in Brownfields Management and Avoidance-Urban Land Management 2065. Available at: www.zerobrownfields.eu (accessed 26/2/2018)

Holistic Management of Brownfield Regeneration (HOMBRE). Available at: http://www.zerobrownfields.eu/index.aspx (accessed 20/9/2016)

Holland K.S., Lewis R.E., Tipton K., Karnis S., Dona C., Petrovskis E., et al., 2011. Framework for integrating sustainability into remediation projects. Remediation, 21 (3): 7-38. DOI: 10. 1002/rem.20288.

Huysegoms L., Cappuyns V., 2017. Critical review of decision support tools for sustainability assessment of site remediation options. Journal of Environmental Management, 196: 278-296. DOI: 10.1016/j.jenvman.2017.03.002.

International Organization for Standardization (ISO), 2017. ISO 18504: Soil quality -- Sustainable remediation. Available at: https://www.iso.org/standard/62688.html (accessed 24/8/2017)

Interstate Technology and Regulatory Council (ITRC), 2011a. Green and Sustainable Remediation: State of the Science and Practice. Available at: http://www.itrcweb.org/GuidanceDocuments/GSR-1.pdf (accessed 26/2/2018)

Interstate Technology and Regulatory Council (ITRC), 2011b. Green and sustainable remediation: a practical framework. Available at: http://www.itrcweb.org/GuidanceDocuments/GSR-2.pdf (accessed 26/2/2018)

Linn J., 2013. The effect of voluntary brownfields programs on nearby property values: Evidence from Illinois. Journal of Urban Economics, 78: 1-18. DOI: 10.1016/j.jue.2013.04.002

Menger P., Bardos P., Ferber U., Neonato F., Maring L., Beumer V., Track T., Wendler K., 2013. HOMBRE

D5.1: Valuation approach for services from regeneration of Brownfields for soft reuse on permanent or interim basis. Available at: http://www.zerobrownfields.eu/HombreTrainingGallery/HomePage/HOMBRE_D5.1_final_Services_SoftReUse.pdf (accessed 7/7/2016)

Millar A., Simeone R.S., Carnevale J.T., 2001. Logic models: a systems tool for performance management. Evaluation and Program Planning, 24: 73-81.

Moffat A.J., 2015. Climate change and land regeneration. Forest Research Best Practice Guidance for Land Regeneration BPG No. 21, Farnham, 3 pp. Available at: http://www.forestry.gov.uk/pdf/FR_Doick_BPG21_2015.pdf/$FILE/FR_Doick_BPG21_2015.pdf (accessed 26/2/2018)

Nathanail C.P., 2005. Generic and site-specific criteria in assessment of human health risk from contaminated soil. Soil Use and Management, 21: 500-507. DOI: 10.1079/SUM2005341.

Nathanail C.P., Bakker Laurent MM, Bardos Paul, Furukawa Yasuhide, Nardella Alessandro, Smith Garry, Smith Jonathan WN, Goetsche Gabriele. 2017. Towards an international standard: The ISO/DIS 18504 standard on sustainable remediation. Remediation Journal, 28(1): 9-15. DOI: 10.1002/rem.21538.

Nathanail C.P., Bardos R.P., 2004. Reclamation of Contaminated Land. Wiley Online Library. ISBN 9780471985600. DOI: 10.1002/0470020954.

Network of Industrially Contaminated Land in Europe (NICOLE), 2010. NICOLE Sustainable remediation roadmap. Available at: http://www.nicole.org/documents/DocumentList.aspx?w=SR (accessed 30/6/2016)

Ridsdale D.R., Noble B.F., 2016. Assessing sustainable remediation frameworks using sustainability principles. Journal of Environmental Management, 184 (1): 31-44. DOI:

10.1016/j.jenvman.2016.09.015

Rizzo E., Bardos P., Pizzol L., Critto A., Giubilato E., Marcomini A., Albano C., Darmendrail D., Döberl G., Harclerode M., Harries N., Nathanail P., Pachon C., Rodriguez A., Slenders H., Smith G., 2016. Comparison of international approaches to sustainable remediation. Journal of Environmental Management, 184: 4-17. DOI: 10.1016/j.jenvman.2016.07.062.

Rosén L., Back P.E., Söderqvist T., Norrman J., Brinkhoff P., Norberg T., Volchko Y., Norin M., Bergknut M., Döberl G., 2015. SCORE: A novel multi-criteria decision analysis approach to assessing the sustainability of contaminated land remediation. Science of The Total Environment, 511: 621–638. DOI: 10.1016/j.scitotenv.2014.12.058.

Salzman J., Bennett G., Carroll N., Goldstein A., Jenkins M., 2018. The global status and trends of Payments for Ecosystem Services. Nature Sustainability, 1(136): 136-144. DOI: 10.1038/s41893-018-0033-0.

Schädler S., Morio M., Bartke S., Finkel M., 2012. Integrated planning and spatial evaluation of megasite remediation and reuse options. Journal of Contaminant Hydrology, CLG 127: 88- 100. DOI: 10.1016/j. jconhyd.2011.03.003.

Smeets E., Weterings R., 1999. Environmental Indicators:Typology and Overview. Technical report No 25/1999. Available at: www.eea.europa.eu/publications/TEC25 (accessed 8/3/2016)

Smith J.W.N., Kerrison G., 2013. Benchmarking of Decision-Support Tools Used for Tiered sustainable remediation appraisal. Water Air & Soil Pollution, 224: 1706. DOI: 10.1007/s11270-013-1706-y.

Söderqvist T., Brinkhoff P., Norberg T., Rosén L., Back P.E., Norrman J., 2015. Cost-benefit analysis as a part of sustainability assessment of remediation alternatives for contaminated land. Journal of Environmental Management, 157: 267–278. DOI: 10.1016/j.jenvman.2015.04.024.

Sustainable Remediation Forum (SURF), 2009. Sustainable remediation white paper: Integrating sustainable principles, practices, and metrics into remediation projects. Remediation Journal, 19(3): 5-114.

The Land Trust, 2015a. Green Space: annual review 2014-2015. Available at: http://thelandtrust.org.uk/wp-content/uploads/2015/11/The-Land-Trust-Annual-Report-2015.pdf (accessed 30/6/2016)

The Land Trust, 2015b. Port Sunlight River Park Site Development Plan. In confidence.

The Land Trust, 2017. The Hidden Value of our Green Spaces. Available at: https://thelandtrust.org.uk/the-land-trust-charitable-aims/thebenefits (accessed 26/2/2018)

U.S. Sustainable Remediation Forum (SuRF-US), 2009. Sustainable remediation white paper—Integrating sustainable principles, practices, and metrics into remediation projects. Remediation, 19(3): 5-114. DOI: 10.1002/rem.20210.

US Environmental Protection Agency (US EPA), 2008. Green remediation: Incorporating sustainable environmental practices into remediation of contaminated sites. EPA/542/R/08/002, USA.